Soil Study for Proposed Bridge Replacement Project, Bridge along Skiffsville Road over West Branch of Bullskin Creek, Lewis Township, Brown County, Ohio

For

Brown County Engineer's Office
25 Veterans Boulevard
Georgetown, Ohio 45121

Report No. 142304-0108-027R1

January 29, 2008

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4518 Taylorsville Road
P.O. Box 51
Dayton, OH 45401-0051
937-236-8805
937-233-2016 FAX
www.bowser-morner.com

January 29, 2008

Brown County Engineer Office
25 Veterans Boulevard
Georgetown, Ohio 45121

Attention: Mr. Todd Cluxton
County Engineer

Re: Report No. 142304-0108-027R1; Soil Study for Proposed Bridge Replacement Project, Bridge along Skiffsville Road over West Branch of Bullskin Creek, Lewis Township, Brown County, Ohio

Dear Mr. Cluxton:

Bowser-Morner is pleased to submit our report of the soil study for the above-referenced project. The purpose of this study was to determine the physical characteristics of the soil strata on this site and the allowable bearing capacity for the proposed bridge. This report was prepared in accordance with *Specifications for Subsurface Investigations* by the Ohio Department of Transportation dated July, 2007.

The samples collected that were not used to perform the laboratory tests will be kept in our laboratory for 30 days unless you advise us otherwise. If you have any questions, or if we can help you in any way on this project or future work, please call us.

Sincerely,
BOWSER-MORNER ASSOCIATES, INC.

Chris R. Ryan, M.S.C.E., E.I.
Geotechnical Engineer

STATE OF OHIO
RICHARD
TSENG
43351
REGISTERED
PROFESSIONAL ENGINEER

Richard J.Y. Tseng, Ph.D., P.E.
Vice President
Chief Geotechnical Engineer

CRR/RJYT/ccs
6-Client
2-File

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SECTION I

TEXT

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1.0 INTRODUCTION

The bridge along Skiffsville Road on the east side of the intersection of Skiffsville and Bullskin Roads, over the west branch of Bullskin Creek, in Lewis Township, Brown County, Ohio will be replaced. Our findings on the soil conditions and groundwater levels with respect to the potential construction problems, and recommendations for the allowable bearing capacity for the construction of the proposed bridge are given in this report.

We reviewed the "Geologic Map of Ohio" by ODNR, "Ground Water Resources of Brown County" by ODNR, "Glacial Geology Map of Ohio" by ODNR, "Ohio Karst Areas" by ODNR, the *Soil Survey for Brown County*, and aerial photographs during the completion of this report. Based on our study and experience along the project area, no lakebed sediments, organic soil, or peat deposits were encountered in the vicinity of the bridge.

We contacted Mr. Todd Cluxton, County Engineer with Brown County, Ohio, who provided assistance with our study.

Authorization to proceed with this soil study was given by the Brown County Engineer's Office in a signed proposal acceptance sheet dated October 15, 2007. The work was to proceed in accordance with our proposal and agreement, Quotation No. 07-2771-168 dated October 12, 2007.

2.0 GEOLOGY OF THE SITE

Geologically, the site is in a glacial ground moraine deposit composed of an unsorted, unstratified mixture of clay, silt, sand, and coarser fragments, deposited discontinuously by the retreating of ice during a glacier over bedrock. The abutment locations of this site consist of asphalt pavement and granular base placed over the overburden subgrade soil during the construction of the existing bridge. The bedrock at this site consists of the Ordovician age of the Maysville group of shale and limestone.

3.0 WORK PERFORMED

3.1 FIELD WORK

Two soil borings were made at the locations shown on the drawings in Section III. The boring logs and boring locations are shown on the drawings in Section III. The borings were made with a truck-mounted boring rig using hollow-stem augers and standard penetration resistance methods. The standard penetration tests were performed in accordance with ASTM D1586, which includes a 140-pound hammer, 30-inch drops, and two-inch-O.D. split-spoon samplers driven at maximum depth intervals of five feet or at major changes in stratum, whichever occurred first. The disturbed split-spoon samples were visually classified, logged, sealed in moisture-proof jars, and taken to the Bowser-Morner laboratory for study. The depths where these "A"-type split-spoon samples were collected are noted on the corresponding boring logs.

Two, 10-foot-long, NWX-size rock cores were taken from the two borings, one core from each of the borings, made at the locations shown on the drawings in Section III. The core-drilling procedure was performed in accordance with ASTM D2113. The rock cores were taken to confirm the presence of bedrock at the bridge site and to allow the visual verification of the rock quality. The cores were collected with NWX-size, diamond-coring equipment with a specially designed core barrel for maximum core recovery. The samples were taken to our laboratory for further examination. The rock descriptions and the Rock Quality Designations (RQDs) are indicated on the boring logs included with this report. The depths where these “B”-type, rock-core samples were collected are noted on the corresponding boring logs.

3.2 LABORATORY WORK

Five Unified Soil Classification, AASHTO, and ODOT soil-classification tests were performed in accordance with ASTM D422, D2216, D2487, D4318, and D3282, and with ODOT specifications. The purpose of these types of test is to determine parameters that aid in the evaluation of the general behavior of the soils. In addition, seven moisture-content determinations were made in accordance with ASTM D2216.

The results of the soil classification tests are summarized in Table 3-1 are included in Section III of this report.

TABLE 3-1. Summary of Laboratory Test Results

Boring No.	Depth (ft.)	Moisture Content (%)	% Gravel	% Sand	% Silt	% Clay	Atterberg Limits LL	PL	PI	ODOT Classification
B-001-0-07	1.0 – 2.5	5.2	51.8	26.3	11.6	10.3	19	15	4	A-1-b
	3.5 – 4.0	18.9	22.9	2.4	24.7	50.0	50	28	22	A-7-6
	6.0 – 7.5	24.4								
	8.5 – 10.0	20.3	0.0	40.6	31.2	28.2	36	20	16	A-6b
	11.0 – 12.5	8.9								
B-002-0-07	1.0 – 2.5	13.0	7.2	31.5	35.3	26.0	24	16	8	A-4a
	2.5 – 4.0	5.6	53.7	18.2	16.0	12.1	23	17	6	A-2-4

4.0 SOIL AND GROUNDWATER CONDITIONS

Based on the information from the two borings made for this study, the subgrade soil conditions are described in descending order below:

- 0.7 to 0.8 foot of asphalt pavement (five to six inches thick) and gravel base.
- In Boring B-002-0-07 and below the gravel base layer, approximately two feet of medium-stiff, brown sandy silt.
- In Boring B-001-0-07 and below the gravel base layer and in Boring B-002-0-07 and below the brown, sandy silt layer and, approximately two to three feet of medium-dense-to-dense brown gravel with varying amounts of sand, silt, and clay.
- In Boring B-001-0-07 and below the brown gravel with sand layer, five feet of stiff brown clay.
- In Boring B-001-0-07 and below the brown clay layer, 4.5 feet of stiff-to-hard, brown silty clay.
- In Boring B-001-0-07 and below the brown, silty clay layer and Boring B-002-0-07 and below the brown gravel with sand and silt layer, gray limestone bedrock extending to the bottoms of these borings at depths of 16 to 23 feet.

