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MATERIALS ENGINEERS, INC.

SUBGRADE INVESTIGATION
AND PAVEMENT DESIGN
HORSESHOE RIDGE SUBDIVISION
LOT 1, BLOCK 17
PARKER, COLORADO

Prepared for:

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Attention: Mr. Jeffery D. Willis

Project No. DN 46,355.001-135

April 14, 2014
Revised: April 30, 2014

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SCOPE

This report presents the results of our Subgrade Investigation and Pavement Design for the streets in Lot 1, Block 17 of the Horseshoe Ridge Subdivision in Parker, Colorado. The purpose of our investigation was to determine the type of subgrade soils present at the site, evaluate pavement support characteristics, and provide design pavement alternatives.

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 subgrade soils found in exploratory borings, laboratory test results, alternative pavement sections, construction and materials recommendations, and recommendations for maintenance. The pavement alternatives presented in this report were based on the Town of Parker design criteria and method which follows the Colorado Department of Transportation (CDOT) criteria, and our experience. If plans change significantly, we should be contacted to review our recommendations. A brief summary of our conclusions and recommendations is presented below, with more detailed criteria and recommendations contained in the report.

SUMMARY OF CONCLUSIONS

1. Subsoils found in our borings consisted of 5 to 7 feet of clayey sand fill over natural sandy clays to the total depth explored of 5 to 10 feet. Three samples of the clayey sand fill exhibited a swell ranging from 0.2 to 0.6 percent under a confining pressure of 200 psf. The average swell was 0.4 percent.

2. Pavement alternatives include asphalt over prepared subgrade and asphalt over aggregate base course. Pavement alternatives are presented in Table I and on Fig. 3. Design thicknesses, material properties and construction criteria for the pavements are presented in the report.

SITE CONDITIONS

The site is located north of East Hess Road, in Parker, Colorado (Fig. 1). The proposed street segments are approximately 850 feet in length. At the time of our field investigation, grading had been performed, and buried utilities had been installed in the streets.

INVESTIGATION

Subsurface conditions at the site were investigated by drilling four exploratory borings to a depth of 5 to 10 feet, at the approximate locations shown on Fig. 1. Subsoils found in the borings consisted of 5 to 7 feet of clayey sand fill over natural sandy clays to the maximum depth drilled. Free ground water was not encountered in the exploratory borings at the time of drilling.

Laboratory testing was designed to provide index properties of the soils sampled and subgrade support values for those soil types which influence the pavement design. To evaluate potential heave, swell-consolidation testing was performed on three samples of the clay at a depth of 1 foot under a confining pressure of 200 psf. Samples from boring S-1 were not able to have swell-consolidation testing performed due to a lodged piece of gravel in the liner. The swell test results ranged from 0.2 to 0.6 percent, with an average swell of 0.4 percent. Results of laboratory tests are presented in Appendix A and summarized in Table A-I.

A composite sample of the Group I soil (A-6) was subjected to standard Proctor (ASTM D 698, AASHTO T99) compaction test procedures (Fig. A-3) and a Hveem Stabilometer (R-Value) test (ASTM D 2844, AASHTO T 190) to determine a design support value for the subgrade soils. The material squeezed out of the mold during R-Value testing, thus an R-Value of 5 is assumed for the design.

Soluble sulfates were measured on one sample and the result was less than 0.01 percent. The purpose of the sulfate testing was to determine the risk of sulfate attack if portland cement concrete is used. Normal Type I or Type II cement may be used in concrete at this site.

EXPANSIVE SOIL MITIGATION

Swell-consolidation test results ranged from 0.2 to 0.6 percent with an average swell of 0.4 percent. We believe the on-site soils have low swell potential.

The subgrade soils below pavement should be moisture conditioned to optimum to 2 percent above optimum and compacted to at least 95 percent of maximum ASTM D698 dry density prior to base course placement to re-establish moisture in the subgrade prior to paving. A minimum of 12 inches of moisture treatment is also recommended beneath curb and gutter and sidewalks.

Town of Parker Requirements

Town of Parker follows the CDOT design criteria. CDOT and the Town of Parker require mitigation of expansive soils below pavements for soils that have a measured swell greater than 2.0 percent (under a confining pressure of 200 psf). All measured swells were less than 2.0 percent.

PAVEMENT DESIGN

The Town of Parker requires use of the CDOT design method. The streets in this portion of Horseshoe Ridge are classified as local streets. We have calculated a design Equivalent Single Axle Load (ESAL) of 64,640 using the CDOT equation 1.4 (33 residential units), per the Town of Parker Roadway

Design and Construction Criteria Manual section 6.2.3 Item #4. This ESAL value exceeds the minimum design standard for the Town of Parker, and is for a 20-year design life. ESAL values used in our design are presented on Fig. 2.

