REPORT
OF A
PAVEMENT DESIGN

FOR

CIMARRON PLAZA PARKING LOT
AND DECELERATION LANE
FORT COLLINS, COLORADO

ARROWSTONE DEVELOPMENT COMPANY
ENGLEWOOD, COLORADO
PROJECT NO. 6163-85

BY

EMPIRE LABORATORIES, INC.
301 NORTH HOWES STREET
FORT COLLINS, COLORADO 80521

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Empire Laboratories, Inc.
GEOTECHNICAL ENGINEERING & MATERIALS TESTING

P.O. Box 503 • (303) 484-0359
301 No. Howes • Fort Collins, Colorado 80522

September 11, 1985

Arrowstone Development Company
8505 East Orchard Road
Great West Life Center, Suite 820
Englewood, Colorado 80111

Attention: Mr. David Facestel

Gentlemen:

We are pleased to submit our Report of a Pavement Design prepared for the proposed deceleration lane on Shields Street and parking area for Cimarron Plaza P.U.D. in southwest Fort Collins, Colorado.

The accompanying report presents our findings in the subsurface and our recommendations for pavement design based upon these findings.

Very truly yours,

EMPIRE LABORATORIES, INC.

Lisa R. Bilbrey
Geotechnical Engineer

Reviewed by:

Chester C. Smith, P.E.
President

clc

cc: RBD, Inc. - Mr. Lloyd McLaughlin
ZVFK Architects/Planners - Mr. Ed Zdenek

Branch Offices

P.O. Box 1135
Longmont, Colorado 80502
(303) 776-3921

P.O. Box 1744
Greeley, Colorado 80632
(303) 351-0460

P.O. Box 10076
Cheyenne, Wyoming 82003
(307) 632-9224

REPORT
OF A
PAVEMENT DESIGN

SCOPE

This report presents the results of a pavement design prepared for the proposed deceleration lane on Shields Street and the proposed parking lot for Cimarron Plaza P.U.D. in southwest Fort Collins, Colorado. The scope of the project included test borings and laboratory testing of samples obtained from these borings.

The objectives of this study were to (1) determine the soil and ground water conditions at the site, (2) develop criteria for determining pavement design, and (3) make recommendations regarding pavement types and thicknesses for the proposed deceleration lane and parking lot to be constructed at the site.

SITE EXPLORATION

The field exploration, carried out on September 3, 1985, consisted of drilling, logging, and sampling four (4) test borings. The locations of the test borings are shown on the Test Boring Location Plan included in Appendix A of this report. Boring logs prepared from the field logs are shown in Appendix A. These logs show soils encountered, location of sampling, and ground water one day after the exploration. Field resistivity tests were performed at Borings 1, 2, and 3.

The borings were advanced with a four-inch diameter, continuous-type, power-flight auger drill. During the drilling operation, a geotechnical engineer from Empire Laboratories, Inc. was present and made continuous observations of the soils encountered.

SITE LOCATION AND DESCRIPTION

The proposed site is located at the southwest corner of the intersection of Drake Road and Shields Street in southwest Fort Collins, Colorado. More particularly, the site is described as Cimarron Plaza P.U.D., a tract of land situate in the Northeast 1/4 of Section 27, Township 7 North, Range 69 West of the Sixth P.M., Fort Collins, Colorado.

The proposed site is primarily a vacant area vegetated with dense, low grass and weeds. The center of the site is occupied by existing buildings. The west edge of the site has been partially paved. The property is bordered by Drake Road to the north, Shields Street to the east, and Cimarron West P.U.D. to the west and south. The majority of the area slopes slightly to the northeast and exhibits poor surface drainage in this direction.

LABORATORY TESTS AND EVALUATION

Samples obtained from the test borings were subjected to testing in the laboratory to provide a sound basis for evaluating the physical properties of the soils encountered. Moisture contents, dry unit weights, unconfined compressive strengths, water soluble sulfates, pH, and the Atterberg limits were determined. A summary of the test results is included in Appendix B. A Hveem stabilometer test was run to determine the "R" value of representative subgrade material for the deceleration lane at the site, and a curve showing this data is included in Appendix B.

