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SUBGRADE INVESTIGATION AND PAVEMENT DESIGN SOUTH TAFT HILL ROAD RECONSTRUCTION AND OVERLAY FORT COLLINS, COLORADO

Prepared For:

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SCOPE

This report presents the results of our geotechnical investigation for the proposed reconstruction and overlay of South Taft Hill Road, from the alignment of Old Harmony Road to approximately one mile south of West Trilby Road (City boundary), in Fort Collins, Colorado. The purpose of this investigation was to obtain information regarding existing pavement, base course and subsurface conditions within the existing roadway. The report presents geotechnical design and construction criteria for the roadway overlay in general conformance with Chapters 5 and 10 of the *Larimer County Urban Areas Street Standards* dated January 2, 2001 (repealed and reenacted October 1, 2002) as adopted by the City of Fort Collins.

Our report includes a description of the existing pavement, base course, soil and bedrock found in our exploratory borings, laboratory test results, recommended pavement section alternatives and construction and materials guidelines. The recommendations contained herein are based upon laboratory test results, Larimer County Urban Area Street Standards, the American Association of State Highway Transportation Officials (AASHTO) 1993 "*Guide for Design of Pavement Structures,*" and our experience.

SITE AND PROJECT DESCRIPTION

The project site consists of approximately three miles of South Taft Hill Road from the alignment of Old Harmony Road south to the City boundary, approximately one mile south of West Trilby Road, in Fort Collins, Colorado (see Figure 1). The existing road is two-lane asphalt-paved with narrow paved shoulder along the east and west side. The roadway has been widened to four-lane width at the entrance to Larimer County Landfill, to accommodate turn lanes. Cuts up to approximately 15 feet are present along the existing roadway. The roadway crosses six drainages where fills up to approximately 20 feet and culverts are present. The roadway alignment is bounded by platted residential development, Larimer County Landfill, open space land and rural residences. The roadway alignment generally slopes down toward the south.

The City of Fort Collins intends to reconstruct the road by milling and pulverizing the entire thickness of the existing asphalt. The pulverized asphalt will then be used to increase the base course thickness, prior to repaving the road with a new asphalt overlay. The City may also consider chemical stabilization of the subgrade soils to reduce the risk of heave due to swelling soils and/or bedrock and create a more stable subgrade.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of 17 borings drilled to depths of 10 feet. Borings were drilled in both the north and south bound lanes at an approximate spacing of 1,000 feet. Although this spacing does not conform to the *Larimer County Urban Areas Street Standards,* the City decided it would be acceptable for design of the overly reconstruction while also reducing the cost of the investigation. The approximate locations of our borings are illustrated on Figure 1. The borings were drilled on January 16, 2006, with a 4-inch solid stem, truck-mounted auger. Bulk samples were obtained from the upper 10 feet of the borings and California samples were obtained from selected intervals within the borings. The number of blows from a 140-pound hammer falling 30 inches, required to drive the California samplers, were recorded and are presented on our summary logs of the borings, Figures 2 and 3.

Laboratory testing was performed in general accordance with AASHTO and ASTM methods to determine index properties of the soils sampled and subgrade support values for those soil types influencing the pavement design. To evaluate potential heave, swell-consolidation testing was performed on six samples of the subgrade soils, fill and bedrock under a pressure of 150 psf. The soil types were classified and grouped, and Hveem stabilometer tests (R-Value) was performed on two composite samples of clay fill soils and weathered claystone. Three samples were tested for water-soluble sulfate content. Results of laboratory tests are presented in Appendix A and summarized in Table A-I.

SUBSURFACE CONDITIONS

The existing pavement system thicknesses measured in our borings consisted of approximately 4 to 7 inches of asphaltic concrete (AC) pavement over approximately 3 to 12 inches of base course. Table 1 presents the measured asphalt and base course thicknesses for each boring.

The subgrade material encountered beneath the pavement and base course consisted predominantly of sandy clay and clayey sand fill (S-1, S-4, S-6, S-8, S-9, S-10, S-11, S-13, S-15 and S-16). Natural clayey sand and sandy clay were encountered below the base course or fill in three borings (S-5, S-14 and S-17). Weathered and comparatively unweathered claystone bedrock was encountered below the base course fill and natural clayey sand in five borings (S-2, S-3, S-5, S-7 and S-12). The claystone was encountered at depths of 2 to 4 feet.

Samples of the sandy clay and clayey sand fill, tested in the laboratory, contained between 30 and 52 percent clay and silt-sized particles (passing the no. 200 sieve), had liquid limits between 39 and 50 percent, and plasticity indices between 25 and 36 percent. The samples classified as A-2-6, A-2-7 and A-7-6 in accordance with the AASHTO classification method with group indices ranging from 2 to 13. The more plastic fill was found in borings S-8, S-11, S-13, S-15, S-16 and S-17.

Samples of the natural clayey sand, tested in the laboratory, contained 36 and 42 percent clay and silt-sized particles (passing the no. 200 sieve), had liquid limits of 45 and 55 percent, and plasticity indices of 31 and 40 percent. The samples classified as A-7-6 in accordance with the AASHTO classification method with group indices of 5 and 10.

Samples of the weathered claystone, tested in the laboratory, contained between 42 and 64 percent clay and silt-sized particles (passing the no. 200 sieve), had liquid limits between 45 and 53 percent, and plasticity indices between 31 and 37 percent. The samples classified as A-7-6 in accordance with the AASHTO classification method with group indices ranging from 9 to 20.

One sample of the natural clayey sand, tested for swell potential, swelled 1.7 percent when wetted under application of a 150 psf pressure. Two samples of the clay fill swelled 2.5 and 4.4 percent. Three samples of weathered claystone swelled between 5.2 and 12.4 percent. Based on the results of laboratory testing and City of Fort Collins requirements, we believe swell mitigation should be considered for the overlay reconstruction.

Hveem stabilometer testing (R-Value) was performed on composite samples of representative clay fill and weathered claystone from the subgrade alignment. The composite sample for the clay fill (Bulk 2) classified as A-7-6 soil, with 79 percent clay and silt sized particles, a liquid limit of 48 percent and a plasticity index of 34 percent. The Hveem testing resulted in an R-Value of 17. The composite sample for the weathered claystone (Bulk 1) classified as A-7-6 soil, with 83 percent clay and silt sized particles, a liquid limit of 45 percent and a plasticity index of 31 percent. The Hveem testing resulted in an R-Value of less than 5, since the sample squeezed out of the mold.

Soluble sulfate concentrations of 0.013, 0.03 and 0.07 percent were measured on three samples. The purpose of the sulfate testing was to determine the risk of increased swelling if chemical stabilization of the subgrade is performed and the likelihood of sulfate attack if portland cement concrete is used. Sulfate concentrations above 0.5 percent can cause an adverse reaction between the sulfates and the stabilizing agent, resulting in heaving of the subgrade if lime or fly ash stabilization is performed. Based on the results found, we believe there is a low risk of increased swelling due to sulfate reaction to chemical stabilizing agents at this site.

Groundwater was not encountered during drilling of our borings. Groundwater levels will vary seasonally and with changes in precipitation and irrigation amounts in the surrounding area. However, we do not anticipate groundwater will impact the proposed roadway overlay and reconstruction.

EXPANSIVE SOIL MITIGATION

Expansive soils are present in the subgrade at this site. The presence of expansive soils implies that pavements may heave and be damaged. The risks associated with swelling soils can be mitigated by design, construction and maintenance procedures. The subgrade soils tested had a low to moderate swell potential where natural sand and clay and clay fill where encountered and moderate to high swell potential where weathered claystone was encountered. We believe the swell potential of these soils can be controlled by moisture conditioning and fly ash treatment. Moisture conditioning and fly ash treatment are discussed below.

PAVEMENT DESIGN

We used the AASHTO design method in accordance with City of Fort Collins requirements for pavement design calculations. The portion of South Taft Hill Road addressed by this report is classified as a 2-lane arterial with a design Equivalent Daily Load Application (EDLA) of 325. The EDLA value is converted to Equivalent Single Axle Loads (ESALs) for a twenty-year design life. Hveem testing resulted in an R-value of less than 5 and 17. Therefore, we performed pavement design calculations using R-Values of 5 (Appendix B) to represent the highly plastic clays and claystone encountered in the subgrade and an R-value of 10 to represent the sandy clay and clayey sand fill. The resulting structural numbers (SN) where 5.19 and 4.97, respectively.

Our recommended pavement design alternatives for the South Taft Hill Road construction and overlay are presented in Table I below. These alternatives include asphaltic concrete on aggregate base course for untreated subgrade and for fly ash treated subgrade. We understand the City may chose to treat the existing subgrade with 12% fly ash in the upper 1 foot. According to the Larimer County Urban Area Street Standards, as adopted by the City of Fort Collins, credit is not allowed for fly ash treatment in this manner.

In order to use fly ash treated subgrade in the pavement section calculations, a mix design must be performed and the soil/fly ash mixture must achieve a minimum 7-day compressive strength of 150 psi. Our scope of work did not include design of a soil/fly ash mixture. If plans change, we are available to perform a soil/fly ash mix design. We have provided pavement section thickness alternatives for that option in Table II below.

Portland cement concrete pavements were not considered as we understand the City wishes to match the existing pavement surface to the north and south of the project area. Additional discussion regarding advantages and disadvantages of the pavement alternatives and their expected performance is included under PAVEMENT SELECTION.

TABLE I
PAVEMENT SECTION ALTERNATIVES

Pavement Sections	Asphaltic Concrete + Aggregate Base Course on Untreated Subgrade (AC + ABC + SUB)	Asphaltic Concrete + Aggregate Base Course on Fly Ash Treated Subgrade* (AC + ABC + FASS)
R-Value = 5 SN = 5.19	8.0" AC + 15" ABC + 12" SUB	6.5" AC + 10" ABC + 12" FASS
R-Value = 10 SN = 4.97	7.5" AC + 15" ABC + 12" SUB	6.5" AC + 8" ABC + 12" FASS

*Provided fly ash mix design indicates minimum compressive strength of 150 psi

Approximately one third of the native roadway subgrade consists of highly plastic clays and claystone that distributed over the length of the project in numerous areas. Therefore, we believe the recommended pavement section calculated using an R-value of 5 (SN=5.19) would perform better over the entire alignment and minimize discontinuities due to multiple section changes.

