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By: [signature] Date: 9/12/17

City of Fort Collins

City of Fort Collins
Engineering Department

SUBGRADE INVESTIGATION AND PAVEMENT DESIGN FOX GROVE SUBDIVISION FORT COLLINS, COLORADO

Prepared For:

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Attention: Blaine Rappe

Project No. FC07952-135

September 11, 2017

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SCOPE

This report presents the results of our Subgrade Investigation and Pavement Design for the planned roadway improvements within Phase I of Fox Grove in Fort Collins, Colorado. The purpose of our subgrade investigation was to determine the subsurface conditions and to evaluate pavement support characteristics. The report was conducted in general conformance with the Chapters 5 and 10 of the Larimer County Urban Areas Street Standards (LCUASS) updated September 2016, as adopted by the City of Fort Collins (City).

This report was prepared from data developed during field exploration, laboratory testing, engineering analysis, and experience with similar conditions. The report includes a description of the subsurface conditions found in exploratory borings and laboratory test results for the proposed neighborhood roadways. If plans change significantly, we should be contacted to review our investigation and determine if our recommendations still apply. A brief summary of our conclusions is presented below, with more detailed criteria and recommendations contained in the report.

SUMMARY OF CONCLUSIONS

1. Soils encountered in our borings consisted of 4 to 8 feet of sand and clay fill over native sand and gravel to the depths explored. Bedrock was not encountered during our investigation. Groundwater was encountered in one boring during drilling at a depth of 8 feet.

2. The subgrade soils were variable and classified as A-1, A-2, A-2-6 and A-6 group materials.

SITE LOCATION AND PROJECT DESCRIPTION

Fox Grove is located southeast of Interstate 25 and Highway 14 in Fort Collins, Colorado. The project consists of constructing portions of Carriage Parkway, Fox Grove Drive, Huntsman Drive and Vixen Drive and constructing all of Kit Den Drive and Todd Drive. The area slopes down gradually to the south with ground cover consisting of sparse vegetation.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of drilling eight borings to a depth of approximately 10 feet, logging the subsurface conditions, recording penetration-resistance tests, and acquiring samples of the subgrade materials. The approximate boring locations are shown on Figure 1. The borings were drilled with 4-inch diameter solid-stem augers and a truck-mounted drill. Our field representative directed the field investigation and collected samples. Bulk samples were obtained from the upper 4 feet of each boring. Drive samples were taken at selected intervals in each boring by driving a modified California sampler with blows from a 140-pound hammer falling 30 inches. Borings were backfilled following drilling. Summary logs of the borings, including results of field penetration resistance tests, are presented on Figure 2.

Samples were returned to our laboratory and examined by the geotechnical engineer for the project. Laboratory testing was performed in general accordance with AASHTO and ASTM methods to determine index properties, classification, and subgrade support values for those soil types influencing the pavement design. Laboratory tests included moisture content, swell-consolidation, Atterberg limits, particle size analysis, and water-soluble sulfate testing. A Hveem stabilometer test was conducted on a combined sample of the upper 4 feet of our borings. Results of our laboratory tests are presented in Appendix A and summarized in Table A-I.

SUBSURFACE CONDITIONS

Soils encountered in our borings consisted of 4 to 8 feet of sand and clay fill with occasional gravel. The fill was underlain by sand and gravel to the depths of explored. Bedrock was not encountered during this investigation. Samples of the fill tested indicated nil to 8.4 percent swell with only one sample swelling greater than 2 percent. A Hveem stabilometer test was conducted on a composite sample (S-1) of the upper 4 feet from all the borings. The test indicated an R-value of 43, which we converted to a resilient modulus of 10,471 psi according to CDOT criteria.

The sand and gravel encountered in our borings classified as loose to dense based on field penetration test results. Laboratory testing indicated fines contents (percent passing No. 200 sieve) of 5 and 7 percent. These soils are considered low-swelling to non-expansive based on laboratory testing and our experience.

One boring (TH-4) showed groundwater at 8 feet during the time of our investigation. There is a low risk of pavement performance when groundwater is located at least 5 feet below the pavement section. Further description of the subsurface conditions is presented on our boring logs (Figure 2) and in our laboratory test results (Appendix A).

SUBGRADE PREPARATION

Soil samples were tested for swell-consolidation. The majority of the soils were low-swelling to non-expansive with the exception of one swell of 8.4 percent. We judge the existing fill is suitable for support of the majority of the roadway. If larger areas of clay fill are identified during construction, the clay fill should be removed, moisture conditioned and recompacted to a minimum depth of 2 feet. We believe chemical stabilization is not necessary for the soils encountered.

Subgrade soils that do not require stabilization can be prepared with conventional moisture treatment and compaction. To prepare the subgrade for paving with conventional moisture treatment and compaction, subgrade soils should be scarified a minimum of 12 inches deep and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T99). Sand fill should be moisture conditioned to within 2 percent of optimum moisture content. Clay fill should be moisture conditioned to 1 percent to 3 percent above optimum moisture content before compaction.

Scarification and recompaction of the upper 12 inches of subgrade soils should occur as close to the time of pavement construction as possible. The final subgrade surface must be protected from excessive drying or wetting until such time as the pavement section is constructed.

Maintaining moisture contents near optimum will be critical to avoid excessive deflections, rutting and pumping of the subgrade during subgrade preparation of streets. If moisture and density cannot be sufficiently controlled during subgrade preparation and stabilization is required, chemical stabilization, stabilization by removal and replacement, or stabilization using geotextiles and imported granular materials may be used. For isolated or small areas requiring stabilization, removal and replacement or “crowding” crushed, coarse aggregate into the subgrade may be effective. If large areas require stabilization, chemical treatment of the soils may be a more effective alternative.

PAVEMENT DESIGN

New construction is planned for portions of Carriage Parkway, Fox Grove Drive, Huntsman Drive and Vixen Drive and all of Kit Den Drive and Tod Drive. We understand roadway construction is regulated by the Larimer County Urban Area Street Standards (LCUASS) which requires the use of the AASHTO pavement design methods for their roadways. These design methods require input parameters for traffic projections for a specified design life, roadway classification, characteristics of the subgrade materials, type and strength characteristics of pavement materials, groundwater conditions, drainage conditions, condition of the existing pavement, number of construction stages, minimum pavement sections, and statistical data.

Traffic Projections

Traffic projections were provided by City of Fort Collins personnel using a 20-year design life. Traffic projections are expressed as an 18-kip Equivalent Daily Load Application (EDLA) for a single day and as an 18-kip Equivalent Single Axle Load (ESAL) for the design life. Table A presents the Design ESALs used with our calculations.

TABLE A
DESIGN 18-kip EQUIVALENT SINGLE AXLE LOADS (ESALs)

Street	ESAL (20-Year Design Life)
Carriage Parkway	547,500
Fox Grove Drive, Huntsman Drive and Vixen Drive	73,000
Kit Den Drive and Tod Drive	36,500

Pavement Thickness Calculations

We used AASHTO Design methods to develop our pavement thickness recommendations for both flexible and rigid pavements with input values provided by the City, *LCUASS*, and our laboratory tests and observations. For our design, we assumed the pavement will be constructed during a single stage. Input values including initial and terminal serviceability indices, reliability factor, layer strength coefficients, and minimum sections were provided by *LCUASS* for the planned roadways. Other input values not specified by *LCUASS* were estimated based on our experience with similar projects.

Pavement Recommendations

For our design, we assume the pavement will be constructed during a single stage. If multiple-stage construction is desired, we should be consulted to revise our recommendations. Our pavement thickness calculations did not include credit towards chemically treated subgrade soils or the design of a soil/fly ash mixture. If plans change, we are available to perform a soil/fly ash lime mix design.

We have provided pavement design alternatives for new construction including hot mix asphalt (HMA) on aggregate base course (ABC), and portland cement concrete (PCC) pavement. Our pavement thickness alternatives are presented on Table B. Additional discussion regarding advantages and disadvantages of the pavement alternatives and their expected performance is included under the PAVEMENT SELECTION section of this report.

TABLE B
MINIMUM PAVEMENT THICKNESS RECOMMENDATIONS

Roadway	Hot Mix Asphalt (HMA) + Aggregate Base Course (ABC)	Portland Cement Concrete (PCC)
Carriage Parkway	5” HMA + 6” ABC	7.5” PCC
Fox Grove Drive, Huntsman Drive And Vixen Drive	4” HMA + 6” ABC	7” PCC
Kit Den Drive and Tod Drive	4” HMA + 6” ABC	7” PCC

PAVEMENT SELECTION

Both HMA/ABC composite (flexible) and PCC (rigid) pavements are expected to perform well for the roadways. However, PCC pavement has better performance in freeze-thaw conditions and should require less long-term maintenance than HMA pavement. PCC pavement is also recommended for sections that may experience frequent stopping and turning, heavy point loads, or chemical spills.

SUBGRADE AND PAVEMENT MATERIALS AND CONSTRUCTION

The construction materials are assumed to possess sufficient quality as reflected by the strength factors used in our design calculations. Materials and construction requirements of *LCUASS* should be followed.

Based on the results of laboratory testing and *LCUASS*, we believe that mitigation for swell will not be required. Only one of twelve fill samples tested swelled beyond 2 percent. We judge the existing fill is suitable for support of the majority of the roadway. If larger areas of clay fill are identified during construction, the clay fill should be removed, moisture conditioned and recompacted to a minimum depth of 2 feet. We believe conventional moisture treatment and compaction of the subgrade is appropriate for these conditions.

These criteria were developed from analysis of the field and laboratory data, our experience and *LCUASS* requirements. If the materials cannot meet these requirements, our pavement recommendations should be re-evaluated based upon available materials. The use of recycled materials, such as recycled asphalt pavement (RAP) and recycled concrete may be used in place of aggregate base course provided they meet minimum R-values and gradations established by *LCUASS* and CDOT. Materials planned for construction should be submitted and the applicable laboratory tests performed to verify compliance with the specifications. Recommendations for subgrade and pavement materials and construction are presented in Appendix B.

MAINTENANCE

Routine maintenance, such as sealing and repair of cracks, is necessary to achieve the long-term life of a pavement system. 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. A recommended maintenance program is outlined in Appendix C.

Excavation of completed pavement for utility construction or repair can destroy the integrity of the pavement and result in a severe decrease in serviceability. To restore the pavement top original serviceability, careful backfill compaction before repaving is necessary.

WATER-SOLUBLE SULFATES

Concrete that is exposed to sulfate-rich soils can be subject to sulfate attack. If concrete pavements or structures will not be in contact with sulfate-rich soils, by means of an aggregate base course layer or other materials, the risk of sulfate attack should be low. We measured water-soluble sulfate concentrations in eight samples from this site; concentrations were 0.01 percent or less. Water-soluble sulfate concentrations less than 0.1 percent indicate Class 0 exposure to sulfate attack for concrete that is exposed to the soils, according to the American Concrete Institute (ACI). For this level of sulfate concentration, ACI indicates any type of cement can be used for concrete that is exposed to the soils. In our experience, superficial damage may occur to the exposed surfaces of highly permeable concrete, even though sulfate levels are relatively low. To control this risk and to resist freeze-thaw deterioration, the water-to-cementitious material ratio should not exceed 0.50 for concrete in contact with soils that are likely to stay moist due to surface drainage or high water tables. Concrete should be air entrained.

LIMITATIONS

Our borings were spaced to obtain a reasonably accurate indication of subgrade and/or pavement conditions for the proposed construction. The borings are representative of conditions encountered only at the exact boring locations. Variations in the subsurface conditions not indicated by our borings are always possible. A representative of our firm should observe subgrade preparation, subgrade stabilization and pavement construction.

This report was prepared from data developed during our field exploration, laboratory testing, engineering analysis, and experience with similar conditions. The recommendations contained in this report were based upon our understanding of the planned construction. If plans change or differ from the assumptions presented herein, we should be contacted to review our recommendations.

We believe this investigation was conducted with that level of skill and care ordinarily used by geologists and geotechnical engineers practicing in this area at this time. No warranty, express or implied, is made.

If we can be of further service in discussing the contents of this report or in the analysis of the influence of subsoil conditions on design of the pavements, please call the undersigned.