SOIL AND GROUND WATER CONDITIONS

The soil profile at the site consists of strata of materials arranged in different combinations. In order of increasing depths, they are as follows:

(1) Topsoil and Fill Material: A one-half (1/2) foot layer of silty topsoil was encountered at the surface of Borings 1, 2, and 3. The topsoil has been penetrated by root growth and organic matter and should not be used as a pavement subgrade or as a fill and/or backfill material. It is suggested that the topsoil be stripped and stockpiled for use in any planted areas planned at the site. A six (6) foot layer of fill material was encountered at the surface of Boring 4. The fill consists of a heterogeneous mixture of sand, silt, clay, wood fragments and other organic material.

(2) Silty Clay: A layer of brown silty clay underlies the topsoil in Borings 1, 2, and 3 and extends to depths four and one-half (4-1/2) to seven (7) feet below the surface. The silty clay is plastic, contains minor amounts of sand and is damp in its in situ condition.

(3) Sandy Silty Clay: A layer of red sandy silty clay underlies the brown silty clay in Borings 1 and 3 and extends to the underlying sand and gravel stratum or beyond the depth explored. The lower silty clay stratum is plastic, contains varying amounts of sand and traces of gravel, and is damp in its in situ condition.

(4) Silty Clayey Sand and Gravel: A layer of red silty clayey sand and gravel was encountered at depths six (6) to seven (7) feet below the surface in Borings 1, 2, and 4 and extends beyond the depths explored. The sand and gravel stratum contains varying amounts of silt and clay and is medium dense in its dry to damp in situ condition.

(5) Ground Water: One day after the investigation, no free ground water was encountered at the site to a depth of nine (9) feet below the surface. Water levels in this area are subject to change due to seasonal variations.

RECOMMENDATIONS AND DISCUSSION

It is our understanding a parking area is planned for the proposed Cimarron Plaza P.U.D. In addition, a deceleration lane will be constructed on southbound Shields Street on the east side of the planned development. The following are our recommendations for the design and construction of the planned pavement based on the soil and ground water conditions encountered at the site.

Site Grading and Utilities

It is recommended that the upper six (6) inches of topsoil encountered in the proposed parking area be stripped and stockpiled for reuse in planted areas. Portions of the fill encountered in the proposed deceleration lane contain substantial quantities of wood and other organic material. It is recommended that at least one (1) foot of the fill material in this area be stripped and either wasted from the site or stockpiled for reuse depending on the quantities of organics encountered in the fill. However, the fill should be stripped to the level where high quantities of organic material are no longer encountered. The upper six (6) inches of the subgrade below the removed topsoil and fill should be scarified and recompacted at or slightly wet of optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78. (See Appendix C.) If this subgrade compaction cannot be met due to poorly compacted fill below, additional fill should be removed to such a point where the above-required compaction can be obtained.

All additional fill should consist of the on-site soils devoid of any debris or organic matter or imported material having an "R" value of 5 or greater, and this material should be approved by the geotechnical engineer. Any fill placed at the site should be placed in uniform six (6) to eight (8) inch lifts and compacted at or slightly wet of optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78. The finished subgrade in cut sections below pavement should be scarified a minimum of six (6) inches and recompacted at or

slightly wet of optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78.

Utility trenches dug four (4) feet or more into the upper soils should be excavated on slopes no steeper than 1:1. All piping should be adequately bedded for proper load distribution.

Backfill placed in utility trenches in open and planted areas should be compacted in uniform lifts at optimum moisture to at least ninety percent (90%) of Standard Proctor Density ASTM D 698-78 the full depth of the trench. The upper four (4) feet of backfill placed in utility trenches under roadways and paved areas should be compacted at or near optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78, and the lower portion of these trenches should be compacted to at least ninety percent (90%) of Standard Proctor Density ASTM D 698-78. Addition of moisture to and/or drying of the subsoils may be needed for proper compaction.

Stripping, grubbing, subgrade preparation, and fill and backfill placement should be accomplished under continuous observation of the geotechnical engineer. Field density tests should be taken daily in the compacted subgrade, fill, and backfill under the direction of the geotechnical engineer.

Resistivity tests performed in the field and pH and water soluble sulfate tests performed in the laboratory indicate that the subsoils at the site are noncorrosive, and protection of utility pipe should not be required.