PAVEMENT SELECTION

The City of Fort Collins generally requires a pavement section consisting of asphalt over aggregate base course. Asphalt over aggregate base course has had variable reported performance history in swelling soil environments. Some municipalities believe base course provides a flexible layer to help distribute swell of the subgrade and may reduce the likelihood of longitudinal cracks. Conversely, there have been problems where base course has "pushed" into wet clay subgrade. A geotextile fabric, such as Mirafi 500x or equivalent, can be used to help separate the subgrade and aggregate base course thereby reducing co-mingling of the aggregate base with the subgrade soil over time. We regard the use of geotextile fabric as optional for this project. The base course may also allow moisture to infiltrate under the pavement causing the base course to lose strength when wetted.

Asphaltic concrete over stabilized subgrade with or without aggregate base generally performs well in soils exhibiting moderate swell characteristics. The asphaltic concrete pavement over stabilized subgrade has a higher fatigue resistance than the other alternatives and will effectively reduce potential heave related damage to the pavement. We believe serviceability will be increased, and maintenance reduced, if asphalt concrete over stabilized subgrade is used. If stabilization is done during winter months (when soil temperatures are 40°F or lower) should consist of either fly ash or a lime and fly ash combination. Curing and strength gains of fly ash treated soils will decrease significantly in cooler weather.

PAVEMENT MATERIALS

Material properties and construction criteria for the pavement alternatives are provided below. These criteria were developed from analysis of the field and laboratory data, our experience and City of Fort Collins requirements. If the materials cannot meet these recommendations, then the pavement design should be reevaluated based upon available materials. All materials and construction requirements of the City of Fort Collins should be followed. All materials planned for construction should be submitted and the applicable laboratory tests performed to verify compliance with the specifications.

Asphaltic Concrete (AC)

1. Hot mix asphalt 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% 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. Hot mix asphalt should be relatively impermeable to moisture and should be designed with crushed aggregates that have a minimum of 80% of the aggregate retained on the No. 4 sieve with two mechanically fractured faces.

3. Gradations that approach the maximum density line (within 5% between the No. 4 and 50 sieve) should be avoided. A gradation with a nominal maximum size of 3/4 or 1/2 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%. The mixture should have a minimum VMA of 14% and between 65% and 80% of voids filled.

5. Asphalt cement should meet the requirements of the Superpave Performance Graded Binders (PG). The minimum performing asphalt cement should be PG 64-22 for use along the Front Range. The use of PG 58-28 or PG 58-22 asphalt cement has been known to cause tenderness in pavements in the Front Range area and should be avoided.

6. Hydrated lime should be added at the rate of 1% 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 only be performed when subgrade temperatures are above 40°F and air temperature is at least 40°F and rising.

8. Hot mix asphalt 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 mixture temperature drops 20°F.

9. The maximum compacted lift should be 3.0 inches and joints should be staggered. No joints should be placed within wheel paths.

10. Asphalt concrete 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.

11. Placement and compaction of hot mix asphalt should be observed and tested by a representative of our firm. Placement should not commence until the subgrade is properly prepared (or stabilized), observed, and proof-rolled.

Aggregate Base Course or Recycled Asphalt (ABC)

1. A Class 5 or 6 Colorado Department of Transportation (CDOT) specified aggregate base course should be used. A recycled asphalt alternative, which meets the Class 5 or 6 designation, is also acceptable.

2. Aggregate base course should have a minimum Hveem stabilometer value of 77. Aggregate base course or recycled asphalt material must be moisture stable. The change in R-value from 300 psi to 100 psi exudation pressure should be 12 points or less.

3. If used, geotextile fabric (Mirafi 500x or equivalent) should be placed over the approved subgrade within 24 hours prior to placement of aggregate base course or recycled concrete. Fabric should be rolled out longitudinally with minimum overlapped seams of 2.5 feet. No wrinkles should be permitted.

4. Aggregate base course or recycled asphalt should be laid in thin lifts not to exceed 8 inches, moisture treated to within 2% of optimum moisture content, and compacted to at least 95% of modified Proctor maximum dry density (ASTM D 1557, AASHTO T 180).

5. Placement and compaction of aggregate base course or recycled asphalt should be observed and tested by a representative of our firm. Placement should not commence until the underlying subgrade is properly prepared and inspected.

Fly Ash Treatment

We recommend the following general procedures for construction of fly ash stabilized soils in cohesive materials based on requirements from Chapter 22 of the *Larimer County Urban Area Street Standards*, guidelines and information published by The Western Ash Company[1] and the American Society of Civil Engineers[2] (ASCE), and our experience.

1. The subgrades should be shaped to final line and grade.
2. The fly ash used should meet requirements specified in ASTM C 593 and C 618.
3. Fly ash should be spread with a mechanical spreader for the entire width of the roadway alignment.
4. Fly ash and subgrade soils should be mixed, and water added until a homogeneous, uniform mixture is obtained that is within 2 percent of laboratory determined optimum moisture content in accordance with ASTM D 558.
5. The fly ash/soil mixture should be compacted to at least 95% of the mixtures maximum dry density (ASTM D 558) if subsequent sub-base and/or base courses are to be placed.
6. The subgrades should be re-shaped to final line and grade.
7. Mixing, compaction and final shaping should be completed within 2 hours of addition of water to the fly ash/soil mixture.
8. The subgrade should be sealed with a pneumatic-tire roller that is sufficiently light in weight so as to not cause hair-line cracking of the subgrade.
9. The City requires 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. The City of Fort Collins requirements specify that traffic is not permitted on the treated subgrade during the curing period.

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[1]"In Place Soil Treatment With Class C Fly ash", Western Ash Company.

[2]"*Use of Self-cementing Fly ashes as a Soil Stabilization Agent,* Fly ash for Soil Improvement", American Society of Civil Engineers, Geotechnical Special Publication No. 36, October, 1993.

10. We should be given a minimum advanced notice of at least 48 hours to prepare laboratory specimens to determine the fly ash/soil mixtures maximum dry density and optimum moisture content in order to meet the 2-hour compaction requirement specified above.

The treated areas will gain greater strength if they are allowed to cure for 1 to 3 days prior to paving. Previous experience indicates the target strength of the fly ash/soil mixture should be approximately 160 psi at 7 days for 12 percent fly ash. Compressive strength specimens prepared during construction are required to receive full credit for the treated subgrade in pavement section calculations. Laboratory compressive strength specimens should be made and cured according to ASTM D 1632. Field cured specimens should be made according to ASTM D 1632 and cured in a protected area, such as a shallow covered pit, adjacent to the treated subgrade. If compressive strength specimens are not prepared during construction, the allowed credit for the treated subgrade is reduced by 50 percent in the pavement section design calculations. Strength gains will be slower during cooler weather, and are unlikely when the soil temperature is less than 40 degrees (F). 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. Periodic sprinkling of the subgrade surface, covering the subgrade, or other protective measures may be required. Additional guidelines for subgrade preparation are presented below.

Prepared Subgrade

1. Subgrade should be stripped of organic matter, scarified, moisture treated and compacted.

2. Cohesive soils (A-6 to A-7-6) should be moisture conditioned between 1% below to 2% above optimum moisture content and compacted to at least 95% of maximum standard Proctor dry density (ASTM D 698, AASHTO T 99).

3. Granular soils (A-2-6 and A-2-7) should be moisture conditioned between 2% below to 2% above optimum moisture content and compacted to at least 95% of maximum standard Proctor dry density (ASTM D 698, AASHTO T 99).

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 reached and the subgrade compacted and inspected, the area should be proof-rolled with a pneumatic tired vehicle loaded to at least 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. Areas of soft or wet subgrade should be remedied.

CONSTRUCTION DETAILS

The design of a pavement system is as much a function of the quality of the paving materials and construction as the support characteristics of the subgrade. The construction materials are assumed to possess sufficient quality as reflected by the strength coefficients used in the flexible pavement design calculations. These strength coefficients were developed through research and experience to simulate expected material of good quality, as explained herein. During construction careful attention should be paid to the following details:

- Placement and compaction of trench backfill.
- Compaction at curb lines and around manholes and water valves.
- Excavation of completed pavements for utility construction and repair.
- Moisture treating or stabilization of the subgrade to reduce swell potential.
- Design slopes of the adjacent ground and pavement to rapidly remove water from the pavement surface.

MAINTENANCE

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.

LIMITATIONS

The pavement and construction recommendations are based upon our field observation and testing, minimum traffic levels, and design criteria required by the City of Fort Collins and the AASHTO design methods. The design procedures were formulated to provide sections with adequate structural strength. Routine maintenance, such as sealing and repair of cracks, is necessary to achieve the long-term life of a pavement system. If the design and construction recommendations cannot be followed, or anticipated traffic loads change considerably, we should be contacted to review the recommendations.

We believe the geotechnical services for this project were performed in a manner consistent with that level of care and skill ordinarily exercised by members of the geotechnical engineering profession currently practicing under similar conditions in the locality of the 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 analyses of the proposed pavement systems from a geotechnical point of view, please call.

