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APPROVED
By: RLK Date: 3-15-04
City of Fort Collins
Engineering Department

Mitigation Required (See Page 4)

SUBGRADE INVESTIGATION AND PAVEMENT DESIGN WOOD STREET WIDENING FORT COLLINS, COLORADO

Prepared For:

CITY OF FORT COLLINS
Project Management Planning & Design
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Attention: Mr. Ron Kechter

Job No. FC-3051

March 5, 2004

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SCOPE

This report presents the results of our geotechnical investigation for the proposed widening of Wood Street north of Vine Drive in Fort Collins, Colorado. The purpose of this investigation was to obtain information regarding subsurface conditions within the alignment of the proposed widening. The report presents geotechnical design and construction criteria for the roadway widening in general conformance with the Larimer County Urban Area Street Standards as adopted by the City of Fort Collins.

Our report includes a description of the subsoil and bedrock found in our exploratory borings, laboratory test results, recommended pavement sections, and construction and materials guidelines. The recommendations contained herein are based upon laboratory test results, Larimer County Urban Area Street Standards, the AASHTO design method, and our experience.

SITE AND PROJECT DESCRIPTION

The project site consists of approximately 220 feet of Wood Street from the property boundary on the north side of the existing detention pond south (see Figure 1). The existing road is a two-lane asphalt-paved road that serves City facilities and a small residential area to the north. The existing roadway slopes gently down towards the north. The road will be widened as part of the City of Fort Collins vehicle storage buildings project. We believe project plans are to add curb and gutter and widen the road to the west approximately one-lane width.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of 2 borings drilled 5 feet deep in the area of the proposed widening. The approximate locations of our borings are illustrated on Figure 1. The borings were drilled on February 6, 2004, on the west side of the existing road. Bulk samples were obtained from the upper five feet of the borings and relatively undisturbed California samples were obtained from 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, Figure 2.

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 4 samples of the clay under a pressure of 200 psf. A Hveem stabilometer test (R-Value) and a standard Proctor test were performed on samples of the subgrade soil, and a sample was tested for water-soluble sulfate content. Results of laboratory tests are presented on Figures 3 through 7 and summarized in Table I.

SUBSURFACE CONDITIONS

Our borings encountered slightly moist to moist, stiff, sandy clay with varying gravel content to the maximum depth of our borings (5 feet). Boring S-1 included a sandy clay that graded to clayey sand with gravel. We tested samples of the soils in the laboratory for density, moisture, gradation, swell/consolidation properties, water-soluble sulfate concentration, and subgrade support characteristics. The samples tested contained 33 and 62 percent clay and silt-sized particles (passing the no. 200 sieve), had liquid limits of 23 (S-1) and 40 (S-2), and plasticity indices of 6 (S-1) and 27 (S-2). The sand sample was classified as an A-2-4 soil and the clay was classified as an A-6 soil in accordance with the AASHTO classification method. The more plastic of the clays were found in Boring S-2. Our observations and test results suggest the near surface soils encountered in the borings are a man-placed fill material with variable properties.

Two samples were tested for swell potential by wetting the samples after application of a 200-psf pressure. One sample consolidated 1.8 percent. The second sample, from Boring S-2, swelled 6.7 percent indicating a high swell potential. Swell potential in this range requires mitigation according to City of Fort Collins specifications. Our recommendations for mitigation of the swelling soils are presented below in the EXPANSIVE SOIL MITIGATION section of this report.

Hveem stabilometer testing (R-Value) was performed on a representative sample from the subgrade alignment. A sample of the A-6 soil had an R-Value of 21. However, the presence of organics, the swell test results, and the variability between samples suggest the subgrade support characteristics are likely less than are indicated by the R-value results. We believe a design R-value of 10 is more appropriate for pavement design calculations involving these soils.

A sample was tested for water-soluble sulfate content, and had 0.008 percent water-soluble sulfates indicating a negligible concentration. The purpose of the sulfate testing was to determine the risk of increased swelling if chemical stabilization of the subgrade is performed. 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 do not believe such a reaction is likely at this site. This result also indicates class 0 exposure to concrete in contact with site soils.

For this level of sulfate concentration, ACI indicates any type of cement can be used for concrete that comes into contact with the subsoils. 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.

Groundwater

Groundwater was not encountered during drilling of our borings. During drilling for our adjacent investigation for the storage bins, however, groundwater was encountered at an elevation of 4990 feet. The adjacent detention pond floor is at an approximate elevation of 4980 feet, and groundwater flowing beneath the site appears to flow downward towards the north. However, groundwater levels will vary seasonally and with changes in precipitation and irrigation amounts in the surrounding area. Construction that includes excavation near or below elevation 4980 should expect soft soils and the potential for instability.

