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APPROVED

By: [signature] Date: 3-16-16

City of Fort Collins
City of Fort Collins Engineering Department

SUBGRADE INVESTIGATION AND PAVEMENT DESIGN RECOMMENDATIONS PHASE 1 - PAVEMENTS KECHTER FARM FILING 2 FORT COLLINS, COLORADO

Prepared For:
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Project No. FC06547.010-135

March 8, 2016

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TABLE OF CONTENTS

SCOPE

This report presents the results of our subgrade investigation and pavement design for the planned interior roadways of Phase 1 of Kechter Farm subdivision, Filing 2 in Fort Collins, Colorado. The purpose of our investigation was to determine the subsurface conditions and to evaluate pavement support characteristics for pavement recommendations. The report was conducted in general conformance with the Chapter 5 of the *Larimer County Urban Areas Street Standards (LCUASS)* dated January 2, 2001 (repealed and reenacted April 1, 2007) as adopted by the City of Fort Collins (City).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, and laboratory test results. 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 contained in the report.

SUMMARY OF CONCLUSIONS

1. Soils encountered in our borings generally consisted of natural sandy clay to the depths explored. No groundwater was encountered in the borings. Further descriptions of these materials are presented in the body of the report.

2. The subgrade soils classified as A-6 and A-7-6, which are expected to exhibit fair to poor subgrade support.

3. Mitigation for soft subgrade and potential swell is recommended. Mitigation will likely consist of treating the subgrade with fly ash.

4. Asphaltic concrete and Portland cement concrete are appropriate surface pavements. Minimum pavement recommendations are provided in this report.

SITE LOCATION AND PROJECT DESCRIPTION

The project site is located adjacent to a developed setting and rural-residential area in southeast Fort Collins, Colorado (Figure 1). The project includes improvements to a portion of Fall Harvest Way, and Meadow Grass Court and Foothills View Place. At the time of our investigation, roadways were rough graded and buried utilities were installed.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of drilling six borings to a depth of approximately 10 feet. The approximate locations of our borings are presented on Figure 1. The borings were drilled with 4-inch diameter solid-stem augers and a truck-mounted drill. Our field representative logged the soils encountered and collected samples. Bulk samples were obtained from the upper 4 feet of the borings and drive samples were obtained from selected intervals within the borings. Drive samples were collected by driving a modified California sampler twelve inches with blows of a 140-pound hammer falling 30 inches. This method is similar to the standard penetration test and is typical for local practice. Summary logs of the borings, including field penetration test results, are presented on Figure 2.

Samples were returned to our laboratory and examined by the geotechnical engineer for this project. Laboratory testing was conducted in general accordance with AASHTO and ASTM methods to determine classifications and subgrade support values. Laboratory testing included moisture content, dry density, swell-consolidation, water-soluble sulfates, and gradation analyses. Swell tests were wetted at a confining pressure of 150 pounds per square foot (psf) as required by *LCUASS*. Results of our laboratory tests are presented in Appendix A and summarized in Table A-I.

Previous Investigation

CTL|Thompson, Inc. completed previous subgrade and pavement investigations for Kechter Farm Filing 1, Phases 1 through 4. Information from our previous investigations were considered in preparation of this report.

SUBSURFACE CONDITIONS

Soils encountered in our borings generally consisted of natural sandy clay to the depths explored. No groundwater was encountered in the borings. The clays classified as medium stiff to very stiff based on field penetration test results. Swell testing of three samples indicated swell potentials of up to 1.7 percent. Atterberg limits testing indicated moderate to high plasticity. Particle size analyses indicated fines contents (percent passing the No. 200 sieve) of 63 to 84 percent. Further descriptions of the subsurface conditions can be found on our boring logs (Figure 2) and in our laboratory test results (Appendix A).

PAVEMENT DESIGN

We understand roadway improvements for this project will be regulated by the City of Fort Collins, which 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, number of construction stages, 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. Table A presents the EDLA provided for each roadway by the City and calculated ESAL.