Groundwater was not encountered during the boring operations. Free groundwater is defined as water that seeps into an open borehole before it is backfilled. Groundwater observations were made during the boring operations by noting the depth of water on the boring tools and in the open boreholes following withdrawal of the boring augers. However, it should be noted that short-term water level readings are not necessarily a reliable indication of the groundwater level and that significant fluctuations may occur due to variations in rainfall and other factors. For specific questions on the soil conditions, please refer to the individual boring logs in Section III.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 PROJECT DESCRIPTION

The single-span bridge along Skiffsville Road on the east side of the intersection of Skiffsville and Bullskin Roads, over the west branch of Bullskin Creek, in Lewis Township, Brown County, Ohio will be replaced. The span is about 90 feet long. The distance from the top of the bridge deck to the bottom of the creek is about 15 feet. No design loading information for the proposed bridge was provided for this report.

The following recommendations are based on this information. If the above statements are incorrect or changes are made, Bowser-Morner should be notified so that the new data can be reviewed and additional recommendations and services can be given if required to meet the needs of your project.

5.2 FOUNDATION RECOMMENDATIONS

Based on the information from Borings B-001-0-07 and B-002-0-07, the bridge abutments are covered with five- to six-inch-thick asphalt pavement and granular base. The pavement and the granular base extend to the approximate depths and elevations outlined in Table 4-1.

Table 4-1. Depths to Bottoms of Fill Layer

Boring No.	Depth to Bottom of Fill Layer (ft)	Elevation at Bottom of Fill Layer (ft)
B-001-0-07	1.0	617.3
B-002-0-07	1.0	614.8

Below the granular-base layer, medium-stiff-to-hard brown clay, brown silty clay, and brown sandy silt, and medium-dense-to-dense brown gravel with sand and silt were encountered. Limestone bedrock was encountered in Borings B-001-0-07 and B-002-0-07 at the depths and elevations outlined in Table 4-2. Based on the two recovered rock cores from Borings B-001-0-07 and B-002-0-07, the RQD values of the bedrock within the top 10 feet of depth are 0% and 7.5% in Borings B-001-0-07 and B-002-0-07, respectively.

Table 4-2. Depths to Top of Bedrock

Boring No.	Depth to Top of Bedrock (ft)	Elevation at Top of Bedrock (ft)
B-001-0-07	13.0	605.3
B-002-0-07	4.0	611.8

The bottoms of the abutment foundations will have to extend below the bottom of the granular base at the depths and elevations outlined in Table 4-1. Since bedrock was encountered at a depth of four feet below the top of the bridge deck, driven piles will not be feasible. Two methods are available to support the bridge abutments. These methods are:

- Spread-footing foundations supported on bedrock
- Drilled piers socketed into bedrock.

Our recommendations for each of these methods follow.

5.2.1 SPREAD-FOOTING FOUNDATIONS

We recommend that the abutment foundation excavations extend to the competent bedrock layer below the depths and elevations outlined in Table 4-2.

A side slope of 1 (horizontal) to 1 (vertical) should be provided for stability and for the safety of the workers for the excavations to extend to a depth of five feet or more below the existing grade. Alternatively, a temporary shoring system should be installed on all sides of the excavations during the abutment foundation excavations.

The bottoms of the abutment foundations should be supported on the bedrock. The foundations supported on the weathered bedrock can be designed with a net allowable bearing capacity of 8,000 pounds per square foot (psf). For the allowable bearing capacity recommended above, the estimated settlement for the abutment foundations supported on bedrock should be less than one-half inch. Rock anchors to be grouted into the limestone bedrock can be installed to provide the resistance against the uplift forces and the horizontal forces from the backfill behind the abutment foundations.

Free groundwater was not encountered during the boring operations. During the foundation excavations, the perimeters of the excavation should be diked to keep the creek water from flooding the excavations.

5.2.2 DRILLED PIERS

Alternatively, drilled piers can be installed to support the abutment foundations. The depths to the top of the bedrock are tabulated in Table 4-2. The bottoms of the drilled piers should be socketed into the competent limestone bedrock.

For drilled piers socketed into bedrock, an allowable end-bearing capacity of 15,000 psf can be used in the design of the drilled piers. A 10-foot-long pilot hole should be drilled into the center at the bottom of each drilled pier. An "L"-shaped steel rod should be used to probe the sides of the pilot holes to verify the continuity of the bedrock below the bottoms of the bearing stratum. If voids are encountered in the rock formation within a 10-foot-depth below the bottom of the rock socket, the drilled-pier socket should extend deeper. Otherwise, the allowable end-bearing capacity must be reduced to account for the weaker rock formation. A side-friction capacity of 500 psf can be assigned to the sides of the drilled piers in contact with limestone bedrock.

Temporary steel casings should be installed through the overburden soil layer to keep the drilled-pier shafts from caving in. If groundwater or surface water infiltration is encountered in the drilled-pier shafts and the water cannot be lowered before the concrete is placed, a tremie method of placing the concrete should be used during the installation of the drilled piers.

To determine the actual allowable capacity of the deep foundations or if an allowable end-bearing capacity greater than 15,000 psf is needed, we recommend that static pile-load tests be performed to verify the allowable drilled-pier capacity.

5.2.3 SITE CLASSIFICATION FOR SEISMIC DESIGN

Based on the results of the standard penetration tests (SPT) in Borings B-001-0-07 and B-002-0-07, the average "N" values are approximately 22 to 24 blows per foot for the soil layer at depths of 4 to 13 feet below the top of the bridge deck. However, the abutment foundations will be supported on limestone bedrock. As a result, it is our opinion that the site will be classified as a "B" type in accordance with the *Ohio Building Code*.

5.3 FOUNDATION EXCAVATIONS

During the foundation excavations, the subsurface conditions should be verified. Changes in subsurface conditions other than what are shown on the boring logs warrant additional subsurface investigation before the foundations are constructed.

The foundation excavations should be observed to ensure that the bottoms of the abutment foundations will be supported directly on limestone bedrock.

The contractor should maintain temporary cut slopes in accordance with the current OSHA regulations governing trenching and slope stability.

Bedrock exposed at the bases of satisfactory foundation excavations should be protected against any detrimental change in condition such as from construction disturbances, rain, and freezing. Surface runoff should be drained away from the excavation and not allowed to pond and to avoid the caving of over burden soil on the sides of the excavations. If possible, foundation concrete should be placed the same day the excavation is made. If this is not practical, the foundation excavations should be adequately protected. Also, for this reason, proper drainage should be maintained after construction. It must be emphasized that all excavations must conform to all state, federal, and local regulations relative to slope geometry.

5.4 CONSTRUCTION DEWATERING

At the time of our study, free groundwater was not encountered during the boring operations. During the foundation excavations, the perimeters of the excavation should be diked to keep the creek water from entering the excavation.

For the installation of drilled piers, temporary steel casings should be used. If the groundwater cannot be lowered before the concrete is placed, a tremie method of placing the concrete should be used during the installation of the drilled piers. The steel casings should be removed after the concrete for the drilled piers is placed.