CTL | THOMPSON, INC. by:

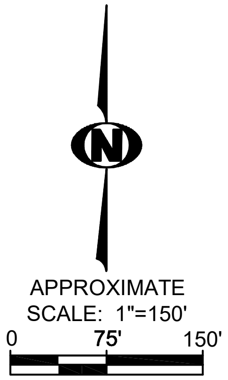
Taylor H. Ray, EI
Staff Geotechnical Engineer

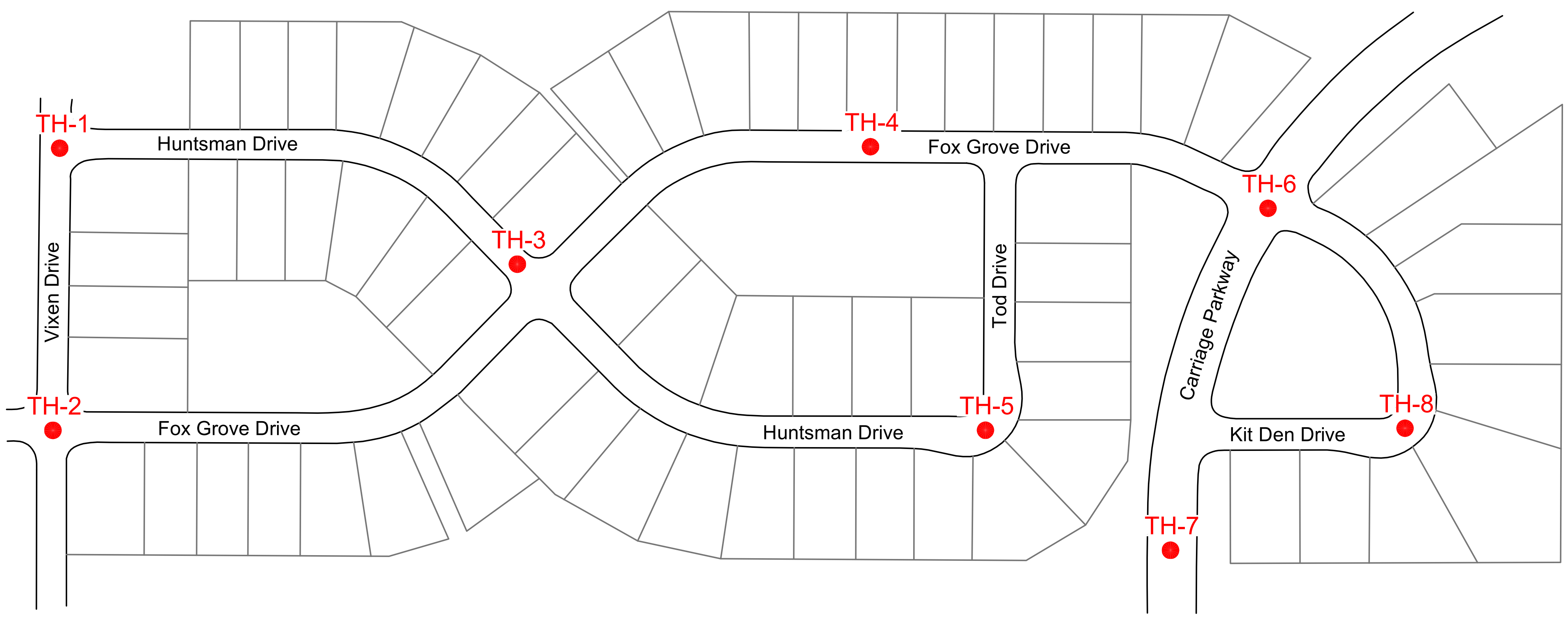
Spencer Schram, PE
Project Engineer

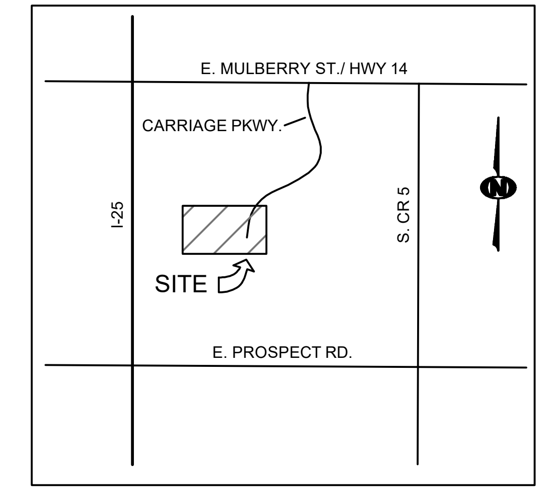
COLORADO LICENSED PROFESSIONAL ENGINEER
SPENCER A. SCHRAM
48576
SEP 11 2017

THR:SAS

(2 Copies)







VICINITY MAP
FT. COLLINS, CO
NOT TO SCALE

LEGEND:

TH-1 ● INDICATES APPROXIMATE LOCATION OF EXPLORATORY BORING

Locations of Exploratory Borings

FIGURE 1

LC HOMES AT FOX GROVE, LLC
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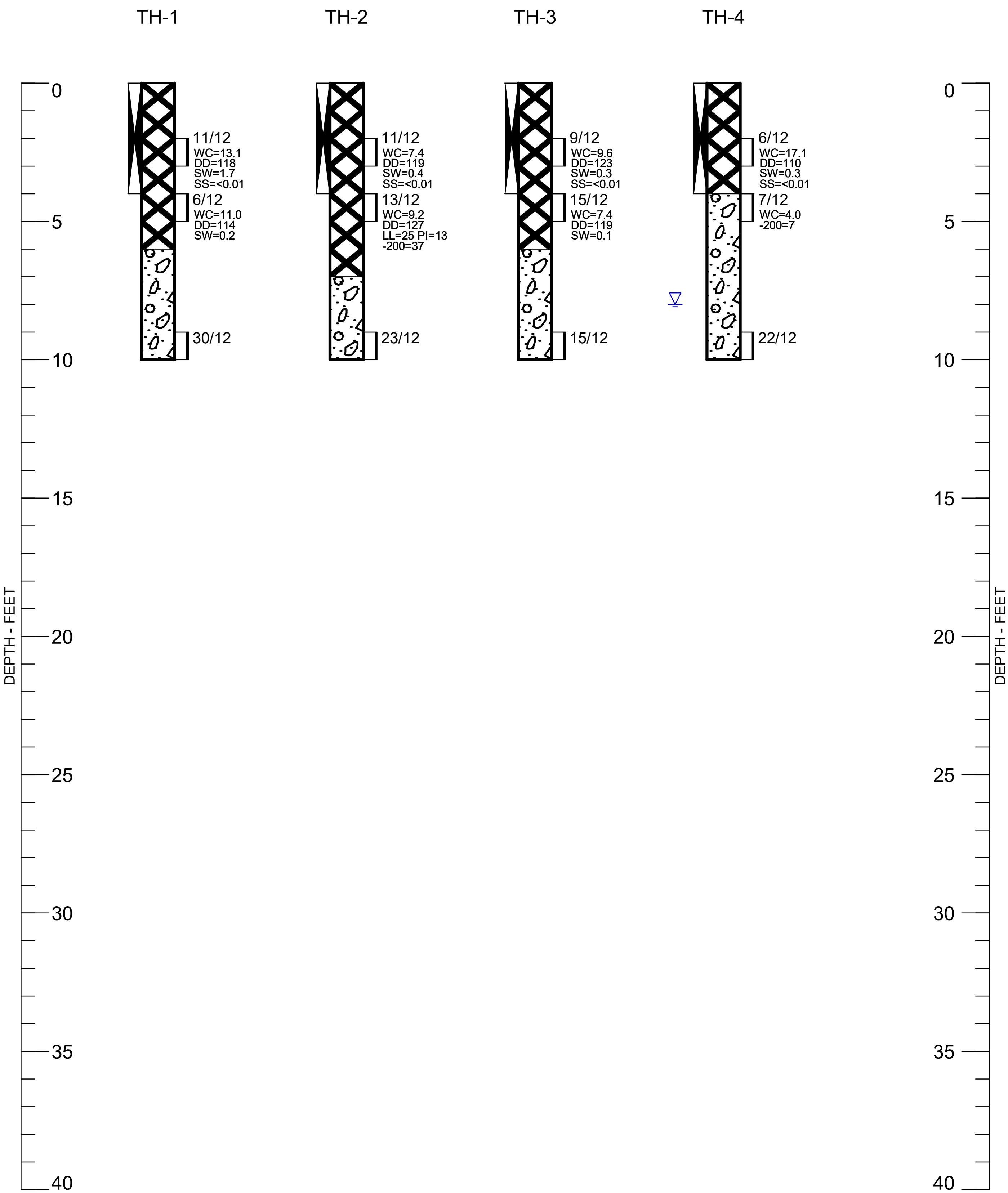

Summary Logs of Exploratory Borings

FIGURE 2

LC HOMES AT FOX GROVE, LLC
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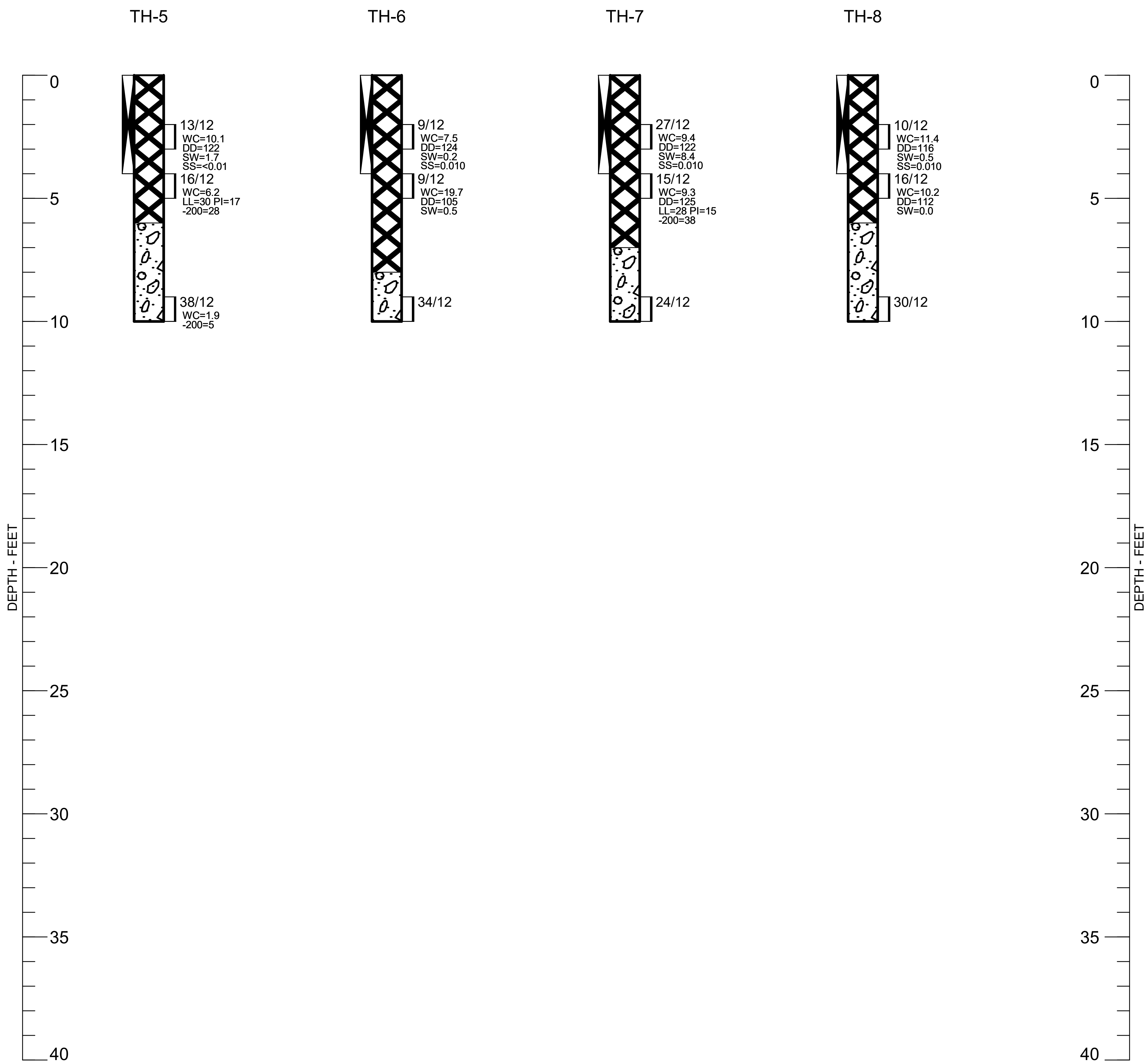


LEGEND:

- FILL, SAND, CLAY, MOIST, LOOSE TO MEDIUM DENSE, MEDIUM STIFF TO VERY STIFF, BROWN, DARK BROWN
- SAND AND GRAVEL, MOIST, LOOSE TO DENSE, BROWN (SP, SP-SC, GP, GW-GC)
- DRIVE SAMPLE. THE SYMBOL 13/12 INDICATES 13 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.
- BULK SAMPLE FROM AUGER CUTTINGS.
- WATER LEVEL MEASURED AT TIME OF DRILLING.