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 variable swell potential that ranged from consolidation to more than 6 percent swell. More plastic clay with a high swell potential was encountered in boring S-2 (the north end of the planned widening), however it is not feasible to determine the area over which the high swelling materials exist without extensive additional investigation. Given the small area planned for widening (generally less than 10 feet wide and about two hundred feet long) we believe that excavation of the upper three feet of subgrade soils and replacement with non-swelling, granular materials is a more practical mitigation technique than moisture and/or chemical treatment of the existing soils. Treatment of the subgrade should extend beneath curb, gutter and attached sidewalks. Construction recommendations are provided below.

The high swelling subgrade soils should be excavated to a depth at least 3 feet below proposed subgrade. Granular materials such as base course can allow moisture to infiltrate under the pavement and aggregate base course can lose strength when wetted. Therefore the subgrade surface should be graded so that water will not collect at the base of the sub-excavated area or in the base course.

Fill should consist of granular materials compacted to a minimum 95 percent of the maximum dry density as determined in accordance with ASTM D 698 at a moisture content within 2 percent of the optimum moisture content. Fill should be free of organic, frozen, or other deleterious material. We believe recycled concrete or asphalt base course would be suitable fill material, and would improve the subgrade support characteristics of the soils and reduce the swell potential to a low level. Care should be taken to ensure the recycled asphaltic or concrete material is uniformly mixed and any fragments with a diameter larger than 2" in any dimension are removed prior to compaction. We recommend the recycled material have a gradation similar to a CDOT Class 5 or 6 aggregate base course for best results.

A fabric such as Mirafi 500x or equivalent, separating the subgrade and aggregate base can be used to reduce co-mingling of the aggregate base with the subgrade soil. We regard the fabric as optional in this area.

PAVEMENT DESIGN

We used the AASHTO design method in accordance with City of Fort Collins requirements. The City of Fort Collins Engineering Department recommended a design Equivalent Daily Load Application (EDLA) of 50 be used for this portion of Wood Street. The EDLA was converted to an Equivalent Single Axle Load (ESAL) of 365,000 for a twenty-year design life. A design R-value of 10 was used for the existing subgrade soil. However, if at least 3 feet of the existing soil is removed and replaced with a base course material that has properties similar to a CDOT class 5 or 6 base course, we believe an R-value of 40 is more appropriately used for design of the pavement structure.

On Table A (below) we have provided pavement design alternatives for this portion of Wood Street including asphaltic concrete on aggregate base course and asphaltic concrete on subgrade that has been sub-excavated and replaced with granular materials as recommended in this report. The City of Fort Collins normally does not permit full depth asphalt pavements, however in this case the full depth pavement section would be constructed on a granular, engineered fill and would therefore function essentially as a composite pavement section.

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

TABLE I

PAVEMENT THICKNESS ALTERNATIVES

Pavement Sections	Asphaltic Concrete & Prepared Subgrade (AC + PS)	Asphaltic Concrete & Aggregate Base (AC + ABC)
Wood Street Widening	6" AC on prepared subgrade*	4" AC + 8" ABC on prepared subgrade

* Subgrade with high swell potential should be treated to a minimum depth of 3 feet.

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 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. If used, 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. We recommend paving 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.

<u>Aggregate Base Course (ABC)</u>

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 designations, is also acceptable.

2. Aggregate base course should have a minimum Hveem stabilometer value of 77. 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. 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 base course should be placed in thin lifts not to exceed 8 inches, moisture treated to within 2% of optimum moisture content, and compacted to at least 95% of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99).

5. 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 inspected.

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 optimum 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-1 to A-5) 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 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.

CTL | THOMPSON, INC.

COLORADO REGISTERED PROFESSIONAL ENGINEER THOMAS A. CHAPEL 33848 3/5/04

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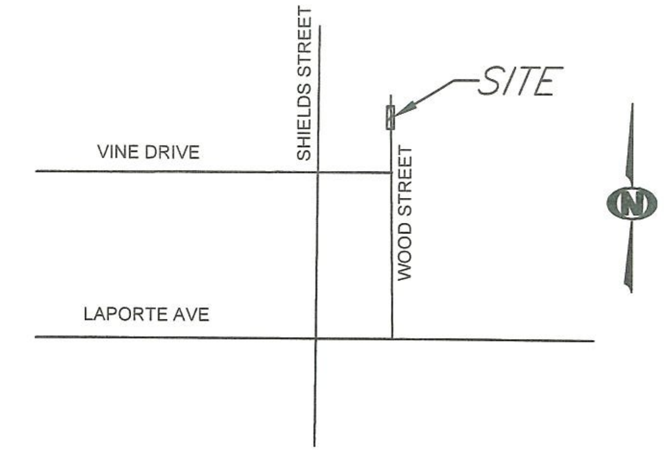