TABLE A
DESIGN EDLA AND ESAL VALUES

Roadway	EDLA	ESAL
Fall Harvest Way	15	109,500
Foothills View Place, Meadow Grass Court	10	73,000

Subgrade and Groundwater Conditions

The subgrade soils consist of sandy clays that classify as A-6 and A-7-6 in accordance with AASHTO classification methods. A Hveem stabilometer test of a composite sample of the subgrade soil resulted in an R-value of 11. For this soil, we believe a design R-value of 5 is more appropriate.

No subgrade soils exhibited swelling that will require stabilization. However, the previous investigation for Phase 1 showed swell in some samples that require stabilization prior to the application of road base to reduce swell. Soft, yielding soil is likely in some areas due to high moisture contents. Stabilization should also improve support over soft soils. Based on these considerations and to be consistent with adjoining roadways, we recommend the subgrade soil be stabilized. Fly-ash treated subgrade is commonly used in this area to improve stability of swelling and soft soil. Water-soluble sulfate tests indicate a single application of fly-ash is applicable to this site.

Pavement Thickness Calculations

We used 1993 AASHTO pavement design procedures to develop our pavement thickness calculations 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 would 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*. Hveem testing of a composite sample of the subgrade soil in the laboratory resulted in a design R-value of 5, which we converted to a resilient modulus of 3,020 psi based on CDOT criteria. For rigid pavement design, we estimated a modulus of subgrade reaction (k-value) of 100 psi/in based on degree of saturation and soil classification.

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 included one-half credit towards fly ash stabilized subgrade soils.

We have provided pavement design alternatives for new construction and/or reconstruction 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)+ Chemically Stabilized Subgrade (CSS)	Portland Cement Concrete (PCC) + Chemically Stabilized Subgrade (CSS)
Fall Harvest Way ESAL = 109,500	5" HMA + 6" ABC + 12" CSS	6" PCC + 12" CSS
Foothills View Place, Meadow Grass Court ESAL = 73,000	4" HMA + 6" ABC + 12" CSS	6" PCC + 12" CSS

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 and CDOT Standard Specifications for Road and Bridge Construction* should be followed. Subgrade preparation will only apply to areas planned for new construction.

Based on the results of laboratory testing, *LCUASS,* and experience with similar soils of the area, we recommend mitigation for swell and soft soils. We understand for swell mitigation, the City typically uses a prescribed amount of about 12 percent fly ash stabilizing agent for 12 inches of the subgrade when a mix design is not prepared. Lime may also be considered as an effective stabilizing agent for this project. If a mix design with the selected chemical stabilizing agent is performed and a strength gain specified in *LCUASS* is achieved, credit is allowed towards a reduction in the recommended thicknesses of pavement materials. Minimum 7-day compressive strengths of 150 psi for fly ash treated subgrade and 160 psi for lime treated subgrade, verified with field tests from samples obtained during the field mixing operations, are required for full credit. In the event swell is not reduced to 2 percent or less, we should be consulted to amend our recommendations.

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 measured in three samples at or below 0.03 percent. 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.

WATER-SOLUBLE SULFATES

In addition to the interaction of water-soluble sulfates with chemical treatment agents, 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 three samples from this site. Concentrations were at or below 0.03 percent.

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.

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 has been prepared for the exclusive use of Toll Brothers Inc. for the purpose of providing geotechnical design and construction criteria for the proposed project. 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 existing pavements and subsurface conditions. The borings 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.

Due to the changing nature of site characterization, 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 provide, if necessary, any updated recommendations as appropriate for the engineering methodologies used at that time.

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 call.

CTL | THOMPSON, INC. by:

Trace S. Krausse, EI
Staff Geotechnical Engineer

Spencer Schram, P.E.
Project Engineer

COLORADO LICENSED PROFESSIONAL ENGINEER SPENCER A. SCHRAM 46576 MAR 09 2018

(2 Copies)

