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By: [signature] Date: 5-20-14

City of Fort Collins
City of Fort Collins
Engineering Department

SUBGRADE INVESTIGATION
AND PAVEMENT RECOMMENDATIONS
INTERIOR ROADWAYS
BELLA VIRA SUBDIVISION
FORT COLLINS, COLORADO

Prepared For:
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Attention: Mr. Kelly Martinez

Project No. FC06224.003-135

May 19, 2014

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SCOPE

This report presents the results of our subgrade investigation and pavement design for the planned interior roadways for Bella Vira Subdivision in Fort Collins, Colorado. The purpose of our investigation was to determine the subsurface conditions and to evaluate pavement support characteristics for our pavement recommendations. The report was conducted in general conformance with Chapter 5 and 10 of the *Larimer County Urban Areas Street Standards (LCUASS)* dated January 2, 2001 (repealed and reenacted April 1, 2007) as adopted by the City of Fort Collins (City).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, laboratory test results for the construction of parts of West Elizabeth Street, Banyan Drive, Fiore Court, Sunflower Drive and Pratolina Court. If plans change significantly, we should be contacted to review our investigation and determine if our test results still apply. Detailed criteria and recommendations are contained in this report.

SUMMARY OF CONCLUSIONS

1. Soils encountered in our borings consisted of fill material comprised of sandy clay and clayey sand with gravel and clayey gravel. No groundwater was encountered in the borings.

2. The soils classified as A-6, A-2-6, and A-7-6 soils in accordance with AASHTO procedures which exhibit fair to poor subgrade support. Expansion potentials range from low to medium. Mitigation of the subgrade for swell will likely be required.

3. Recommendations for flexible (asphalt) and rigid (concrete) pavements, and chemically treated subgrade are provided.

SITE LOCATION AND PROJECT DESCRIPTION

Bella Vira Subdivision is located in a partly developed area in west Fort Collins, Colorado (Figure 1). This report includes parts of West Elizabeth Street, Banyan Drive, Fiore Court, Sunflower Drive and Pratolina Court. The installation of the sanitary sewer was completed and the roadway subgrade was roughly at grade when fieldwork for this report was conducted. Fill material was required to achieve the planned elevations for the roadways. A representative of CTL performed compaction testing of the fill during installation. The site varies in topography with a general slope to the east.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of drilling eight borings to a depth of approximately 10 feet over areas outside underground utilities. Due to the width of the sewer line trench, backfill was encountered in most of the borings located outside of the utility envelope. During drilling, our field representative logged the subsurface conditions, recorded penetration-resistance tests, and acquired samples of the subgrade materials. Borings were drilled at approximate 500-foot spacing, or less. The approximate locations of our borings are presented on Figure 1. We used 4-inch diameter solid-stem augers and a truck-mounted drill, and obtained bulk samples from the upper 4 feet of the borings and modified California samples from selected intervals. Summary logs of the borings, including results of field penetration resistance tests, are presented on Figure 2.

After the samples were returned to our laboratory, our geotechnical engineer examined the samples and assigned laboratory testing. The 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. Swell-consolidation testing was performed on samples of the subgrade soils under a pressure of 150 pounds per square foot (psf) as required under *LCUASS* to evaluate potential heave. Other laboratory tests included moisture content, dry density, Atterberg limits, gradation analysis, Hveem Stabilometer (R-value), and water-soluble sulfate tests. Results are presented in Appendix A and summarized in Table A-I.

PREVIOUS INVESTIGATIONS

Prior to this investigation, we prepared a Preliminary Geotechnical Investigation for the development under Project No. FC06224-115, dated July 8, 2013 and a Subgrade Investigation and Pavement Recommendations report for the widening of Overland Trail under Project No. FC06224.002-135, dated May 5, 2014.

SUBSURFACE CONDITIONS

Generally, the subsurface materials encountered in the borings consisted of variable sandy clay, clayey sand and clayey gravel fill. The fill was placed as overlot grading fill and backfill for underground utility installation. Our records indicate the fill was well compacted. Four samples contained 13 to 54 percent clay and silt-sized particles (passing the No. 200 sieve) with liquid limits from 31 to 41 and plasticity indices of 15 to 22. The clay classified as A-7-6 in accordance with the AASHTO classification method with a group index of 9. The sand and gravel classified as A-6 and A-2-6 with group indices ranging from 0 to 3. Swell tests indicate swells ranging from 0.6 to 3.8 percent, which represent low to moderate expansion potentials. The subgrade soils are considered to exhibit poor to fair subgrade support. A design R-value of 8 was determined for the fill material. No groundwater was encountered. Further descriptions of subsurface conditions are provided in our summary logs of on Figures 2 and 3.

WATER-SOLUBLE SULFATES

Concrete that is exposed to sulfate-rich soils can be subject to sulfate attack. If concrete 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. In addition, the performance of chemically stabilized soil can also be affected by sulfates from the formation of ettringite, which can expand and be detrimental to pavement as discussed previously.

We measured water-soluble sulfate concentrations in four samples ranging from below detectable limits to 0.50 percent with 3 samples over 0.2 percent. For this level of sulfate concentration, ACI 332-08 *Code Requirements for Residential Concrete* indicates concrete shall be made with ASTM C150 Type V cement, or an ASTM C595 or C1157 hydraulic cement meeting high sulfate-resistant hydraulic cement (HS) designation and shall have a specified minimum compressive strength of 3000 psi at 28 days. Alternative combination of cements and supplementary cementitious materials, such as Class F fly ash, shall be permitted with acceptable test records for sulfate durability.

Superficial damage may occur to the exposed surfaces of highly permeable concrete. To control this risk and to resist freeze-thaw deterioration, the water-to-cementitious materials 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 have a total air content of 6 percent ± 1.5 percent.

PAVEMENT DESIGN

The City of Fort Collins requires the use of the AASHTO and CDOT 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, minimum pavement sections, and statistical data.

Traffic Projections

The traffic projections are based on vehicle loading, traffic volume, design period, and growth factor. 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 period, which is typically 20 years. The City provided an EDLA of 15 for West Elizabeth Street, Banyan Drive and Sunflower Drive and an EDLA of 5 for Fiore Court and Pratolina Court which were converted to ESALs of 109,500 and 365,000, respectively.

Subgrade Conditions

A Hveem stabilometer test of soil resulted in R-value of 8. We converted the R-value of 8 to a resilient modulus of 3,311 psi based on CDOT criteria. Four samples of subgrade soil were tested for expansion (swell) to determine if mitigation of the subgrade soil will be required. Three samples tested had an Expansion Potential of medium (1-5 percent) based on Table 10-3 of *LCUASS*. One sample had a low expansion potential (<1 percent). *LCUASS* requires swell mitigation where swell is 2 percent or greater. Based on the results of laboratory testing and *LCUASS*, we believe that mitigation for swell will be required. We recommend that swell mitigation consists of treating the subgrade soils with fly ash.