We have provided two pavement design alternatives for these streets, including asphalt concrete on prepared subgrade and asphalt on aggregate base course. Our pavement thickness alternatives are presented on Table I and shown on Fig. 3. Additional discussion regarding advantages and disadvantages of the pavement alternatives and their expected performance is included under PAVEMENT SELECTION.

TABLE I
PAVEMENT THICKNESS ALTERNATIVES

Classification	Asphalt Concrete + Prepared Subgrade (AC + PS)	Asphalt Concrete + Aggregate Base (AC + ABC)
Local Pavement (ESAL = 64,640)	6.5" AC + 12.0" PS	5.0" AC + 6.0" ABC

PAVEMENT SELECTION

Asphalt concrete over a prepared subgrade is expected to perform well in areas with sand or low plasticity clay (PI < 30) subgrade soils. The asphalt concrete provides a stiff, stable pavement to withstand heavy loading and will provide a good fatigue resistant pavement.

In areas of higher plasticity clay (PI > 30) and/or sites which have undergone deep subexcavation and moisture treatment, some longitudinal cracking of full-depth asphalt pavements due to heaving subgrade may occur. These cracks typically appear 1.5 to 3 feet from the curb lines, predominately in areas which are not subject to traffic. Once the street is subject to traffic loads, the cracks tend to knead themselves back together. Minor rutting of full-depth asphalt pavements may also develop in areas of higher plasticity clays due to wetting of the clays and loss of subgrade strength. A composite of asphalt over aggregate base or asphalt over chemically stabilized subgrade alternative is likely to perform better than a full-depth pavement in areas of higher plasticity clays and moisture treated fill over a 20-year service life.

Asphalt over aggregate base course generally has had good 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 (mentioned above). Conversely, there have been problems where base course has “pushed” into wet clay subgrade. The base course may allow moisture to infiltrate under the pavement. Some aggregate base course that is available in the front range area is highly sensitive to moisture and can lose a significant portion of its strength when wetted. An alternative to aggregate base course would be to use recycled concrete.

We understand that some municipalities and developers prefer to pave the streets low, allowing for a final overlay after residential construction is completed. Construction traffic is the heaviest loading a residential pavement will handle during its life cycle, and we do not recommend placing a thinner section. If a final overlay is desired after construction is completed, we recommend the streets be constructed with the full design section, but with less crown in the center. This will provide better support for the construction traffic and will reduce the risk of water ponding along the curb face or gutter. When construction of the area is completed, the edges can be rotomilled and a final overlay placed, thus providing the smooth finish with a proper crown to facilitate drainage.

Garbage, drywall, sod and concrete trucks are often times over the legal weight limit. The driving and parking of these types of overweight trucks can cause pavement rutting in areas where the underlying subgrade is wet. We recommend these types of trucks be required to be beneath the legal load limit of

18,000 pounds per axle. Where possible, drivers should be instructed to avoid driving and/or parking near the curblines. These precautions should reduce the risk of additional pavement damage during construction.

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 Town of Parker requirements. If the materials cannot meet these recommendations, then the pavement design should be reevaluated based upon available materials. Materials and construction requirements of the Town of Parker should be followed. Materials planned for construction should be submitted and the applicable laboratory tests performed to verify compliance with the specifications.

Asphalt Concrete (AC) or 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 sieve) 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 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 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 only be performed when subgrade temperatures are above 40^{o}F and air temperature is at least 40^{o}F and rising.

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

11. Placement and compaction of HMA should be observed and tested by a representative of our firm. Placement should not commence until the subgrade is properly prepared (or stabilized), tested and proof-rolled. Proof rolling should be performed with the heaviest machine available at the time. The proof roller should be selected from machines providing both mass and high contact pressure.

Aggregate Base Course (ABC)

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

2. Aggregate base course should have a minimum Hveem stabilometer value of 78. Aggregate base course or recycled concrete 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. Aggregate base course or recycled concrete should be laid in thin lifts not to exceed 8 inches, moisture treated to within 2 percent of optimum moisture content, and compacted to at least 95 percent of maximum modified Proctor dry density (ASTM D 1557, AASHTO T 180).

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

Prepared Subgrade (PS)

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

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

3. Granular soils (A-1 to A-5) should be moisture conditioned to between 2 percent below and 2 percent above optimum moisture content and compacted to at least 95 percent of maximum modified Proctor dry density (ASTM D 1557, AASHTO T 180).

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 tested, the area should be proof-rolled with the heaviest machine available at the time. The proof roller should be selected from machines providing both mass and high contact pressure.