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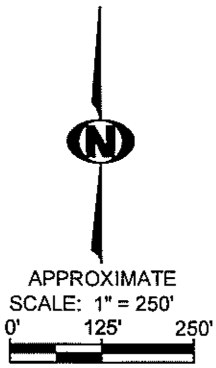
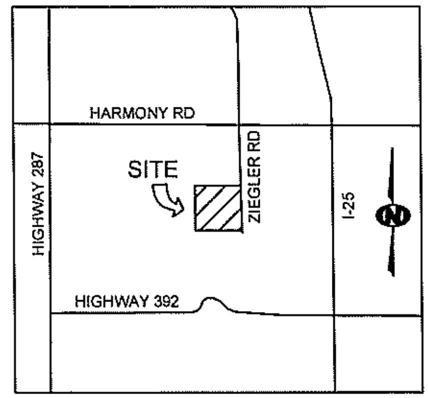


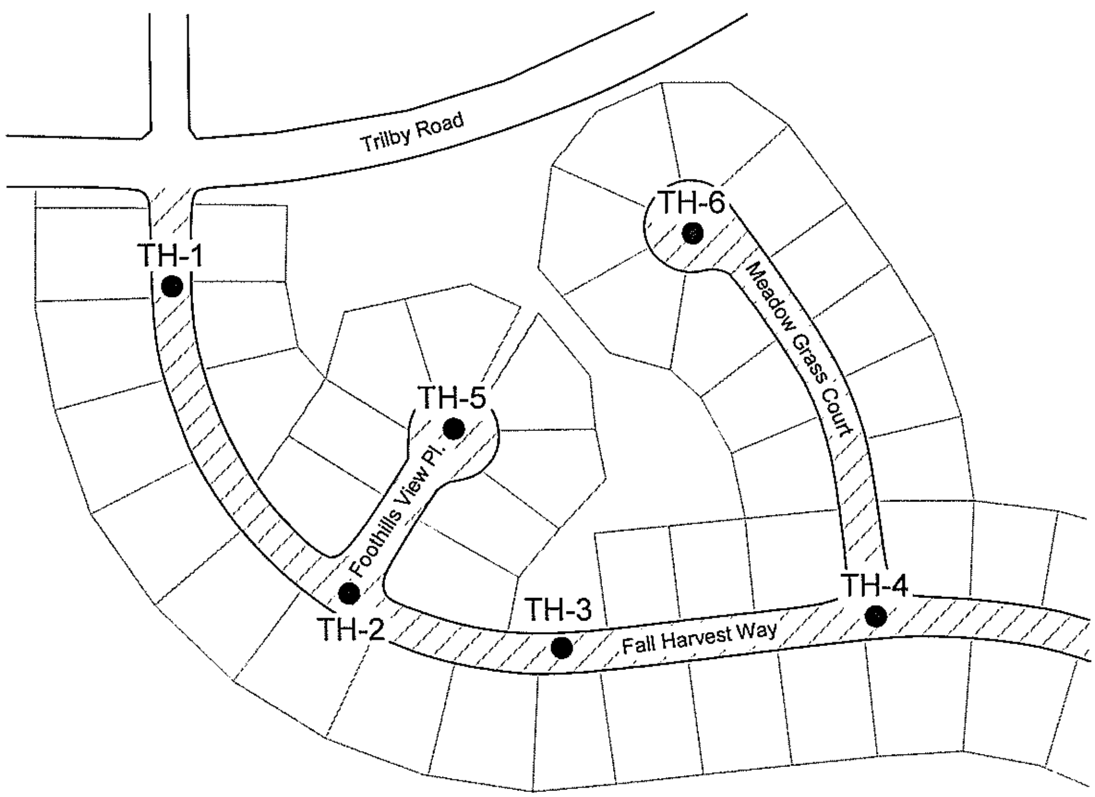


VICINITY MAP
FORT COLLINS, COLORADO
NOT TO SCALE

LEGEND:

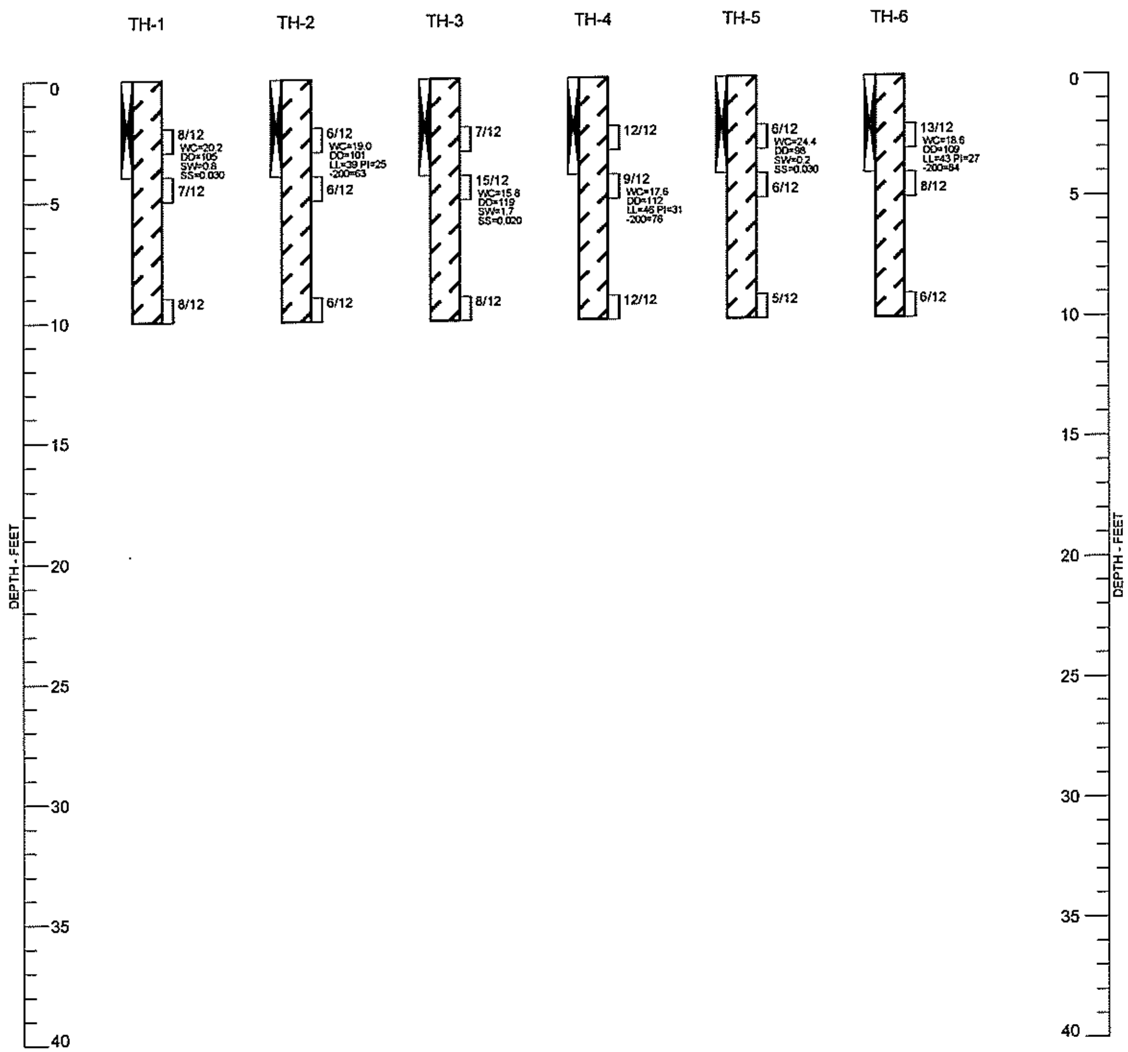
TH-1 ● INDICATES APPROXIMATE LOCATION OF EXPLORATORY BORING

▨ INDICATES ROADWAYS INCLUDED IN THIS INVESTIGATION



Locations of Exploratory Borings

FIGURE 1



LEGEND:

CLAY, SANDY, MOIST, MEDIUM STIFF TO STIFF, BROWN (CL)

DRIVE SAMPLE. THE SYMBOL 8/12 INDICATES 8 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 FEBRUARY 19, 2016, 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.