We understand the City typically uses a prescribed amount of about 12% fly ash stabilizing agent for 12 inches of the subgrade when a mix design is not prepared. Lime may also be considered. The method of applying the stabilizing agent to the soil will depend partly on the level of water-soluble sulfates in the subgrade soil. A reaction of water-soluble sulfates in the soil and available calcium in the stabilizing agent can form the mineral ettringite, which can swell and cause detrimental effects to the pavement surface. If unacceptable concentrations of water-soluble sulfates are present in the soil, a double-application method can reduce the risk of pavement heave due to ettringite formation to an acceptable level. Our threshold limit of water-soluble sulfates in soils for single application of fly ash or lime for stabilization is 0.5 percent. Based on our test results discussed in the following section, WATER-SOLUBLE SULFATES, we believe single application is appropriate for the site. Fly ash treatment should extend underneath curbs, gutters, and attached sidewalks.

<u>Pavement Thickness Calculations</u>

We used DARWin™ software to develop our pavement thickness calculations for flexible 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 roadway types. Other input values not specified by *LCUASS* were estimated based on our experience with similar projects. Computer generated printouts of the DARWin™ calculations are presented in Appendix B. We have provided pavement design alternatives for new pavement including hot mix asphalt (HMA) on aggregate base course (ABC). Our pavement thickness alternatives are presented on Table A. Due to minimum sections provide by LCUASS, sections will be thicker than calculated for the cul-de-sac areas on Pratolina Court and Fiore Court.

TABLE A
MINIMUM PAVEMENT THICKNESS RECOMMENDATIONS

Roadways	Hot Mix Asphalt (HMA) + Aggregate Base Course (ABC)+ Fly Ash Treated Subgrade (FATS)
W. Elizabeth Street Banyan Drive Sunflower Drive ESAL = 109,500 (EDLA = 15)	4" HMA + 6" ABC+ 12" FATS
Fiore Court Patolina Court ESAL = 365,000 (EDLA = 5)	4" HMA + 6" ABC+ 12" FATS
Fiore Court Patolina Court (Cul-de-sac)	5.4" HMA + 6" ABC+ 12" FATS

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 and CDOT Standard Specifications for Road and Bridge Construction* should be followed.

Based on the results of laboratory testing and *CDOT- PDM* and *LCUASS*, we believe that mitigation for swell will not be required. However, due to the swell potential of the fill, we recommend the subgrade soils be chemically treated. The City typically uses a prescribed amount of about 12% fly ash stabilizing agent for 12 inches of the subgrade when a mix design is not prepared. We understand the City allows credit for 10 inches of the FATS with one-half strength coefficient if 12 inches of the subgrade is treated and no mix design is conducted.

The method of applying the stabilizing agent to the soil will depend partly on the level of water-soluble sulfates in the subgrade soil. A reaction of water-soluble sulfates in the soil and available calcium in the stabilizing agent can occur creating the mineral ettringite, which can swell causing detrimental effects to the pavement surface. If unacceptable concentrations of water-soluble sulfates are present in the soil, the double-application method can reduce the risk of pavement heave due to ettringite formation to an acceptable level. Concentrations of water-soluble sulfates were below detectable limits in two samples. Our threshold limit of water-soluble sulfates in soils for single application of fly ash or lime for stabilization is 0.5 percent. Based on our test results, we believe single application is appropriate for the site. Recommendations for chemically stabilized subgrades are presented in Appendix C. Preparation of the subgrade should extend from back-of walk to back-of-walk where feasible.

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. Materials planned for construction should be submitted and the applicable laboratory tests performed to verify compliance with the specifications.

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 D.

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.

SURFACE DRAINAGE

A primary cause of premature pavement deterioration is infiltration of water into the pavement system. This increase in moisture content usually results in the softening of base course and subgrade soil and eventual failure of the pavement. In addition, parts of Colorado experience many freeze-thaw cycles each season that can result in deterioration of the pavement. We recommend that subgrade, pavement, and surrounding ground surface be sloped to cause surface water to run off rapidly and away from pavements. Backs of curbs and gutters should be backfilled with compacted fill and sloped to prevent ponding adjacent to backs of curbs and to paving. The final grading of the subgrade should be carefully controlled so the pavement design cross-section can be maintained. Low spots in the subgrade that can trap water should be eliminated. Seals should be provided within the curb and pavement and in all joints to reduce the possibility of water infiltration.

LIMITATIONS

This report was prepared from data developed during our field exploration, laboratory testing, engineering analysis, and experience with similar conditions. The borings were spaced to obtain a reasonably accurate understanding of the subsurface conditions, and are representative of conditions encountered only at the exact boring locations. Variations in subsurface conditions not indicated by our borings are always possible. 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.

A representative of our firm should observe subgrade preparation and pavement construction. Our representative should also conduct tests of construction materials for compliance with recommendations presented in this report and/or specifications of the controlling agency.

Due to the evolving nature of site characterization, pavement design methods, standards, and practices, the information and recommendations provided in this report are only valid for one year following the date of issue. Following that time, our office should be contacted to determine if any updated recommendations and design criteria are merited.

We believe this investigation was conducted in a manner consistent with that level of skill and care ordinarily used by members of the profession currently practicing under similar conditions in the locality of this project. 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 subsurface conditions on design of the pavements, please contact the undersigned.