The amount and type of dewatering required during construction will depend on the weather and groundwater levels at the time of construction, and the effectiveness of the contractor's techniques in preventing surface runoff from entering open excavations. Typically, groundwater levels are highest during winter and spring, and lower in summer and early fall.

6.0 CLOSURE

6.1 BASIS OF RECOMMENDATIONS

The evaluations, conclusions, and recommendations in this report are based on our interpretation of the field and laboratory data obtained during the exploration, our understanding of the project and our experience with similar sites and subsurface conditions. Data used during this exploration included, but were not necessarily limited to:

- Two exploratory borings performed during this study.
- Observations of the project site by our staff.
- The results of the laboratory soil tests.
- The site plan and profile sheet provided by Clifton Engineering LLC.
- Limited interaction with Mr. Todd Cluxton, County Engineer of Brown County Engineer's Office and Mr. Mike Brunner of Clifton Engineering LLC.

- Published soil or geologic data of this area.

In the event that changes in the project characteristics are planned, or if additional information or differences from the conditions anticipated in this report become apparent, Bowser-Morner should be notified so that the conclusions and recommendations contained in this report can be reviewed and, if necessary, modified or verified in writing.

6.2 LIMITATIONS AND ADDITIONAL SERVICES

The subsurface conditions discussed in this report and those shown on the boring logs represent an estimate of the subsurface conditions based on interpretation of the boring data using normally accepted geotechnical engineering judgments. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates shown, they are not necessarily indicative of subsurface conditions at other locations or at other times.

Regardless of the thoroughness of a subsurface exploration, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by designers, or that the construction process has altered the soil conditions. As variations in the soil profile are encountered, additional subsurface sampling and testing may be necessary to provide data required to reevaluate the recommendations of this report. Consequently, after submission of this report, it is recommended that Bowser-Morner be authorized to perform additional services to work with the designer(s) to minimize errors and omissions regarding the interpretation and implementation of this report.

Before construction begins, we recommend that Bowser-Morner:

- Work with the designers to implement the recommended geotechnical design parameters into plans and specifications.
- Consult with the design team regarding interpretation of this report.
- Establish criteria for the construction observation and testing for the soil conditions encountered at this site.

- Review final plans and specifications pertaining to geotechnical aspects of design.

During construction, we recommend that Bowser-Morner:

- Observe the construction, particularly the site preparation, fill placement, foundation excavation or installation, and/or installation of drilled piers.
- Perform in-place density testing of all compacted fill.
- Perform materials testing of soil and other materials as required.
- Consult with the design team to make design changes in the event that differing subsurface conditions are encountered.

If Bowser-Morner is not retained for these services, we shall assume no responsibility for construction compliance with the design concepts, specifications or recommendations.

6.3 WARRANTY

Our professional services have been performed, our findings obtained and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. No other warranty, express or implied, is made.

The scope of this study did not include an environmental assessment for the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater or air, on, within or beyond the site studied. Any statements in the report or on the boring logs regarding odors, staining of soils or other unusual items or conditions observed are strictly for the information of our client.

To evaluate the site for possible environmental liabilities, we recommend an environmental assessment, consisting of a detailed site reconnaissance, a record review, and report of findings. Additional subsurface drilling and sampling, including groundwater sampling, may be required. Bowser-Morner can provide this service and would be pleased to provide a cost proposal to perform such a study, if requested.

This report has been prepared for the exclusive use of the Brown County Engineer's Office for specific application to the proposed bridge replacement along Skiffsville Road over West Branch of Bullskin Creek in Lewis Township, Brown County, Ohio (see the drawings in Section III of this report). Specific design and construction recommendations have been provided in the various sections of the report. The report shall therefore, be used in its entirety. This report is not a bidding document and shall not be used for that purpose. Anyone reviewing this report must interpret and draw their own conclusions regarding specific construction techniques and methods chosen. Bowser-Morner is not responsible for the independent conclusions, opinions or recommendations made by others based on the field exploration and laboratory test data presented in this report.

SECTION II

SPECIFICATIONS

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SPECIFICATION FOR DRILLED PIERS

Drilled piers shall be constructed in accordance with American Concrete Institute (ACI) Standard 336. The Contractor shall have a copy of this standard available on the job site. The specifications include but are not limited to the following:

1. The Contractor shall furnish all labor, equipment and materials necessary to complete the drilled piers (caissons), in strict accordance with the plans and specifications.

2. The piers shall be formed by means acceptable to the Owner and shall extend to the depth shown on the drawing unless otherwise approved by the Owner.

3. The work includes the excavation of all materials, both wet and dry, and the removal of all excavated material from the job site if directed.

4. The maximum variation of the center of any pier from the required location shall be 2 inches at the ground surface, and no pier shall be out of plumb more than 1% (one percent) of its drilled length including bell. If these tolerances are exceeded, alterations as required by the Owner shall be provided without additional cost to the Owner.

5. The diameter of each pier and bell shall conform to the dimensions shown on the plans.

6. Boulders shall be removed as extra work. The Contractor shall establish in this contract a unit price for removing boulders. Boulders are considered as being larger than one cubic foot in size. Smaller material shall not be classified as boulders.

7. The depth of drilled piers, for contract work purposes, is shown on the drawings. If, in order to reach suitable material (as determined by the Owner or his representative) the depth of piers is deeper or more shallow, the price shall be adjusted in accordance with the contract.

8. Each pier shall be inspected by the Owner or his representative to insure that the pier is bearing on suitable material, that the bell is of the required size and is free of debris and water before concrete is poured. The Contractor shall case any pier into which workmen or an inspector will enter. Concrete shall not be placed until the pier is approved by the Owner or his representative.

9. The Contractor shall provide and operate all equipment necessary to pump and remove all water that may be encountered in the construction of piers, without additional payment therefore. The Contractor shall case all piers where necessary to stop the flow of water and belling shall be done in a dry shaft below the casing.

10. The drilled pier shall be filled with concrete as specified below. In instances where the shaft has been cased to stop water flow, the concrete shall be brought to a point equal in depth to the head of water above the bottom of the casing before pulling of the casing is started. The casing shall be pulled by a slow, even lift utilizing a pulling beam. Once begun, the pulling shall be continuous and the placing of the concrete shall follow the casing up, with a constant head of concrete equal to the head of water above the bottom of the casing maintained. In instances where the shaft has been cased to prevent caving or sloughing of the sides, the concrete shall be brought to a point five feet above the bottom edge of the casing before the pulling of the casing is started.

    The casing shall be pulled in a uniform manner so as to maintain a minimum of five feet head of concrete in the casing.

11. Concrete shall have a compressive strength of 4,000 psi in 28 days at a slump of 3" to 6".

12. Concrete shall be placed in accordance with ACI 336.3R-4 in such a manner that segregation of the concrete is avoided. The concrete shall be placed by means of chutes or some other method so the concrete drops vertically into the center of the pier.

13. The Contractor shall use mechanical vibrators to consolidate the concrete placed in the top five feet of the piers.

14. The pouring of concrete for any one pier shall be continuous. Any interruption in the progress of excavation, protection of the excavation with steel liners, or pouring of the concrete must have the approval of the Owner or his representative.