NOTES:

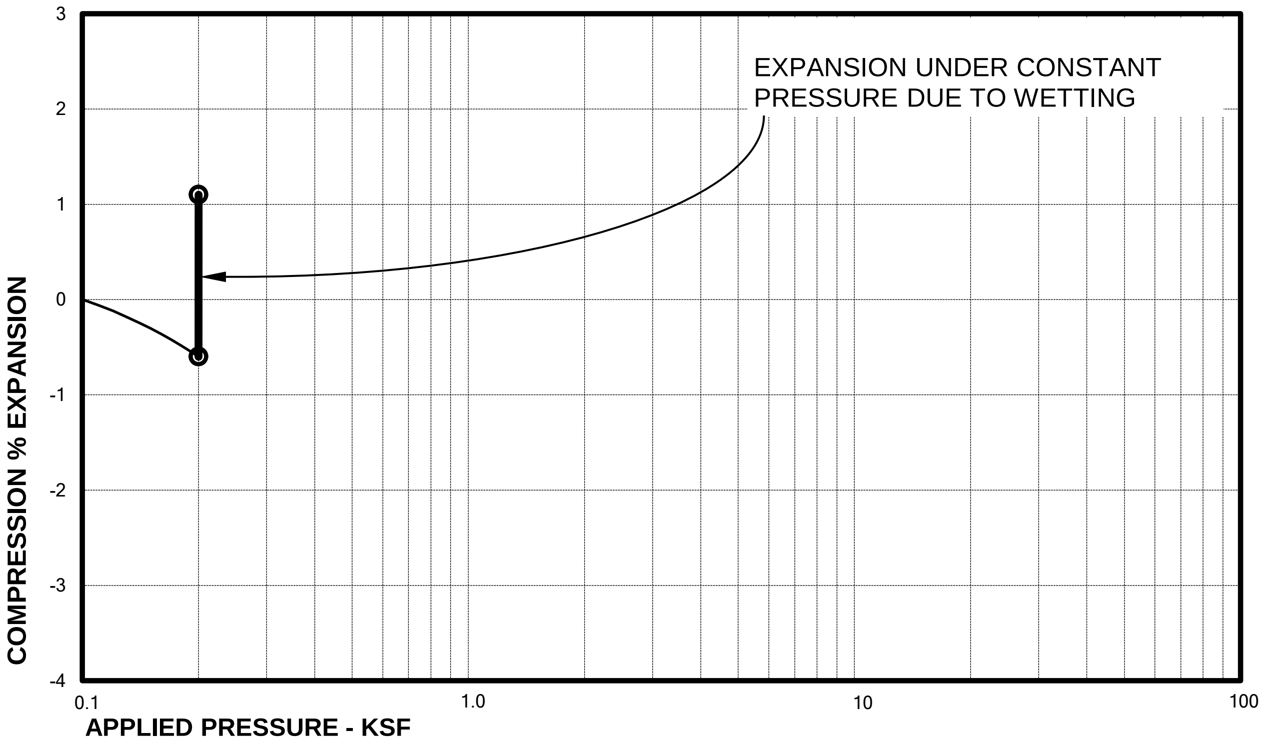
1. THE BORINGS WERE DRILLED ON JULY 28, 2017 USING 4-INCH DIAMETER CONTINUOUS-FLIGHT AUGERS AND A TRUCK-MOUNTED DRILL RIG.
2. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS, AND CONCLUSIONS IN THIS REPORT.
3. WC - INDICATES MOISTURE CONTENT (%).
   DD - INDICATES DRY DENSITY (PCF).
   SW - INDICATES SWELL WHEN WETTED UNDER OVERBURDEN PRESSURE (%).
   -200 - INDICATES PASSING NO. 200 SIEVE (%).
   LL - INDICATES LIQUID LIMIT.
   PI - INDICATES PLASTICITY INDEX.
   UC - INDICATES UNCONFINED COMPRESSIVE STRENGTH (PSF).
   SS - INDICATES SOLUBLE SULFATE CONTENT (%).

Summary Logs of Exploratory Borings

FIGURE 3

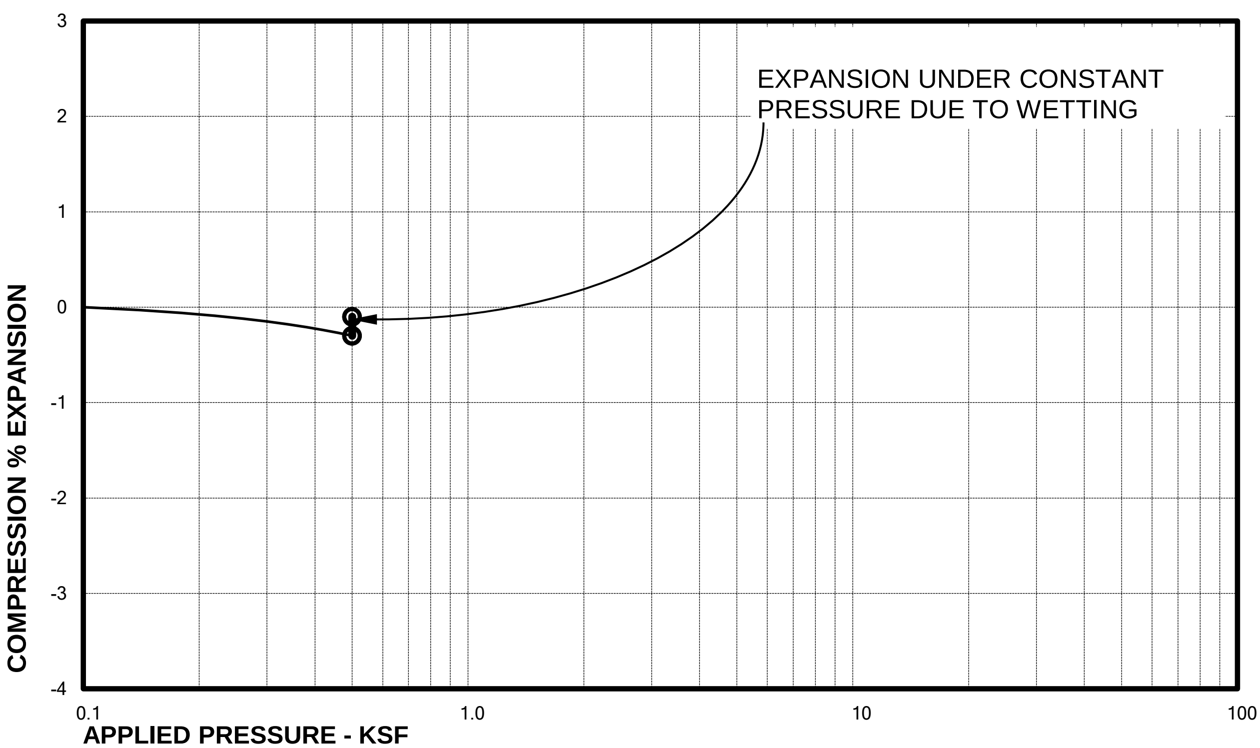
APPENDIX A

RESULTS OF LABORATORY TEST



Sample of FILL, CLAY, SANDY (CL)
From TH - 1 AT 2 FEET

DRY UNIT WEIGHT= 118 PCF
MOISTURE CONTENT= 13.1 %



Sample of FILL, CLAY, SANDY (CL)
From TH - 1 AT 4 FEET

DRY UNIT WEIGHT= 114 PCF
MOISTURE CONTENT= 11.0 %

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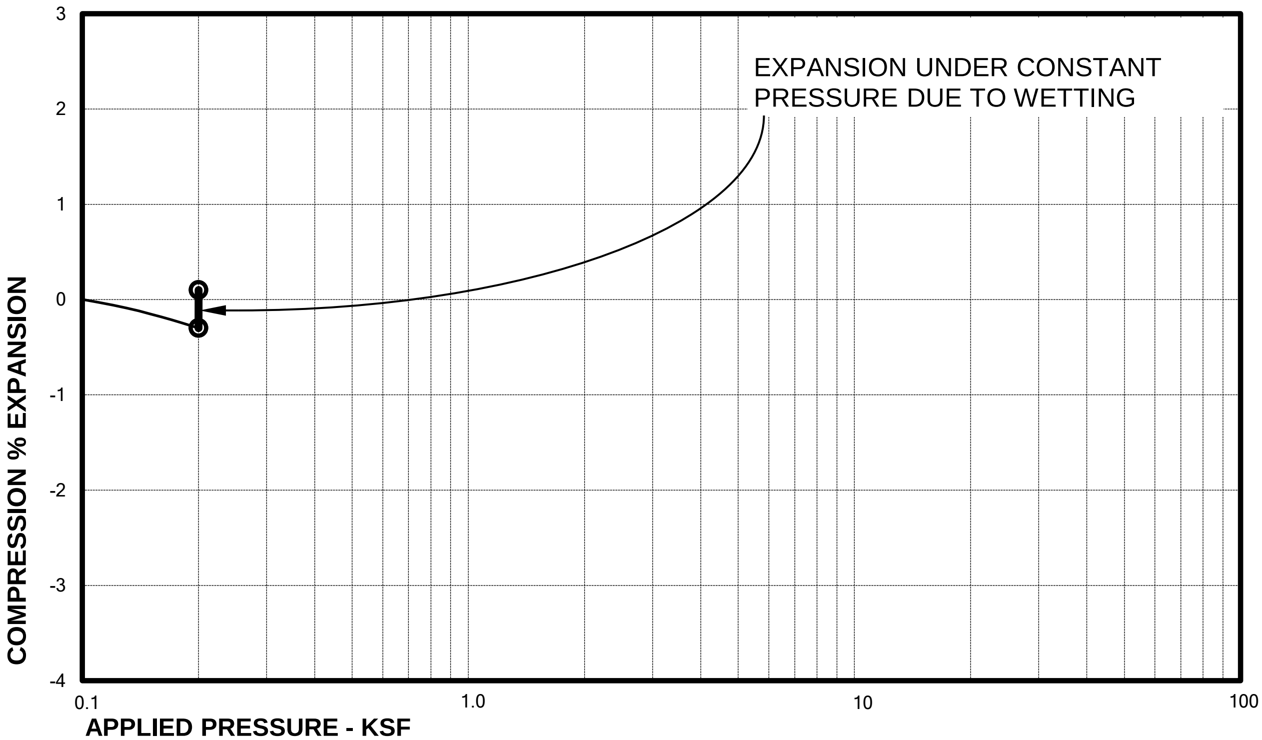
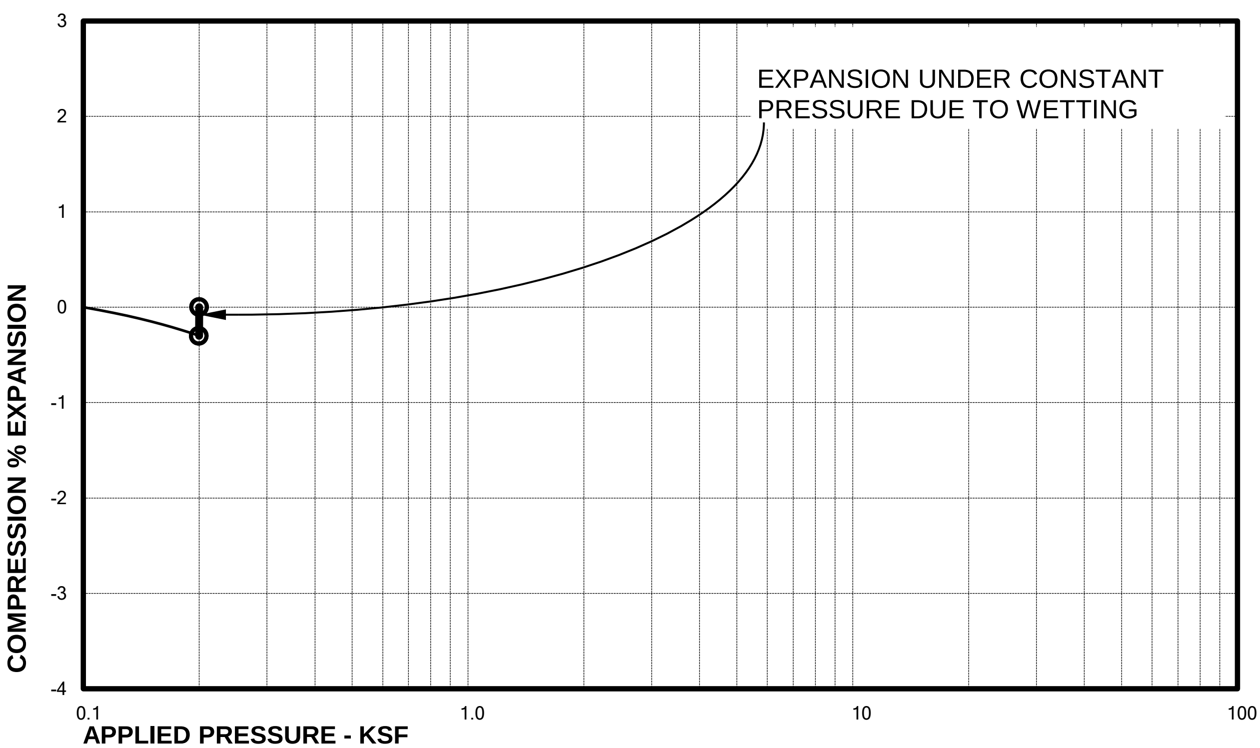
Swell Consolidation