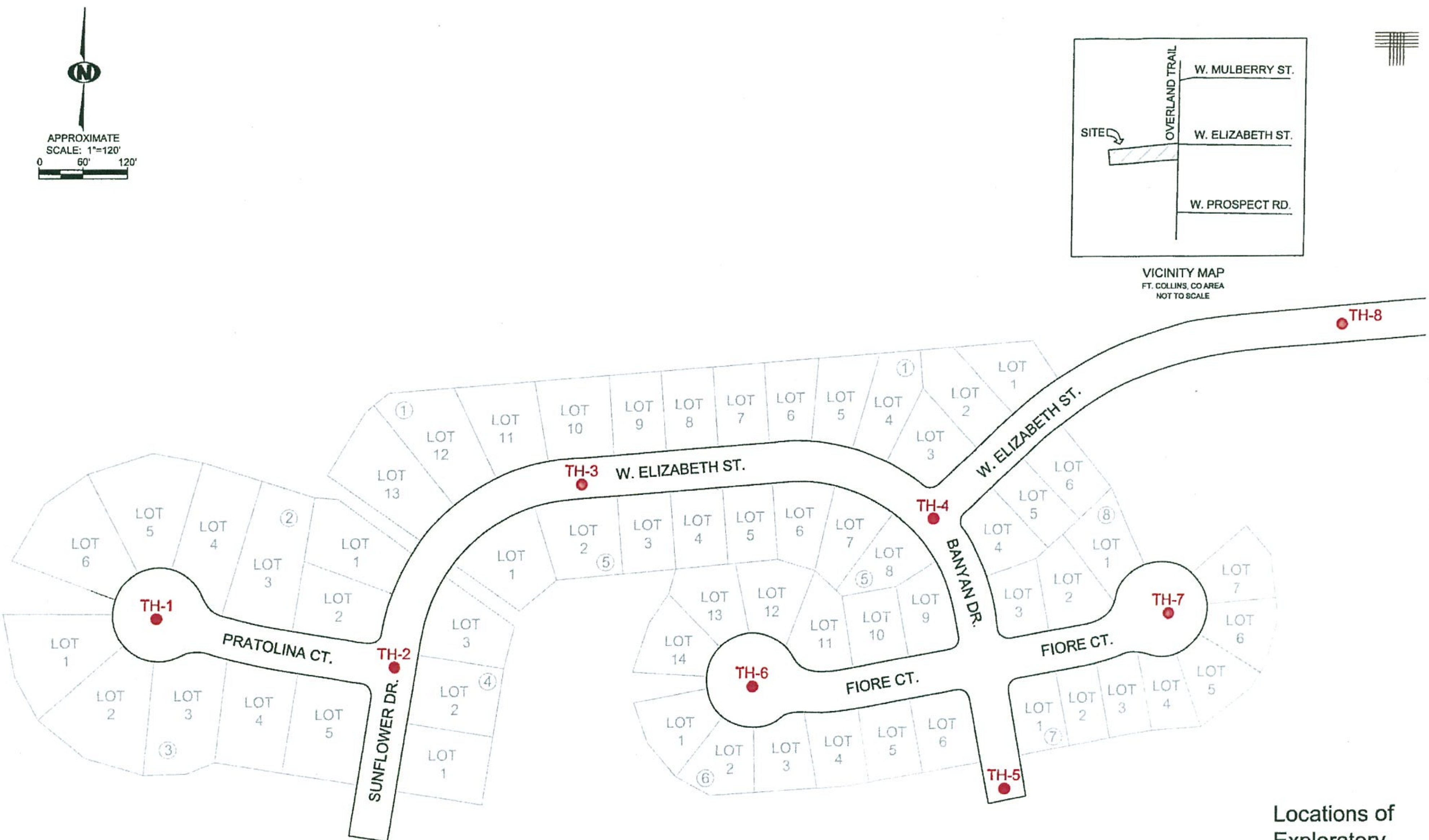
CTL | THOMPSON, INC. by:

COLORADO LICENSED SPENCER A. SCHRAM 46576 MAY 19 2014 PROFESSIONAL ENGINEER

Spencer Schram, PE
Project Manager

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS CERTIFICATE NUMBER 10346 AIPG THOMAS W. FINLEY CERTIFIED PROFESSIONAL GEOLOGIST

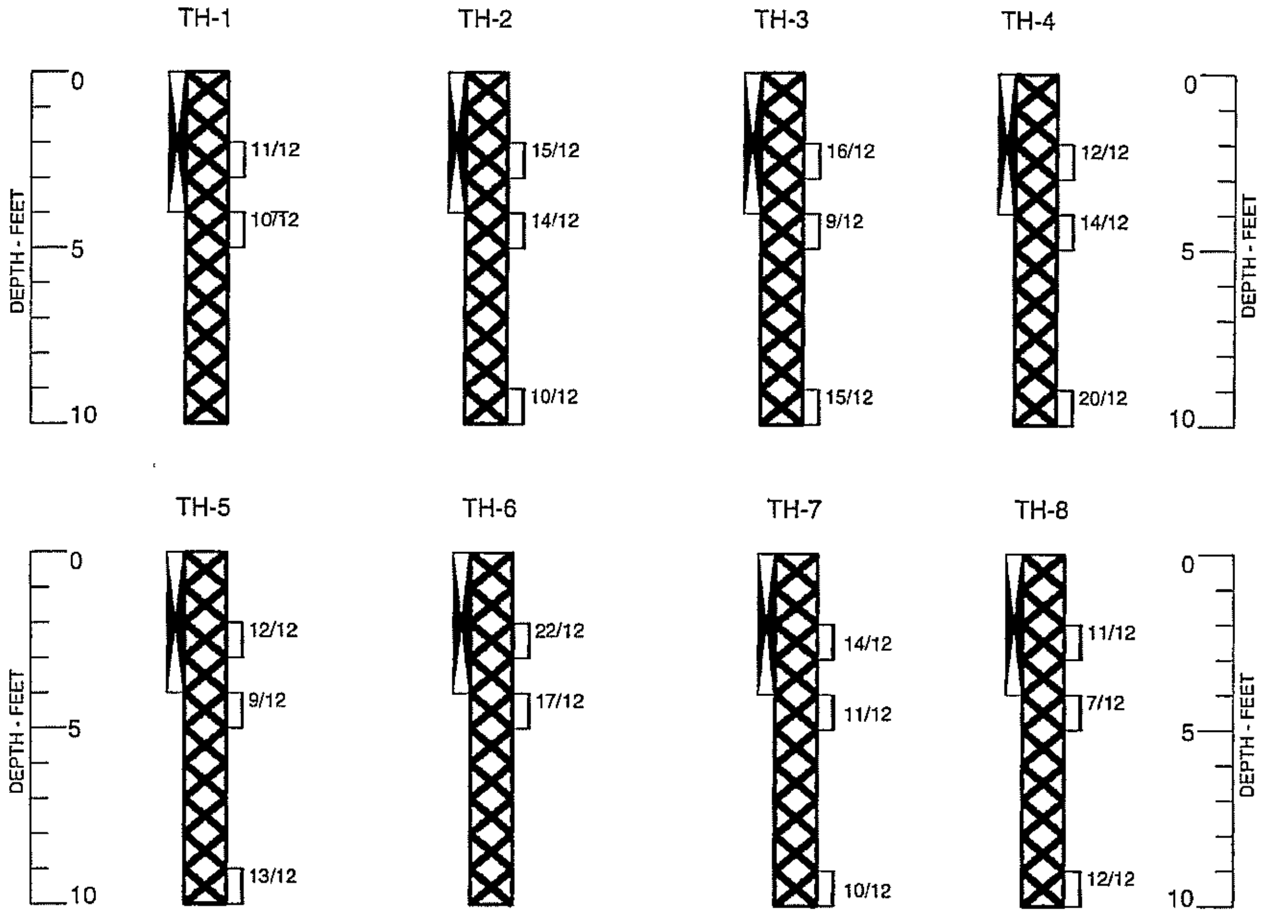
Thomas W. Finley, CPG
Senior Geologist



Locations of Exploratory Borings

FIGURE 1

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL I T PROJECT NO. FC06224.003-120



LEGEND:

FILL; CLAY, SANDY, WITH OCCASIONAL GRAVEL, STIFF TO VERY STIFF; SAND, CLAYEY WITH OCCASIONAL GRAVEL, MEDIUM DENSE; AND GRAVEL, CLAYEY, MEDIUM DENSE, SLIGHTLY MOIST TO MOIST , BROWN, YELLOWISH BROWN, DARK BROWN, TAN (CL, SC, GC)

DRIVE SAMPLE. THE SYMBOL 11/12 INDICATES 11 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.