6. 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 curblines 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

Routine maintenance, such as sealing and repair of cracks, is necessary to achieve the long-term life of a pavement system. We recommend a preventive maintenance program be developed and followed for all pavement systems to assure the design life can be realized. Choosing to defer maintenance usually results in accelerated deterioration leading to higher future maintenance costs, and/or repair. A recommended maintenance program is outlined in Appendix C.

CONSTRUCTION OBSERVATIONS

This report has been prepared for the exclusive use of BH Parker, Inc. for the purpose of providing geotechnical design and construction criteria for the proposed project. The information, conclusions, and recommendations presented herein are based upon consideration of many factors including, but not limited to, the type of construction, geologic setting, and subsurface conditions encountered. The conclusions and recommendations contained in the report are not valid for use by others. Standards of practice change continuously in the area of geotechnical engineering. The recommendations provided are appropriate for about three years. If the proposed pavements are not constructed within about three years, we should be contacted to determine if we should update this report.

We recommend that CTL | Thompson, Inc. provide construction observation services to allow us the opportunity to confirm whether soil conditions are consistent with those found during this investigation. If others perform these observations, they must accept responsibility to judge whether the recommendations in this report remain appropriate.

GEOTECHNICAL RISK

The concept of risk is an important aspect with any geotechnical evaluation primarily because the methods used to develop geotechnical recommendations do not comprise an exact science. We never have complete knowledge of subsurface conditions. Our analysis must be tempered with engineering judgment and experience. Therefore, the recommendations presented in any geotechnical evaluation should not be considered risk-free. We cannot provide a guarantee that the interaction between the soils and pavements will be as desired or intended. Our recommendations represent our judgment of those measures that are necessary to increase the chances that the streets will perform satisfactorily. It is critical that all recommendations in this report are followed during construction. Upon final acceptance, the Town of Parker must assume responsibility for maintaining the streets and use appropriate practices regarding maintenance and repair.

LIMITATIONS

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

We believe this investigation was conducted with that level of skill and care ordinarily used by geotechnical engineers practicing in this area at this time. No warranty, express or implied, is made. If we can be of further service in discussing the contents of this report or in the analysis of the influence of subsoil conditions on design of the pavements, please call.

CTL | THOMPSON, INC.

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PROFESSIONAL ENGINEER

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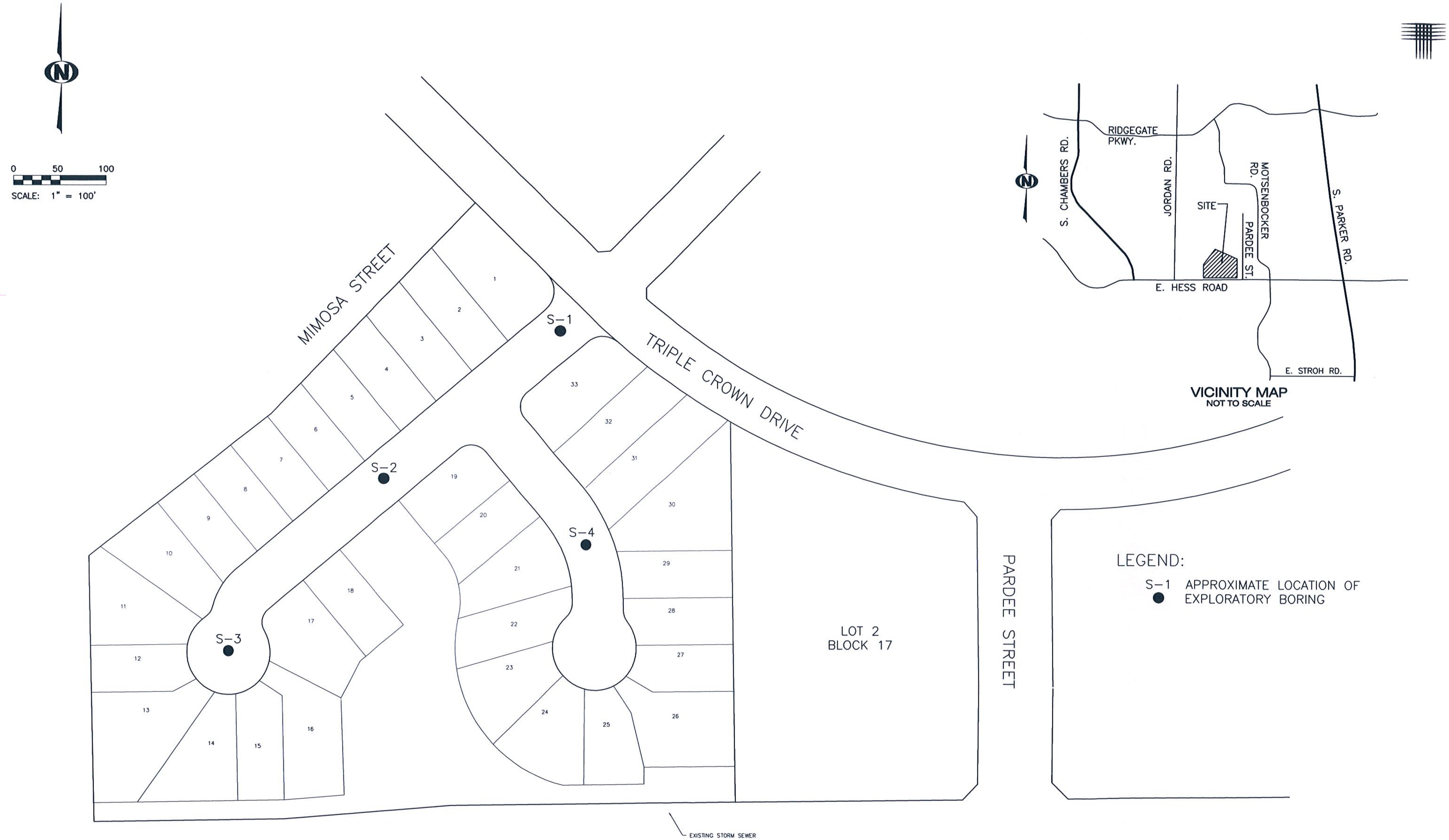
Materials Division Manager