Flexible Pavement

It is our opinion that flexible pavement is suitable for the proposed parking area and deceleration lane at the site. A flexible pavement alternate should consist of asphaltic concrete underlain by crushed aggregate base course (and subbase in the deceleration lane) or asphaltic concrete underlain by plant mix bituminous base course. Using the City of Fort Collins "Design Criteria and Standards for Streets," a serviceability index of 2.5, a regional factor of 0.75, an "R" value of 5,

a twenty (20) year design life, an eighteen (18) kip equivalent daily load application of 115, and a weighted structural number of 3.65, the following pavement thicknesses are recommended for the proposed deceleration lane:

Deceleration Lane	
Asphaltic Concrete	4"
Crushed Aggregate Base Course	8"
Select Subbase	9"
Total Pavement Thickness	21"

Asphaltic Concrete	3"
Plant Mix Bituminous Base Course	7"
Total Pavement Thickness	10"

Based on the soil conditions encountered at the site and the type and volume of traffic and using a group index of 12 as the criterion for pavement design, the following pavement thicknesses are recommended for the proposed parking area:

Passenger Car Parking	
Asphaltic Concrete	2½"
Crushed Aggregate Base Course	7"
Total Pavement Thickness	9½"

Asphaltic Concrete	2½"
Plant Mix Bituminous Base Course	2½"
Total Pavement Thickness	5"

Loading and Driveway Areas	
Asphaltic Concrete	2½"
Crushed Aggregate Base Course	10"
Total Pavement Thickness	12½"

Asphaltic Concrete	2½"
Plant Mix Bituminous Base Course	3½"
Total Pavement Thickness	6"

The select subbase should meet City of Fort Collins Class 1 specifications, and the crushed aggregate base course should meet City of Fort Collins Class 6 specifications. The subgrade below the proposed asphalt pavement should be prepared in accordance with the recommendations discussed in the "Site Grading and Utilities" section of this report. Upon proper preparation of the subgrade, the subbase and base course should be placed and compacted at optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78. (See Appendix C.)

It is recommended that the asphaltic concrete and/or plant mix bituminous base course be placed in two (2) to three (3) inch lifts. All plant mix bituminous base course and asphaltic concrete shall meet City of Fort Collins specifications and should be placed in accordance with these specifications. All subbase material shall have an "R" value of 70 or greater, the crushed aggregate base course shall have an "R" value of 78 or greater, the plant mix bituminous base course shall have an Rt value of 90 or greater, and the asphaltic concrete shall have an Rt value of 95 or greater. The "R" value of the pavement materials used should be verified by laboratory tests. Field density tests should be taken in the aggregate base course, bituminous base course, and asphaltic concrete under the direction of the geotechnical engineer.

Rigid Pavement

A feasible pavement alternate at the site would be rigid pavement. Using the eighteen (18) kip equivalent daily load application described above, a modulus of subgrade reaction of one hundred (100) pounds per square inch per inch based on an "R" value of 5, a design life of twenty (20) years, and concrete designed with a modulus of rupture of five hundred fifty (550) pounds per square inch, the following pavement thickness is recommended for the proposed deceleration lane:

Deceleration Lane

Nonreinforced Concrete - 7½"

Using a modulus of subgrade reaction of one hundred fifty (150) pounds per square inch per inch, a design life of twenty (20) years, and concrete with a modulus of rupture of five hundred fifty (550) pounds per square inch, the following pavement thicknesses are recommended for the proposed parking area:

Passenger Car Parking

Nonreinforced Concrete - 4½"

Loading and Driveway Areas

Nonreinforced Concrete - 5"

Subgrade below proposed pavements should be prepared in accordance with the recommendations discussed in the "Site Grading and Utilities" section of this report. Concrete pavement should be placed directly on the subgrade that has been uniformly and properly prepared in accordance with the above recommendations. All concrete used in the paving shall meet ASTM specifications, and all aggregate shall conform to ASTM C-33 specifications. The concrete should be designed with a minimum modulus of rupture of five hundred fifty (550) pounds per square inch in twenty-eight (28) days. It is recommended that laboratory mix designs be done to determine the proper proportions of aggregates, cement, and water necessary to meet these requirements. It is essential that the concrete have a low water-cement ratio, an adequate cement factor, and sufficient quantities of entrained air. Joints should be carefully designed and constructed in accordance with the City of Fort Collins "Design Criteria and Standards for Streets" to ensure good performance of the pavement. It is recommended that all concrete pavement be placed in accordance with City of Fort Collins specifications. If paving is done during cold weather, acceptable cold weather procedures as outlined in the City specifications should be utilized. The concrete pavement should be properly cured and protected in accordance

with the above specifications. Concrete injured by frost should be removed and replaced. It is recommended that the pavement not be opened to traffic until a flexural strength of four hundred (400) pounds per square inch is obtained or a minimum of fourteen (14) days after the concrete has been placed.