NOTES:

1. THE BORINGS WERE DRILLED ON APRIL 19, 2014 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.

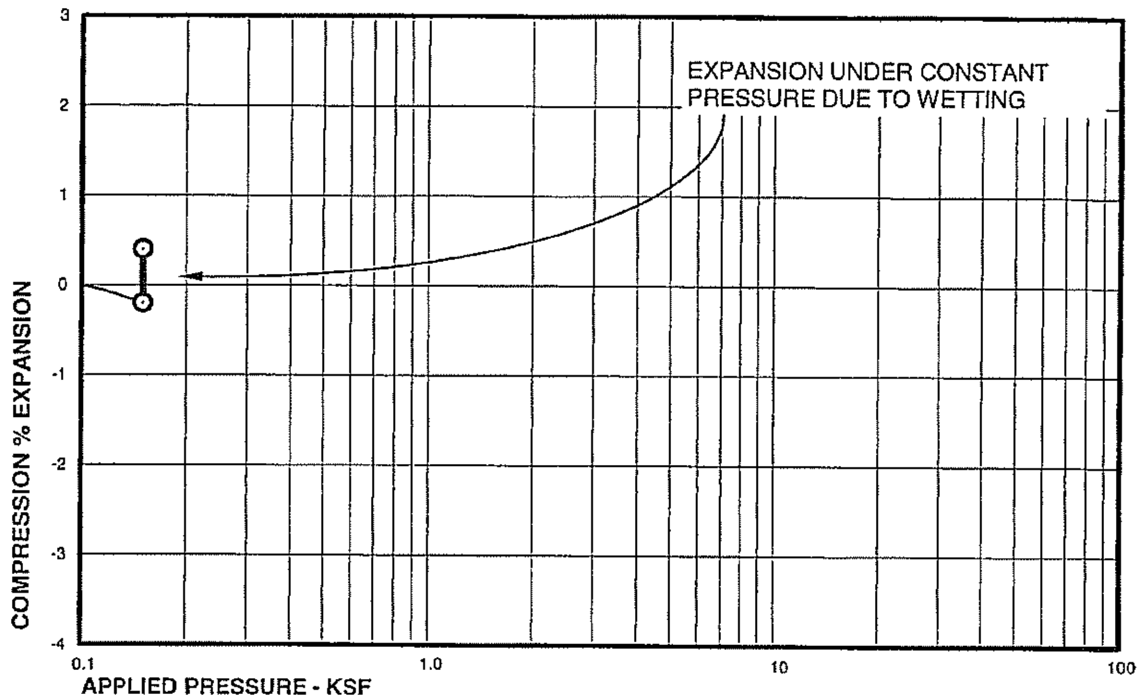
Summary Logs of Exploratory Borings

FIGURE 2

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO FC06224.003-135

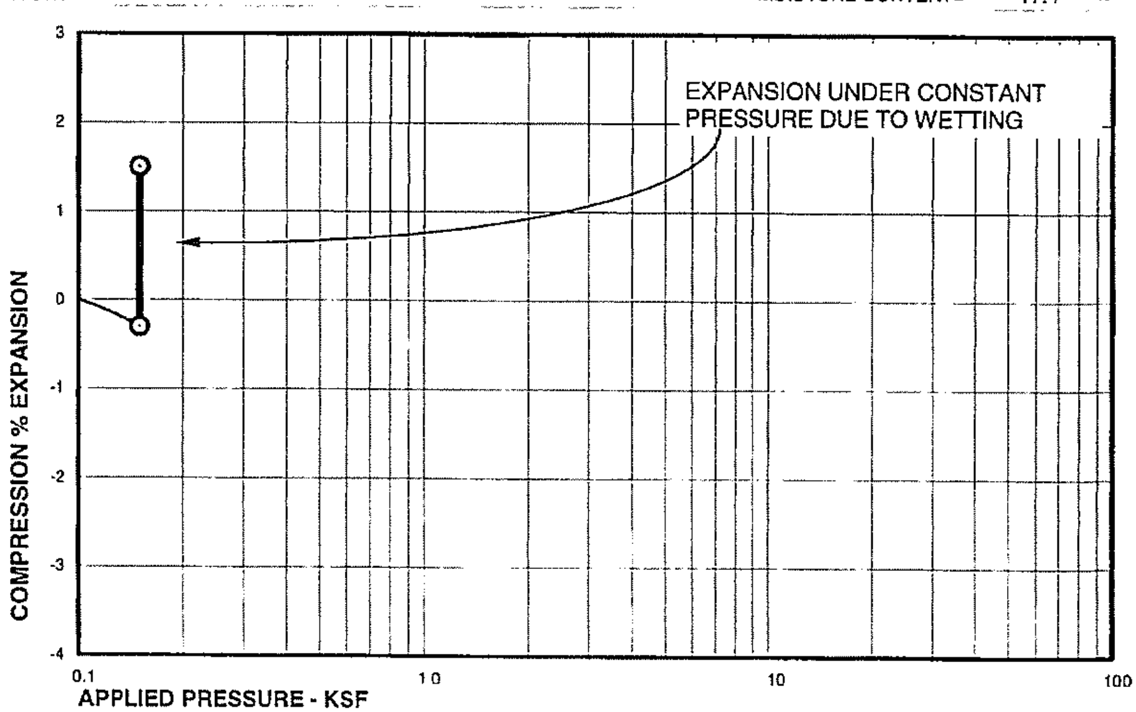
APPENDIX A

RESULTS OF LABORATORY TESTING



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

