

REPORT
OF A
PAVEMENT DESIGN

FOR
BOARDWALK CROSSING P.U.D.
FORT COLLINS, COLORADO

MR. GEORGE HOLTER
FORT COLLINS, COLORADO
PROJECT NO. 6136-85

BY

EMPIRE LABORATORIES, INC.
301 NORTH HOWES STREET
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Empire Laboratories, Inc.

GEOTECHNICAL ENGINEERING & MATERIALS TESTING

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August 22, 1985

Mr. George Holter
Holter Realty
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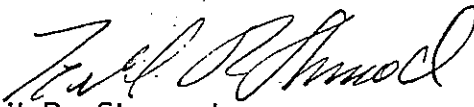
Dear George:

We are pleased to submit our Report of a Pavement Design prepared for Boardwalk Drive located in the Boardwalk Crossing P.U.D. in south Fort Collins, Colorado.

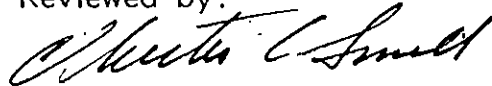
The accompanying report presents our findings in the subsurface and our recommendations for pavement design based upon these findings.

Very truly yours,

EMPIRE LABORATORIES, INC.


Neil R. Sherrod
Senior Engineering Geologist

Reviewed by:


Chester C. Smith, P.E.
President



clc

cc: James H. Stewart & Associates, Inc. - Mr. Dick Rutherford



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REPORT
OF A
PAVEMENT DESIGN

SCOPE

This report presents the results of a pavement design prepared for Boardwalk Drive located west of South College Avenue in the Boardwalk Crossing P.U.D. in south 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 groundwater conditions at the site, (2) develop criteria for determining pavement design, and (3) make recommendations regarding pavement types and thicknesses for the proposed streets to be constructed at the site.

SITE EXPLORATION

The field exploration, carried out on August 16, 1985, consisted of drilling, logging, and sampling two (2) 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 groundwater at the time of the exploration. Field resistivity tests were performed at each boring location.

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 consists of Boardwalk Drive located south of College Avenue in south Fort Collins, Colorado. More particularly, the site is described as Boardwalk Crossing P.U.D., Filing One being a part of Lot 7, Garth Commercial Plaza, situate in the Northeast 1/4 of Section 35, Township 7 North, Range 69 West of the Sixth P.M., Fort Collins, Larimer County, Colorado.

Boardwalk Drive was being constructed at the time of the site exploration. The area adjacent to College Avenue was being cut. Approximately one and one-half (1-1/2) to two and one-half (2-1/2) feet of the area to the east is being filled several feet. Utilities have already been placed below the proposed street.

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 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) Fill Material: A one and one-half (1-1/2) to four and one-half (4-1/2) foot layer of fill material was encountered at the surface of the two borings drilled at the site. The fill consists of a heterogeneous mixture of sand, silt, and clay.

- (2) Sandy Silty Clay: This stratum underlies the fill and extends to the bedrock below. The silty clay is plastic, contains varying amounts of sand, and exhibits low "R" values in its damp to moist in situ condition.
- (3) Siltstone-Sandstone Bedrock: The bedrock was encountered below the upper clays at depths four and one-half (4-1/2) to five (5) feet below the surface. The upper one and one-half (1-1/2) to greater than five (5) feet of the bedrock is highly weathered; however, the underlying rock is firm.
- (4) Ground Water: At the time of the investigation, free ground water was encountered in Boring 2 at a depth of six (6) feet below the surface. No free ground water was encountered in Boring 1 to a depth of nine (9) feet below the surface. Water levels in this area are subject to change due to seasonal variations and irrigation demands on and/or adjacent to the project.

RECOMMENDATIONS AND DISCUSSION

Boardwalk Drive, classified as a collector street, is to be constructed in the project area.

Site Grading and Utilities

It is recommended that the upper six (6) inches of any topsoil encountered at the site be stripped and stockpiled for reuse in planted areas. The upper six (6) inches of the subgrade below filled areas should be scarified and recompactd at or wet of optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78. (See Appendix C.)