15. Testing and observation services will be provided by the Owner and be done in accordance with ACI 336.3R-5.

SECTION III

BORING LOG TERMINOLOGY, BORING LOGS, LABORATORY DATA, AND PRINTS

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BORING LOG TERMINOLOGY

Stratum Depth:

Distance in feet and/or inches below ground surface.

Stratum Elevation:

Elevation in feet below ground surface elevation.

Description of Materials:

Major types of soil material existing at boring location. Soil classification based on one of the following systems: Unified Soil Classification System., Ohio State Highway Classification System, Highway Research Board Classification System, Federal Aviation Authority Classification System, Visual Classification.

Sample No.:

Sample numbers are designated consecutively, increasing with depth for each boring.

Sample Type:

"A" Split spoon, 2" O.D., 1-3/8" I.D., 18" in length.

"B" Rock Core

"C" Shelby Tube 3" O.D. except where noted

"D" Soil Probe

"E" Auger Cuttings

"F" Sonic

Sample Depth:

Depth below top of ground at which appropriate sample was taken.

Blows per 6" on Sampler:

The number of blows required to drive a 2" O.D., 1-3/8" I.D., split spoon sampler, using a 140 pound hammer with a 30-inch free fall, is recorded for 6" drive increments. (Example: 3/8/9).

"N" Blows/Ft.:

Standard penetration resistance. This value is based on the total number of blows required for the last 12" of penetration. (Example: 3/8/9: N = 8 + 9 = 17)

Water Observations:

Depth of water recorded in test boring is measured from top of ground to top of water level. Initial depth indicates water level during boring, completion depth indicates water level immediately after boring, and depth after "X" number hours indicates water level after letting water rise or fall over a time period. Water observations in pervious soil are considered reliable ground water levels for that date. Water observations in impervious soils can not be considered accurate ground water measurements for that date unless records are made over several days' time. Factors such as weather, soil porosity, etc., will cause the ground water level to fluctuate for both pervious and impervious soils.

SOIL DESCRIPTION

Color:

When the color of the soil is uniform throughout, the color recorded will be such as brown, gray, or black and may be modified by adjectives such as light and dark. If the soil's predominant color is shaded by a secondary color, the secondary color precedes the primary color, such as: gray-brown, yellow-brown. If two major and distinct colors are swirled throughout the soil, the colors will be modified by the term mottled, such as: mottled brown and gray.

Particle Size		Visual
Boulders		Larger than 8"
Cobbles		8" to 3"
Gravel	– Coarse	3" to 3/4"
	– Fine	2 mm. To 3/4"
Sand	– Coarse	2 mm. – 0.6 mm. (Pencil lead size)
	– Medium	0.6 mm. – 0.2mm. Table sugar and salt size)
	– Fine	0.2 mm. – 0.06 mm. (Powdered sugar and human hair size)
Silt		0.06 mm. – 0.002 mm.
Clay		0.002 and smaller (Particle size of both Silt and Clay not visible To naked eye

Soil Components

Major Component:	Minor Component Term
Gravel	Trace 1-10%
Sand	Some 11-35%
Silt	And 36-50%
Clay	

Moisture Content

Term	Relative Moisture
Dry	Powdery
Damp	Moisture content below plastic limit
Moist	Moisture content above plastic limit but below liquid limit
Wet	Moisture content Above liquid limit

Condition of Soil Relative to Compactness Granular Material

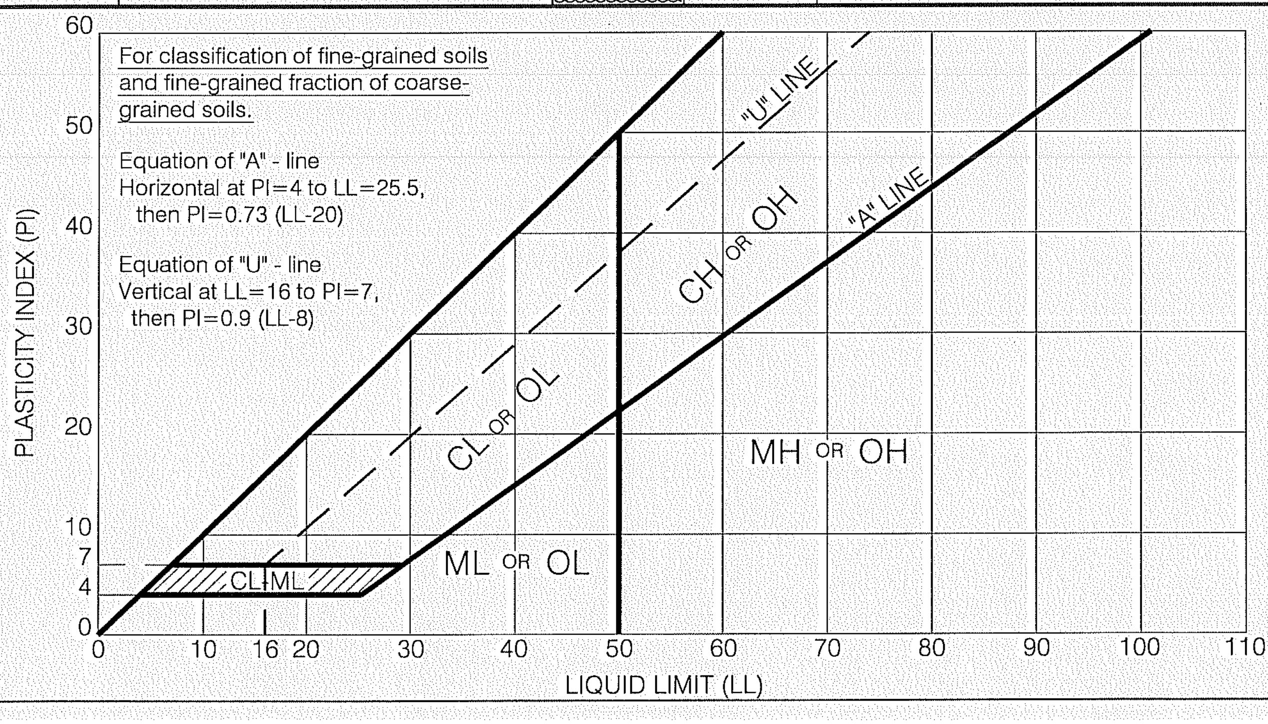
Very Loose	5 blows/ft. or less
Loose	6 to 10 blows/ft.
Medium Dense	11 to 30 blows/ft.
Dense	30 to 50 blows/ft.
Very Dense	51 blows/ft. or more