DRY UNIT WEIGHT= 109 PCF
MOISTURE CONTENT= 17.4 %



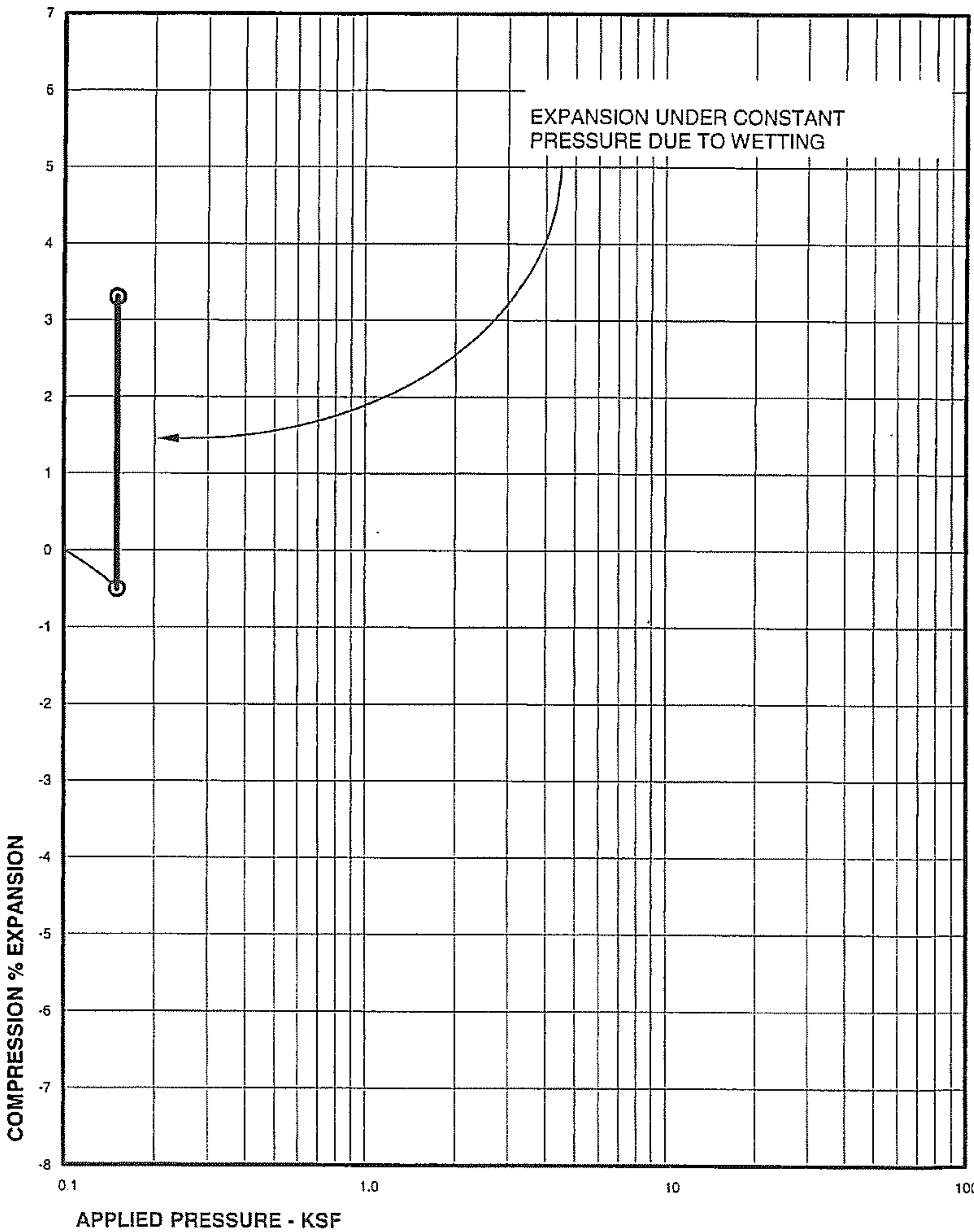
Sample of FILL, CLAY, SANDY (CL)
From TH - 4 AT 2 FEET

DRY UNIT WEIGHT= 109 PCF
MOISTURE CONTENT= 16.6 %

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO. FC06224.003-135

Swell Consolidation Test Results

FIGURE A-1



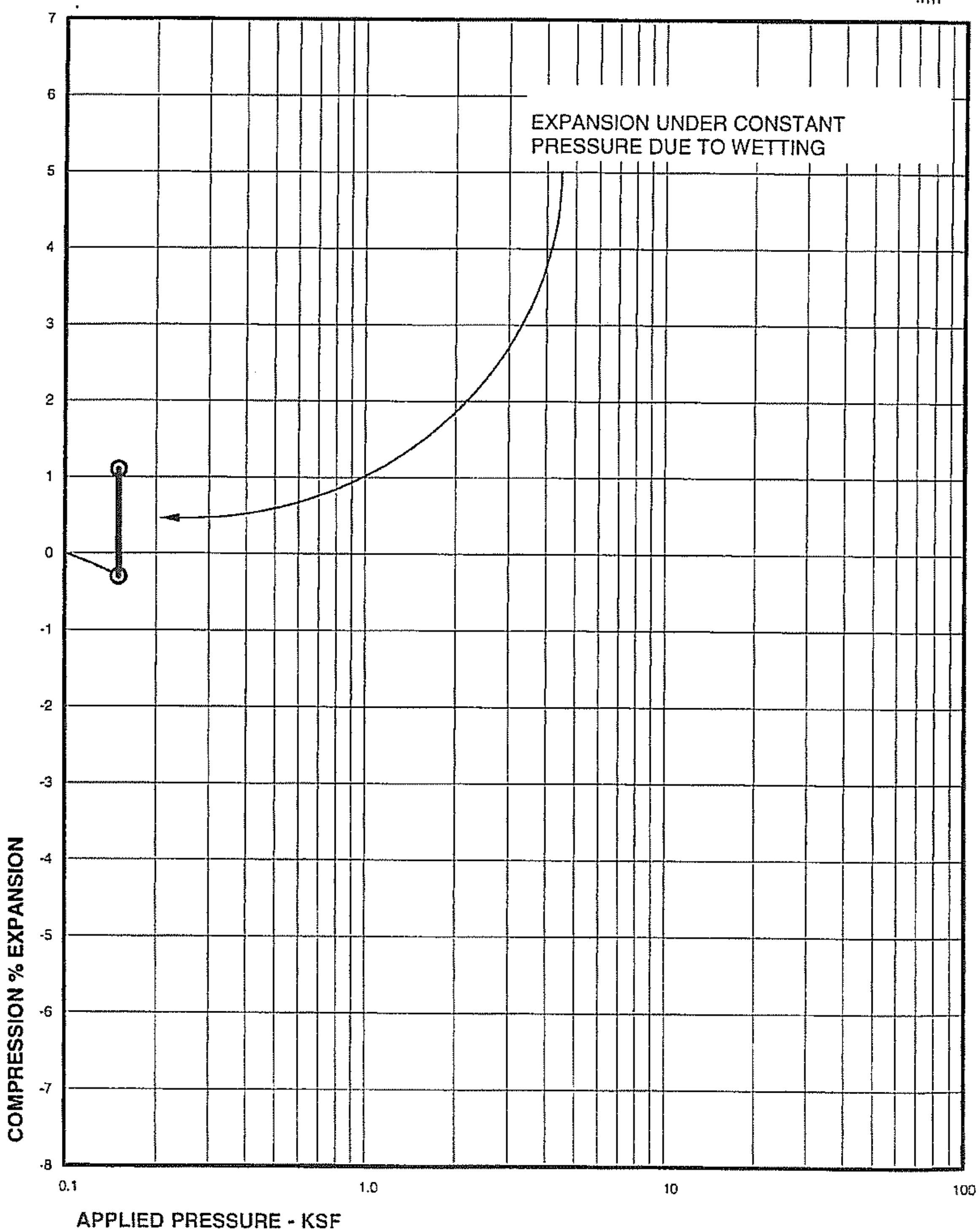
Sample of FILL, CLAY, SANDY (CL)
From TH - 6 AT 2 FEET