GENERAL COMMENTS

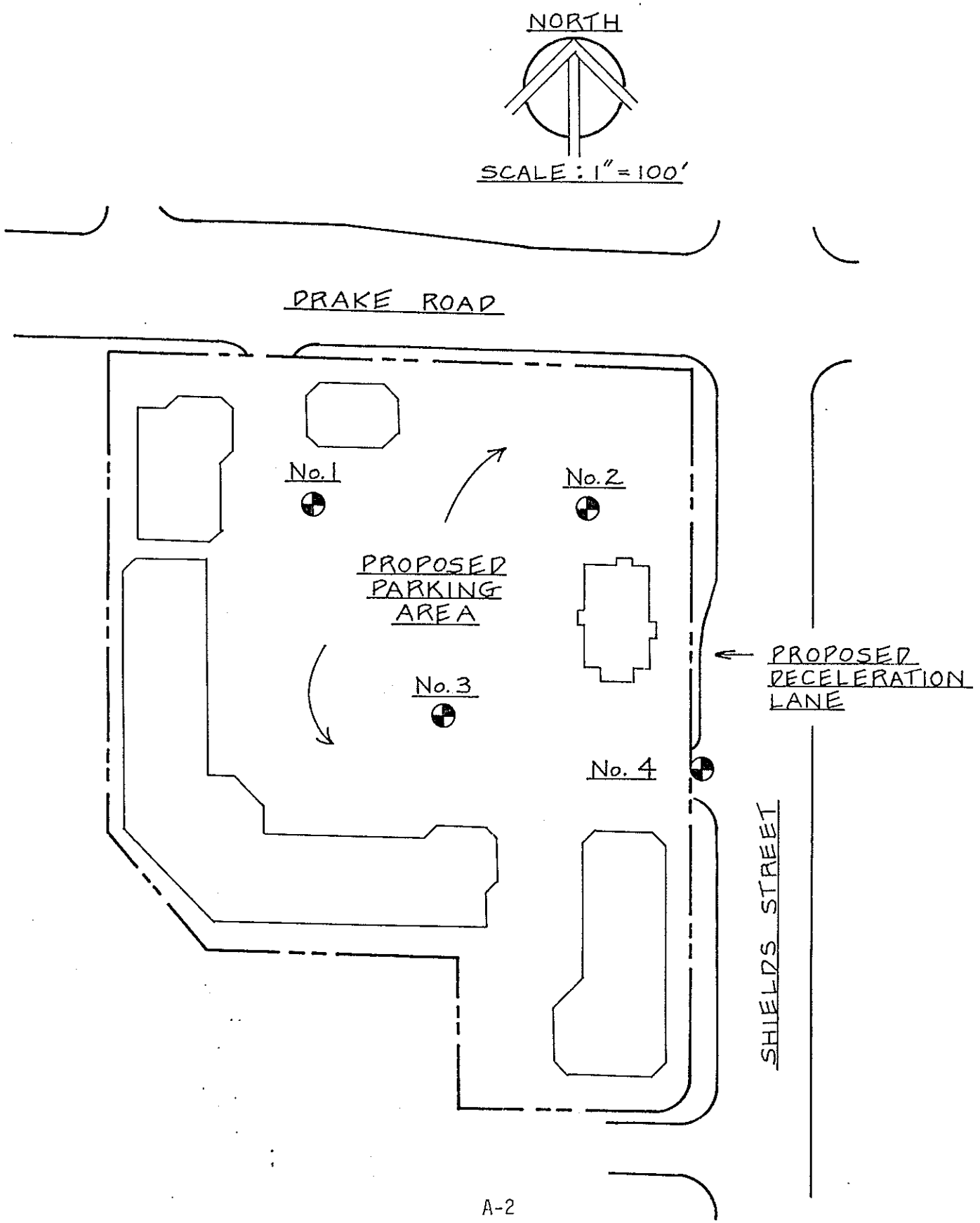
This report has been prepared to aid in the evaluation of the property and to assist the engineer in the design of this project. In the event that any changes in the street grade or designs are planned, the conclusions and recommendations contained in this report will not be considered valid unless said changes are reviewed and conclusions of this report modified or approved in writing by Empire Laboratories, Inc, the geotechnical engineer of record.