Condition of Soil Relative to Consistency Cohesive Material

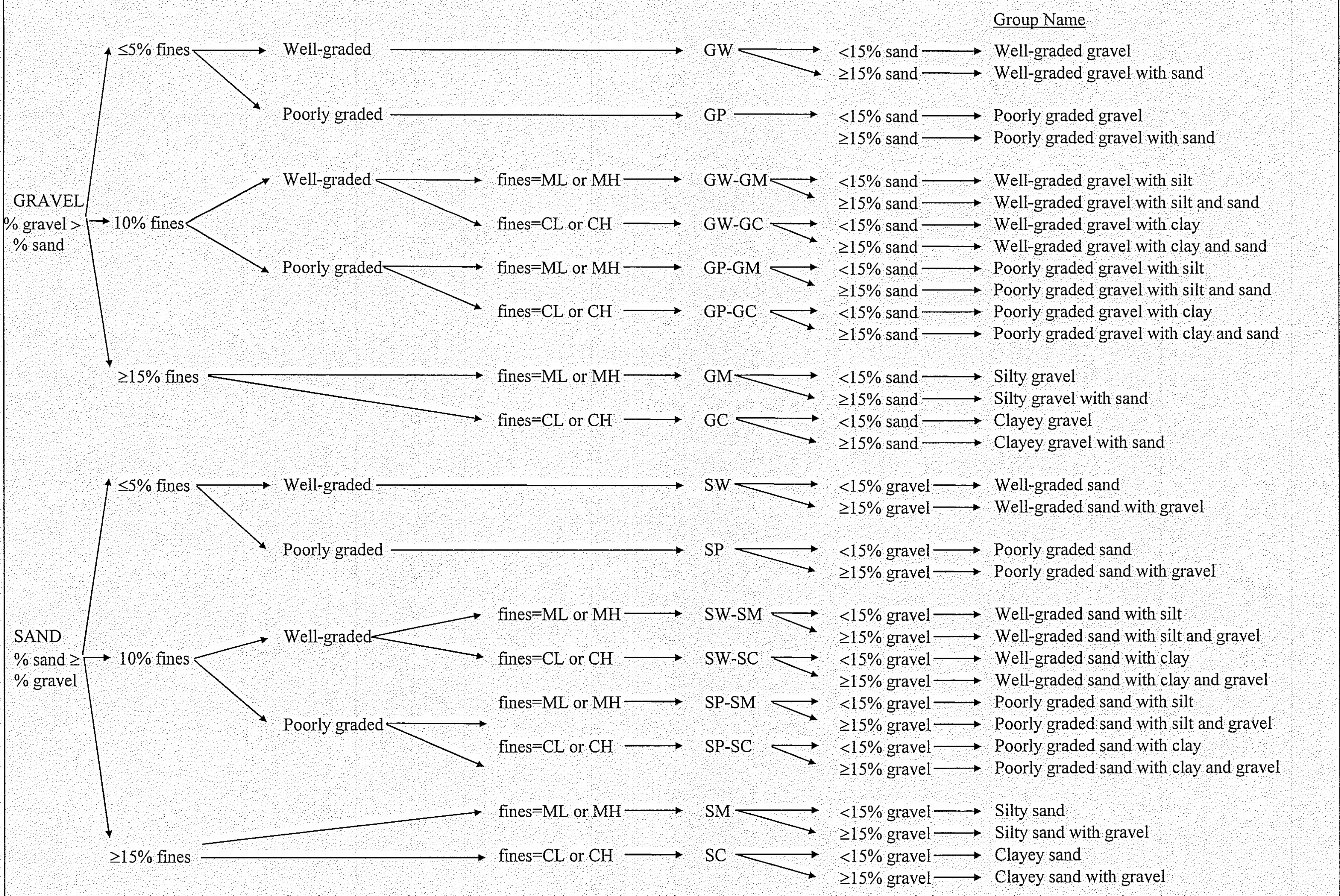
Very Soft	3 blows/ft. or less
Soft	4 to 5 blows/ft.
Medium Stiff	6 to 10 blows/ft.
Stiff	11 to 15 blows/ft.
Very stiff	16 to 30 blows/ft.
Hard	31 blows/ft. or more

UNIFIED CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVEL WELL-GRADED GRAVEL WITH SAND
				GP	POORLY GRADED GRAVEL POORLY GRADED GRAVEL WITH SAND
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES APPRECIABLE AMT. OF FINES)		GM	SILTY GRAVEL SILTY GRAVEL WITH SAND
				GC	CLAYEY GRAVEL CLAYEY GRAVEL WITH SAND
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SAND WELL-GRADED SAND WITH GRAVEL
				SP	POORLY GRADED SAND POORLY GRADED SAND WITH GRAVEL
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMT. OF FINES)		SM	SILTY SAND SILTY SAND WITH GRAVEL
				SC	CLAYEY SAND CLAYEY SAND WITH GRAVEL
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILT AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	SILT, SILT WITH SAND, SANDY SILT GRAVELLY SILT, GRAVELLY SILT WITH SAND
				CL	LEAN CLAY WITH SAND, SANDY LEAN CLAY GRAVELLY LEAN CLAY WITH SAND
				OL	ORGANIC CLAY, SANDY ORGANIC CLAY ORGANIC SILT, SANDY ORGANIC SILT WITH GRAVEL
	SILT AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	ELASTIC SILT WITH SAND, SANDY ELASTIC SILT GRAVELLY ELASTIC SILT WITH SAND
				CH	FAT CLAY WITH SAND, SANDY FAT CLAY GRAVELLY FAT CLAY WITH SAND
				OH	ORGANIC CLAY WITH SAND, SANDY ORGANIC CLAY, ORGANIC SILT, SANDY ORGANIC SILT
	HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS



Flow Chart for Visually Identifying Soils Based on ASTM D-2488



Flow Chart for Visually Identifying Soils Based on ASTM D-2488

Group Name

- CL
  - <30% plus No. 200
    - <15% plus No. 200 → Lean clay
    - 15-25% plus No. 200
      - % sand ≥% gravel → Lean clay with sand
      - % sand <% gravel → Lean clay with gravel
  - ≥30% plus No. 200
    - % sand ≥% gravel
      - <15% sand → Sandy lean clay
      - ≥15% sand → Sandy lean clay with gravel
    - % sand <% gravel
      - <15% sand → Gravelly lean clay
      - ≥15% sand → Gravelly lean clay with sand
- ML
  - <30% plus No. 200
    - <15% plus No. 200 → Silt
    - 15-25% plus No. 200
      - % sand ≥% gravel → Silt with sand
      - % sand <% gravel → Silt with gravel
  - ≥30% plus No. 200
    - % sand ≥% gravel
      - <15% sand → Sandy silt
      - ≥15% sand → Sandy silt with gravel
    - % sand <% gravel
      - <15% sand → Gravelly silt
      - ≥15% sand → Gravelly silt with sand
- CH
  - <30% plus No. 200
    - <15% plus No. 200 → Fat clay
    - 15-25% plus No. 200
      - % sand ≥% gravel → Fat clay with sand
      - % sand <% gravel → Fat clay with gravel
  - ≥30% plus No. 200
    - % sand ≥% gravel
      - <15% sand → Sandy fat clay
      - ≥15% sand → Sandy fat clay with gravel
    - % sand <% gravel
      - <15% sand → Gravelly fat clay
      - ≥15% sand → Gravelly fat clay with sand
- MH
  - <30% plus No. 200
    - <15% plus No. 200 → Elastic silt
    - 15-25% plus No. 200
      - % sand ≥% gravel → Elastic silt with sand
      - % sand <% gravel → Elastic silt with gravel
  - ≥30% plus No. 200
    - % sand ≥% gravel
      - <15% sand → Sandy elastic silt
      - ≥15% sand → Sandy elastic silt with gravel
    - % sand <% gravel
      - <15% sand → Gravelly elastic silt
      - ≥15% sand → Gravelly elastic silt with sand