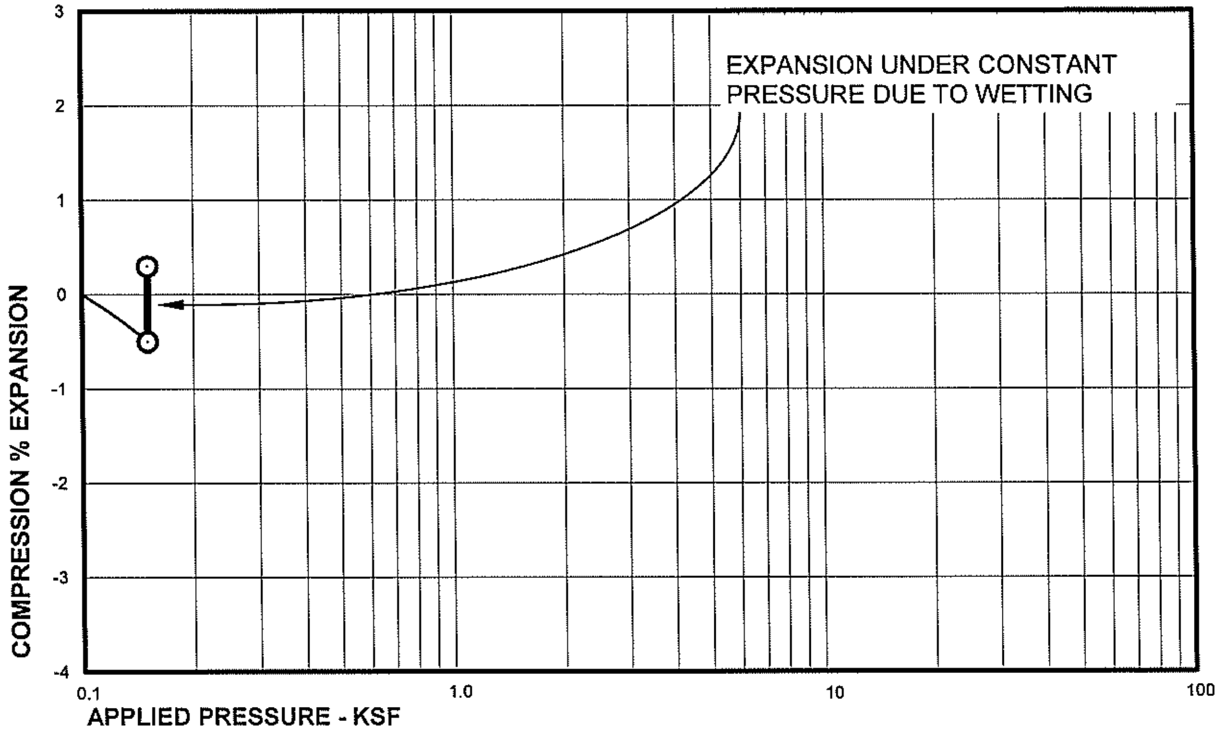
3. WC - INDICATES MOISTURE CONTENT (%).
DD - INDICATES DRY DENSITY (PCF).
SW - INDICATES SWELL WHEN WETTED UNDER OVERBURDEN PRESSURE (%).
-200 - INDICATES PASSING NO. 200 SIEVE (%).
LL - INDICATES LIQUID LIMIT.
PI - INDICATES PLASTICITY INDEX.
UC - INDICATES UNCONFINED COMPRESSIVE STRENGTH (PSF).
SS - INDICATES SOLUBLE SULFATE CONTENT (%).