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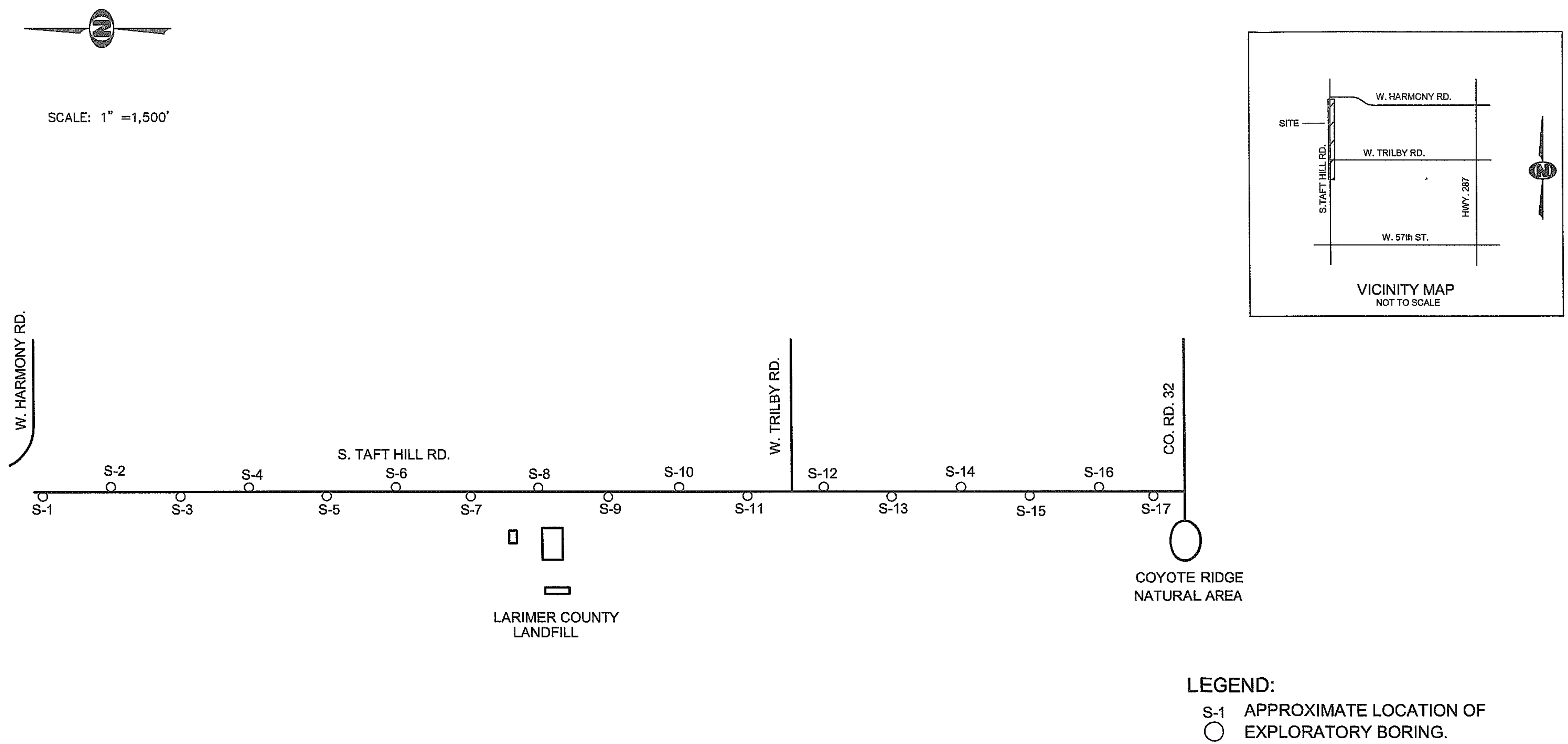
Gary A. Diewald
Project Engineer

(4 copies sent)

Reviewed by:

COLORADO REGISTERED PROFESSIONAL ENGINEER ROBERT B. LEADBETTER III 35616

Robert B. "Chip" Leadbetter, III, PE
Project Engineer



Locations of Subgrade Borings

FIGURE 1

CITY OF FORT COLLINS-ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
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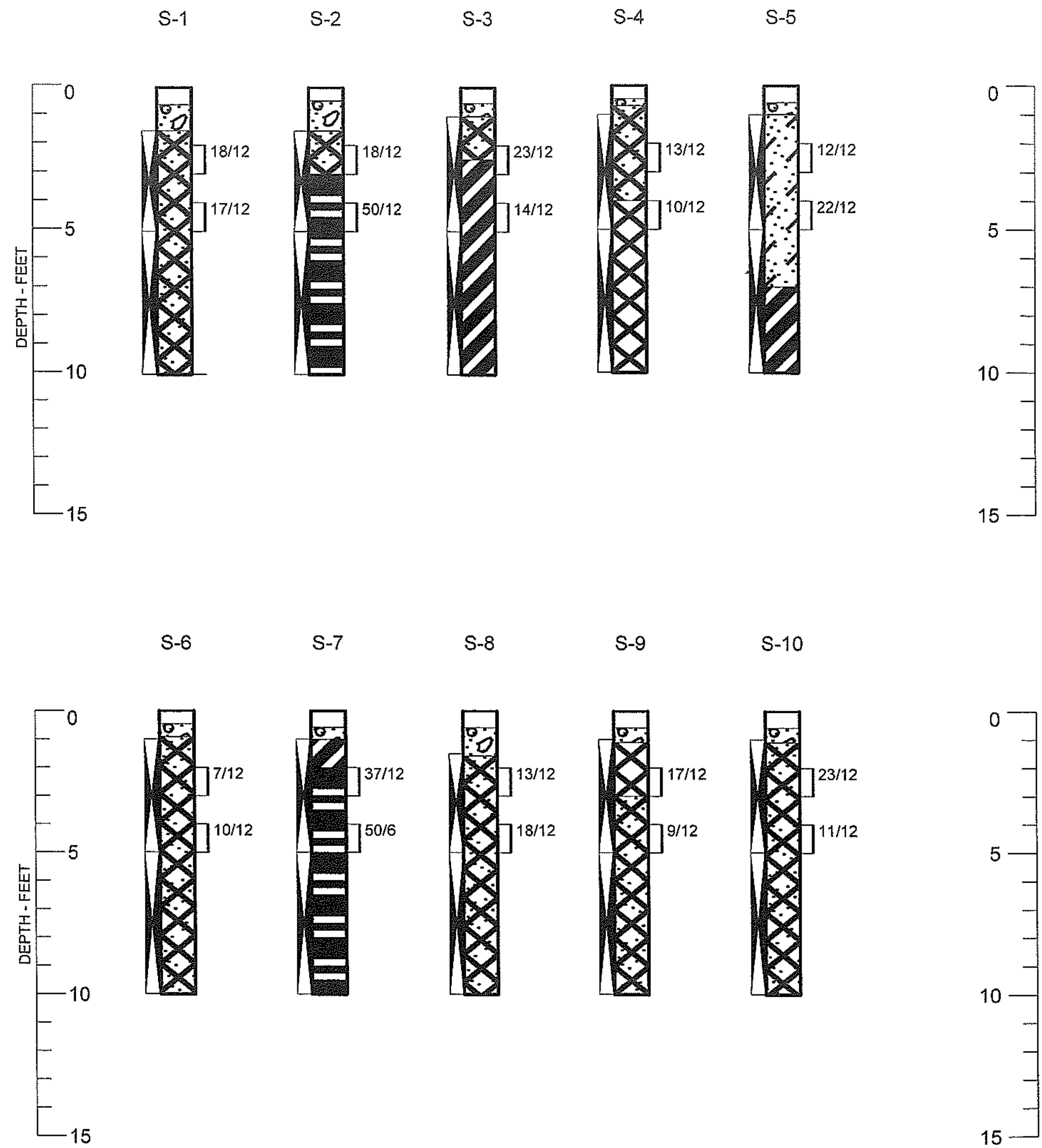

SUMMARY LOGS OF EXPLORATORY BORINGS

FIGURE 2

CITY OF FORT COLLINS - ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
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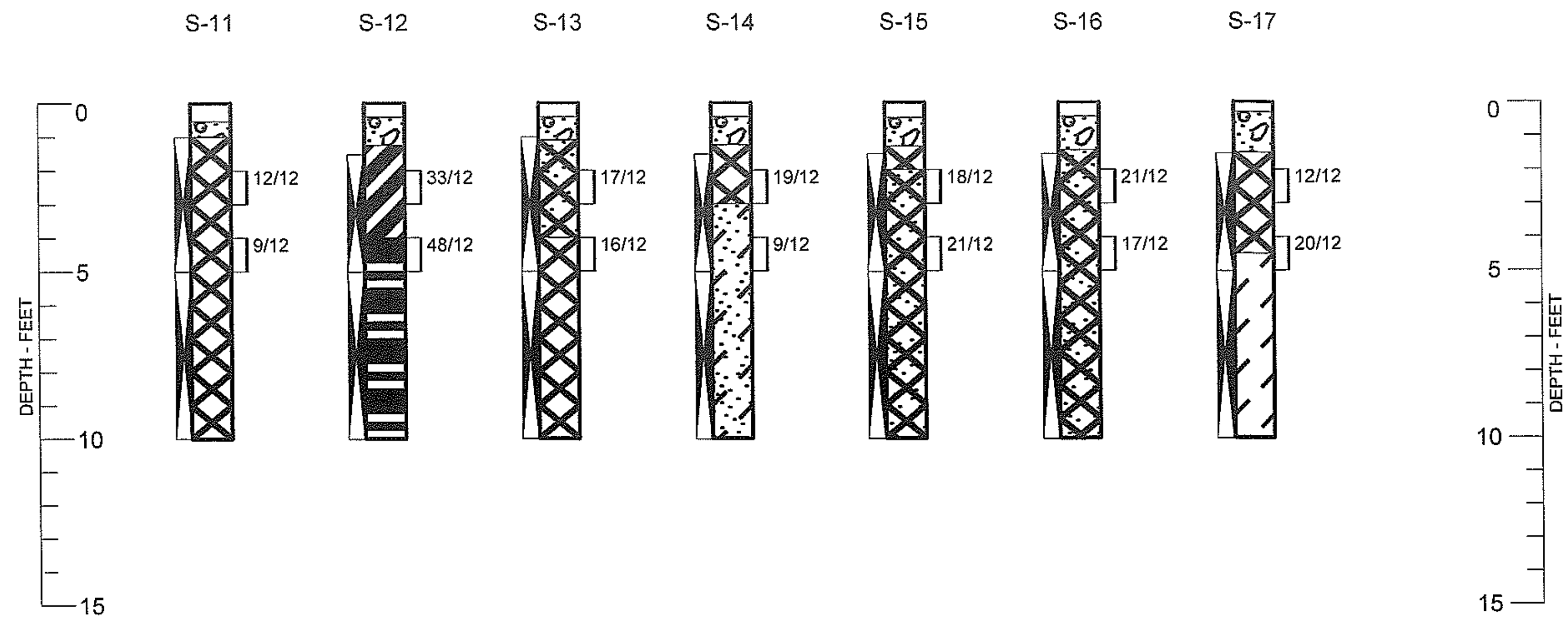

LEGEND:

ASPHALT.

BASE COURSE.

FILL, CLAY, SANDY, WITH OCCASIONAL GRAVEL, STIFF TO VERY STIFF, MOIST, BROWN, OLIVE BROWN AND DARK GREY BROWN.