ZJB:DBT
(5 copies sent)



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Project No. DN46,355.001-135

Approximate Locations of Exploratory Borings

Fig. 1

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Design Traffic Values Fig. 2

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Project No. DN46,355.001-135

Recommended Pavement Design Alternatives

Fig. 3

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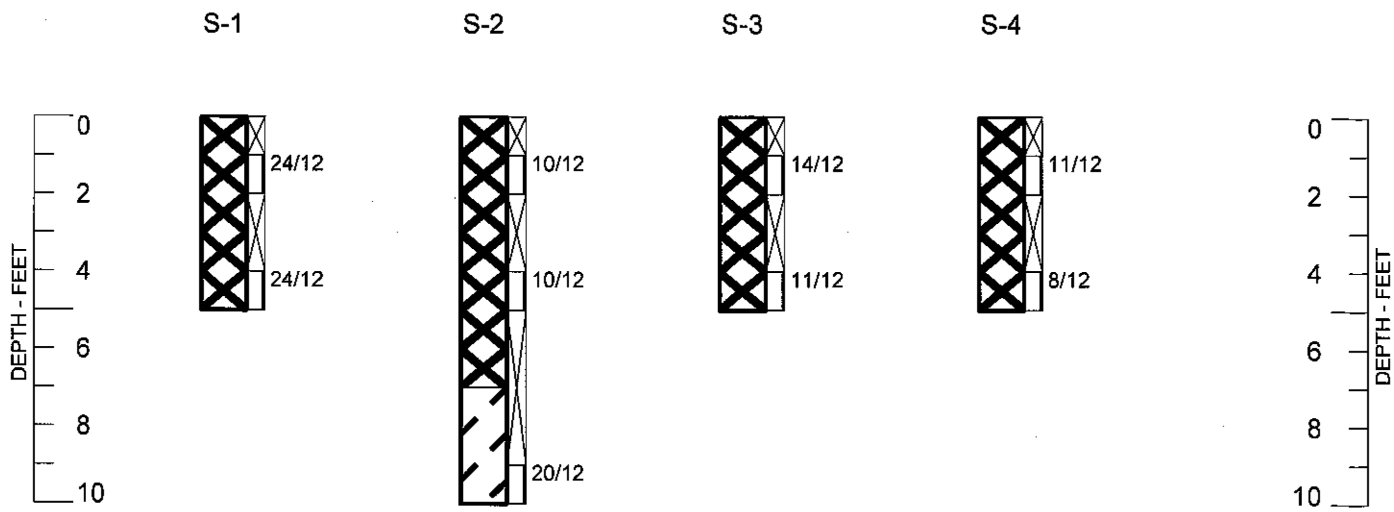

LEGEND:

FILL, SAND, CLAYEY, DENSE, MOIST, BROWN.

CLAY, SANDY, VERY STIFF, MOIST, BROWN (CL).

DRIVE SAMPLE. THE SYMBOL 24/12 INDICATES 24 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.

BULK SAMPLE.