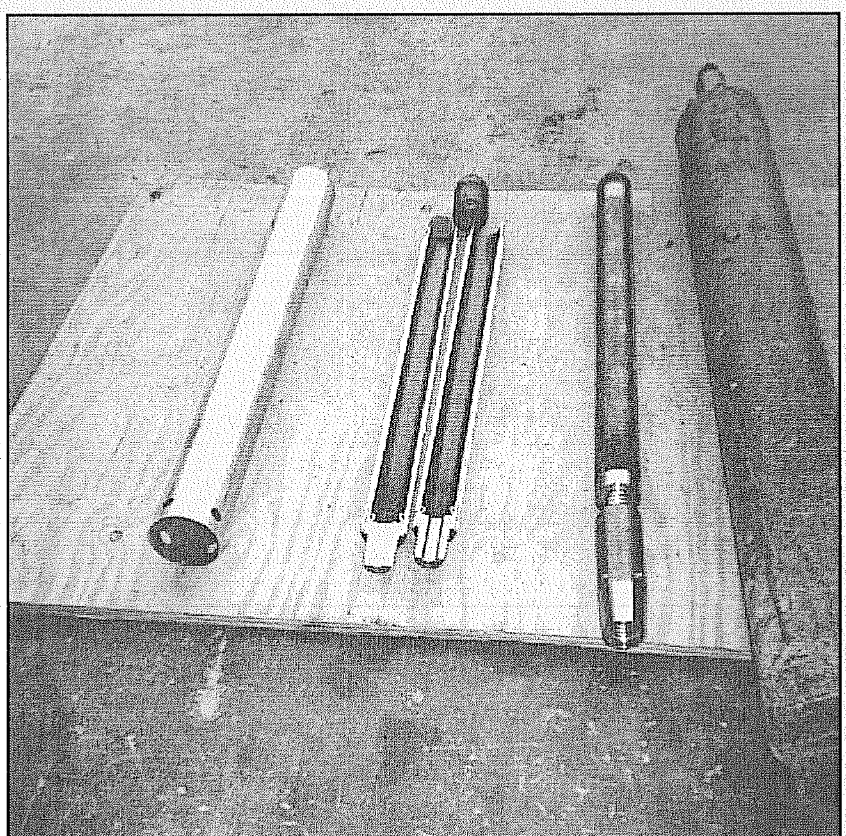
STANDARD PENETRATION RESISTANCE (ASTM D1586)

The purpose of this test is to determine the relative consistency of the soils in a boring, or from boring over the site. This method consists of making a hole in the ground and driving a 2-inch O.D. split spoon sampler into the soil with a 140-pound hammer dropped from a height of 30 inches. The sampler is driven 18 inches and the number of blows recorded for each 6 inches of penetration. Values of standard penetration (N) are determined in blows per foot, summarizing the flows required for the last two 6-inche increments of penetration.

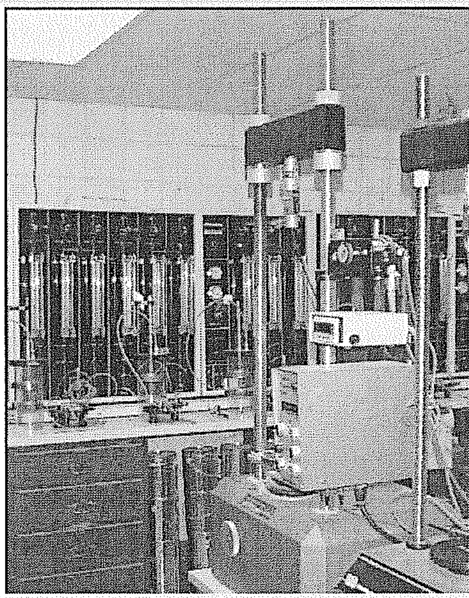
Example : 2-6-8; N = 14

THIN-WALLED SAMPLER (ASTM D1587)

The purpose of the thin-walled sampler is to recover a relatively undisturbed soil sample for laboratory tests. The sampler is a thin-walled seamless tube with a 3-inch outside diameter, which is hydraulically pressed into the ground, at a constant rate. The ends are then sealed to prevent soil moisture loss, and the tube is returned to the laboratory for tests.

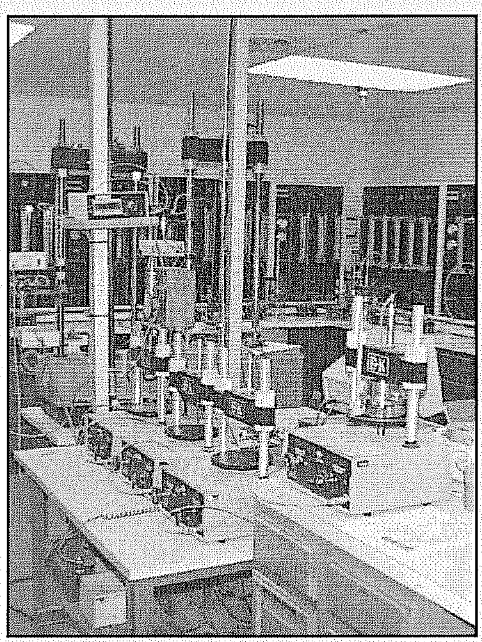


UNCONFINED COMPRESSION OR TRIAXIAL TESTS (ASTM D 2166)



The unconfined compression test and the triaxial tests are performed to determine the shearing strength of the soil, to use in establishing its safe bearing capacity. In order to perform the unconfined compression test, it is necessary that the soil exhibit sufficient cohesion to stand in an unsupported cylinder. These tests are normally performed on samples which are 6.0 inches in height and 2.85 inches in diameter. In the triaxial test, various lateral stresses can be applied to more closely simulate the actual field conditions. There are several different types of triaxial tests. These are, however, normally performed on constant strain apparatus with a deformation rate of 0.05 inches per minute.

CONSOLIDATION TEST (ASTM D 2435)



The purpose of this test is to determine the compressibility of the soil. This test is performed on a sample of soil which is 2.5 inches in diameter and 1.0 inch in height, and has been trimmed from relatively "undisturbed" samples. The test is performed with a lever system or an air activated piston for applying load. The loads are applied in increments and allowed to remain on the sample for a period of 24 hours. The consolidation of the sample under each individual load is measured and a curve of void ratio vs. Pressure is obtained. From the information obtained in this manner and the column loads of the structure, it is possible to calculate the settlement of each individual building column. This information, together with the shearing strength of the soil, is used to determine the safe bearing capacity for a particular structure.