FIGURE A-1



Sample of FILL, CLAY, SANDY (CL)
From TH - 2 AT 2 FEET

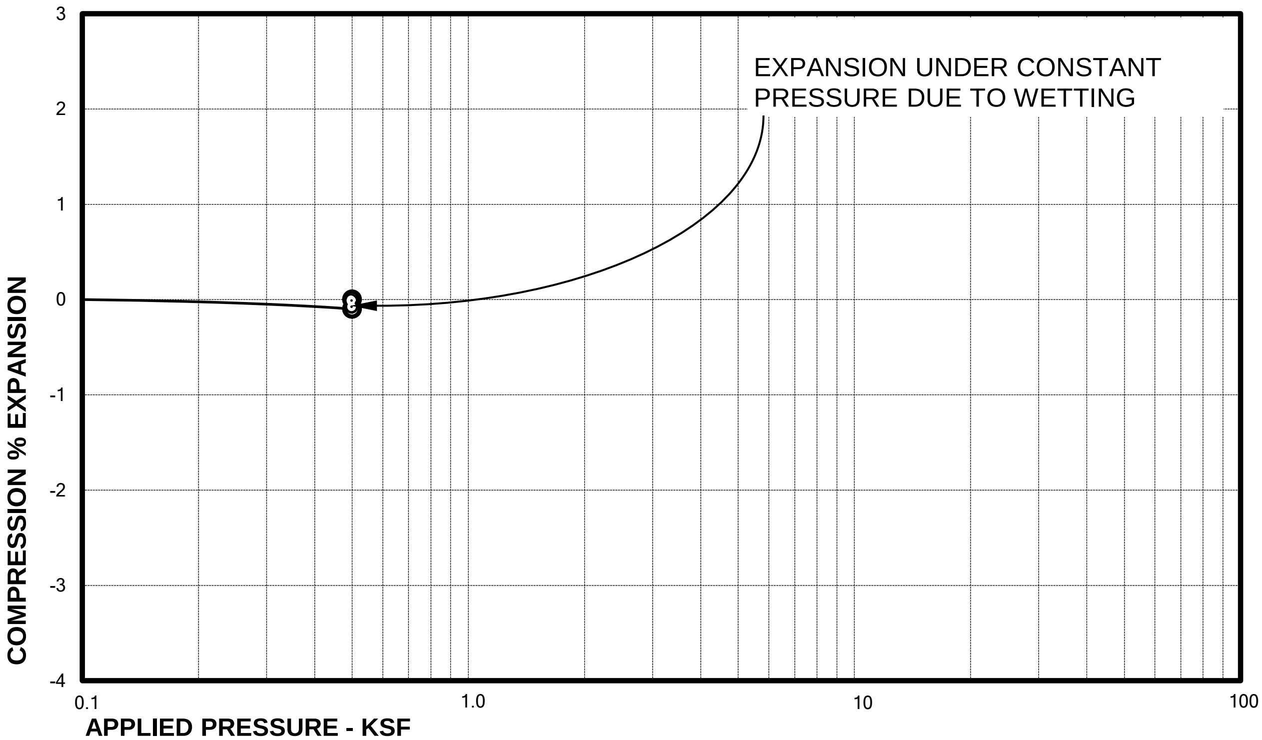
DRY UNIT WEIGHT= 119 PCF
MOISTURE CONTENT= 7.4 %



Sample of FILL, CLAY, SANDY (CL)
From TH - 3 AT 2 FEET

DRY UNIT WEIGHT= 123 PCF
MOISTURE CONTENT= 9.6 %

Swell Consolidation

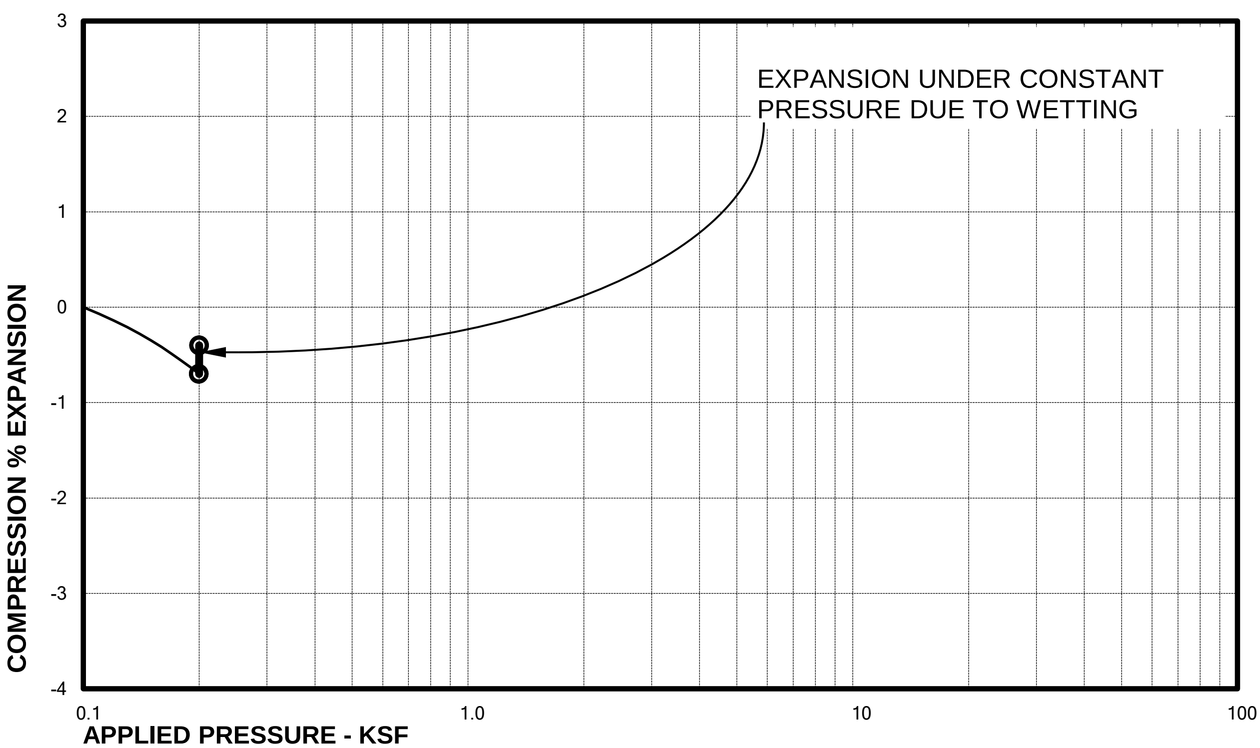


Sample of FILL, SAND, CLAYEY (SC)

From TH - 3 AT 4 FEET

DRY UNIT WEIGHT= 119 PCF

MOISTURE CONTENT= 7.4 %



Sample of FILL, SAND, CLAYEY (SC)

From TH - 4 AT 2 FEET

DRY UNIT WEIGHT= 110 PCF

MOISTURE CONTENT= 17.1 %

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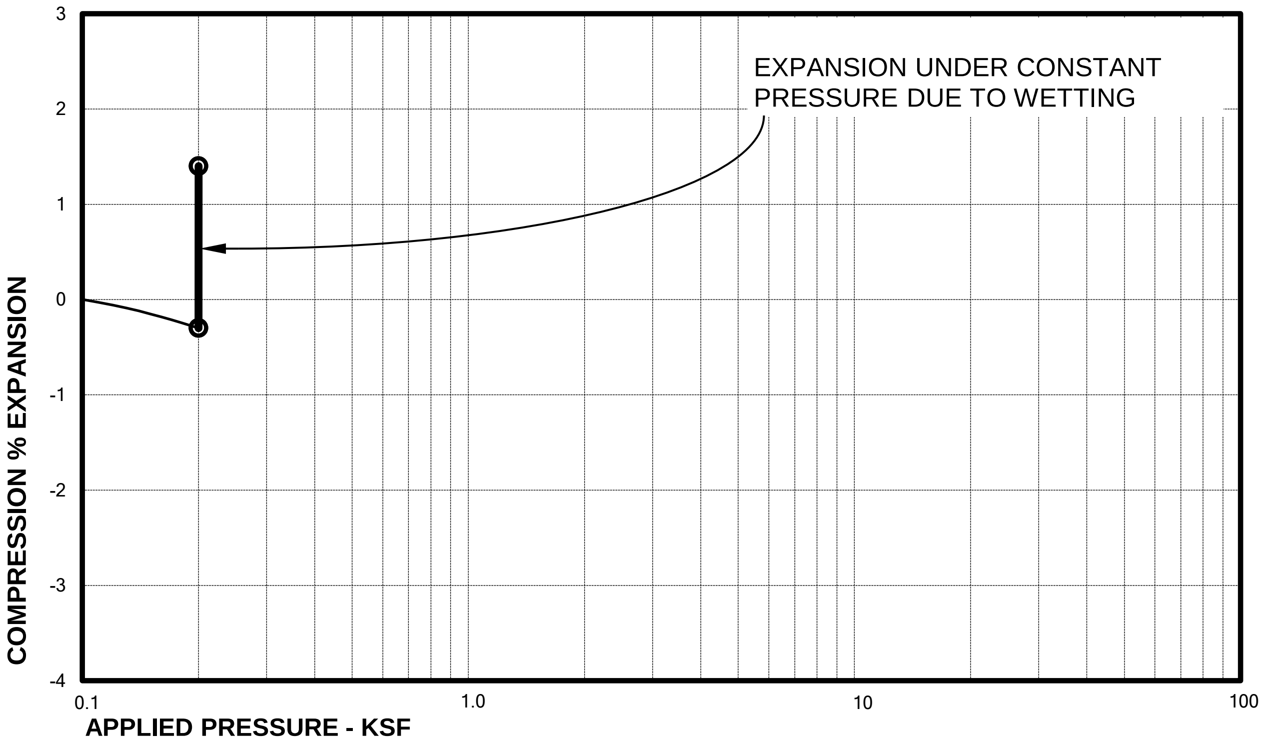
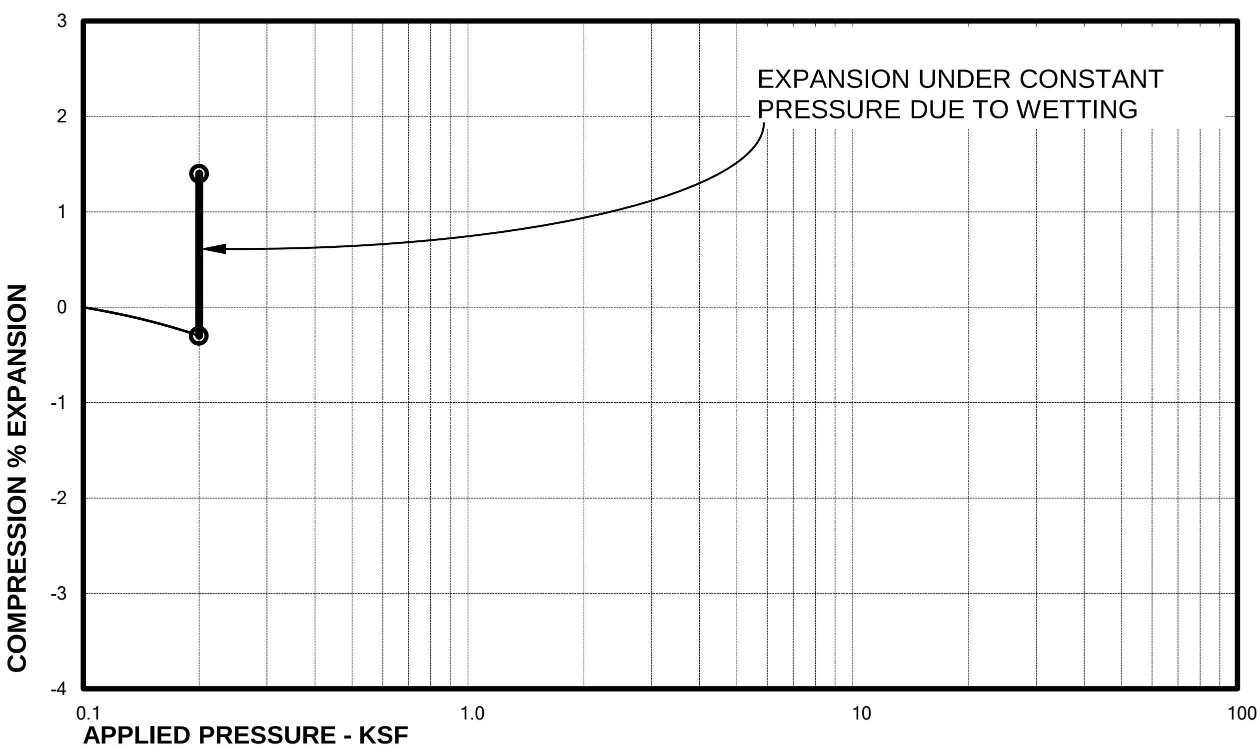
Swell Consolidation