NOTES:

1. THE BORINGS WERE DRILLED / USING 4-INCH DIAMETER, CONTINUOUS-FLIGHT AUGER AND A TRUCK-MOUNTED DRILL RIG.
2. GROUNDWATER WAS NOT ENCOUNTERED DURING THIS INVESTIGATION.
3. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS CONTAINED IN THIS REPORT.

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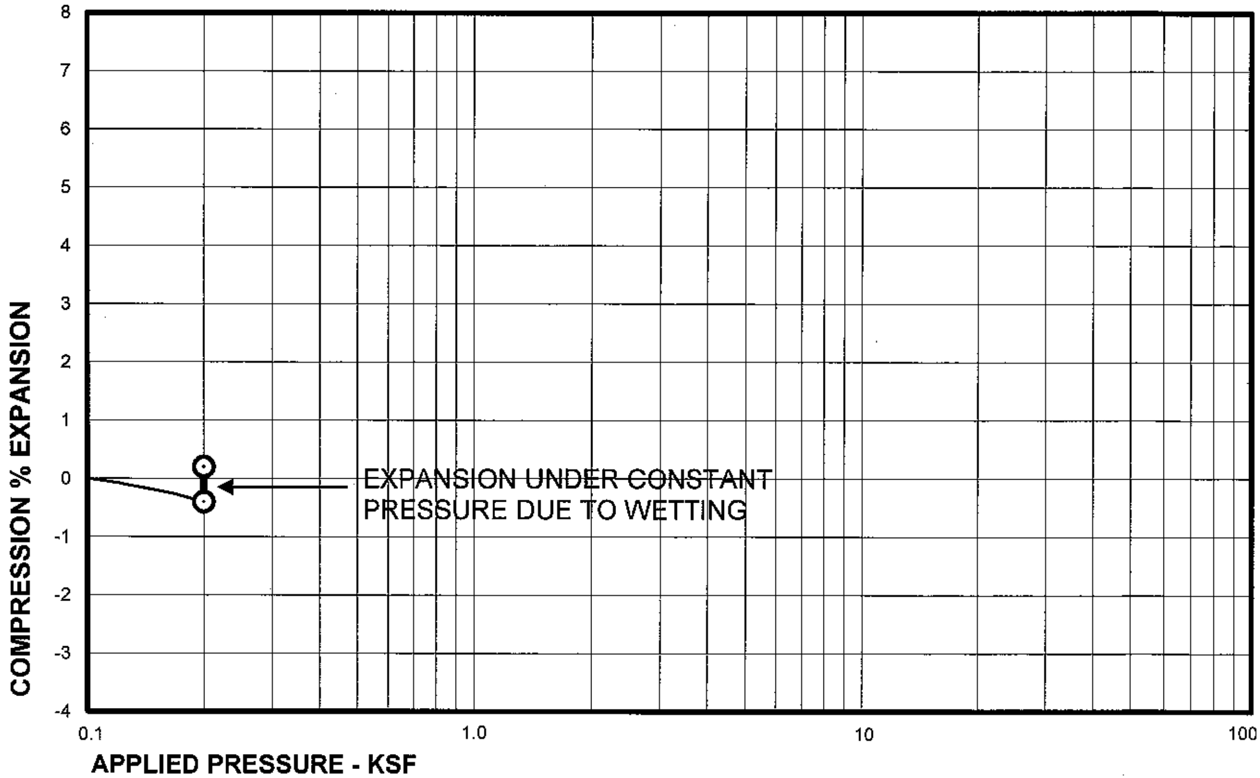
SUMMARY LOGS OF EXPLORATORY BORINGS