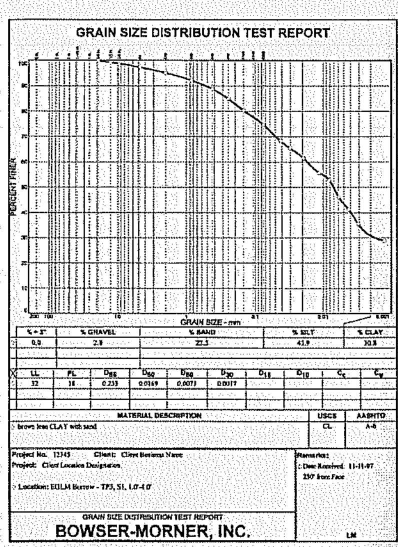
BOWSER MORNER®

REVISED TO ASTM D4318
ATTERBERG LIMITS (ASTM D423 AND D424)

These tests determine the liquid and plastic limits of soils having a predominant percentage of fine particle (silt and clay) sizes. The liquid limit of a soil is the moisture content expressed as a percent at which the soil changes from a liquid to a plastic state, and the plastic limit is the moisture content at which the soil changes from a plastic to a semi-solid state. Their difference is defined as the plasticity index (P.I. = L.L. - P.L.), which is the change in moisture content required to change the soil from a "semi-solid" to a liquid. These tests furnish information about the soil properties which is important in determining their relative swelling potential and their classifications.

MECHANICAL ANALYSIS (ASTM D422)

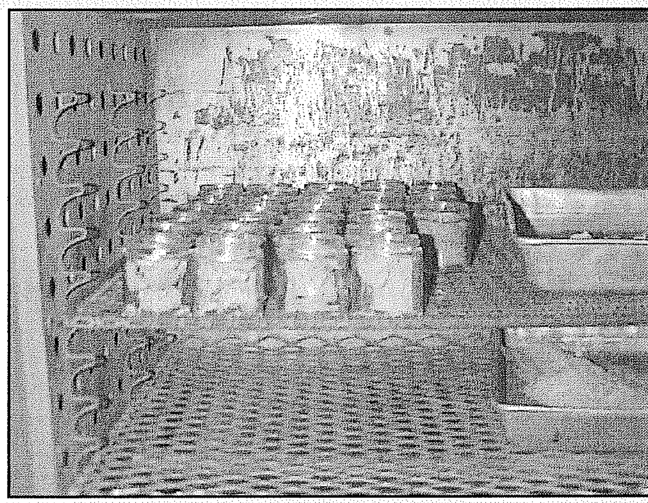
This test determines the percent of each particle size of a soil. A sieve analysis is conducted on particle sizes greater than a No. 200 sieve (0.074 mm), and a hydrometer test on particles smaller than the No.200 sieve. The gradation curve is drawn through the points of cumulative percent of particle size, and plotted on semi-logarithmic paper for the combined sieve and hydrometer analysis. This test, together with the Atterberg Limits tests, is used to classify a soil.



BOWSER MORNER®

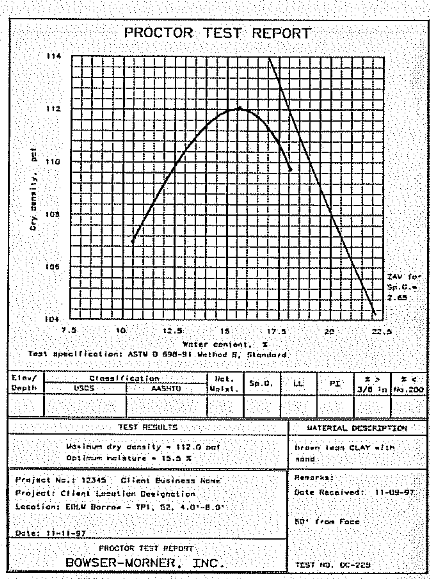
NATURAL MOISTURE CONTENT (ASTM D2216)

The purpose of this test is to indicate the range of moisture contents present in the soil. A wet sample is weighed, placed in the constant temperature oven at 105° for 24 hours, and re-weighed. The moisture content is the change in weight divided by the dry weight.



PROCTOR TESTS

The purpose of these tests is to determine the maximum density and optimum moisture content of a soil. The Modified Proctor test is performed in accordance with ASTM D1557-70. The test is performed by dropping a 10-pound hammer 25 times from an 18-inch height on each of 5 equal layers of soil in a 1/30 cubic foot mold, which represents a compaction effort of 56,250 foot pounds per cubic foot. The moisture content is then raised, and this procedure is repeated. A moisture density curve is then plotted, with the density on the ordinate axis and the moisture on the abscissa axis. The moisture content at which the maximum density requirement can be achieved with a minimum compactive effort is designated as the optimum moisture content (O.M.C.). The Standard Proctor test is performed in accordance with ASTM D698-70. This test is similar to the Modified Proctor test and is performed by dropping a 5.5 pound hammer 25 times from a height of 12 inches on 3 equal layers of soil in a 1/30 cubic foot mold, which represents a compaction effort of 12,375 foot pounds per cubic foot. This test gives proportionately lower results than the Modified Proctor test.



Test specification: ASTM D 698-91 Method B, Standard

Elev/ Depth	Classification USCS	Classification AASHTO	Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in	% < No.200

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 112.0 pcf Optimum moisture = 15.5 %	brown lean CLAY with sand

Project No.: 12345 Client Business Name
Project: Client Location Designation
Location: EDLM Borrow - TP1, S2, 4.0'-8.0'

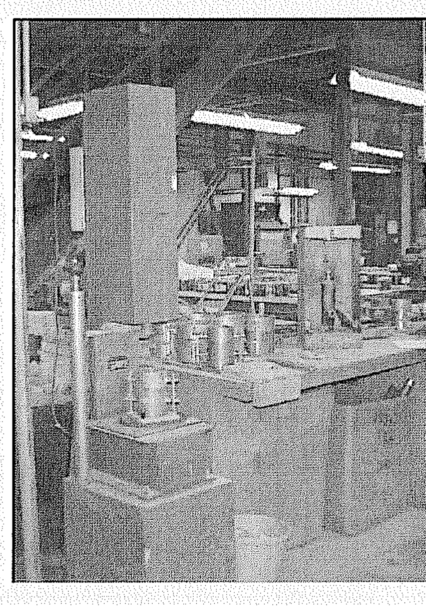
Date: 11-11-97

Remarks:
Date Received: 11-09-97

50' from Face

PROCTOR TEST REPORT
BOWSER-MORNER, INC.

TEST NO. OC-229



BOWSER MORNER®

Bowser-Morner, Inc.

Job Number: 142304
Client: Brown County Engineer Office
Project Description: Soil Study for Proposed Bridge Replacement Project, Bridge along Skiffsville Rd over West Branch of Bullskin Creek, Lewis Twp, Brown Co, OH

Date Started: 10/22/07 | Sampler: Type: Split Spoon | Dia. ____ | Water Elev. (ft): None
Date Completed: 10/22/07 | Casing: Length ____ | Dia. ____
Boring No. B-001-0-07
Sheet 1 of 1 | Station & Offset 14+68.1, 4.0' Lt. | Surface Elev. (ft) 618.3

Elev. (ft)	Depth (ft)	Std. Pen./ RQD	Rec. (ft)	Loss (ft)	Description	Sample No.	% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	ODOT Class
618.3	0														
617.9					(FILL) ASPHALT pavement (0.4')										
617.6	2	13/12/12			(FILL) GRAVEL base (0.3')	SS-1	52	15	11	12	10	19	4	5	A-1-b
					(ORIGINAL) Medium dense brown GRAVEL with sand, little silt, trace clay - moist										
614.8	4	4/4/7			Stiff brown CLAY, some silt, some gravel, trace sand - damp	SS-2	23	1	2	25	50	50	22	19	A-7-6
	6	4/5/8				SS-3								24	
609.8	8	4/4/6			Stiff brown silty CLAY, and sand - moist	SS-4	0	2	39	31	28	36	16	20	A-6b
	10														
	12	12/14/50 (0.2')			(Becomes hard with trace cobbles at 11.0')	SS-5								9	
605.3	14	0%	6.0	4.0	LIMESTONE, gray, hard, horizontal bedding, highly fractured, RQD = 0% (7" clay seam at 13.6')										
	16				(4" clay seam at 15.1')										
	18														
	20														
	22														
595.3															

Bottom of Boring at 23'

Particle Sizes: Agg => 2.00mm, Coarse Sand = 2.00-0.42mm, Fine Sand = 0.42-0.074mm, Silt = 0.074-0.005mm, Clay =< 0.005mm.