Summary Logs of Exploratory Borings

FIGURE 2

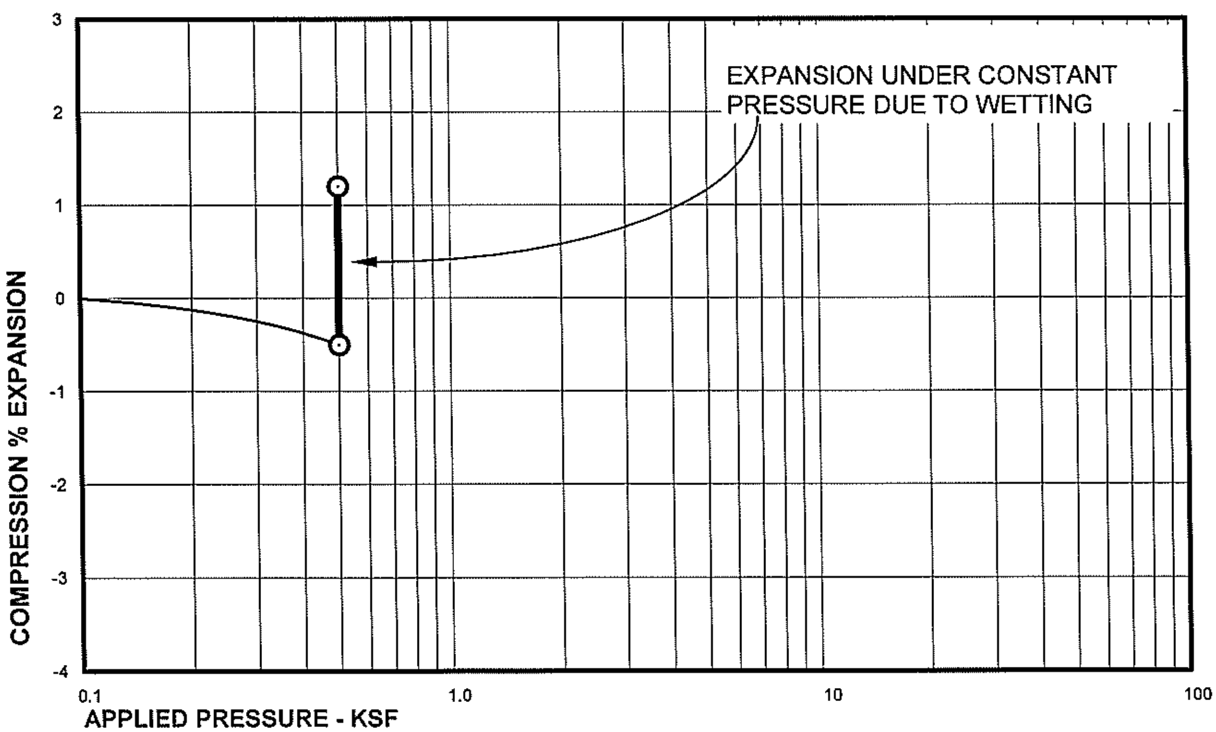
APPENDIX A

RESULTS OF LABORATORY TESTING



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

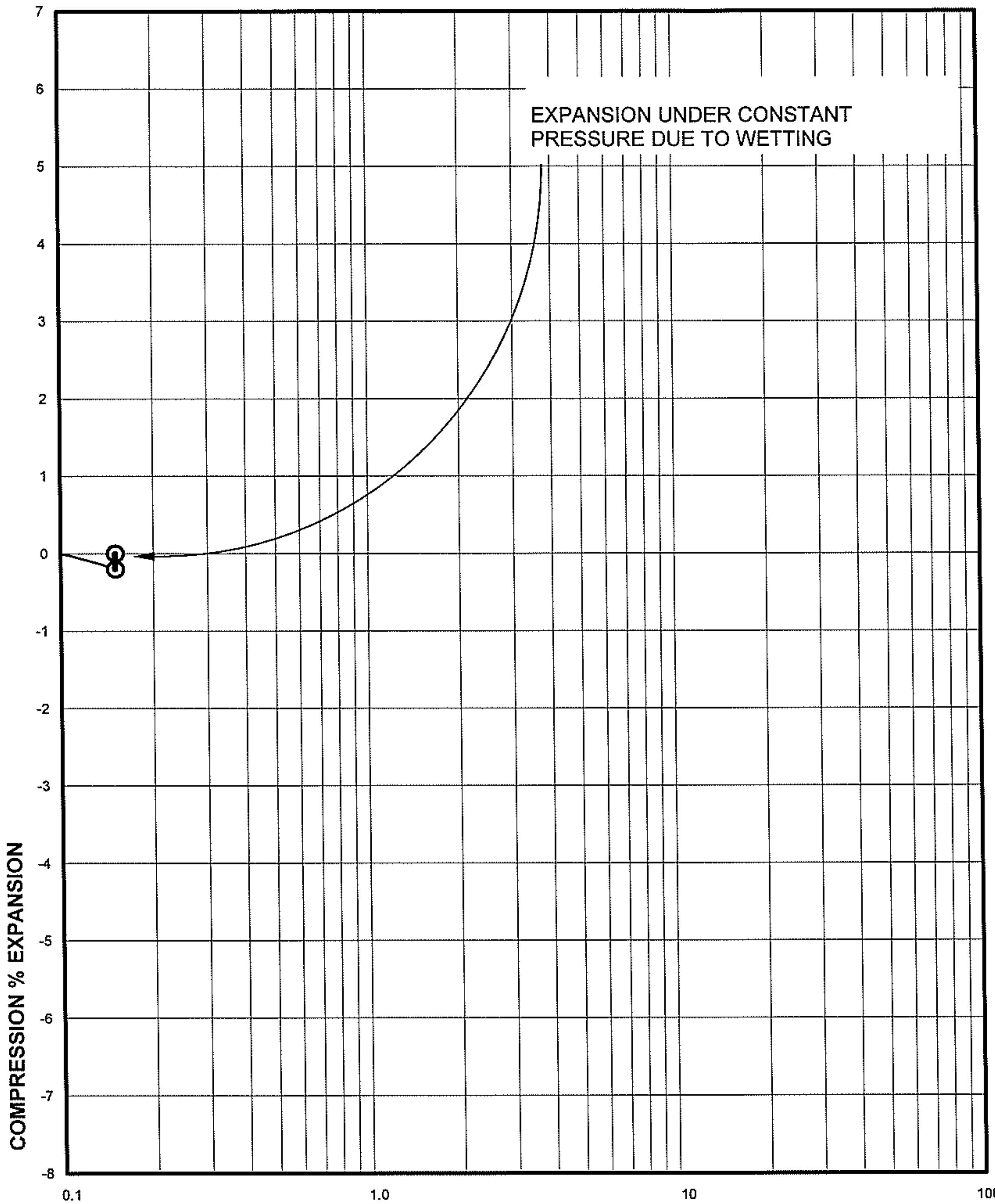
DRY UNIT WEIGHT= 105 PCF
MOISTURE CONTENT= 20.2 %



Sample of CLAY, SANDY (CL)
From TH - 3 AT 4 FEET

DRY UNIT WEIGHT= 119 PCF
MOISTURE CONTENT= 15.8 %

Swell Consolidation



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

DRY UNIT WEIGHT= 98 PCF
MOISTURE CONTENT= 24.4 %

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CTL | T PROJECT NO. FC06547.010-135

Swell Consolidation Test Results

FIGURE A-2

TABLE A-I

SUMMARY OF LABORATORY TESTING

BORING	DEPTH (FEET)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	ATTERBERG LIMITS		SWELL TEST RESULTS*		PASSING NO. 200 SIEVE (%)	WATER-SOLUBLE SULFATES (%)	DESCRIPTION
				LIQUID LIMIT	PLASTICITY INDEX	SWELL* (%)	APPLIED PRESSURE (PSF)			
TH-1	2	20.2	105			0.8	150		0.03	CLAY, SANDY (CL)
TH-2	2	19.0	101	39	25			63		CLAY, SANDY (CL)
TH-3	4	15.8	119			1.7	500		0.02	CLAY, SANDY (CL)
TH-4	4	17.6	112	46	31			76		CLAY, SANDY (CL)
TH-5	2	24.4	98			0.2	150		0.03	CLAY, SANDY (CL)
TH-6	2	18.6	109	43	27			84		CLAY, SANDY (CL)

* NEGATIVE VALUE INDICATES COMPRESSION.

APPENDIX B

SAMPLE SITE GRADING SPECIFICATIONS

SAMPLE SITE GRADING SPECIFICATIONS

1. <u>DESCRIPTION</u>

This item shall consist of the excavation, transportation, placement, and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve site elevations.

2. <u>GENERAL</u>

The Soils Engineer shall be the Owner's representative. The Soils Engineer shall approve fill materials, method of placement, moisture contents, and percent compaction, and shall give written approval of the completed fill.

3. <u>CLEARING JOB SITE</u>

The Contractor shall remove all trees, brush, and rubbish before excavation or fill placement is begun. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill or where the material will support structures of any kind.