FIGURE A-3



Sample of FILL, CLAY, SANDY (CL)
From TH - 5 AT 2 FEET

DRY UNIT WEIGHT= 122 PCF
MOISTURE CONTENT= 10.1 %



Sample of FILL, CLAY, SANDY (CL)
From TH - 5 AT 2 FEET

DRY UNIT WEIGHT= 122 PCF
MOISTURE CONTENT= 10.1 %

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FOX GROVE SUBDIVISION
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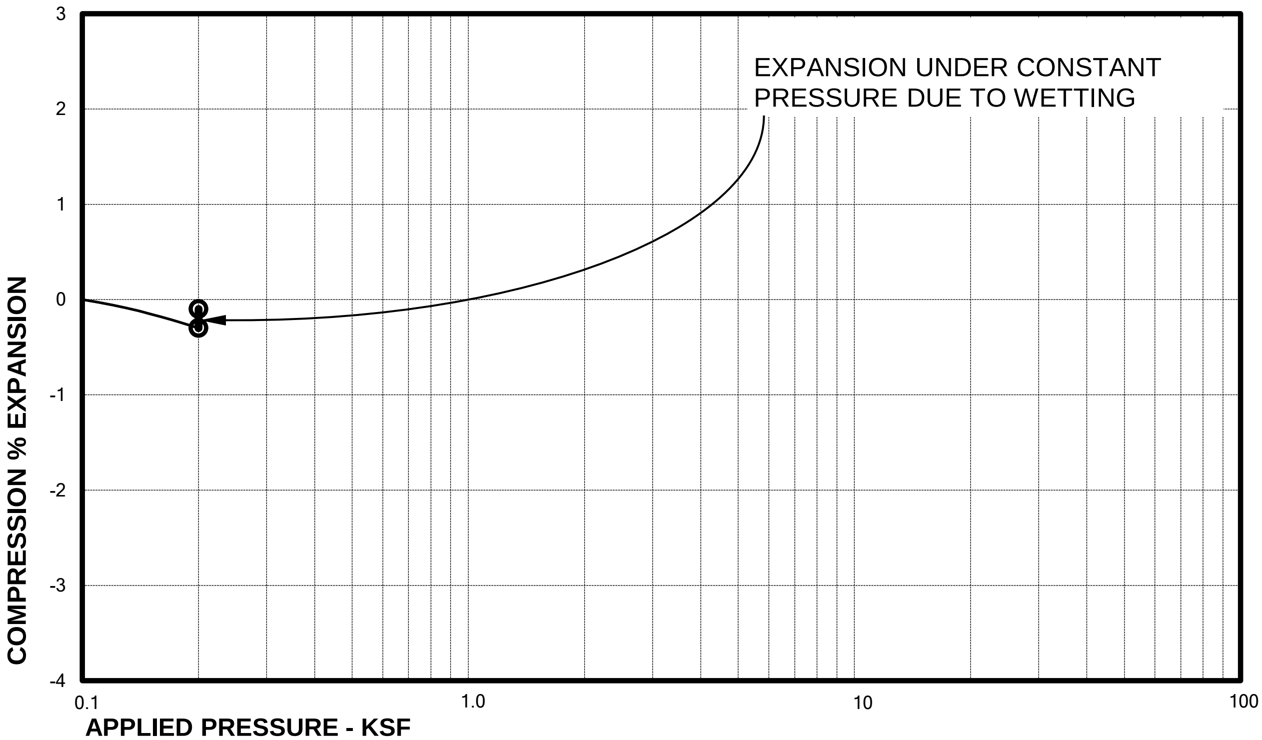
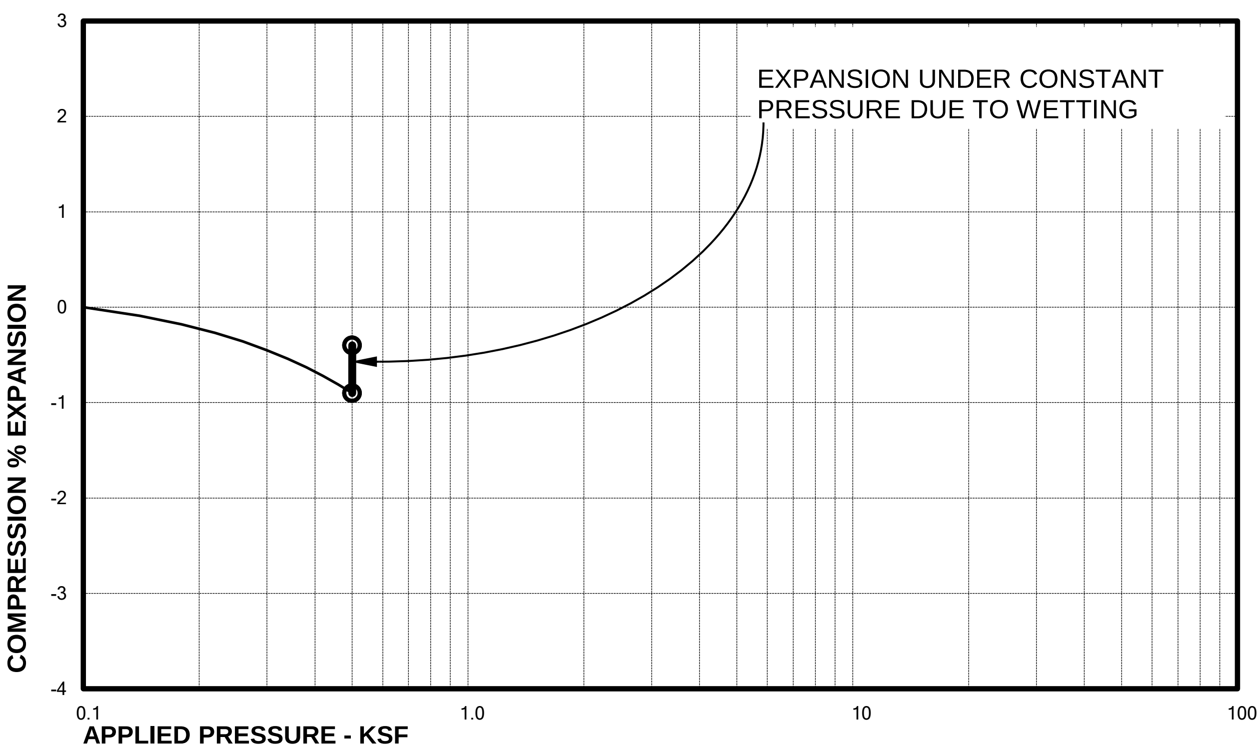
Swell Consolidation

FIGURE A-4



Sample of FILL, SAND, CLAYEY (SC)
From TH - 6 AT 2 FEET

DRY UNIT WEIGHT= 124 PCF
MOISTURE CONTENT= 7.5 %



Sample of FILL, CLAY, SANDY (CL)
From TH - 6 AT 4 FEET

DRY UNIT WEIGHT= 105 PCF
MOISTURE CONTENT= 19.7 %

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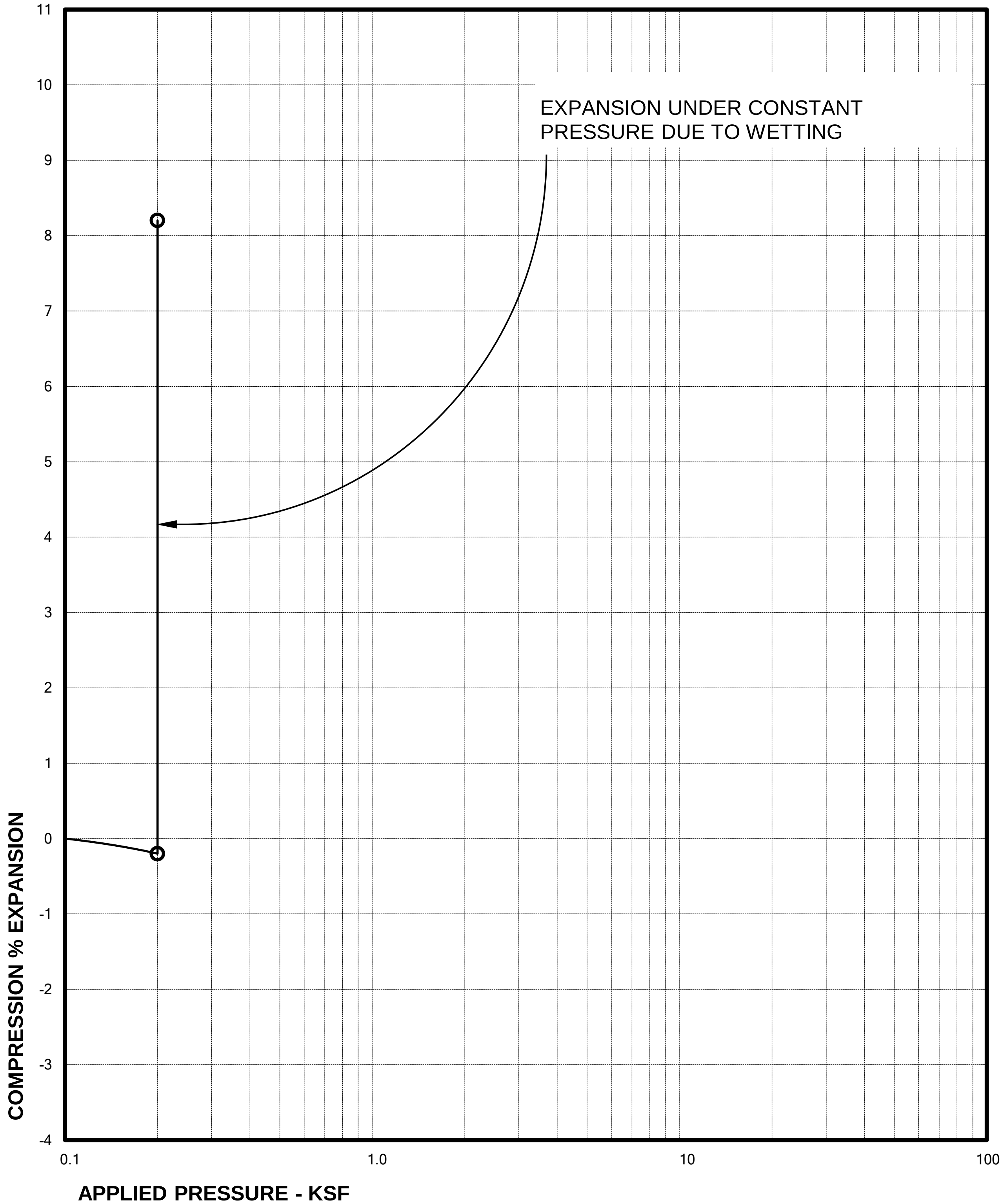
Swell Consolidation

FIGURE A-5



Sample of FILL, CLAY, SANDY (CL)