DRY UNIT WEIGHT= 118 PCF
MOISTURE CONTENT= 14.0 %

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO. FC06224.003-135

Swell Consolidation Test Results

FIGURE A-2



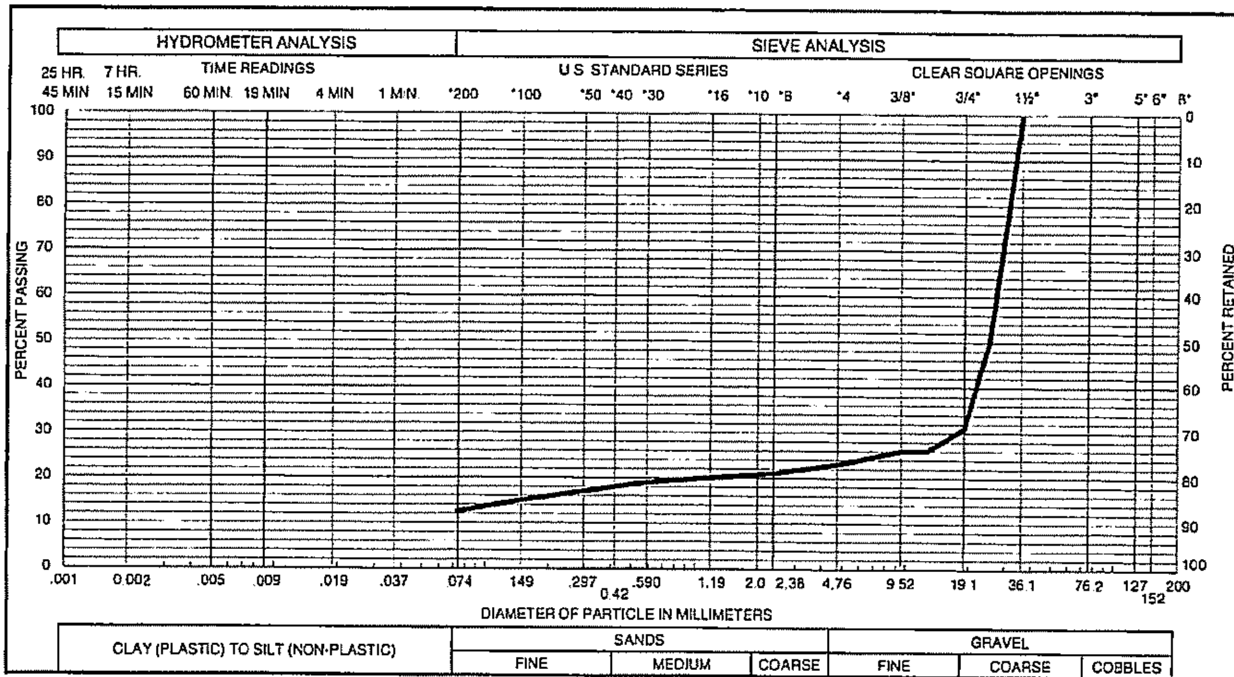
Sample of FILL, CLAY, SANDY (CL)
From TH - 8 AT 2 FEET