VICINITY MAP
(FORT COLLINS AREA)
NO SCALE

LEGEND :

S-1 ○ INDICATES LOCATION OF SUBGRADE BORING

4990 ——— INDICATES EXISTING CONTOURS
CONTOUR INTERVAL = 1 FOOT

4990 ——— INDICATES PROPOSED CONTOURS
CONTOUR INTERVAL = 1 FOOT

▨ INDICATES AREA OF PLANNED WIDENING

CITY OF FORT COLLINS
WOOD STREET WIDENING
JOB NO. FC-3051

FC-3051 AGV 2/23/2004

Location of Exploratory Borings

FIGURE 1

LEGEND:

CLAY, SANDY, SOME GRAVEL, STIFF, MOIST, BROWN, DARK BROWN (CL)

SAND, CLAYEY, WITH GRAVEL, MEDIUM DENSE, SLIGHTLY MOIST, DARK BROWN (SC)

13/12 DRIVE SAMPLE.THE SYMBOL 13/12 INDICATES THAT 13 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.

INDICATES GRADUAL CHANGE IN STRATA

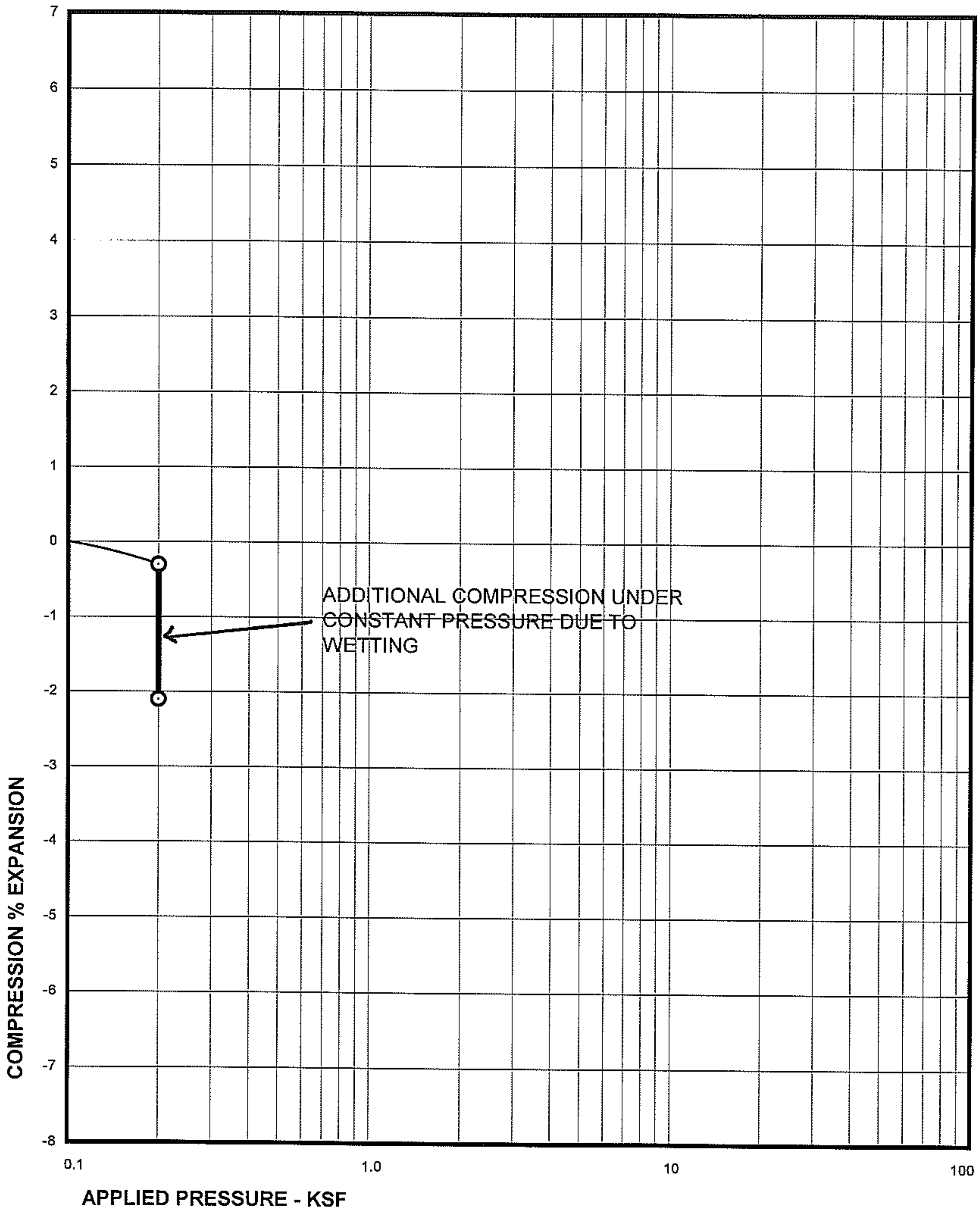
NOTES:

1. THE BORINGS WERE DRILLED ON FEBRUARY 6, 2004 USING 4-INCH DIAMETER CONTINUOUS-FLIGHT AUGER AND A TRUCK-MOUNTED DRILL RIG.
2. BORING ELEVATIONS WERE DETERMINED FROM TOPOGRAPHIC INFORMATION PROVIDED BY TEC.
3. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS IN THIS REPORT.

SUMMARY LOGS OF EXPLORATORY BORINGS

APPENDIX A

LABORATORY TEST RESULTS



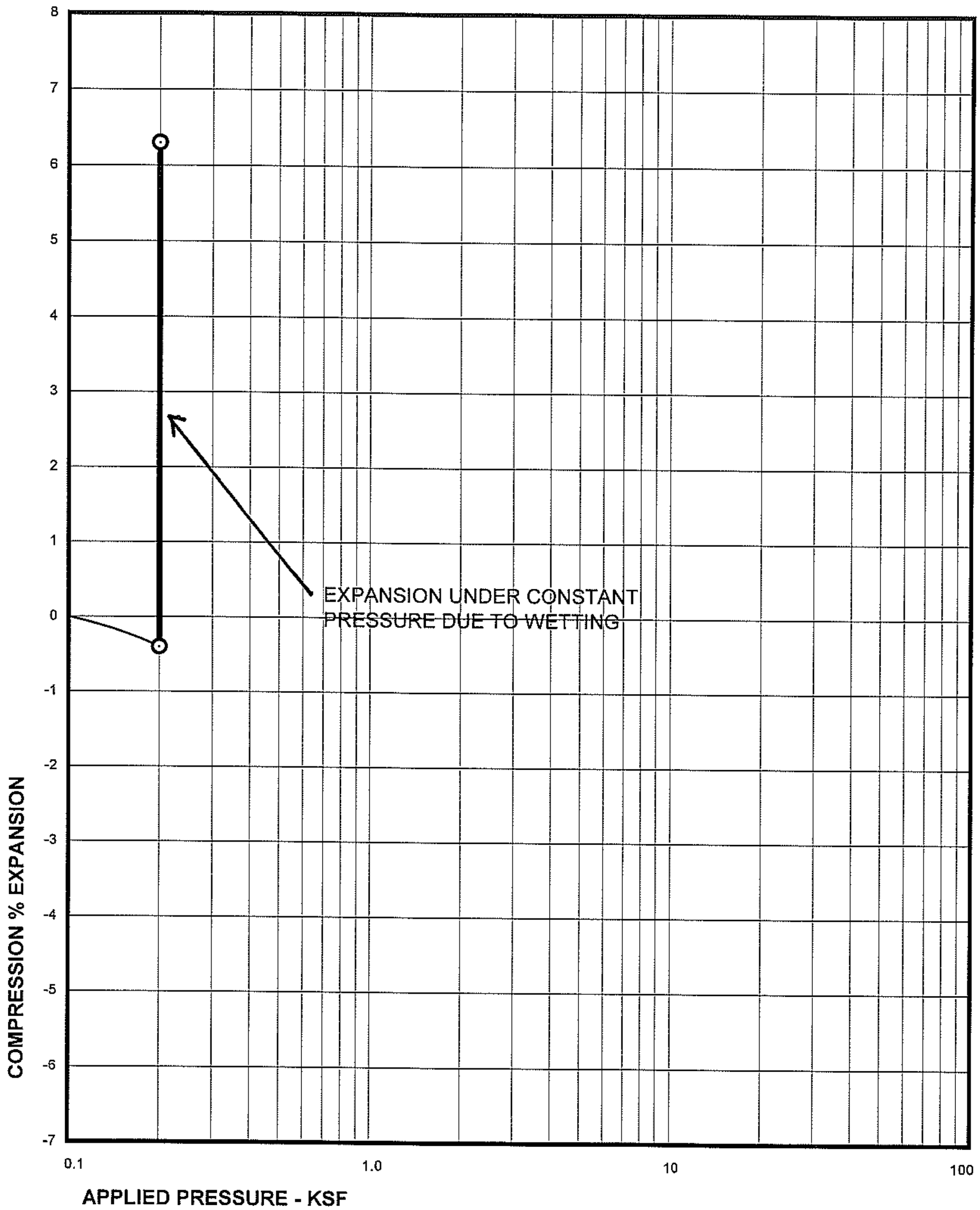
Sample of SAND, CLAYEY (SC)
From S-1 AT 4 FEET