From TH - 7 AT 2 FEET

DRY UNIT WEIGHT= 122 PCF

MOISTURE CONTENT= 9.4 %

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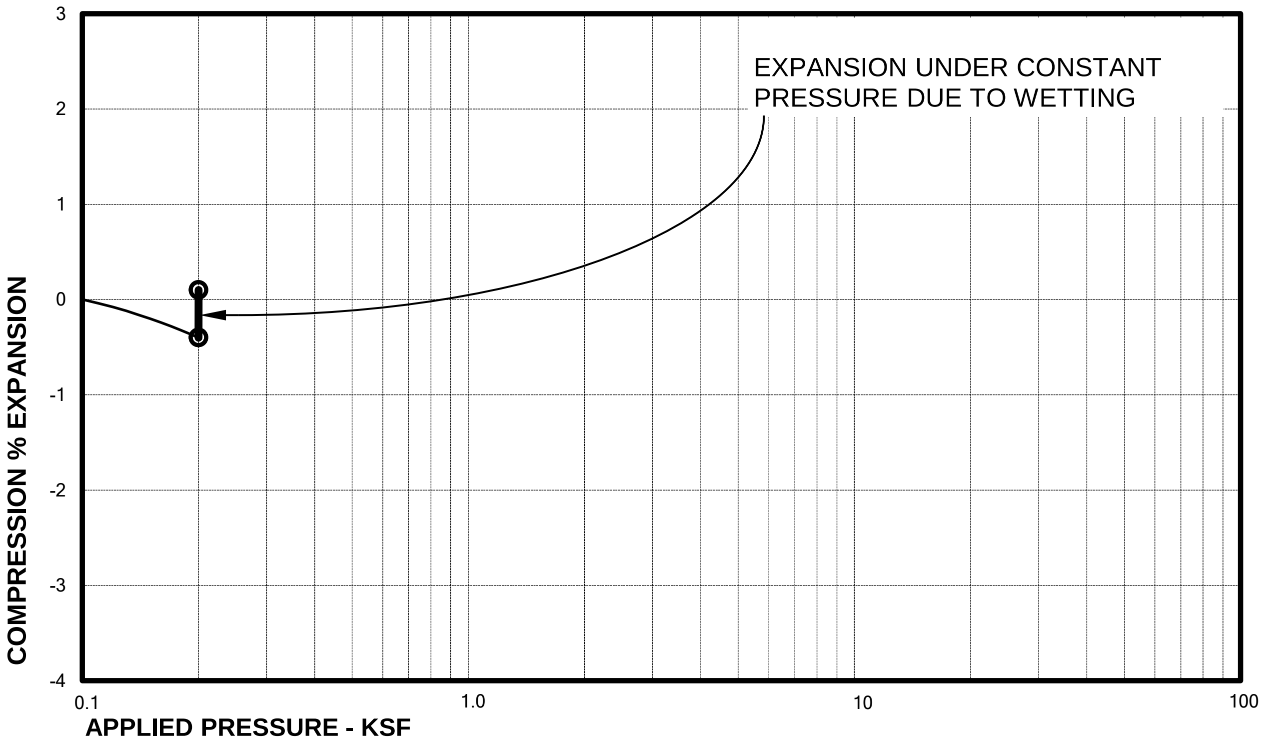
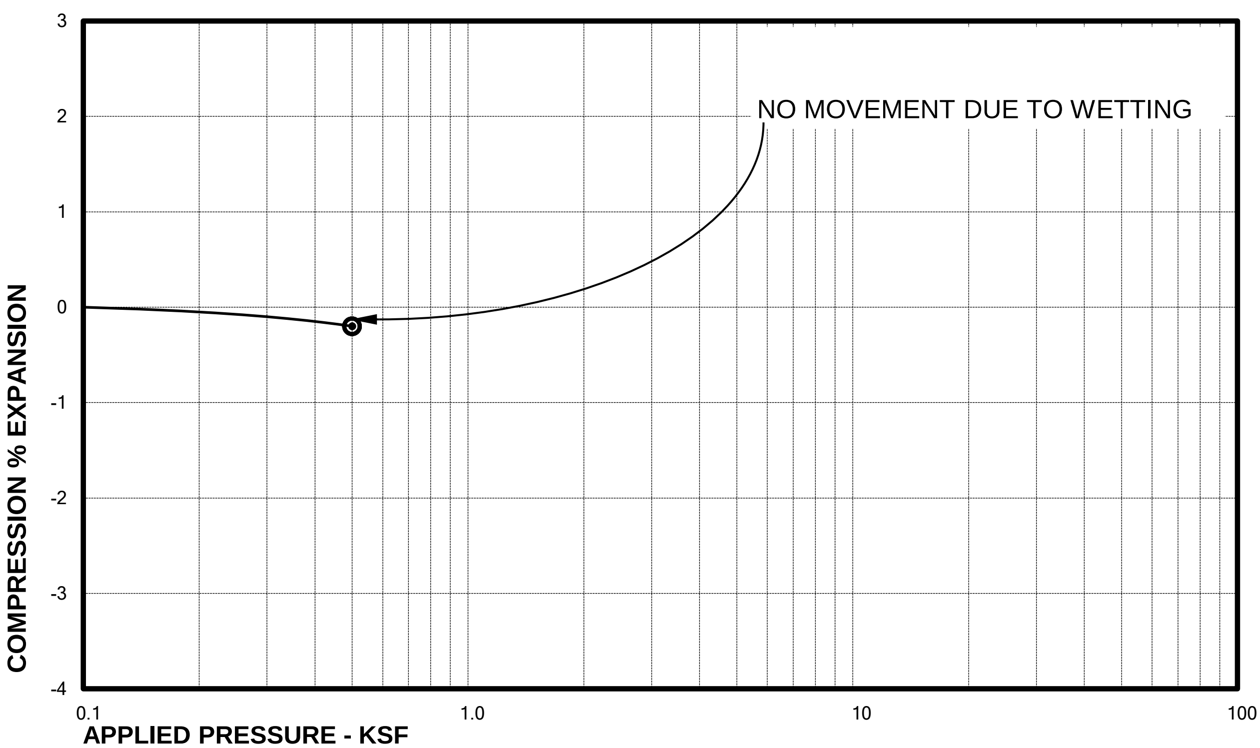
Swell Consolidation Test Results

FIGURE A-6



Sample of FILL, SAND, CLAYEY (SC)
From TH - 8 AT 2 FEET

DRY UNIT WEIGHT= 116 PCF
MOISTURE CONTENT= 11.4 %

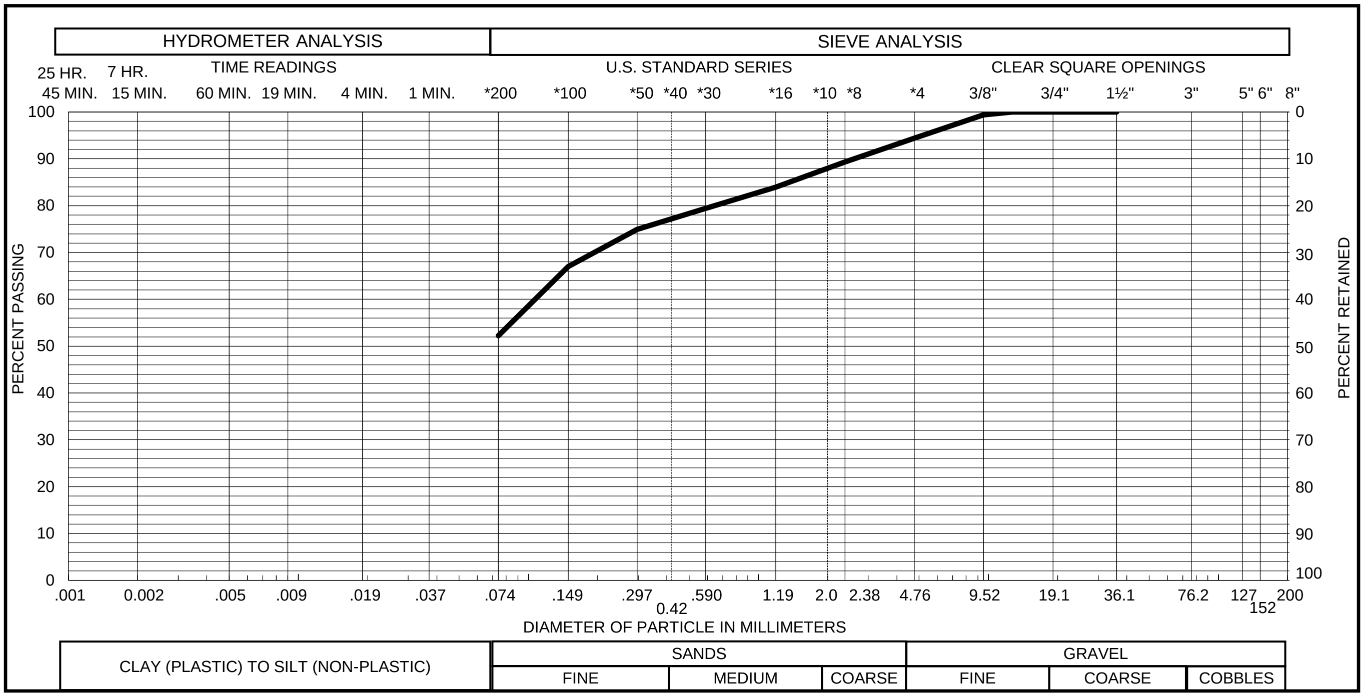


Sample of FILL, SAND, CLAYEY (SC)
From TH - 8 AT 4 FEET

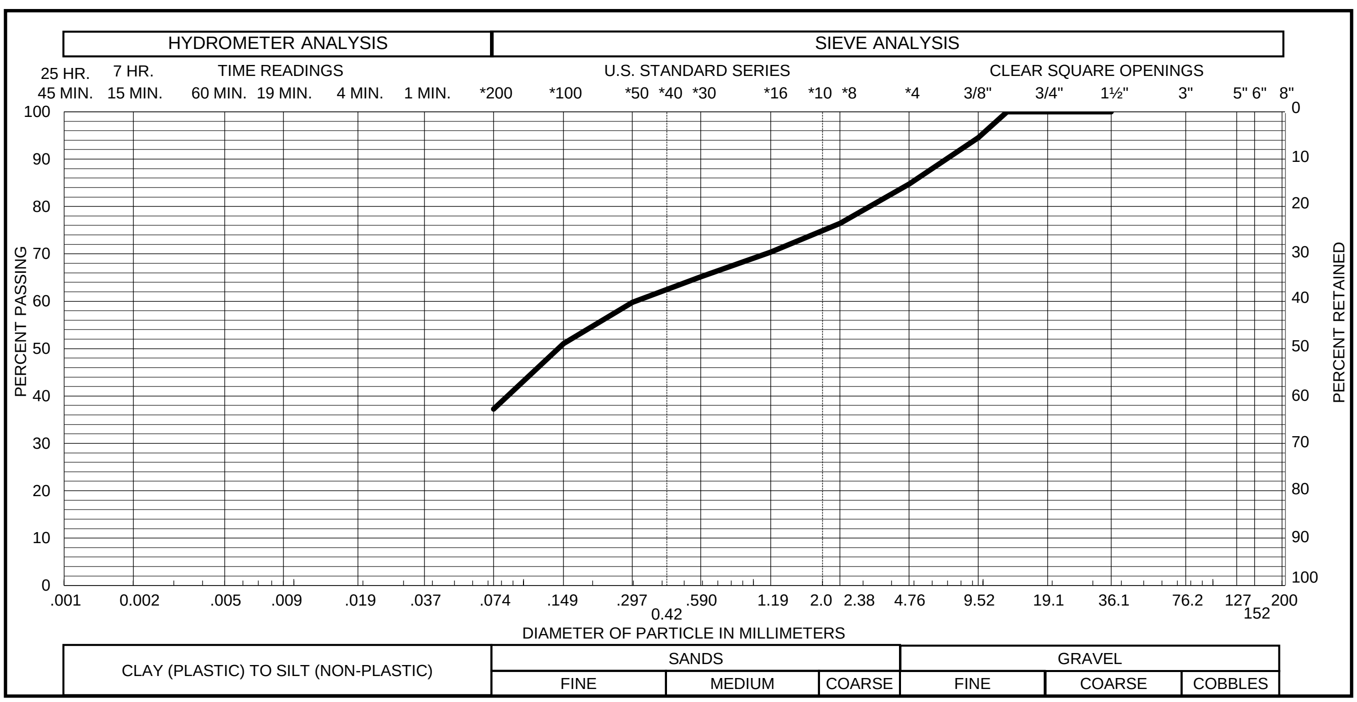
DRY UNIT WEIGHT= 112 PCF
MOISTURE CONTENT= 10.2 %

Swell Consolidation

FIGURE A-7



Sample of	FILL, CLAY, SANDY (CL)	GRAVEL	6 %	SAND	42 %
From	Bulk - Test AT 0-4 FEET	SILT & CLAY	52 %	LIQUID LIMIT	33 %
		PLASTICITY INDEX			21 %



Sample of	FILL, SAND, CLAYEY (SC)	GRAVEL	15 %	SAND	48 %
From	TH - 2 AT 4 FEET	SILT & CLAY	37 %	LIQUID LIMIT	25 %
		PLASTICITY INDEX			13 %