FILL, SAND, CLAYEY, WITH GRAVEL, MEDIUM DENSE, BROWN, REDDISH BROWN AND LIGHT OLIVE BROWN.

CLAY, SANDY, VERY STIFF, MOIST, SOME ORGANICS, DARK GREY BROWN (CL).

SAND, CLAYEY WITH GRAVEL, LOOSE TO MEDIUM DENSE, MOIST, LIGHT BROWN TO BROWN (SC).

WEATHERED CLAYSTONE, FIRM TO MEDIUM HARD, SLIGHTLY MOIST TO MOIST, LIGHT OLIVE BROWN TO OLIVE BROWN (WEATHERED BEDROCK).

CLAYSTONE, MEDIUM HARD TO HARD, MOIST, OLIVE BROWN (BEDROCK).

DRIVE SAMPLE. THE SYMBOL 12/12 INDICATES 12 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 JANUARY 16, 2005, USING 4-INCH DIAMETER CONTINUOUS-FLIGHT AUGER AND A TRUCK-MOUNTED DRILL RIG.

2. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS IN THIS REPORT.

CITY OF FORT COLLINS - ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
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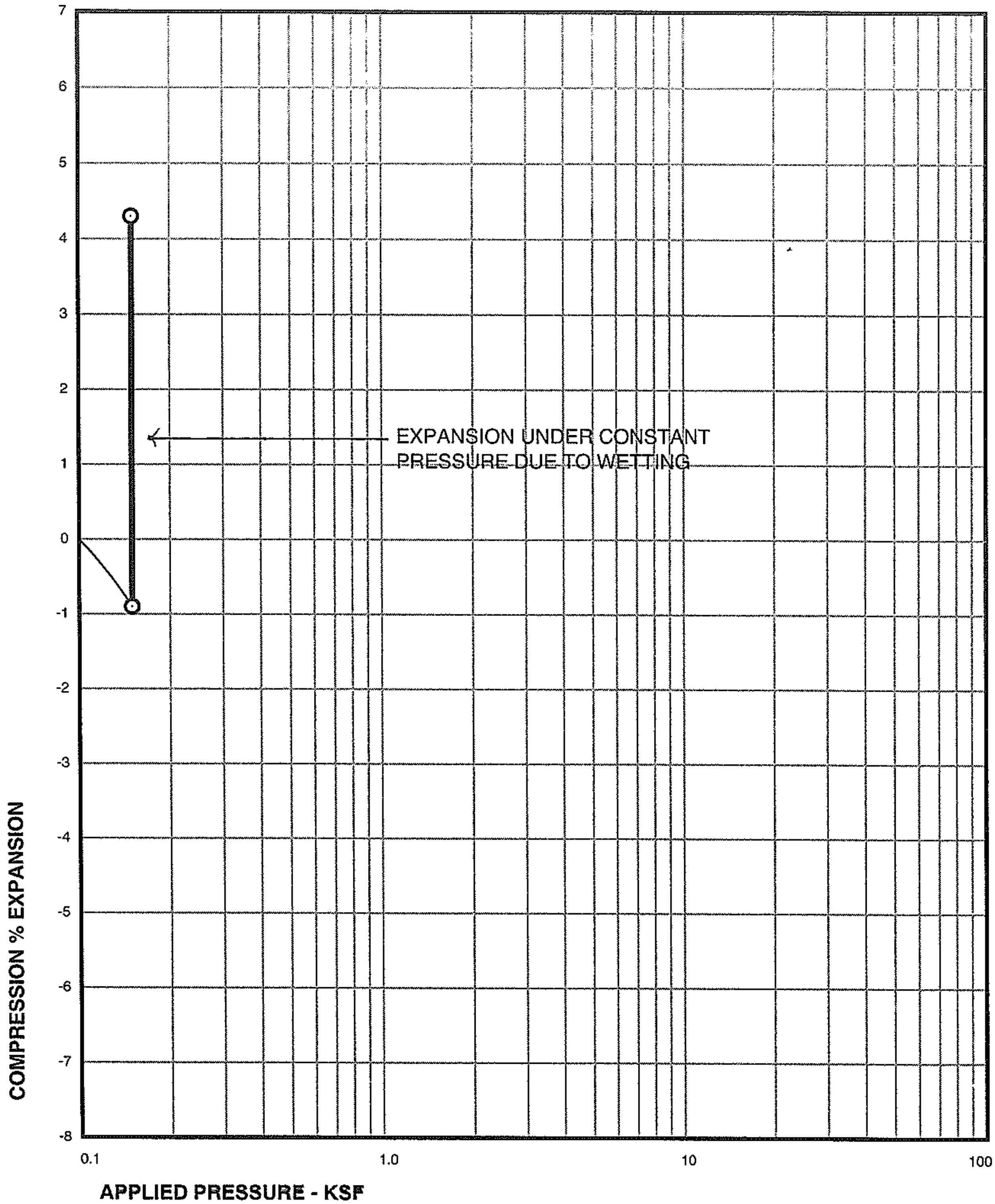
SUMMARY LOGS OF EXPLORATORY BORINGS

FIGURE 3

TABLE 1
ASPHALT AND BASE COURSE THICKNESSES
South Taft Hill Road Overlay Project

MATERIAL	SUBGRADE BORING																
	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17
Asphalt (inches)	7.0	5.5	6.5	5.5	7.0	5.5	7.0	7.0	7.0	7.0	6.5	5.0	5.0	5.0	5.5	5.0	4.0
Base Course (inches)	11.0	11.5	5.5	3.0	5.0	5.5	5.0	12.0	6.0	6.0	5.5	10.0	8.0	10.0	10.5	12.0	14.0
Total Thickness (inches)	18.0	17.0	12.0	8.5	12.0	11.0	12.0	19.0	13.0	13.0	12.0	15.0	13.0	15.0	16.0	17.0	18.0

APPENDIX A
LABORATORY TEST RESULTS



Sample of WEATHERED CLAYSTONE

From S-3 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 116 PCF

SAMPLE MOISTURE CONTENT= 15.2 %

Swell Consolidation Test Results

FIG. A-1

CITY OF FORT COLLINS
ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
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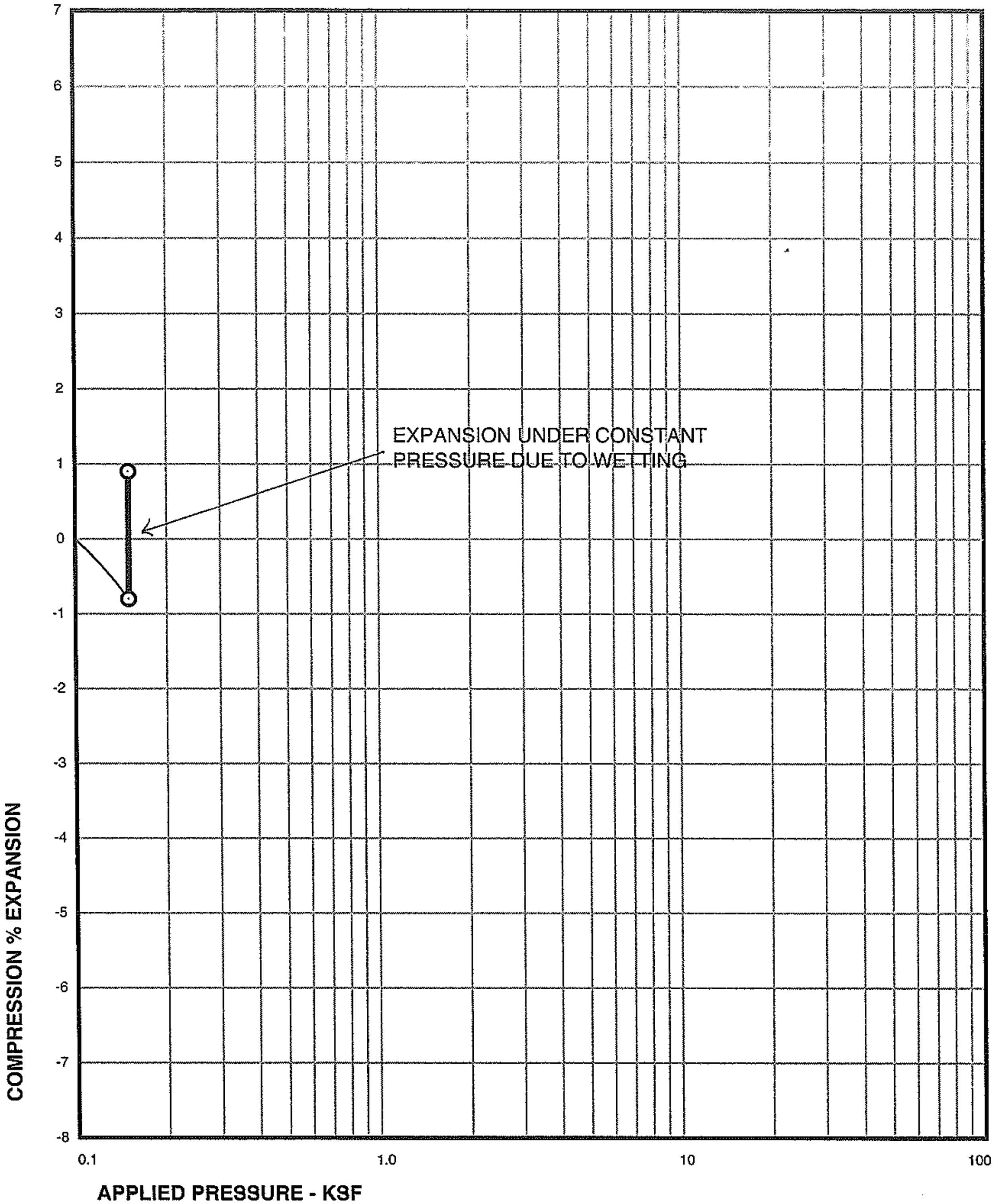

Sample of SAND, CLAYEY (SC)
From S-5 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 106 PCF
SAMPLE MOISTURE CONTENT= 22.0 %