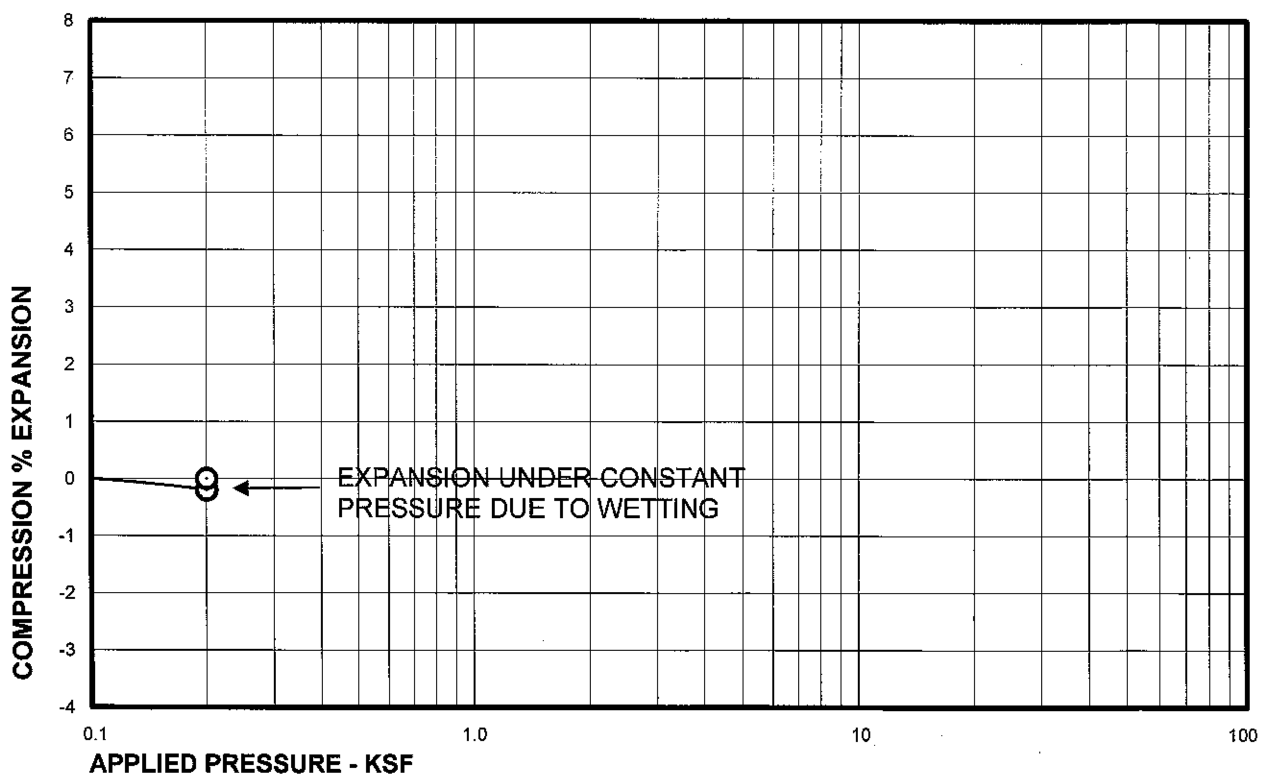
APPENDIX A

LABORATORY TEST RESULTS



Sample of FILL, SAND, CLAYEY
From S-2- AT 1 FEET

NATURAL DRY UNIT WEIGHT= 116 PCF
NATURAL MOISTURE CONTENT= 13.7 %



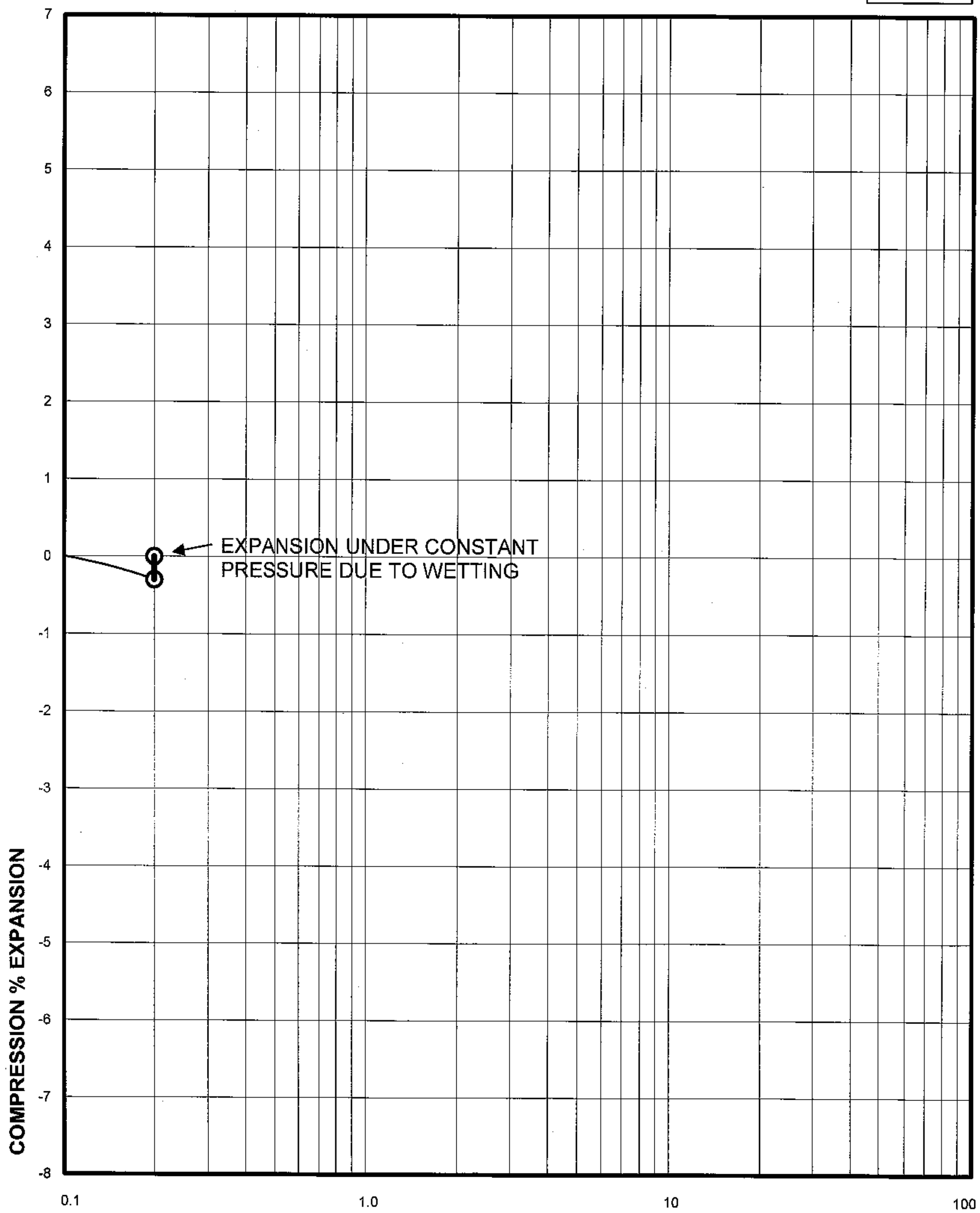
Sample of FILL, SAND, CLAYEY
From S-3- AT 1 FEET