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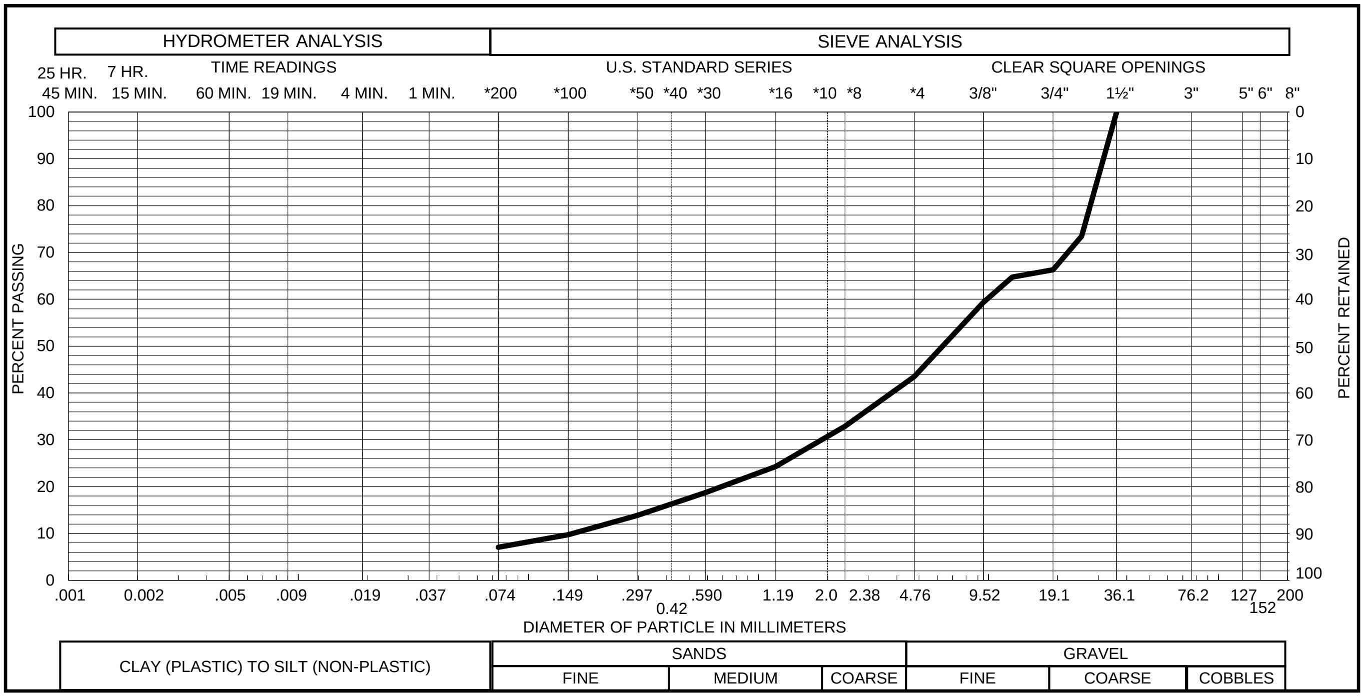
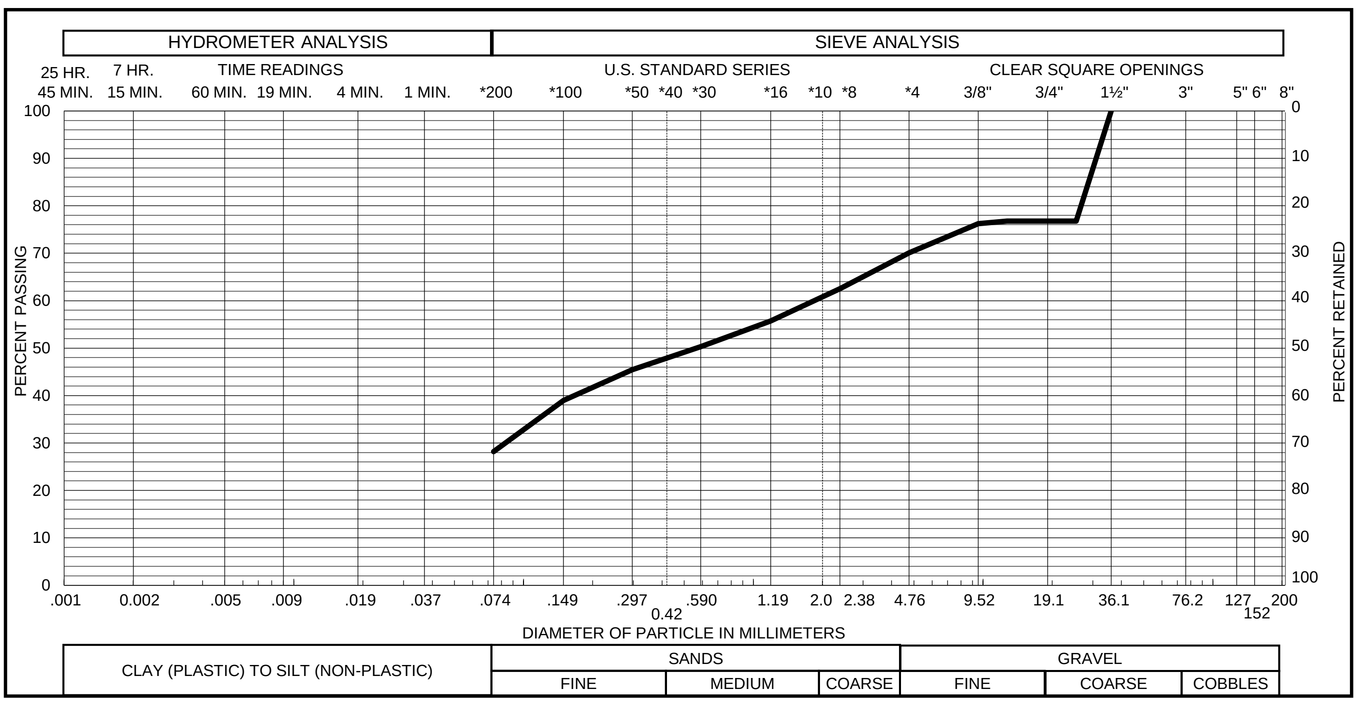
Gradation Test Results

FIGURE A-8



Sample of From: GRAVEL, SANDY, SLIGHTLY CLAYEY (GP-GC)
TH - 4 AT 4 FEET

GRAVEL 56 % SAND 37 %
SILT & CLAY 7 % LIQUID LIMIT %
PLASTICITY INDEX %



Sample of From: FILL, SAND, GRAVELLY, CLAYEY (SC)
TH - 5 AT 4 FEET

GRAVEL 30 % SAND 42 %
SILT & CLAY 28 % LIQUID LIMIT 30 %
PLASTICITY INDEX 17 %

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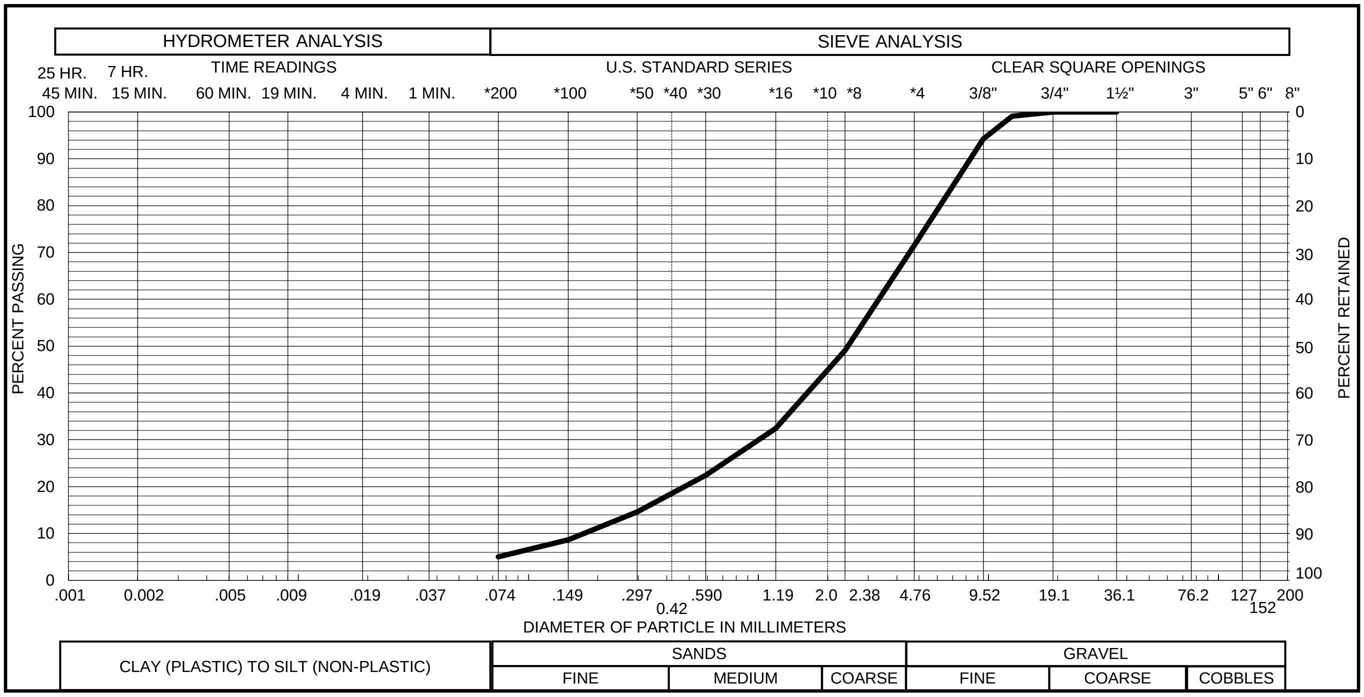
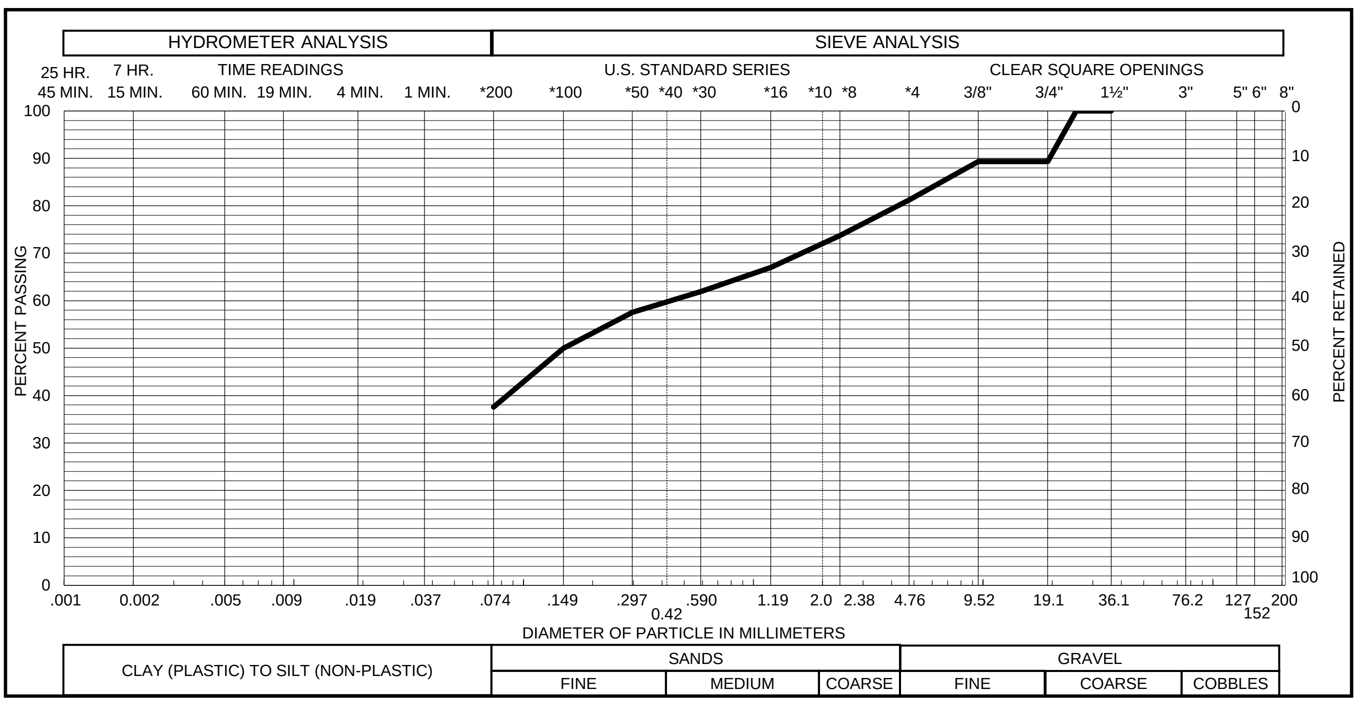
Gradation Test Results

FIGURE A-9



Sample of From: SAND, GRAVELLY, SLIGHTLY CLAYEY (SP-SC)
TH - 5 AT 9 FEET

GRAVEL 28 % SAND 67 %
SILT & CLAY 5 % LIQUID LIMIT %
PLASTICITY INDEX %



Sample of From: FILL, SAND, CLAYEY (SC)
TH - 7 AT 4 FEET

GRAVEL 19 % SAND 43 %
SILT & CLAY 38 % LIQUID LIMIT 28 %
PLASTICITY INDEX 15 %

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Gradation Test Results

FIGURE A-10

TABLE A-I

SUMMARY OF LABORATORY TESTING

BORING	DEPTH (FEET)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	SWELL TEST RESULTS* SWELL* (%)	SWELL TEST RESULTS* APPLIED PRESSURE (PSF)	PASSING NO. 200 SIEVE (%)	WATER-SOLUBLE SULFATES (%)	R-VALUE	DESCRIPTION
S-1	0-4	6.4		33	21			52		43	FILL, CLAY, SANDY (CL)
TH-1	2	13.1	118			1.7	200		<0.01		FILL, CLAY, SANDY (CL)
TH-1	4	11.0	114			0.2	500				FILL, CLAY, SANDY (CL)
TH-2	2	7.4	119			0.4	200		<0.01		FILL, CLAY, SANDY (CL)
TH-2	4	9.2	127	25	13			37			FILL, SAND, CLAYEY (SC)
TH-3	2	9.6	123			0.3	200		<0.01		FILL, CLAY, SANDY (CL)
TH-3	4	7.4	119			0.1	500				FILL, SAND, CLAYEY (SC)
TH-4	2	17.1	110			0.3	200		<0.01		FILL, SAND, CLAYEY (SC)
TH-4	4	4.0						7			GRAVEL, SANDY, SLIGHTLY CLAYEY (GP-GC)
TH-5	2	10.1	122			1.7	200		<0.01		FILL, CLAY, SANDY (CL)
TH-5	4	6.2		30	17			28			FILL, SAND, GRAVELLY, CLAYEY (SC)
TH-5	9	1.9						5			SAND, GRAVELLY, SLIGHTLY CLAYEY (SP-SC)
TH-6	2	7.5	124			0.2	200		0.01		FILL, SAND, CLAYEY (SC)
TH-6	4	19.7	105			0.5	500				FILL, CLAY, SANDY (CL)
TH-7	2	9.4	122			8.4	200		0.01		FILL, CLAY, SANDY (CL)
TH-7	4	9.3	125	28	15			38			FILL, SAND, CLAYEY (SC)
TH-8	2	11.4	116			0.5	200		0.01		FILL, SAND, CLAYEY (SC)
TH-8	4	10.2	112			0.0	500				FILL, SAND, CLAYEY (SC)

* NEGATIVE VALUE INDICATES COMPRESSION.