4. <u>SCARIFYING AREA TO BE FILLED</u>

All topsoil and vegetable matter shall be removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified to a depth of 8 inches until the surface is free from ruts, hummocks or other uneven features, which would prevent uniform compaction by the equipment to be used.

5. <u>COMPACTING AREA TO BE FILLED</u>

After the foundation for the fill has been cleared and scarified, it shall be disked or bladed until it is free from large clods, brought to the proper moisture content and compacted to not less than 95 percent of maximum density as determined in accordance with ASTM D 698.

6. <u>FILL MATERIALS</u>

Materials classifying as CL, SC, SM, SW, SP, GP, GC, and GM are acceptable. Fill soils shall be free from organic matter, debris, or other deleterious substances, and shall not contain rocks or lumps having a diameter greater than three (3) inches.

7. MOISTURE CONTENT

Fill materials shall be moisture treated. Clay soils should be moisture-treated to between optimum and 3 percent above optimum moisture content as determined from Standard Proctor compaction tests. Sand soils should be moistened to within 2 percent optimum moisture content. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas.

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor may be required to rake or disk the fill soils to provide uniform moisture content through the soils.

The application of water to embankment materials shall be made with any type of watering equipment approved by the Soils Engineer, which will give the desired results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling, and all work on that section of the fill shall be delayed until the material has been allowed to uniformly dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

8. COMPACTION OF FILL AREAS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density. Fill materials shall be placed such that the thickness of loose material does not exceed 8 inches and the compacted lift thickness does not exceed 6 inches.

Compaction, as specified above, shall be obtained by the use of sheepsfoot rollers, multiple-wheel pneumatic-tired rollers, or other equipment approved by the Engineer. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to insure that the required density is obtained.

9. COMPACTION OF SLOPES

Fill slopes shall be compacted by means of sheepsfoot rollers or other suitable equipment. Compaction operations shall be continued until slopes are stable, but not too dense for planting, and there is no appreciable amount of loose soil on the slopes. Compaction of slopes may be done progressively in increments of three to five feet (3' to 5') in height or after the fill is brought to its total height. Permanent fill slopes shall not exceed 3:1 (horizontal to vertical).

10. DENSITY TESTS

Field density tests shall be made by the Soils Engineer at locations and depths of his choosing. Where sheepsfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate that the density or moisture content of any layer of fill or portion thereof is below that required, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

11. COMPLETED PRELIMINARY GRADES

All areas, both cut and fill, shall be finished to a level surface and shall meet the following limits of construction:

A. Overlot cut or fill areas shall be within plus or minus 2/10 of one foot.

B. Street grading shall be within plus or minus 1/10 of one foot.

The civil engineer, or duly authorized representative, shall check all cut and fill areas to observe that the work is in accordance with the above limits.

12. SUPERVISION AND CONSTRUCTION STAKING

Observation by the Soils Engineer shall be continuous during the placement of fill and compaction operations so that he can declare that the fill was placed in general conformance with specifications. All site visits necessary to test the placement of fill and observe compaction operations will be at the expense of the Owner. All construction staking will be provided by the Civil Engineer or his duly authorized representative. Initial and final grading staking shall be at the expense of the owner. The replacement of grade stakes through construction shall be at the expense of the contractor.

13. SEASONAL LIMITS

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Engineer indicates that the moisture content and density of previously placed materials are as specified.

14. NOTICE REGARDING START OF GRADING

The contractor shall submit notification to the Soils Engineer and Owner advising them of the start of grading operations at least three (3) days in advance of the starting date. Notification shall also be submitted at least 3 days in advance of any resumption dates when grading operations have been stopped for any reason other than adverse weather conditions.

15. REPORTING OF FIELD DENSITY TESTS

Density tests made by the Soils Engineer, as specified under "Density Tests" above, shall be submitted progressively to the Owner. Dry density, moisture content, of each test taken, and percentage compaction shall be reported for each test taken.

16. DECLARATION REGARDING COMPLETED FILL

The Soils Engineer shall provide a written declaration stating that the site was filled with acceptable materials, or was placed in general accordance with the specifications.

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 opti-

mum 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 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 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.

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 600 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 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.

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.