Swell Consolidation Test Results

FIG. A-2

CITY OF FORT COLLINS
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SOUTH TAFT HILL ROAD OVERLAY
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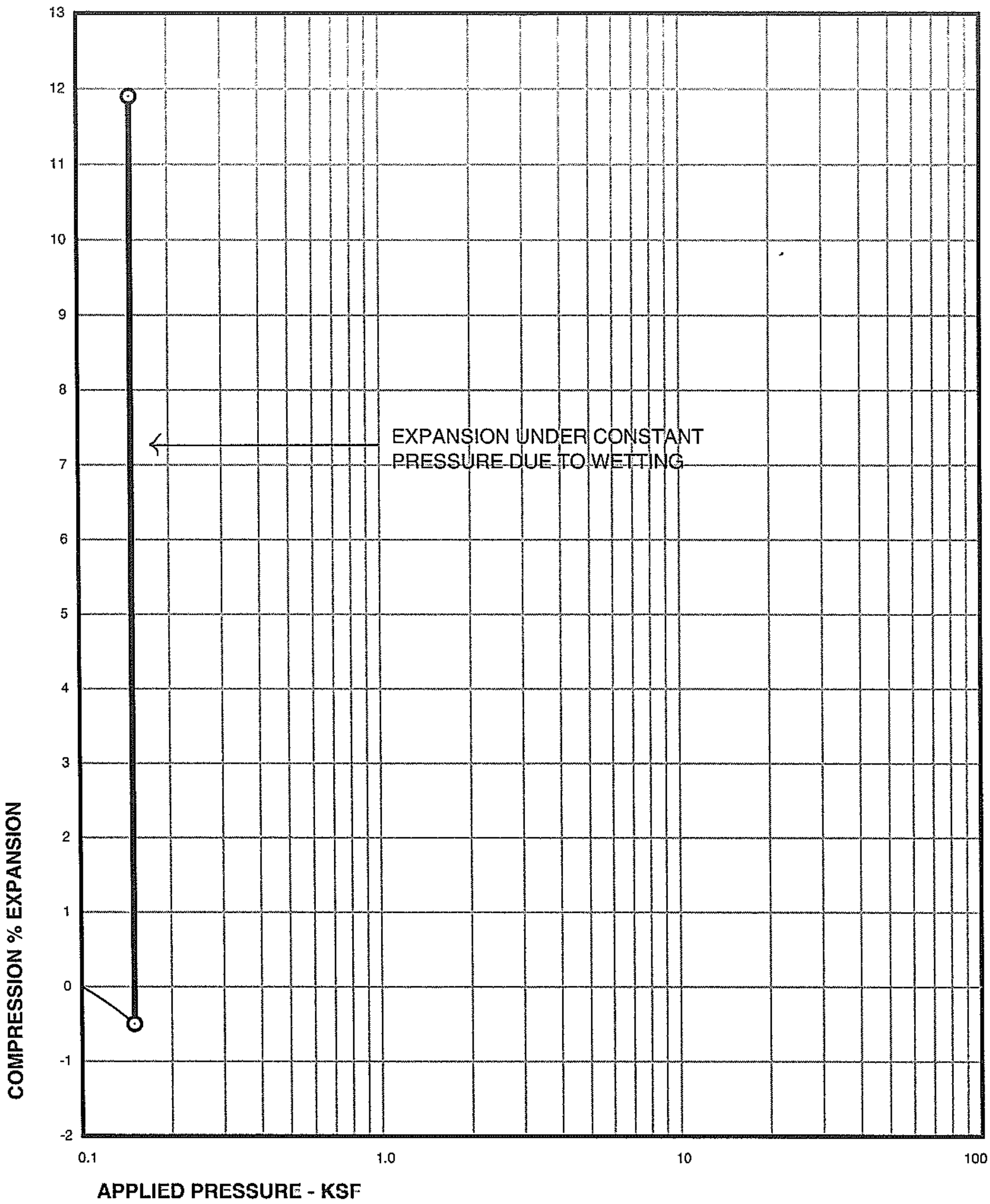

Sample of WEATHERED CLAYSTONE

From S-7 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 118 PCF

SAMPLE MOISTURE CONTENT= 15.2 %

Swell Consolidation Test Results

FIG. A-3

CITY OF FORT COLLINS
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SOUTH TAFT HILL ROAD OVERLAY
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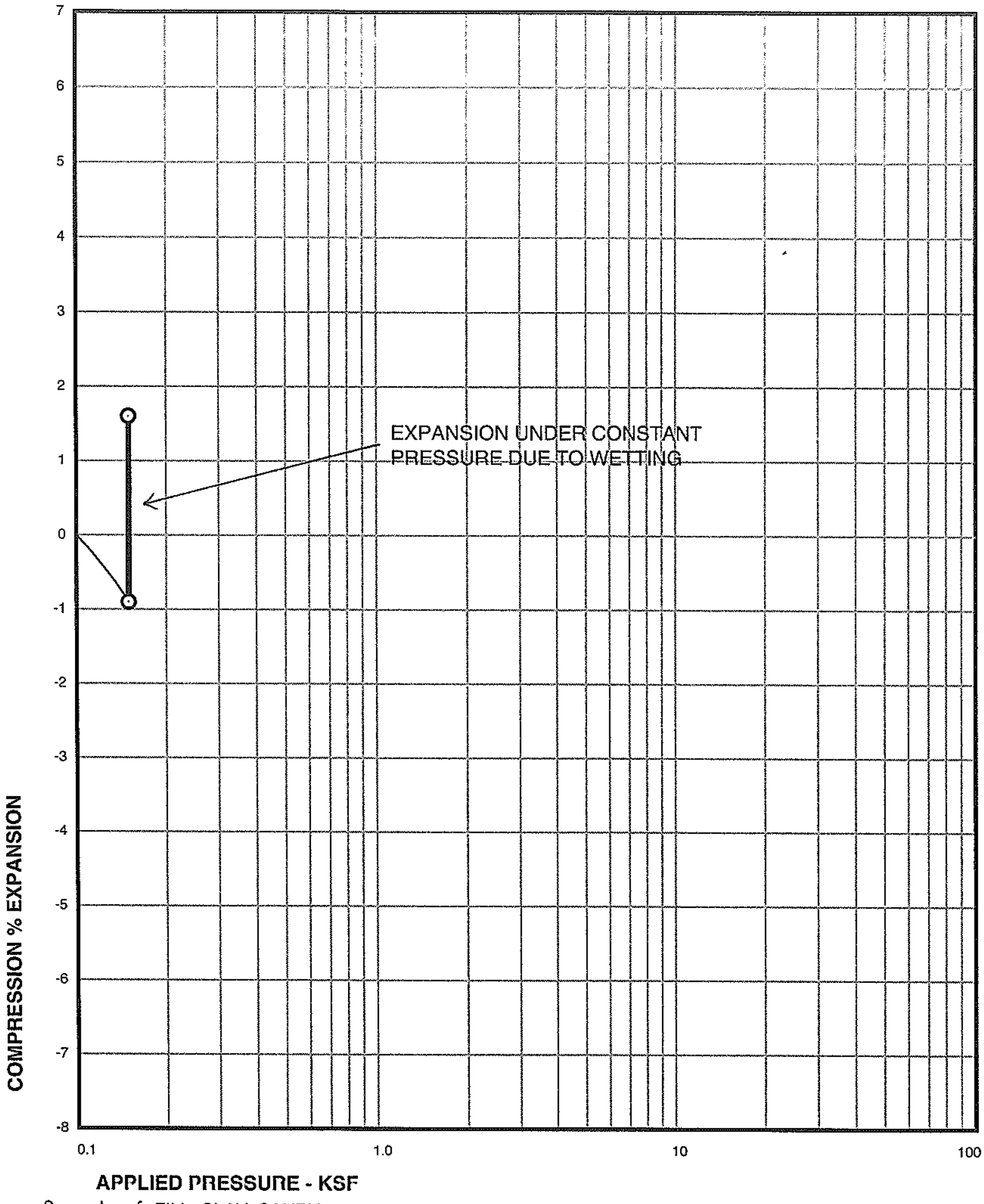

Sample of FILL, CLAY, SANDY

From S-9 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 115 PCF

SAMPLE MOISTURE CONTENT= 13.4 %

Swell Consolidation Test Results

FIG. A-4

CITY OF FORT COLLINS
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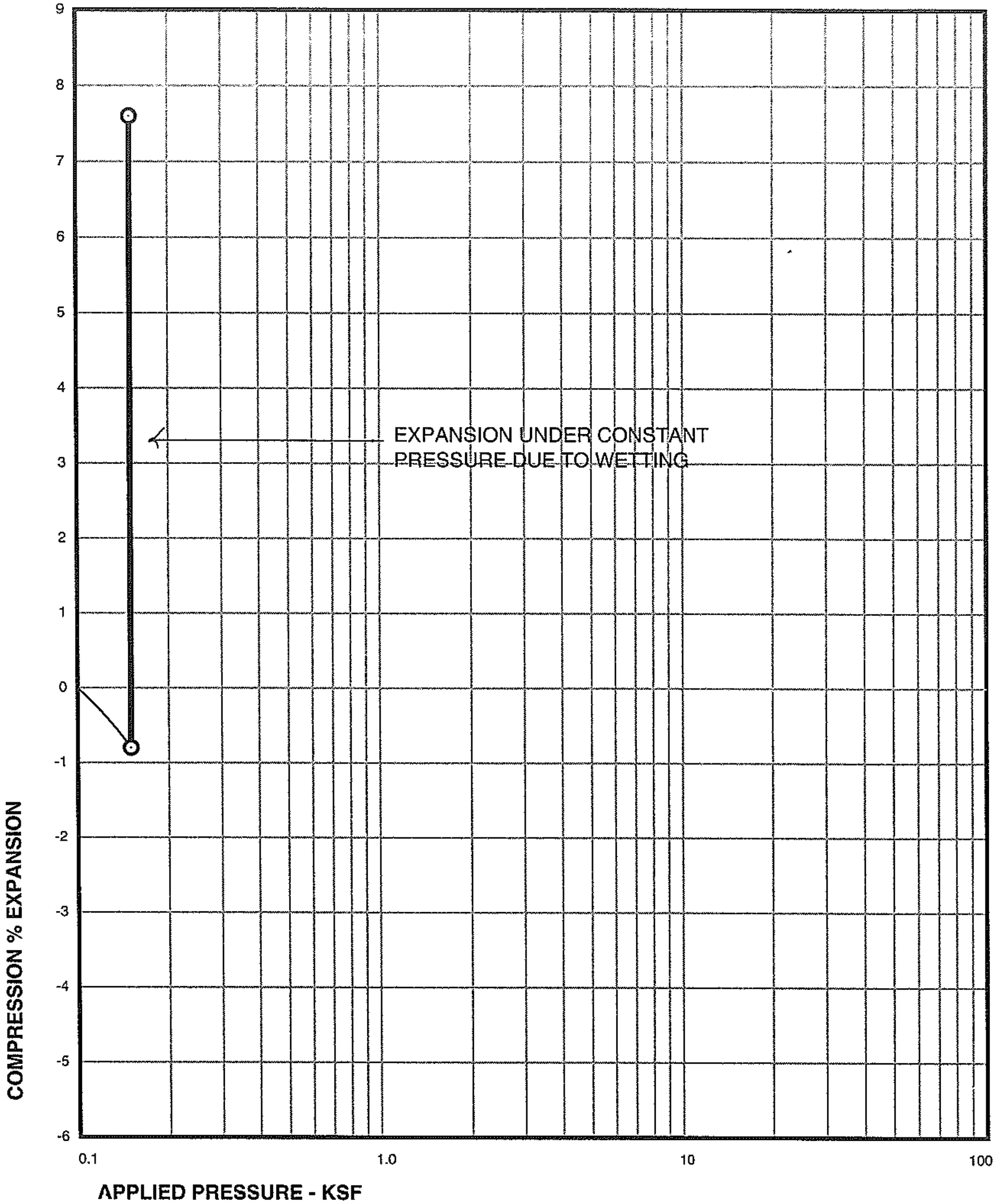
SOUTH TAFT HILL ROAD OVERLAY
CTL | T PROJECT NO. FC03689-135