DRY UNIT WEIGHT= 101 PCF
MOISTURE CONTENT= 21.9 %

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO. FC06224.003-135

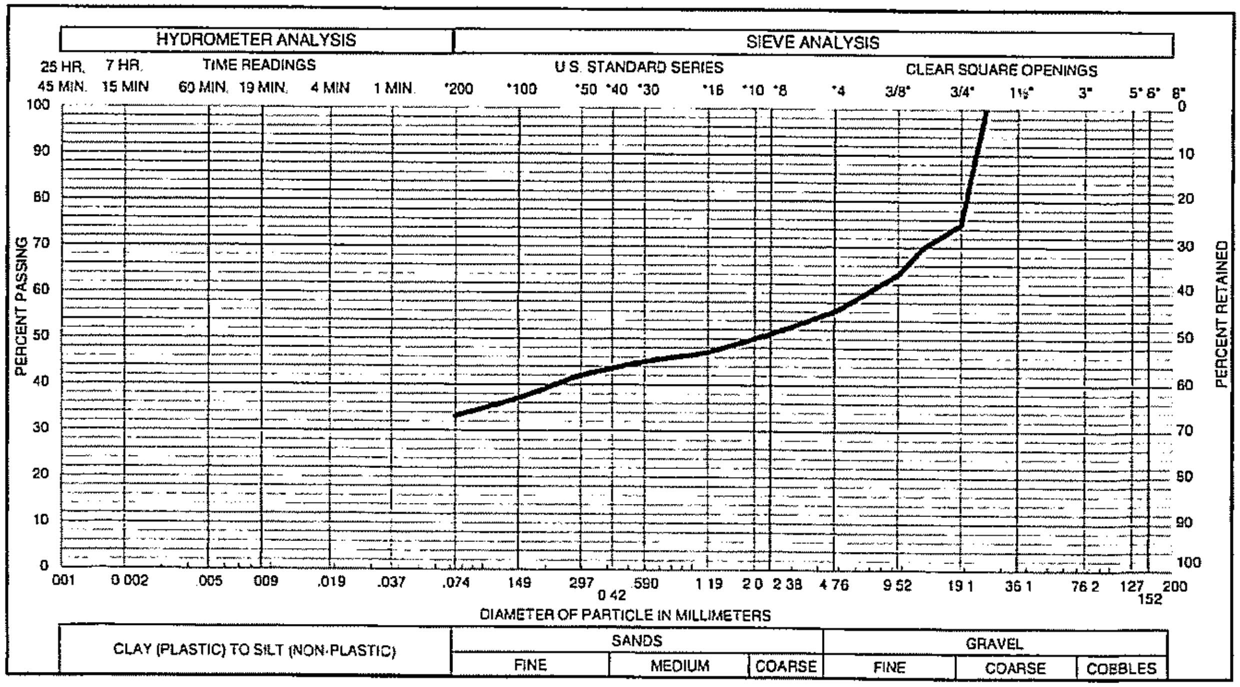
Swell Consolidation Test Results

FIGURE A-3



Sample of FILL, GRAVEL, CLAYEY (GC)
From TH - 1 AT 4 FEET

GRAVEL 77 % SAND 10 %
SILT & CLAY 13 % LIQUID LIMIT 31 %
PLASTICITY INDEX 15 %



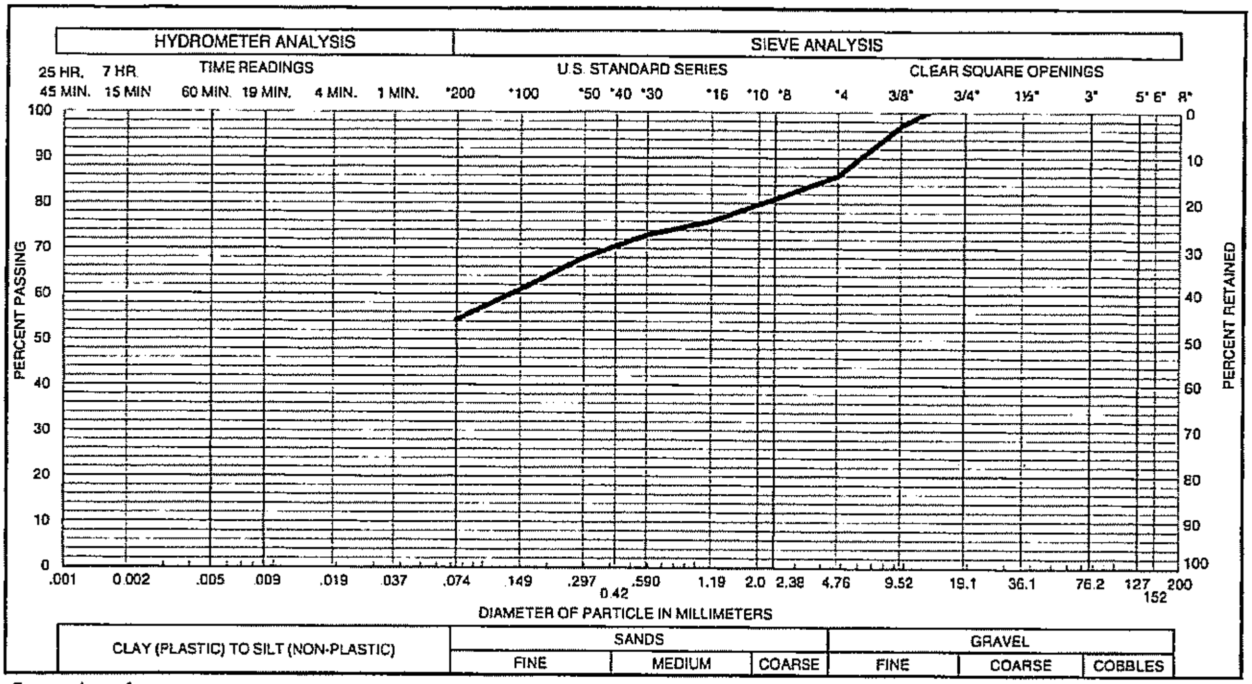
Sample of FILL, SAND, CLAYEY (SC)
From TH - 3 AT 2 FEET