All fill should consist of the on-site soils or imported material having an "R" value of 9 or greater, and this material should be approved by

the geotechnical engineer. Fill placed at the site should be placed in uniform six (6) to eight (8) inch lifts and compacted at or 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 streets should be scarified a minimum of six (6) inches and recompactd at or wet of optimum moisture to at least ninety-five percent (95%) of Standard Proctor Density ASTM D 698-78. Finished subgrade below all pavement should be placed a minimum of three (3) feet above existing groundwater, or the area should be dewatered to allow for a minimum of three (3) feet between the ground water and the pavement subgrade. In areas where subgrade compaction cannot be met due to saturated or unstable conditions, the subgrade should be stabilized by use of granular pit run or geotextiles.

Utility trenches dug four (4) feet or more into the upper soils should be excavated on slopes no steeper than 1:1. The firm bedrock may be excavated on vertical slopes. Excavation of the firm bedrock may require the use of heavy-duty construction equipment and/or possibly blasting. Where utilities are excavated below groundwater, dewatering will be needed during placement of pipe and backfilling for proper construction. 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. Proper placement of the bedrock as backfill may be difficult.

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 will not be required.

Flexible Pavement

It is our opinion that flexible pavement is suitable for the proposed street construction at the site. A flexible pavement alternate should consist of asphaltic concrete underlain by crushed aggregate base course and subbase 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 9, a twenty (20) year design life, an eighteen (18) kip equivalent daily load application of 80 as provided by the City of Fort Collins, and a weighted structural number of 3.25, the following pavement thicknesses are recommended:

Asphaltic Concrete	3"
Crushed Aggregate Base Course	6"
Select Subbase	<u>11"</u>
Total Pavement Thickness	20"

Asphaltic Concrete	3"
Plant Mix Bituminous Base Course	<u>5½"</u>
Total Pavement Thickness	8½"

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 five (105) pounds per square inch per inch based on an "R" value of 9, 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:

Nonreinforced Concrete - 7"

Subgrade below proposed streets 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.

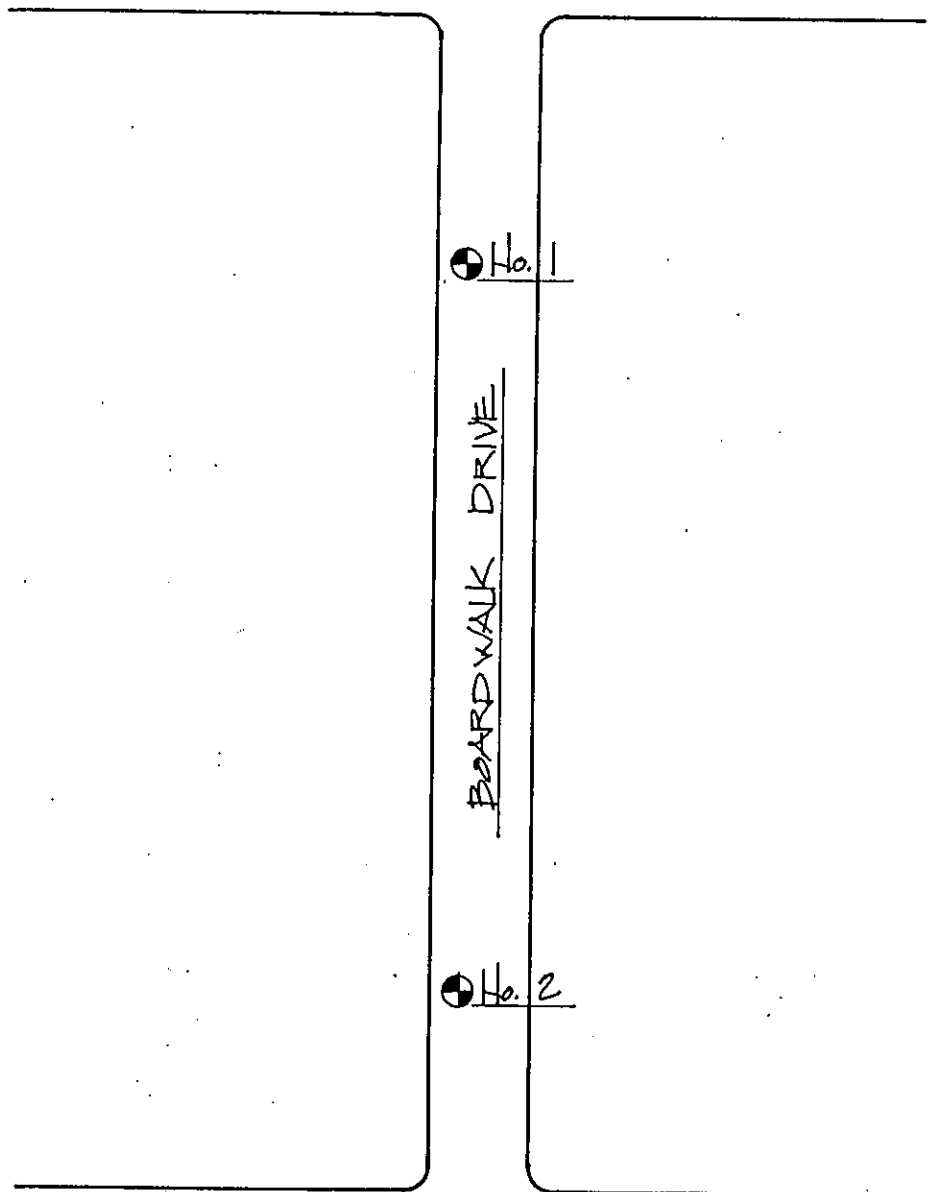
Every effort was made to provide comprehensive site coverage through careful locations of the test borings, while keeping the site investigation economically feasible. Variations in soil and groundwater conditions between test borings may be encountered during construction. In order to permit correlation 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.