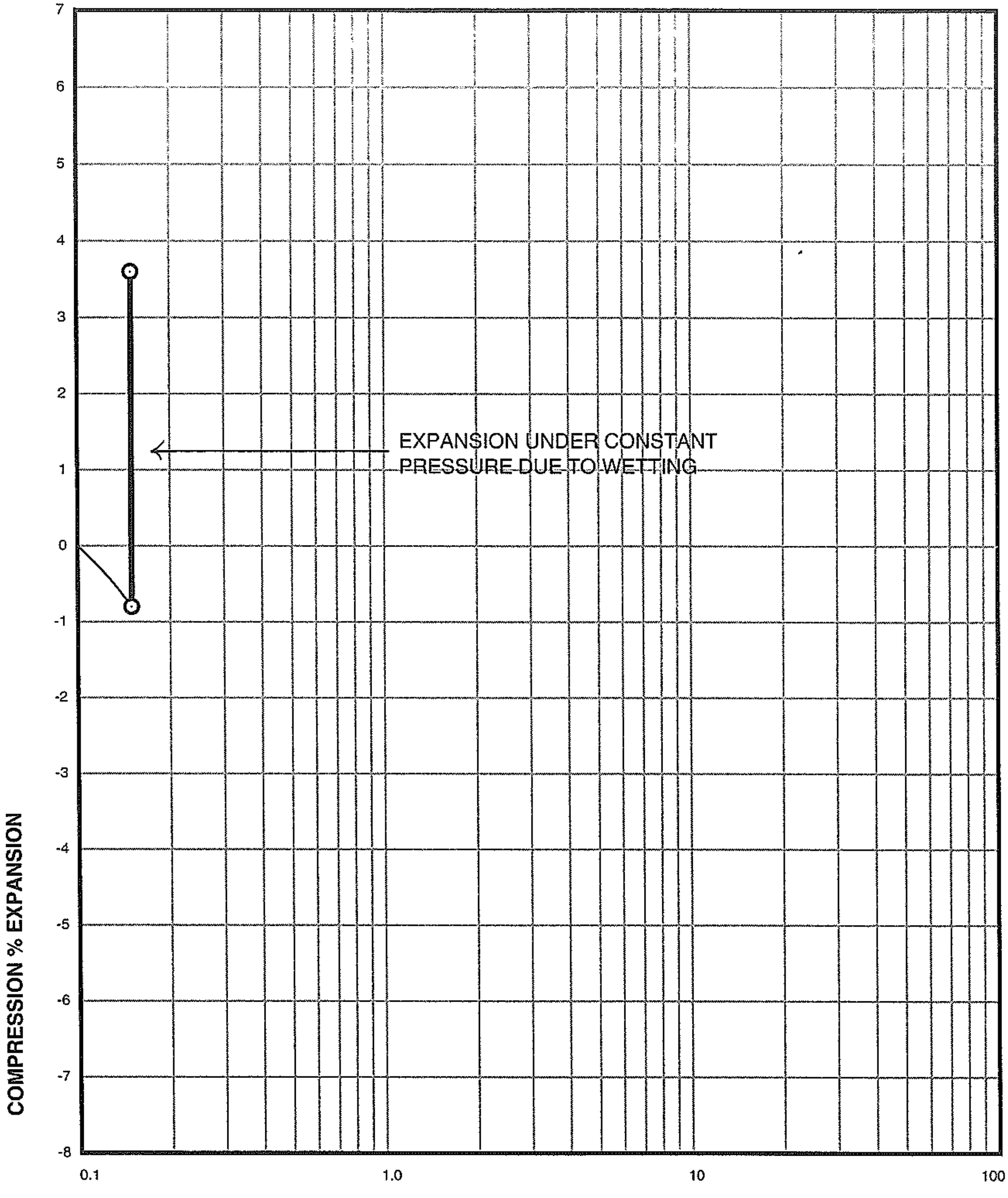
Sample of WEATHERED CLAYSTONE
From S-12 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 123 PCF
SAMPLE MOISTURE CONTENT= 13.3 %

Swell Consolidation Test Results

FIG. A-5

CITY OF FORT COLLINS
ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
CTL | T PROJECT NO. FC03689-135



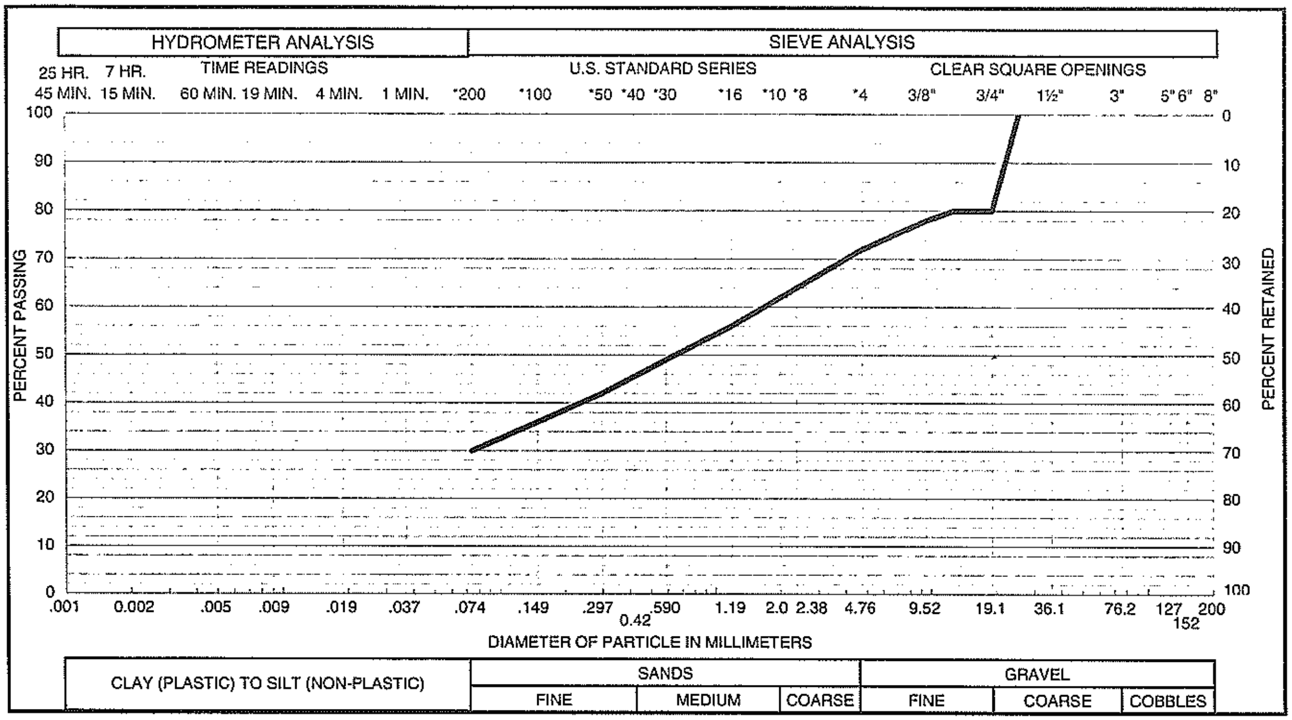
Sample of FILL, CLAY, SANDY
From S-15 AT 2 FEET