NATURAL DRY UNIT WEIGHT= 102 PCF
NATURAL MOISTURE CONTENT= 5.5 %

JOB NO. FC-3051

Swell Consolidation Test Results

FIG. A-1



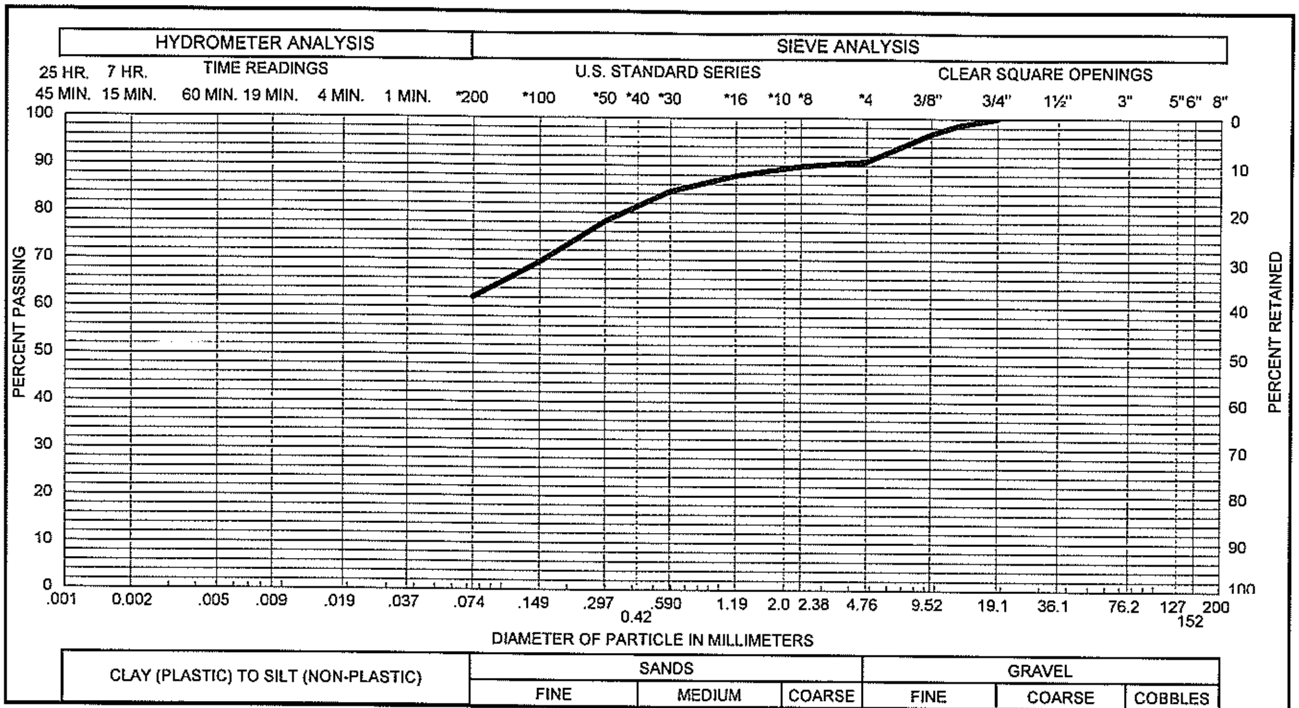
Sample of CLAY, SANDY (CL)
From S-2 AT 4 FEET