GRAVEL 44 % SAND 23 %
SILT & CLAY 33 % LIQUID LIMIT 39 %
PLASTICITY INDEX 22 %

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO. FC06224.003-135

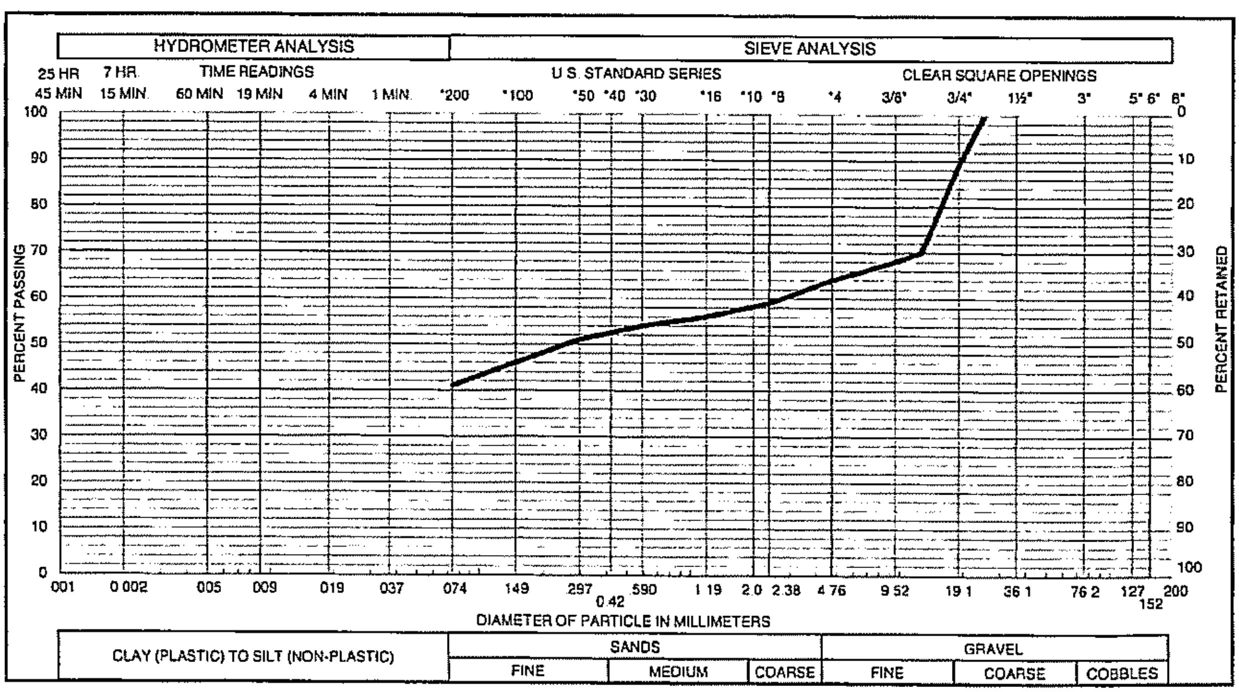
Gradation Test Results

FIGURE A-4



Sample of FILL, CLAY, SANDY (CL)
From TH - 5 AT 4 FEET

GRAVEL	14 %	SAND	32 %
SILT & CLAY	54 %	LIQUID LIMIT	41 %
PLASTICITY INDEX			22 %



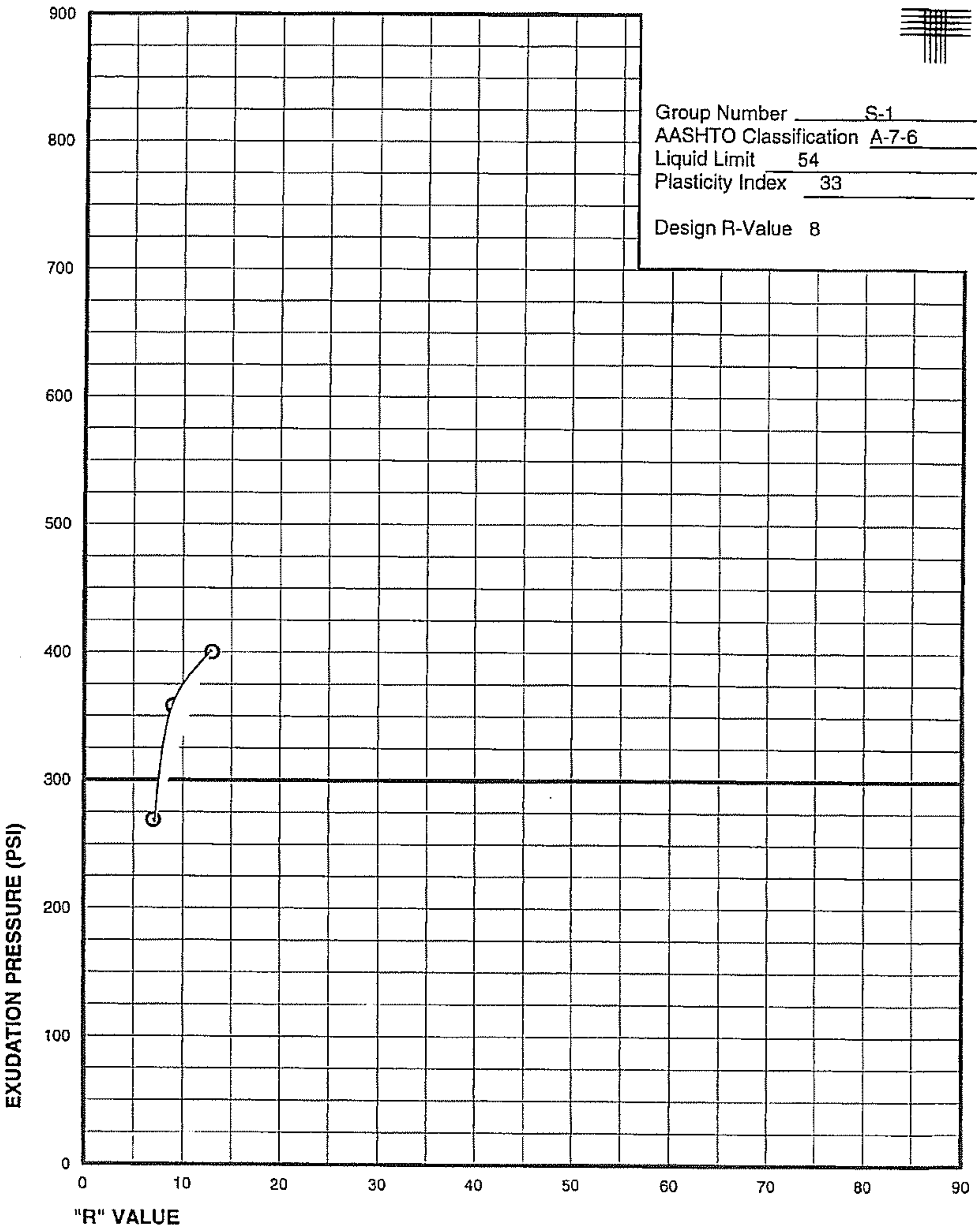
Sample of FILL, SAND, CLAYEY (SC)
From TH - 7 AT 2 FEET

GRAVEL	36 %	SAND	23 %
SILT & CLAY	41 %	LIQUID LIMIT	36 %
PLASTICITY INDEX			16 %

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA SUBDIVISION
CTL | T PROJECT NO. FC06224.003-135

Gradation Test Results

FIGURE A-5



RICHMOND AMERICAN HOMES
OVERLAND TRAIL WIDENING AT BELLA VIRA
CTL | T PROJECT NO. FC06224.003-135

Hveem Stabilometer Test Results

FIGURE A-6

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 (%)	AASHTO CLASSIFICATION (GROUP INDEX)	R-VALUE	DESCRIPTION
S-1											8	FILL, CLAY, SANDY (CL)
TH-1	4	7.6		31	15			13		A-2-6(0)		FILL, GRAVEL, CLAYEY (GC)
TH-2	2	17.4	109			0.6	150		0.32			FILL, CLAY, SANDY (CL)
TH-3	2	10.3	118	39	22			33		A-2-6(2)		FILL, SAND, CLAYEY (SC)
TH-4	2	16.6	109			1.8	150		0.15			FILL, CLAY, SANDY (CL)
TH-5	4	14.6	113	41	22			54		A-7-6(9)		FILL, CLAY, SANDY (CL)
TH-6	2	14.0	118			3.8	150		0.50			FILL, CLAY, SANDY (CL)
TH-7	2	11.7		36	16			41		A-6(3)		FILL, SAND, CLAYEY (SC)
TH-8	2	21.9	101			1.4	150		<0.01			FILL, CLAY, SANDY (CL)

* NEGATIVE VALUE INDICATES COMPRESSION.

APPENDIX B

PAVEMENT DESIGN CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

CTL Thompson, Inc.

Flexible Structural Design Module

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA
CTL|T PROJECT NO. FC06224.003-135
(Elizabeth Street, Banyon Drive, and Sunflower Drive)

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	109,500
Initial Serviceability	4.5
Terminal Serviccability	2
Reliability Level	75 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,311 psi
Stage Construction	1
Calculated Design Structural Number	2.83 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HMA	0.44	1	4	24	1.76
2	ABC	0.11	1.05	6	24	0.69
3	FATS	0.05	1	10	24	0.50
Total	-	-	-	20.00	-	2.95

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

CTL Thompson, Inc.

Flexible Structural Design Module

RICHMOND AMERICAN HOMES
INTERIOR ROADWAYS, BELLA VIRA
CTL|T PROJECT NO. FC06224.003-135
(Fiore Court and Pratolina Court)

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	36,500
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	80 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,311 psi
Stage Construction	1
Calculated Design Structural Number	2.47 in

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(in)	Width (ft)	Calculated SN (in)
1	HMA	0.44	1	4	24	1.76
2	ABC	0.11	1.05	6	24	0.69
3	FATS	0.05	1	10	24	0.50
Total	-	-	-	20.00	-	2.95

APPENDIX C

PAVEMENT CONSTRUCTION RECOMMENDATIONS

SUBGRADE PREPARATION

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 seven 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°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.

PAVEMENT MATERIALS AND CONSTRUCTION

Aggregate Base Course (ABC)

1. A Class 5 or 6 Colorado Department of Transportation (CDOT) specified ABC should be used.

2. Bases should have a minimum Hveem stabilometer value of 72, or greater. ABC 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 gradation 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.

APPENDIX D

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.