SAMPLE DRY UNIT WEIGHT= 111 PCF
SAMPLE MOISTURE CONTENT= 17.7 %

Swell Consolidation Test Results

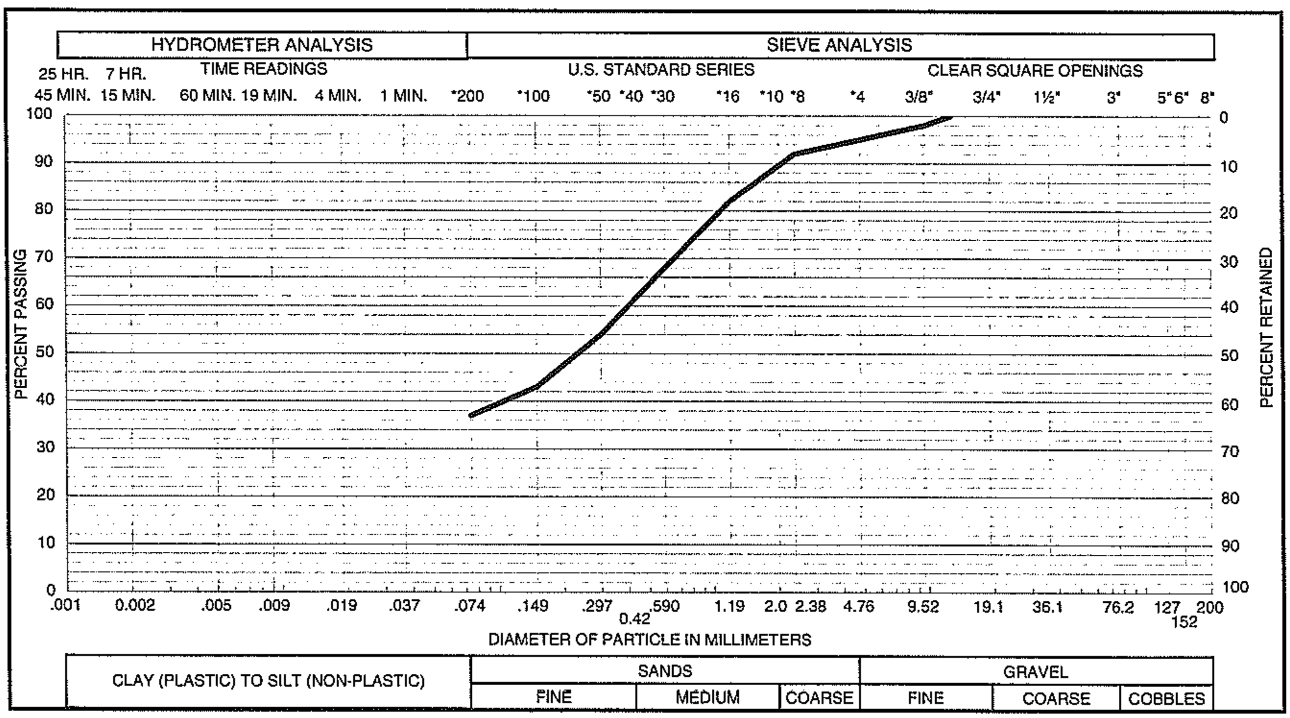
FIG. A-6

CITY OF FORT COLLINS
ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
CTL | T PROJECT NO. FC03689-135



Sample of FILL, SAND, CLAYEY WITH GRAVEL
From S-2 AT 2 FEET

GRAVEL 28 % SAND 42 %
SILT & CLAY 30 % LIQUID LIMIT 39 %
PLASTICITY INDEX 25 %



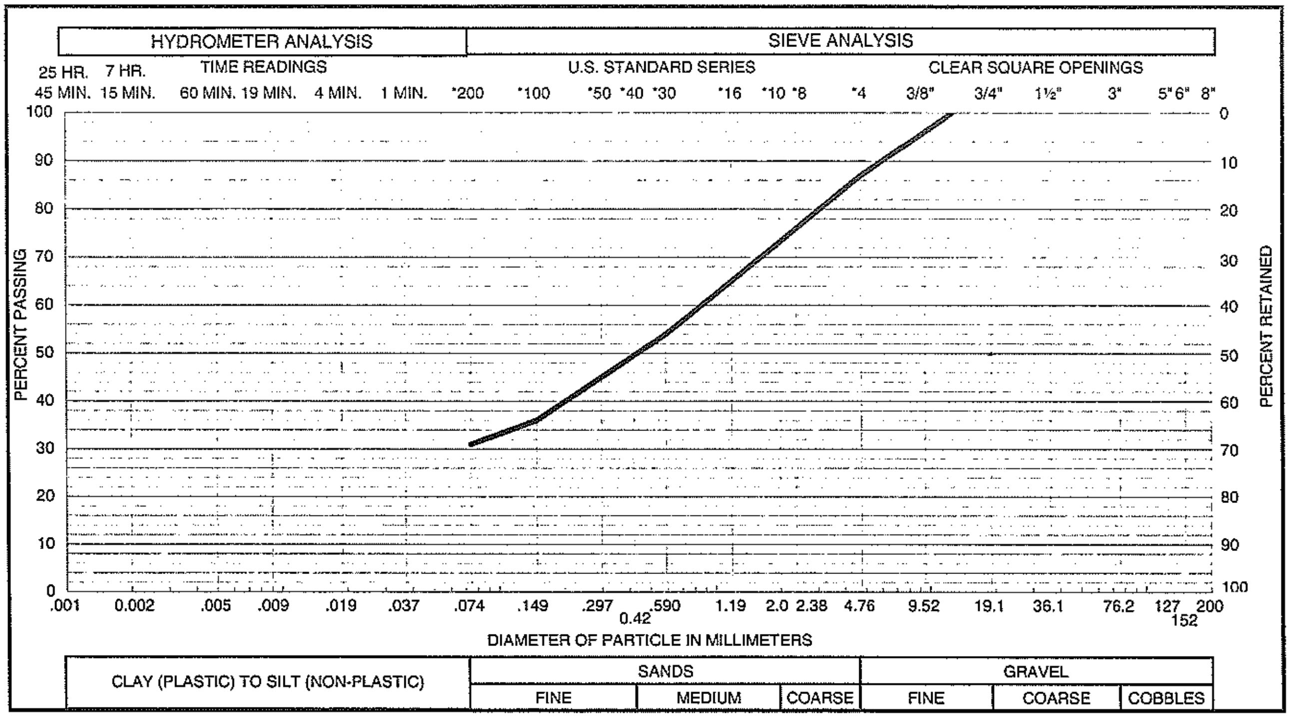
Sample of FILL, SAND, CLAYEY
From S-4 AT 1 TO 4 FEET

GRAVEL 5 % SAND 58 %
SILT & CLAY 37 % LIQUID LIMIT 43 %
PLASTICITY INDEX 29 %

CITY OF FORT COLLINS
ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
CTL | T PROJECT NO. FC03689-135