NATURAL DRY UNIT WEIGHT= 107 PCF
NATURAL MOISTURE CONTENT= 18.5 %

Swell Consolidation Test Results

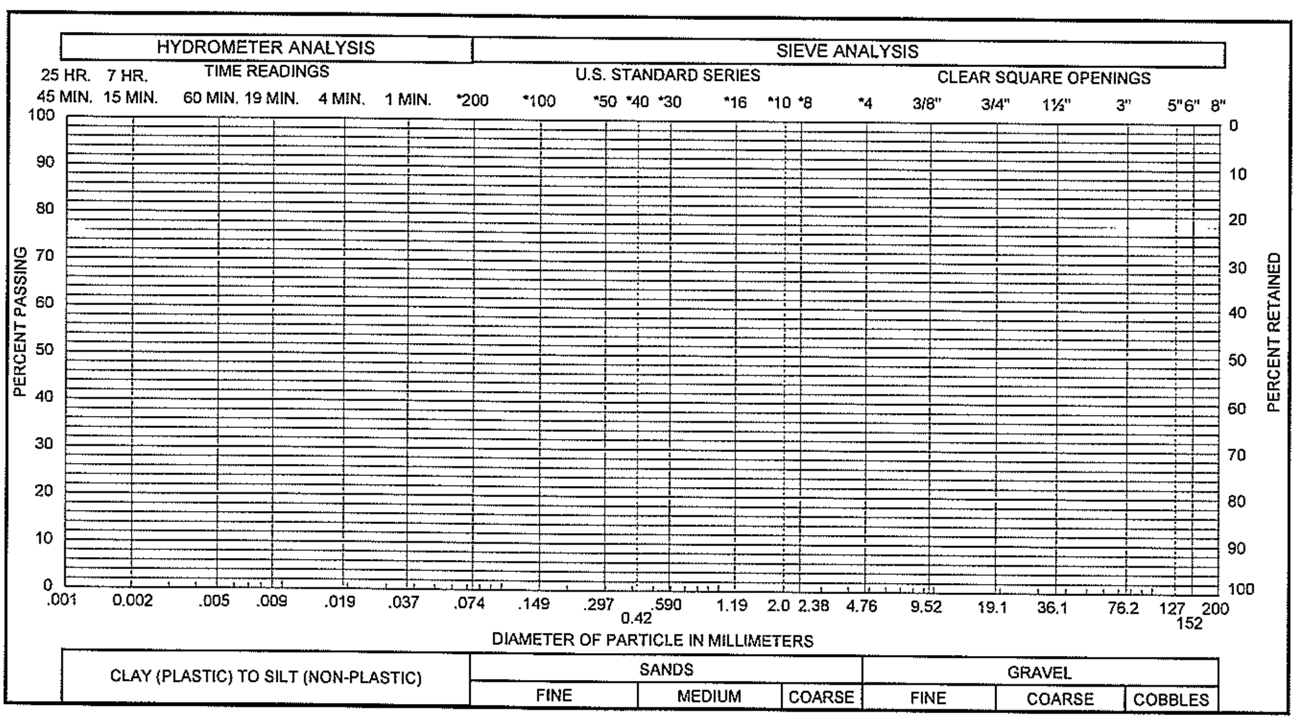
JOB NO. FC-3051

FIG. A-2



Sample of CLAY, SANDY (CL)
From S-2 AT 0 TO 5 FEET (C-1)