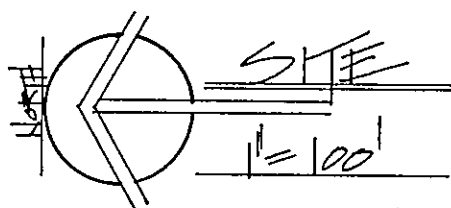
APPENDIX A.

TEST BORING LOCATION PLAN





























SOUTH COLLEGE AVE



SOUTH MASON



KEY TO BORING LOGS

	TOPSOIL		GRAVEL
	FILL		SAND & GRAVEL
	SILT		SILTY SAND & GRAVEL
	CLAYEY SILT		COBBLES
	SANDY SILT		SAND, GRAVEL & COBBLES
	CLAY		WEATHERED BEDROCK
	SILTY CLAY		SILTSTONE BEDROCK
	SANDY CLAY		CLAYSTONE BEDROCK
	SAND		SANDSTONE BEDROCK
	SILTY SAND		LIMESTONE
	CLAYEY SAND		GRANITE
	SANDY SILTY CLAY		
	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

~~DEPTH~~

No. 1

No. 2

0

10/12

14/12

5

17/12

10/12

10

50/1

21/12



APPENDIX B.

RESISTANCE R-VALUE AND EXPANSION PRESSURE OF COMPACTED SOIL

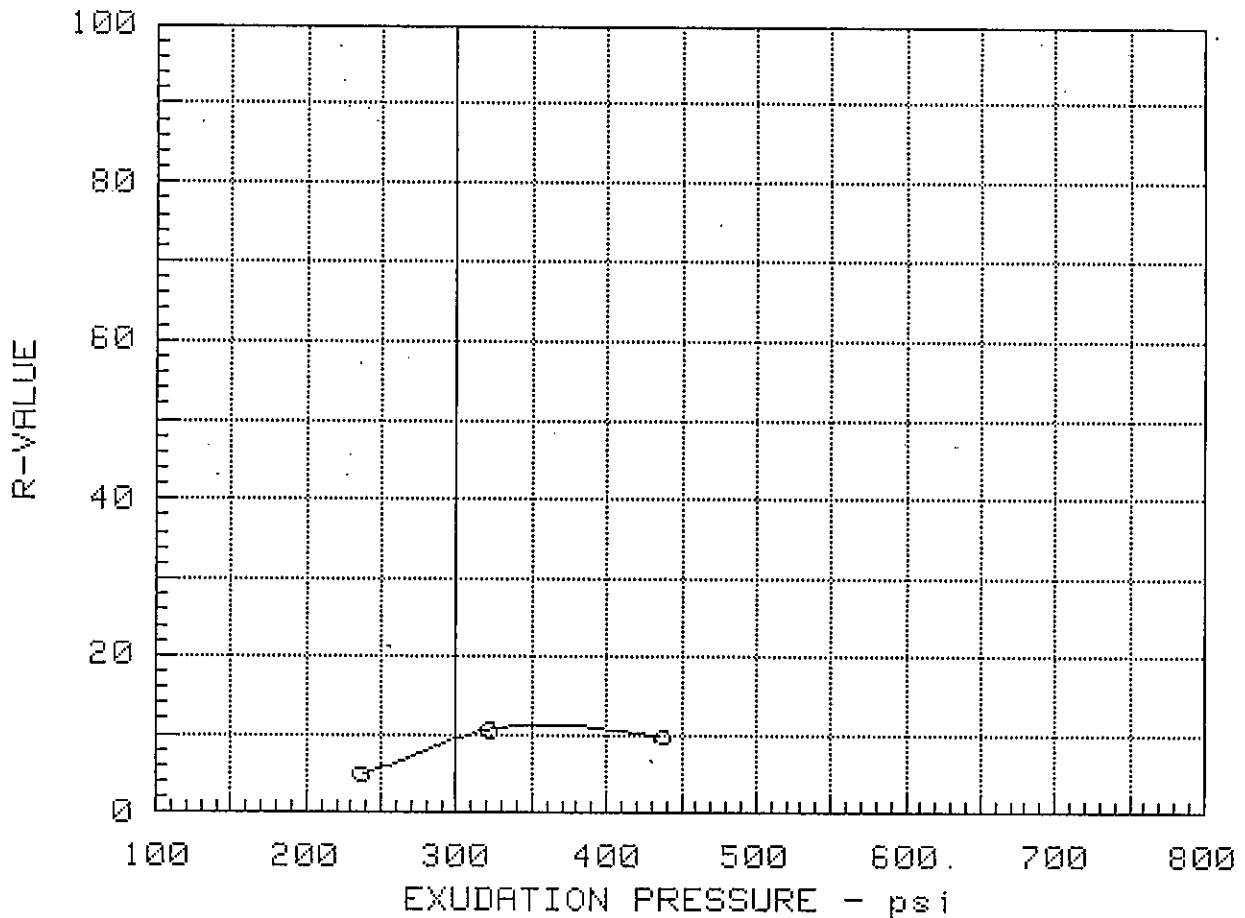
ASTM - D 2844

CLIENT: GEORGE HOLTEN
 PROJECT: BOARDWALK CROSSING
 LOCATION OF SAMPLE: BORING #2 @ 1.0'-3.0'

SAMPLE DATA

TEST SPECIMEN	1	2	3
COMPACTION PRESSURE - PSI	0	0	100
DENSITY - PCF	101.6	106.6	110.5
MOISTURE - %	22.6	19.6	18.3
EXPANSION PRESSURE - PSI	0.18	0.06	0.00
HORIZONTAL PRESSURE @ 160 psi	148	136	140
SAMPLE HEIGHT - in.	2.44	2.63	2.63
EXUDATION PRESSURE - PSI	237	322	438
UNCORRECTED R-VALUE	5.1	10.0	9.2
CORRECTED R-VALUE	5.0	10.7	9.8

R-VALUE AT 300 PSI EXUDATION PRESSURE = 9.4



EMPIRE LABORATORIES INC.

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	21.6	104.7	5520				39.4	20.5	7.6	A-6(8); CL	2960	10/12
	2.0-3.0	18.4											17/12
	4.0-5.0	17.3											50/1
	9.0-9.1	9.2											
2	1.0-2.0	10.5	94.6	2090		.0046	7.7					3830	14/12
	2.0-3.0	12.6											10/12
	4.0-5.0	12.5											21/12
	9.0-10.0	26.3											
Composite Sample	1.0-3.0							31.2	14.7	6.4	A-6(6); CL		

APPENDIX C.

APPENDIX C.

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

GENERAL

A soils 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 soils 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 soils 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 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 soils 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 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 soils 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 soils 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 recompact until the required density is obtained. Sufficient density tests shall be made and submitted to support the soils engineer's recommendations. The results of density tests will also be furnished to the owner, the project engineer, and the contractor by the soils engineer.