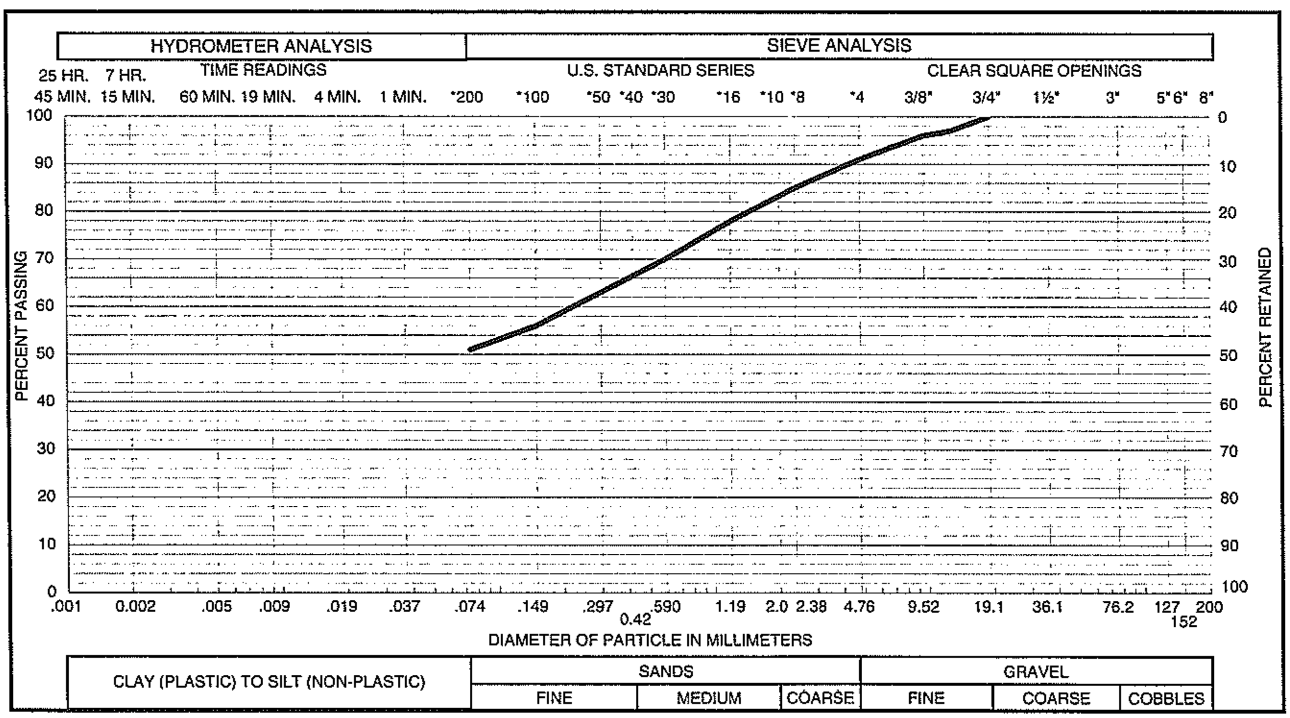
Gradation Test Results

FIG. A-7



Sample of FILL, SAND, CLAYEY
From S-10 AT 2 FEET

GRAVEL 13 % SAND 56 %
SILT & CLAY 31 % LIQUID LIMIT 46 %
PLASTICITY INDEX 32 %



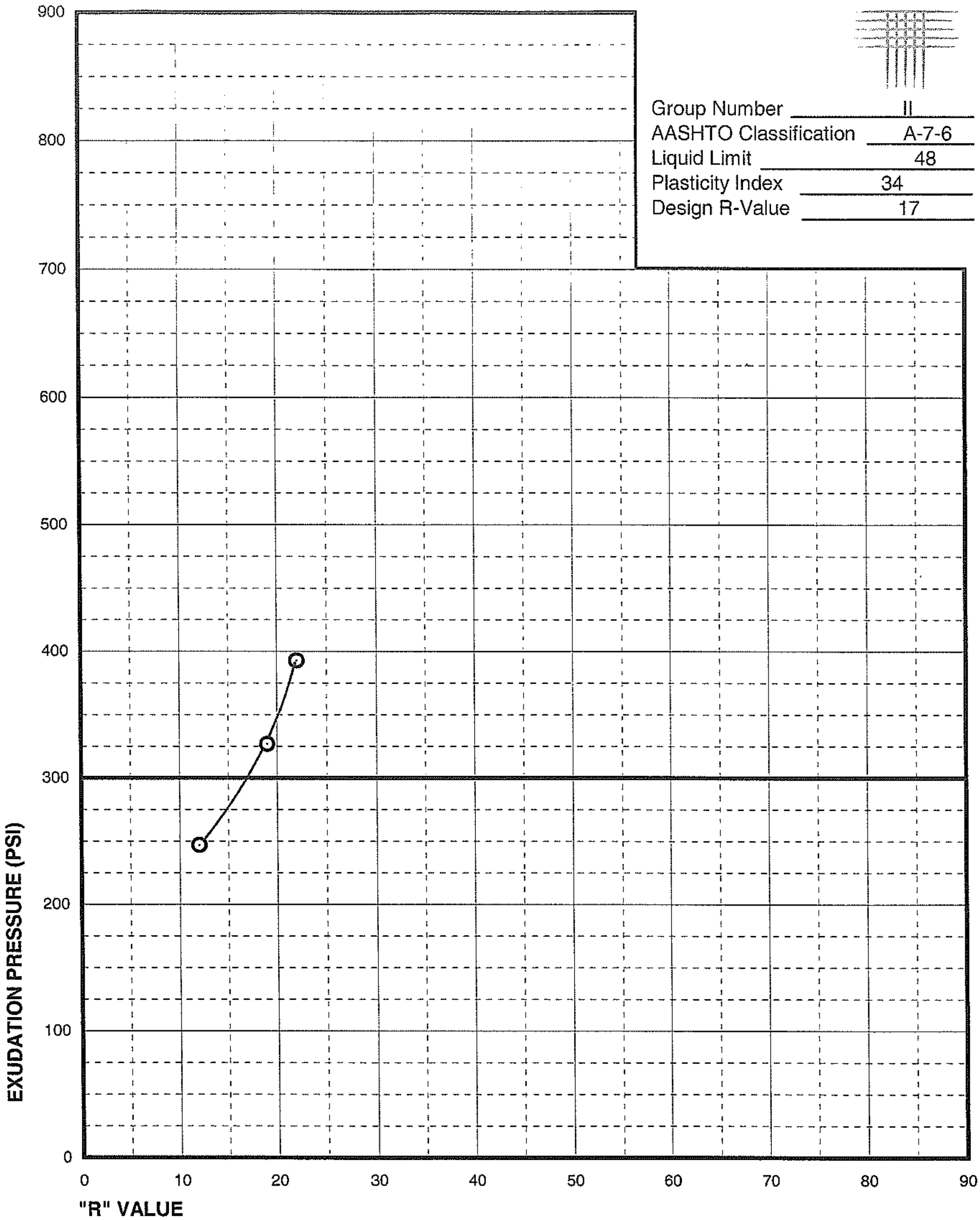
Sample of FILL, CLAY, SANDY
From S-17 AT 2 FEET

GRAVEL 9 % SAND 40 %
SILT & CLAY 51 % LIQUID LIMIT 50 %
PLASTICITY INDEX 36 %

CITY OF FORT COLLINS
ENGINEERING
SOUTH TAFT HILL ROAD OVERLAY
CTL | T PROJECT NO. FC03689-135

Gradation Test Results

FIG. A-8



Group Number	II
AASHTO Classification	A-7-6
Liquid Limit	48
Plasticity Index	34
Design R-Value	17

Hveem Stabilometer Test Results

TABLE A-I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	TYPE	MOISTURE (%)	DRY DENSITY (PCF)	SWELL TEST DATA SWELL (%)	SWELL TEST DATA APPLIED PRESSURE (PSF)	PASSING NO. 200 SIEVE (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTICITY INDEX (%)	R-VALUE	AASHTO CLASSIFICATION	GROUP INDEX	WATER SOLUBLE SULFATES (%)	ORGANIC CONTENT (%)	SOIL TYPE (USC CLASSIFICATION)
S-1	1 TO 4	BULK	17.5				31	41	28		A-2-7	3			FILL, SAND, CLAYEY (SC)
S-1	4	CAL	17.3	112											FILL, SAND, CLAYEY
S-2	2	CAL	10.0	127			30								FILL, SAND, CLAYEY (SC)
S-2	1 TO 4	BULK	12.7					39	25		A-2-6	2			FILL, SAND, CLAYEY (SC)
S-3	2	CAL	15.2	116	5.2	150									WEATHERED CLAYSTONE
S-3	4 TO 9	BULK	19.7				42	53	37		A-7-6	9			WEATHERED CLAYSTONE (SC)
S-4	2	CAL	20.3	107									0.070		FILL, SAND, CLAYEY
S-4	1 TO 4	BULK	16.4				37	43	29		A-7-6	5			FILL, SAND, CLAYEY (SC)
S-5	2	CAL	22.0	106	1.7	150									SAND, CLAYEY
S-5	1 TO 4	BULK	19.4				36	45	31		A-7-6	5			SAND, CLAYEY (SC)
S-6	1 TO 4	BULK	15.0				47	45	30		A-7-6	9			FILL, SAND, CLAYEY (SC)
S-6	4	CAL	16.6	106											FILL, SAND, CLAYEY
S-7	2	CAL	15.2	118	12.4	150									WEATHERED CLAYSTONE
S-7	1 TO 4	BULK	14.4				63	51	36		A-7-6	20			WEATHERED CLAYSTONE (CH)
S-8	1 TO 4	BULK	18.9				37	48	33		A-7-6	6			FILL, SAND, CLAYEY (SC)
S-8	4	CAL	23.5	95											FILL, CLAY, SANDY
S-9	2	CAL	13.4	115	2.5	150									FILL, CLAY, SANDY
S-9	1 TO 4	BULK	17.9				44	46	32		A-7-6	9			FILL, SAND, CLAYEY (SC)
S-10	2	CAL	12.5	113			31								FILL, SAND, CLAYEY (SC)
S-10	1 TO 4	BULK	15.5					46	32		A-2-7	4			FILL, SAND, CLAYEY (SC)
S-11	2	CAL	16.9	109											FILL, CLAY, SANDY
S-11	1 TO 4	BULK	15.5				52	49	32		A-7-6	12			FILL, CLAY, SANDY (CL)
S-12	2	CAL	13.3	123	8.4	150							0.013		WEATHERED CLAYSTONE
S-12	1 TO 4	BULK	12.8				64	45	31		A-7-6	17			WEATHERED CLAYSTONE (CL)
S-13	1 TO 4	BULK	17.8				40	49	33		A-7-6	7			FILL, SAND, CLAYEY (SC)
S-13	4	CAL	19.5	107										1.7	FILL, CLAY, SANDY
S-14	2	CAL	20.0	108											FILL, CLAY, SANDY
S-14	4 TO 9	BULK	20.4				42	55	40		A-7-6	10			SAND, CLAYEY (SC)
S-15	2	CAL	17.7	111	4.4	150									FILL, CLAY, SANDY
S-15	1 TO 4	BULK	17.5				42	49	35		A-7-6	9			FILL, SAND, CLAYEY (SC)
S-16	2	CAL	18.0	112									0.030		FILL, SAND, CLAYEY
S-16	1 TO 4	BULK	17.3				49	49	34		A-7-6	12			FILL, SAND, CLAYEY (SC)
S-17	2	CAL	19.4	107			51								FILL, CLAY, SANDY (CL)
S-17	1 TO 4	BULK	18.9					50	36		A-7-6	13			FILL, CLAY, SANDY (CL)
S-17	4	CAL	24.8	95										4.100	FILL, CLAY, SANDY
COMBINED															
BULK 1															
S-3, S-7, S-12	1 TO 4	BULK	10.2				83	45	31	< 5	A-7-6	25			WEATHERED CLAYSTONE
BULK 2															
S-8, S-13, S-14	1 TO 4	BULK	15.7				79	48	34	17	A-7-6	26			FILL, CLAY, SANDY (CL)

APPENDIX B
DESIGN CALCULATIONS

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: **South Taft Hill Overlay**
Job No. **FC03689-135**

What is the Design ESAL ?	**2,372,500**	
What is the Serviceability Loss ?	**2.0**	
What is the Reliability ?	**90**	
What is the Standard Deviation ?	**0.44**	
What is the R-value ?	**5**	
Computed Resilient Modulus =	**3,026**	psi
If R is not available, Input Resilient Modulus =		psi
DESIGN RESILIENT MODULUS =	**3,026**	psi
DESIGN STRUCTURAL NUMBER (SN) =	**5.19**	

Full Depth AC Thickness on Subgrade is **11.8** inches

What is the AC Layer Coefficient ?	**0.44**
What is the ABC Layer Coefficient ?	**0.11**
What is the FASS Layer Coefficient?	**0.10**

8.0 **inches AC over** **15.2** **inches Aggregate Base Course**

6.6 **inches AC over** **10.0** **inches ABC over** **12.0** **inches FASS**

NOTES: AC = Asphalt Concrete, ABC = Aggregate Base Course, FASS = Fly Ash Stabilized Subgrade
This table presents design parameters and pavement thickness calculations, and should not be used for construction purposes. Final pavement thicknesses are presented in the report.

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: **South Taft Hill Overlay**
Job No. **FC03689-135**

What is the Design ESAL ?	**2,372,500**	
What is the Serviceability Loss ?	**2.0**	
What is the Reliability ?	**90**	
What is the Standard Deviation ?	**0.44**	
What is the R-value ?	**10**	
Computed Resilient Modulus =	**3,563**	psi
If R is not available, Input Resilient Modulus =		psi
DESIGN RESILIENT MODULUS =	**3,563**	psi
DESIGN STRUCTURAL NUMBER (SN) =	**4.97**	

Full Depth AC Thickness on Subgrade is **11.3** inches

What is the AC Layer Coefficient ?	**0.44**
What is the ABC Layer Coefficient ?	**0.11**
What is the FASS Layer Coefficient?	**0.10**

7.5 inches AC over 15.2 inches Aggregate Base Course

6.6 inches AC over 8.0 inches ABC over 12.0 inches FASS

NOTES: AC = Asphalt Concrete, ABC = Aggregate Base Course, FASS = Fly Ash Stabilized Subgrade
This table presents design parameters and pavement thickness calculations, and should not be used for construction purposes. Final pavement thicknesses are presented in the report.

APPENDIX C

GUIDELINE MAINTENANCE RECOMMENDATIONS
MAINTENANCE RECOMMENDATIONS FOR FLEXIBLE PAVEMENTS

APPENDIX C

GUIDELINE MAINTENANCE RECOMMENDATIONS
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.