Every effort was made to provide comprehensive site coverage through careful locations of the test borings, while keeping the site investigation economically feasible. Variations in soil and groundwater conditions between test borings may be encountered during construction. In order to permit correlation between the reported subsurface conditions and the actual conditions encountered during construction and to aid in carrying out the plans and specifications as originally contemplated, it is recommended that Empire Laboratories, Inc. be retained to perform continuous construction review during the subgrade preparation, fill placement, and paving phases of the work. Empire Laboratories, Inc. assumes no responsibility for compliance with the recommendations included in this report unless they have been retained to perform adequate on-site construction review during the course of subgrade preparation and pavement placement.

APPENDIX A.

TEST BORING LOCATION PLAN

CIMARRON PLAZA P.U.D.



KEY TO BORING LOG


TOPSOIL


FILL


SILT


CLAYEY SILT


SANDY SILT


CLAY


SILTY CLAY


SANDY CLAY


SAND


SILTY SAND


CLAYEY SAND


SANDY SILTY CLAY


GRAVEL


SAND & GRAVEL


SILTY SAND & GRAVEL


COBBLES


SAND, GRAVEL & COBBLES


WEATHERED BEDROCK


SILTSTONE BEDROCK


CLAYSTONE BEDROCK


SANDSTONE BEDROCK


LIMESTONE


GRANITE


SHELBY TUBE SAMPLE

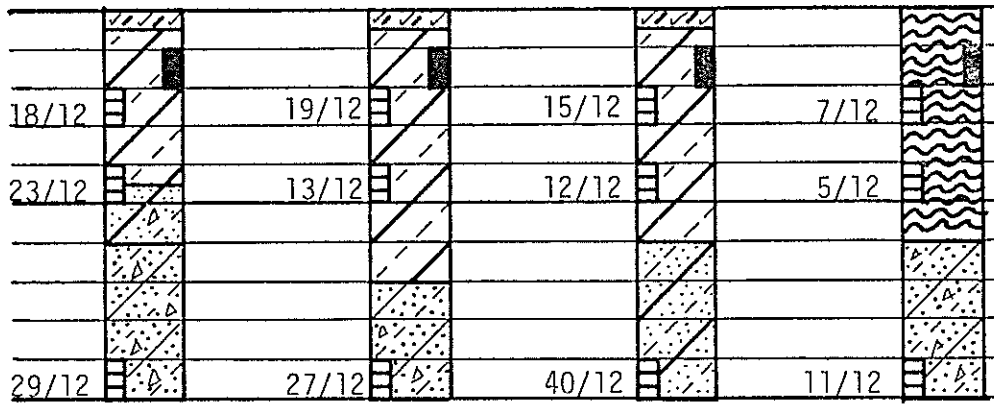

STANDARD PENETRATION DRIVE SAMPLER


WATER TABLE 24 hours AFTER DRILLING

HOLE CAVED

5/12 Indicates that 5 blows of a 140 pound hammer falling 30 inches was required to penetrate 12 inches.

LOG OF BORINGS



APPENDIX B.