GRAVEL 9 % SAND 29 %
SILT & CLAY 62 % LIQUID LIMIT 23 %
PLASTICITY INDEX 6 %



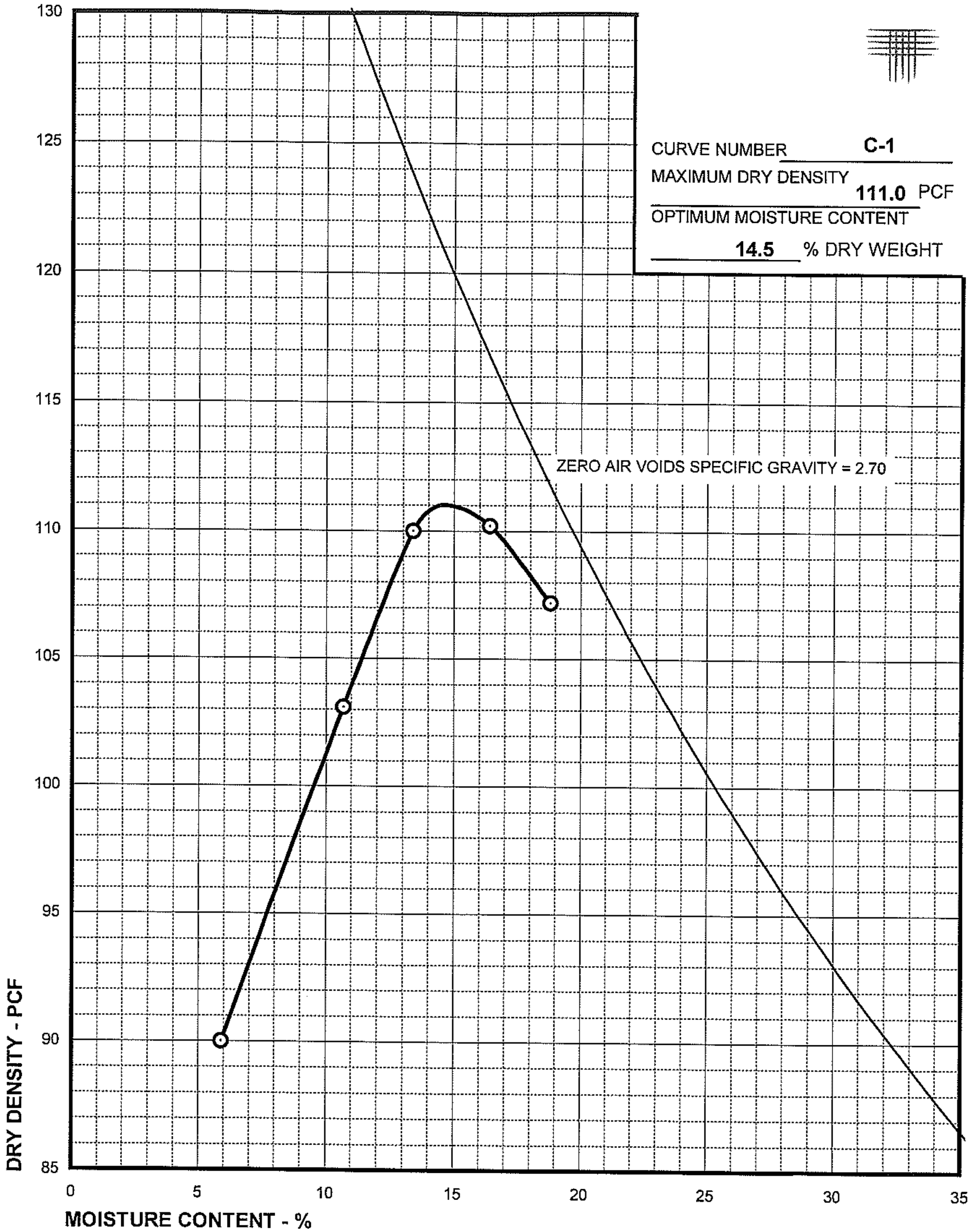
Sample of
From

GRAVEL % SAND %
SILT & CLAY % LIQUID LIMIT %
PLASTICITY INDEX %

Gradation Test Results

JOB NO. FC-3051

FIG. A-3



Sample Description CLAY, SANDY (CL)