APPENDIX B

PAVEMENT CONSTRUCTION RECOMMENDATIONS

SUBGRADE PREPARATION

Moisture Treated Subgrade (MTS)

1. The subgrade should be stripped of organic matter, scarified, moisture treated and compacted to the specifications stated below in Item 2. The compacted subgrade should extend at least 3 feet beyond the edge of the pavement where no edge support, such as curb and gutter, are to be constructed.

2. Sandy and gravelly soils (A-1-a, A-1-b, A-3, A-2-4, A-2-5, A-2-6, A-2-7) should be moisture conditioned near optimum moisture content and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99). Clayey soils (A-6, A-7-5, A-7-6) should be moisture conditioned between optimum and 3 percent above optimum moisture content and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99).

3. Utility trenches and all subsequently placed fill should be properly compacted and tested prior to paving. As a minimum, fill should be compacted to 95 percent of standard Proctor maximum dry density.

4. Final grading of the subgrade should be carefully controlled so the design cross-slope is maintained and low spots in the subgrade that could trap water are eliminated.

5. Once final subgrade elevation has been compacted and tested to compliance and shaped to the required cross-section, the area should be proof-rolled using a minimum axle load of 18 kips per axle. The proof-roll should be performed while moisture contents of the subgrade are still within the recommended limits. Drying of the subgrade prior to proof-roll or paving should be avoided.

6. Areas that are observed by the Engineer that have soft spots in the subgrade, or where deflection is not uniform of soft or wet subgrade shall be ripped, scarified, dried or wetted as necessary and recompacted to the requirements for the density and moisture. As an alternative, those areas may be sub-excavated and replaced with properly compacted structural backfill. Where extensively soft, yielding subgrade is encountered; we recommend a representative of our office observe the excavation.

Chemically Stabilized Subgrade (CSS)

1. Utility trenches and all subsequently placed fill should be properly compacted and tested prior to subgrade preparation. As a minimum, fill should be compacted to 95 percent of standard Proctor maximum dry density.

2. The subgrade should be stripped of organic matter and should be shaped to final line and grade.

3. The contractor or owner's representative should have a mix design performed in general accordance with ASTM D 558 using the actual site soils and the approved stabilizing agent (lime, fly ash or a combination of lime and fly ash). Scheduling should allow at least two weeks for the mix design to be completed prior to construction.

4. High calcium quicklime should conform to the requirements of ASTM C 977 and ASTM C 110. Dolomitic quicklime, magnesia quicklime with magnesium oxide contents in excess of 4 percent, or carbonated quicklime should not be used.

5. Fly ash should consist of Class C in accordance with ASTM C 593 and C 618.

6. All stabilizing agents should come from the same source as used in the mix design. If the source is changed, a new mix design should be performed.

7. Stabilizing agents should be spread with a mechanical spreader from back of curb to back of curb for detached sidewalks or back of walk to back of walk for attached sidewalks, where applicable.

8. The subgrade should be mixed to the specified depth and at the specified concentration until a uniform blend of soil, stabilizing agent and water is obtained and the moisture content is at least 2 percent (for fly ash) and 3 percent (for lime) above the optimum moisture content of the design mixture (ASTM D 558).

9. If lime is used, a mellowing period of up to seven days may be required following initial mixing. Once the pH of the mixture is 12.3 or higher and the plasticity index is less than 10, the soils shall again be mixed and moisture conditioned to at least 3 percent over optimum moisture content and compacted to at least 95 percent of the mixture's maximum dry density (ASTM D 558). Up to sev-

en additional days may be required for curing prior to paving. The treated surface shall be kept moist or sealed with emulsified asphalt. Traffic should not be allowed on the surface during the mellowing and curing periods.

10. If fly ash is used, the mixture should be moisture conditioned to at least 2 percent over optimum moisture content and compacted to at least 95 percent of the mixture's maximum dry density (ASTM D 558) within 2 hours from the time of initial fly ash mixing.

11. If a lime/fly ash combination is used, the lime should be mixed first and allowed to mellow as indicated for lime treatment in item 9. Following the mellowing period, the fly ash should be added, moisture conditioned and compacted as indicated above within 2 hours of initial fly ash mixing.

12. Samples of loose, blended stabilizing agent/soil mixture should be sampled by a representative of CTL Thompson, Inc. for compressive strength testing (ASTM D 1663) to determine compliance (optional) when full credit for the FASS layer is used in the pavement thickness design.

13. Batch tickets should be supplied to the owner or owner's representative with the application area for that batch to determine compliance with the recommended proportions of fly ash to soil.

14. The subgrade should be re-shaped to final line and grade.

15. The subgrade should be sealed with a pneumatic-tire roller that is sufficiently light in weight so as to not cause hairline cracking of the subgrade.

16. Where sulfate concentrations are over 0.5 percent, a double treatment method should be performed. When a double treatment is required, the first half of the stabilizing agent should be placed, moisture treated and allowed to mellow or cure for at least two weeks. The remaining half of the stabilizing agent plus an additional 0.5 (for lime) to 2 (for fly ash) percent shall then be applied.

17. Mixing of the fly ash, lime, or lime/fly ash treated subgrade should not occur if the temperature of the soil mixture is below 40^{o}F.

18. We recommend a minimum of 2 days curing prior to paving. The surface of the stabilized area should be kept moist during the cure period by periodic, light sprinkling if needed. Strength gains will be

slower during cooler weather. Traffic should not be permitted on the treated subgrade during the curing period. The subgrade should be protected from freezing or drying at all times until paving.

19. The treated areas will gain greater strength if they are allowed to cure for 1 to 3 days prior to paving. Construction traffic on the treated subgrade prior to pavement section construction should be limited and the subgrade should be protected from freezing or drying at all times until paving.

20. Placement, mixing and compaction of stabilized subgrade should be observed and tested by a representative of our firm.

Geogrid Stabilized Subgrade (GSS)

1. Utility trenches and all subsequently placed fill should be properly compacted and tested prior to subgrade preparation. As a minimum, fill should be compacted to 95 percent of standard Proctor maximum dry density.

2. For areas identified as requiring stabilization, at least 3 feet of soil should be removed from below the subgrade elevations and discarded or stockpiled for reuse.

3. The sub-excavation should be flat so that there are no ridges or depressions prior to placement of the geogrid.

4. Tensar® BX1100 geogrid, or equal, should be placed over the sub-excavation, making any overlaps at seams per the manufacturer's recommendations.

5. Recycled concrete or other crushed, granular material should be placed and compacted over the geogrid, being careful not to cause any distortion of the geogrid. Construction equipment should not be allowed over the surface until at least 18 inches of fill overlies the geogrid.

6. The crushed concrete or other approved fill should have a maximum particle size no more than 3 inches and at least 50 percent fractured faces. The top 12 inches of the fill may consist of the native soil that was removed from the sub-excavation.

7. The native soil fill should be compacted and proof-rolled to the requirements for the MTS.

PAVEMENT MATERIALS AND CONSTRUCTION

Aggregate Base Course (ABC)

1. A Class 5 or 6 Colorado Department of Transportation (CDOT) specified ABC should be used. Reclaimed asphalt pavement (RAP) or reclaimed concrete pavement (RCP) alternative which meets the Class 5 or 6 designation and design R-value/strength coefficient is also acceptable.

2. Bases should have a minimum Hveem stabilometer value of 72, or greater. ABC, RAP, and RCP must be moisture stable. The change in R-value from 300-psi to 100-psi exudation pressure should be 12 points or less.

3. ABC, RAP or RCP bases should be placed in thin lifts not to exceed 6 inches and moisture treated to near optimum moisture content. Bases should be moisture treated to near optimum moisture content, and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99).

4. Placement and compaction of ABC, RAP, or RCP should be observed and tested by a representative of our firm. Placement should not commence until the underlying subgrade is properly prepared and tested.

Hot Mix Asphalt (HMA)

1. HMA should be composed of a mixture of aggregate, filler, hydrated lime and asphalt cement. Some mixes may require polymer modified asphalt cement, or make use of up to 20 percent reclaimed asphalt pavement (RAP). A job mix design is recommended and periodic checks on the job site should be made to verify compliance with specifications.

2. HMA should be relatively impermeable to moisture and should be designed with crushed aggregates that have a minimum of 80 percent of the aggregate retained on the No. 4 sieve with two mechanically fractured faces.

3. Gradations that approach the maximum density line (within 5 percent between the No. 4 and 50 sieves) should be avoided. A gra-

dation with a nominal maximum size of 1 or 2 inches developed on the fine side of the maximum density line should be used.

4. Total void content, voids in the mineral aggregate (VMA) and voids filled should be considered in the selection of the optimum asphalt cement content. The optimum asphalt content should be selected at a total air void content of approximately 4 percent. The mixture should have a minimum VMA of 14 percent and between 65 percent and 80 percent of voids filled.

5. Asphalt cement should meet the requirements of the Superpave Performance Graded (PG) Binders. The minimum performing asphalt cement should conform to the requirements of the governing agency.

6. Hydrated lime should be added at the rate of 1 percent by dry weight of the aggregate and should be included in the amount passing the No. 200 sieve. Hydrated lime for aggregate pretreatment should conform to the requirements of ASTM C 207, Type N.

7. Paving should be performed on properly prepared, unfrozen surfaces that are free of water, snow and ice. Paving should only be performed when both air and surface temperatures equal, or exceed, the temperatures specified in Table 401-3 of the 2006 Colorado Department of Transportation Standard Specifications for Road and Bridge Construction.

8. HMA should not be placed at a temperature lower than 245°F for mixes containing PG 64-22 asphalt, and 290°F for mixes containing polymer-modified asphalt. The breakdown compaction should be completed before the HMA temperature drops 20°F.

9. Wearing surface course shall be Grading S or SX for residential roadway classifications and Grading S for collector, arterial, industrial, and commercial roadway classifications.

10. The minimum/maximum lift thicknesses for Grade SX shall be 1½ inches/2½ inches. The minimum/maximum lift thicknesses for Grade S shall be 2 inches/3½ inches. The minimum/maximum lift thicknesses for Grade SG shall be 3 inches/5 inches.

11. Joints should be staggered. No joints should be placed within wheel paths.

12. HMA should be compacted to between 92 and 96 percent of Maximum Theoretical Density. The surface shall be sealed with a finish roller prior to the mix cooling to 185°F.

13. Placement and compaction of HMA should be observed and tested by a representative of our firm. Placement should not commence until approval of the proof rolling as discussed in the Subgrade Preparation section of this report. Sub base, base course or initial pavement course shall be placed within 48 hours of approval of the proof rolling. If the Contractor fails to place the sub base, base course or initial pavement course within 48 hours or the condition of the subgrade changes due to weather or other conditions, proof rolling and correction shall be performed again.

Portland Cement Concrete (PCC)

1. Portland cement concrete should consist of Class P of the *2005 CDOT - Standard Specifications for Road and Bridge Construction* specifications for normal placement or Class E for fast-track projects. PCC should have a minimum compressive strength of 4,200 psi at 28 days and a minimum modulus of rupture (flexural strength) of 650 psi. Job mix designs are recommended and periodic checks on the job site should be made to verify compliance with specifications.

2. Portland cement should be Type II “low alkali” and should conform to ASTM C 150.

3. Portland cement concrete should not be placed when the subgrade or air temperature is below 40°F.

4. Concrete should not be placed during warm weather if the mixed concrete has a temperature of 90°F, or higher.

5. Mixed concrete temperature placed during cold weather should have a temperature between 50°F and 90°F.

6. Free water should not be finished into the concrete surface. Atomizing nozzle pressure sprayers for applying finishing compounds are recommended whenever the concrete surface becomes difficult to finish.

7. Curing of the portland cement concrete should be accomplished by the use of a curing compound. The curing compound should be applied in accordance with manufacturer recommendations.

8. Curing procedures should be implemented, as necessary, to protect the pavement against moisture loss, rapid temperature change, freezing, and mechanical injury.

9. Construction joints, including longitudinal joints and transverse joints, should be formed during construction or sawed after the concrete has begun to set, but prior to uncontrolled cracking.

10. All joints should be properly sealed using a rod back-up and approved epoxy sealant.

11. Traffic should not be allowed on the pavement until it has properly cured and achieved at least 80 percent of the design strength, with saw joints already cut.

12. Placement of portland cement concrete should be observed and tested by a representative of our firm. Placement should not commence until the subgrade is properly prepared and tested.

APPENDIX C

MAINTENANCE PROGRAM

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 includes 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.