NATURAL DRY UNIT WEIGHT= 117 PCF
NATURAL MOISTURE CONTENT= 10.7 %

Swell Consolidation Test Results

DN46,355.001-135

FIG. A-1



Sample of FILL, SAND, CLAYEY

From S-4- AT 1 FEET

NATURAL DRY UNIT WEIGHT= 124 PCF

NATURAL MOISTURE CONTENT= 11.6 %

Swell Consolidation Test Results

FIG. A-2

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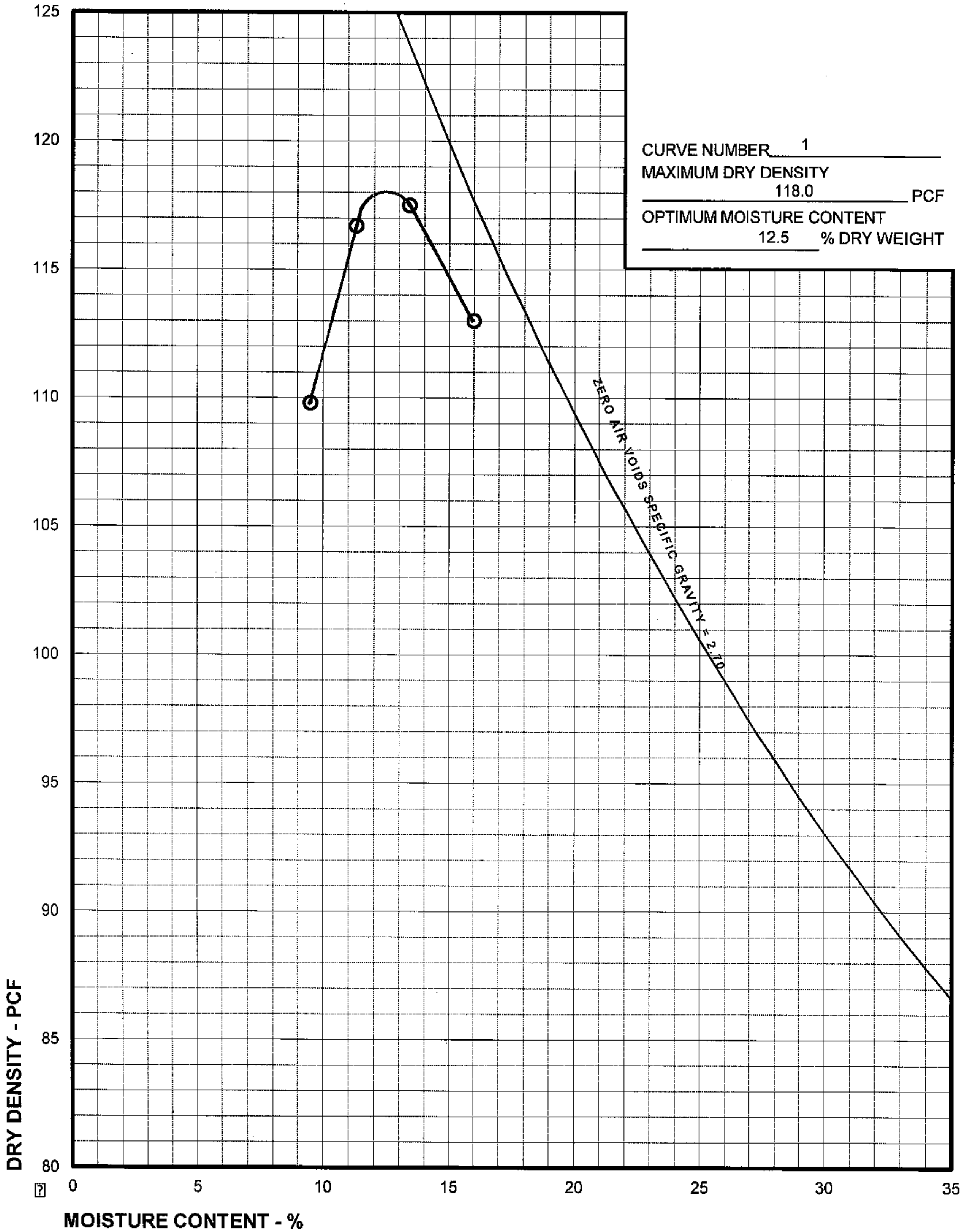