Location S-2 AT 0 TO 5 FEET
WOOD STREET WIDENING

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

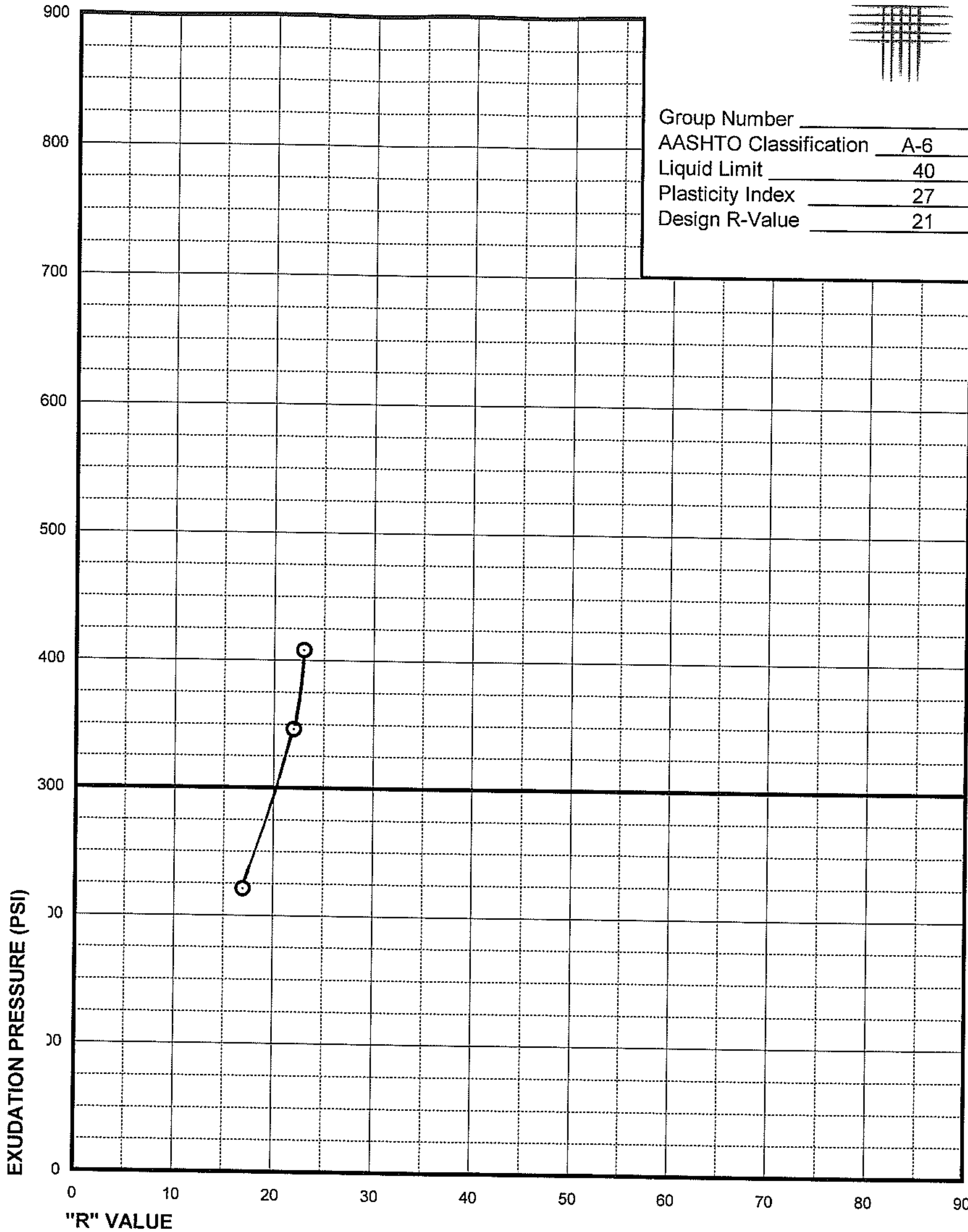
LIQUID LIMIT	40	%
PLASTICITY INDEX	27	%
GRAVEL	9	%
SAND	29	%
SILT AND CLAY	62	%

Compaction Test Results

JOB NO. FC-3051

FIG. A-4

Group Number
AASHTO Classification A-6
Liquid Limit 40
Plasticity Index 27
Design R-Value 21



Hveem Stabilometer Test Results

Job No. FC-3051

Fig. A-5

TABLE A-1

SUMMARY OF LABORATORY RESULTS

BORING	DEPTH (ft)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (pcf)	SWELL TEST DATA		ATTERBERG LIMITS		PASSING NO. 200 SIEVE (%)	R-VALUE	AASHTO CLASSIFICATION	SOLUBLE SULFATE CONTENT (%)	SOIL TYPE
				SWELL (%)	APPLIED PRESSURE (psf)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)					
S-1	4	5.5	101.7	-1.8	200					A-2-6		SAND, CLAYEY (SC)
S-1	0-5	5.7				23.2	5.6	32.6		A-2-6		SAND, CLAYEY (SC)
S-2	4	18.5	106.9	6.7	200					A-6		CLAY, SANDY (CL)
S-2	0-5	11				40	27	62	21	A-6	0.008	CLAY, SANDY (CL)

APPENDIX B

DESIGN CALCULATIONS

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: WOOD STREET WIDENING
Job No.: FC-3051

What is the Design ESAL ?	365,000	
What is the Serviceability Loss ?	2.0	
What is the Reliability ?	80	
What is the Standard Deviation ?	0.44	
What is the R-value ?	40	
Computed Resilient Modulus =	9,502	psi
If R is not available, Input Resilient Modulus =		psi
DESIGN RESILIENT MODULUS =	9,502	psi
Asphalt Thickness on Subgrade is	5.8	inches
What is the ABC Layer Coefficient ?	0.11	
What is the LSS Layer Coefficient ?	0.14	
What is the ACCP Layer Coefficient?	0.44	

4.0	**" AC over**	7.2	**" Aggregate Base Course**
6.0	**" AC over**	-0.6	**" Lime Stabilized Subgrade**

Figure B-1

APPENDIX C

MATERIAL PROPERTIES AND CONSTRUCTION CHECKLIST

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.