RESISTANCE R-VALUE AND EXPANSION PRESSURE OF COMPACTED SOIL

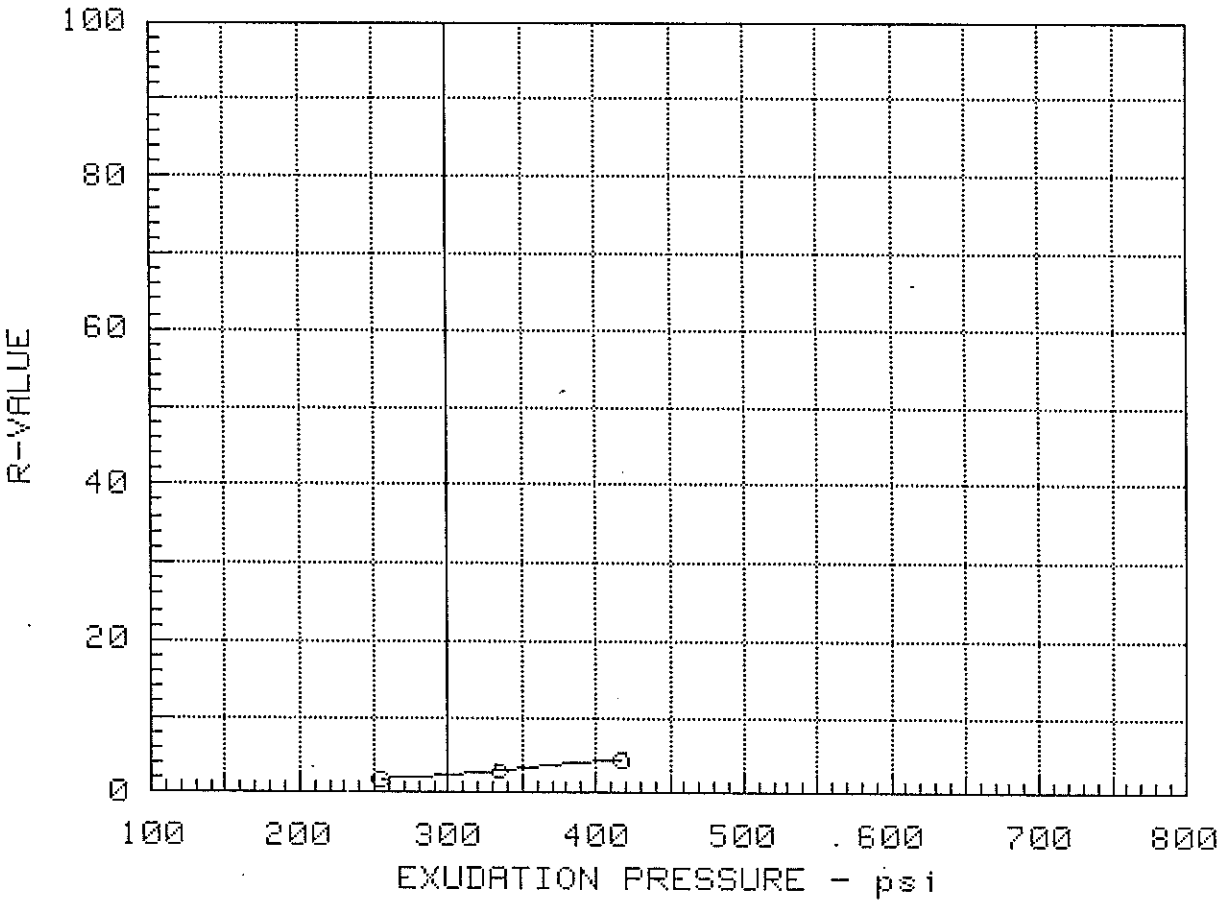
ASTM - D 2844

CLIENT: ARROWSTONE DEVELOPMENT
PROJECT: CIMARRON PLAZA
LOCATION OF SAMPLE: BORING #4 @ 1.0'-3.0'

SAMPLE DATA

TEST SPECIMEN	1	2	3
COMPACTION PRESSURE - PSI	0	0	0
DENSITY - PCF	99.3	105.2	104.4
MOISTURE - %	25.8	23.7	22.8
EXPANSION PRESSURE - PSI	0.00	0.00	0.00
HORIZONTAL PRESSURE @ 160 psi	154	150	146
SAMPLE HEIGHT - in.	2.28	2.42	2.63
EXUDATION PRESSURE - PSI	255	335	418
UNCORRECTED R-VALUE	2.0	3.1	4.2
CORRECTED R-VALUE	1.8	3.0	4.4

R-VALUE AT 300 PSI EXUDATION PRESSURE = 2.4



SUMMARY OF TEST RESULTS

Boring No.	Depth (Ft.)	Moisture (%)	Dry Density (PCF)	Compressive Strength (PSF)	Swell Pressure (PSF)	Soluble Sulfates (%)	pH	Liquid Limit (%)	Plasticity Index (%)	Group Index	Classification AASHTO USCS	Resistivity (OHM-CM)	Penetration Blows/In.
1	1.0-2.0	12.2	102.0	11,710		.0003	7.3	42.8	21.3	16.5	A-7-6(16);CL		
	2.0-3.0	12.1											18/12
	4.0-5.0	10.5										4290	23/12
	9.0-10.0	2.7											29/12
2	1.0-2.0	11.9	98.6	13,820									
	2.0-3.0	11.6											19/12
	4.0-5.0	11.2										8800	13/12
	9.0-10.0	3.9											27/12
3	1.0-2.0	10.4				.0002	7.1	31.4	10.7	5.6	A-6(5);CL		
	2.0-3.0	11.2											15/12
	4.0-5.0	13.7										7810	12/12
	9.0-10.0	4.2											40/12
4	1.0-2.0	15.5	95.0										
	2.0-3.0	12.1											7/12
	4.0-5.0	16.2											5/12
	9.0-10.0	5.3											11/12
Composite Sample	1.0-3.0							36.1	16.4	8.2	A-6(8);CL		

APPENDIX C.