Sample Description Fill, Sand, Clayey, Brown

Location GROUP I SOILS

Compaction Test Procedure ASTM D 698 - 91
METHOD "A"

LIQUID LIMIT	40	%
PLASTICITY INDEX	22	%
GRAVEL	-	%
SAND	-	%
SILT AND CLAY	43	%

Compaction Test Results

PROJECT NO. DN46,355.001-135

Fig. A-3

TABLE A-I
SUMMARY OF LABORATORY TEST RESULTS

Sample No.	Depth (feet)	Group No.	Natural Moisture Content (%)	Natural Dry Density (psf)	Percent Passing No. 200 Sieve	Atterberg Limits		Group Index	Classification		Percent Swell @ 200 psf (%)	Water Soluble Sulfates (%)	Description
						Liquid Limit (%)	Plasticity Index (%)		AASHTO	Unified			
GROUP		I	-	-	43	40	22	5	A-6	SC			Fill, Sand, Clayey
S-1	0-5	I	11.0	-	47	40	23	7	A-6	SC			Fill, Sand, Clayey
S-2	0-5	I	10.1	-	41	41	24	5	A-7-6	SC		<0.01	Fill, Sand, Clayey
S-2	1	I	13.7	116	-	-	-		A-7-6	SC	0.6		Fill, Sand, Clayey
S-3	0-5	I	11.7	-	42	39	22	5	A-6	SC			Fill, Sand, Clayey
S-3	1	I	10.7	117	-	-	-		A-6	SC	0.2		Fill, Sand, Clayey
S-4	0-5	I	9.4	-	38	40	23	4	A-6	SC			Fill, Sand, Clayey
S-4	1	I	11.6	124	-	-	-		A-6	SC	0.3		Fill, Sand, Clayey

APPENDIX B

DESIGN CHARTS AND DESIGN CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

Horseshoe Ridge
Lot 1, Block 17

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	64,640
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	80 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	3,025 psi
Stage Construction	1
Calculated Design Structural Number	2.77 in

DESIGN CALCULATIONS
LOCAL RESIDENTIAL
(GROUP I SOILS)

DESIGN DATA

Equivalent Single Axle Load (ESAL) = 64,640
Hveem Stabilometer (R-Value) = 5
Resilient Modulus (Mr) = 3,025 psi (Calculated from CDOT EQ 2.2)
Structural Number (SN) = 2.77 (from Fig. B-1)

DESIGN EQUATION

$SN = (C_1D_1) + (C_2D_2)$

C_1 = 0.44 - Asphalt Concrete Strength Coefficient
C_2 = 0.12 - Aggregate Base Course Strength Coefficient

D_1 - Depth of Asphalt Concrete (inches)
D_2 - Depth of Aggregate Base Course (inches)

ASPHALT CONCRETE SECTION

D_1 = (2.77) / 0.44 = 6.3 inches of Asphalt Concrete

ASPHALT + AGGREGATE BASE COURSE SECTION

D_2 = ((2.77) - (5.0)(0.44)) / 0.12 = 4.8 inches of Aggregate Base Course

RECOMMENDED SECTIONS

1. 6.5 inches of Asphalt Concrete,
2. 5.0 inches Asphalt Concrete + 6.0 inches Aggregate Base Course

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.