APPENDIX C.

Suggested Specifications for Placement of Compacted Earth Fill and/or Backfills.

GENERAL

A geotechnical engineer shall be on-site to provide continuous observation during filling and grading operations and shall be the owner's representative to inspect placement of all compacted fill and/or backfill on the project. The geotechnical engineer shall approve all earth materials prior to their use, the methods of placing, and the degree of compaction obtained.

MATERIALS

Soils used for all compacted fill and backfill shall be approved by the geotechnical engineer prior to their use. The upper two (2) feet of compacted earth backfill placed adjacent to exterior foundation walls shall be an impervious, nonexpansive material. No material, including rock, having a maximum dimension greater than six (6) inches shall be placed in any fill. Any fill containing rock should be carefully mixed to avoid nesting and creation of voids. In no case shall frozen material be used as a fill and/or backfill material.

PREPARATION OF SUBGRADE

All topsoil, vegetation (including trees and brush), timber, debris, rubbish, and other unsuitable material shall be removed to a depth satisfactory to the geotechnical engineer and disposed of by suitable means before beginning preparation of the subgrade. The subgrade surface of the area to be filled shall be scarified a minimum depth of six (6) inches, moistened as necessary, and compacted in a manner specified below for the subsequent layers of fill. Fill shall not be placed on frozen or muddy ground.

PLACING FILL

No sod, brush, frozen or thawing material, or other unsuitable material shall be placed in the fill, and no fill shall be placed during unfavorable weather conditions. All clods shall be broken into small pieces, and distribution of material in the fill shall be such as to preclude the formation of lenses of material differing from the surrounding material. The materials shall be delivered to and spread on the fill surface in a manner which will result in a uniformly compacted fill. Each layer shall be thoroughly blade mixed during spreading to ensure uniformity of material and moisture in each layer. Prior to compacting, each layer shall have a maximum thickness of eight (8) inches, and its upper surface shall be approximately horizontal. Each successive 6" to 8" lift of fill being placed on slopes or hillsides should be benched into the existing slopes, providing good bond between the fill and existing ground.

MOISTURE CONTROL

While being compacted, the fill material in each layer shall as nearly as practical contain the amount of moisture required for optimum compaction or as specified, and the moisture shall be uniform throughout the fill. The contractor may be required to add necessary moisture to the fill material and to uniformly mix the water with the fill material if, in the opinion of the geotechnical engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. If, in the opinion of the geotechnical engineer, the material proposed for use in the compacted fill is too wet to permit adequate compaction, it shall be dried in an acceptable manner prior to placement and compaction.

COMPACTION

When an acceptable, uniform moisture content is obtained, each layer shall be compacted by a method acceptable to the geotechnical engineer and as specified in the foregoing report as determined by applicable standards. Compaction shall be performed by rolling with approved tamping rollers,

pneumatic-tired rollers, three-wheel power rollers, vibratory compactors, or other approved equipment well-suited to the soil being compacted. If a sheepfoot roller is used, it shall be provided with cleaner bars attached in a manner which will prevent the accumulation of material between the tamper feet. The rollers should be designed so that effective weight can be increased.

MOISTURE-DENSITY DETERMINATION

Samples of representative fill materials to be placed shall be furnished by the contractor to the geotechnical engineer for determination of maximum density and optimum moisture or percent of Relative Density for these materials. Tests for this determination will be made using methods conforming to requirements of ASTM D 698, ASTM D 1557, or ASTM D 2049. Copies of the results of these tests will be furnished to the owner, the project engineer, and the contractor. These test results shall be the basis of control for all compaction effort.

DENSITY TESTS

The density and moisture content of each layer of compacted fill will be determined by the geotechnical engineer in accordance with ASTM D 1556, ASTM D 2167, or ASTM D 2922. Any material found not to comply with the minimum specified density shall be recompacted until the required density is obtained. Sufficient density tests shall be made and submitted to support the geotechnical engineer's recommendations. The results of density tests will also be furnished to the owner, the project engineer, and the contractor by the geotechnical engineer.