Bowser-Morner, Inc.

Date Started 10/22/07 | Sampler: Type Split Spoon | Dia. ____ | Water Elev. (ft) None | Job Number: 142304

Date Completed 10/22/07 | Casing: Length ____ | Dia. ____ | Client: Brown County Engineer Office

Boring No. B-002-0-07 | Project Description: Soil Study for Proposed Bridge Replacement Project, Bridge along Skiffsville Rd over West Branch of Bullskin Creek, Lewis Twp, Brown Co, OH

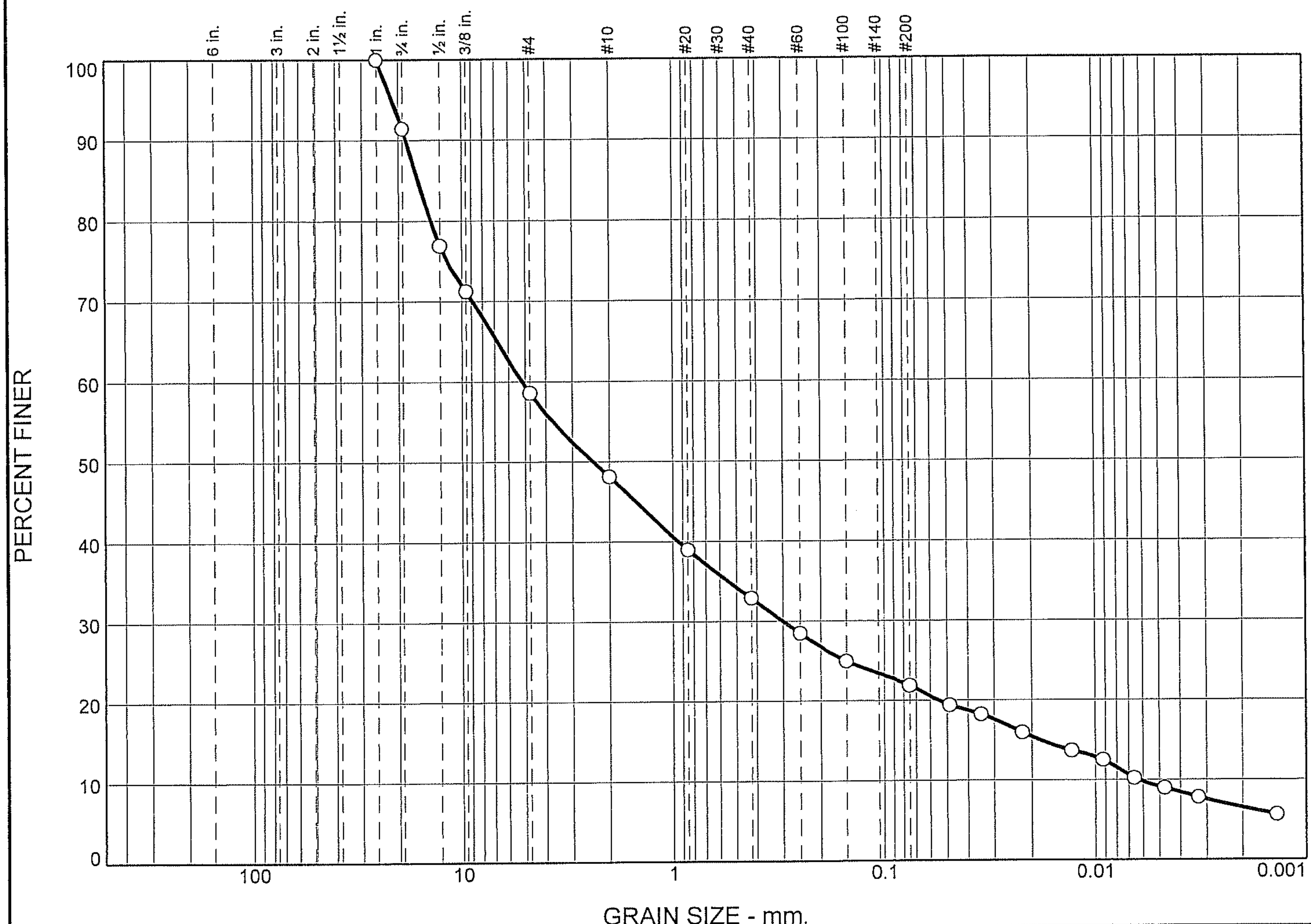
Sheet 1 of 1 | Station & Offset 15+83.6, 4.0' Lt. | Surface Elev. (ft) 615.8

Elev. (ft)	Depth (ft)	Std. Pen./ RQD	Rec. (ft)	Loss (ft)	Description	Sample No.	Physical Characteristics								ODOT Class
							% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	
615.8	0														
615.3					(FILL) ASPHALT pavement (0.5')										
615.0	2	6/5/3			(FILL) GRAVEL base (0.3')	SS-1	7	4	27	35	26	24	8	13	A-4a
613.3					(ORIGINAL) Medium stiff brown sandy SILT, some clay, trace gravel - damp										
611.6	4	9/19/17			Dense brown GRAVEL with sand and silt, little clay - damp	SS-2	54	6	12	16	12	23	6	6	A-2-4
	6	7.5%	7.7	4.1	LIMESTONE, gray, hard, horizontal bedding, RQD = 7.5% (4.5" clay seam at 4.9') (5" clay seam at 5.3')										
	8														
	10														
	12														
	14														
599.8	16														

Bottom of Boring at 16'

Particle Sizes: Agg => 2.00mm, Coarse Sand = 2.00-0.42mm, Fine Sand = 0.42-0.074mm, Silt = 0.074-0.005mm, Clay =< 0.005mm.

GRAIN SIZE DISTRIBUTION REPORT



	% Boulders	% +3"	% Gravel		% Sand		% Fines	
			Coarse	Fine	Coarse	Fine	Silt	Clay
○	0.0	0.0	8.5	43.3	15.3	11.0	12.7	9.2

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	19	15	16.0345	5.1544	2.3800	0.3002	0.0183	0.0063	2.78	819.78

Material Description	USCS	AASHTO
○ brown GRAVEL and/or STONE FRAGMENTS with SAND, little silt, trace clay	GC-GM	A-1-b

Project No. 142304 **Client:** Brown County Engineer Office
Project: Soil Study for Proposed Bridge Replacement Project

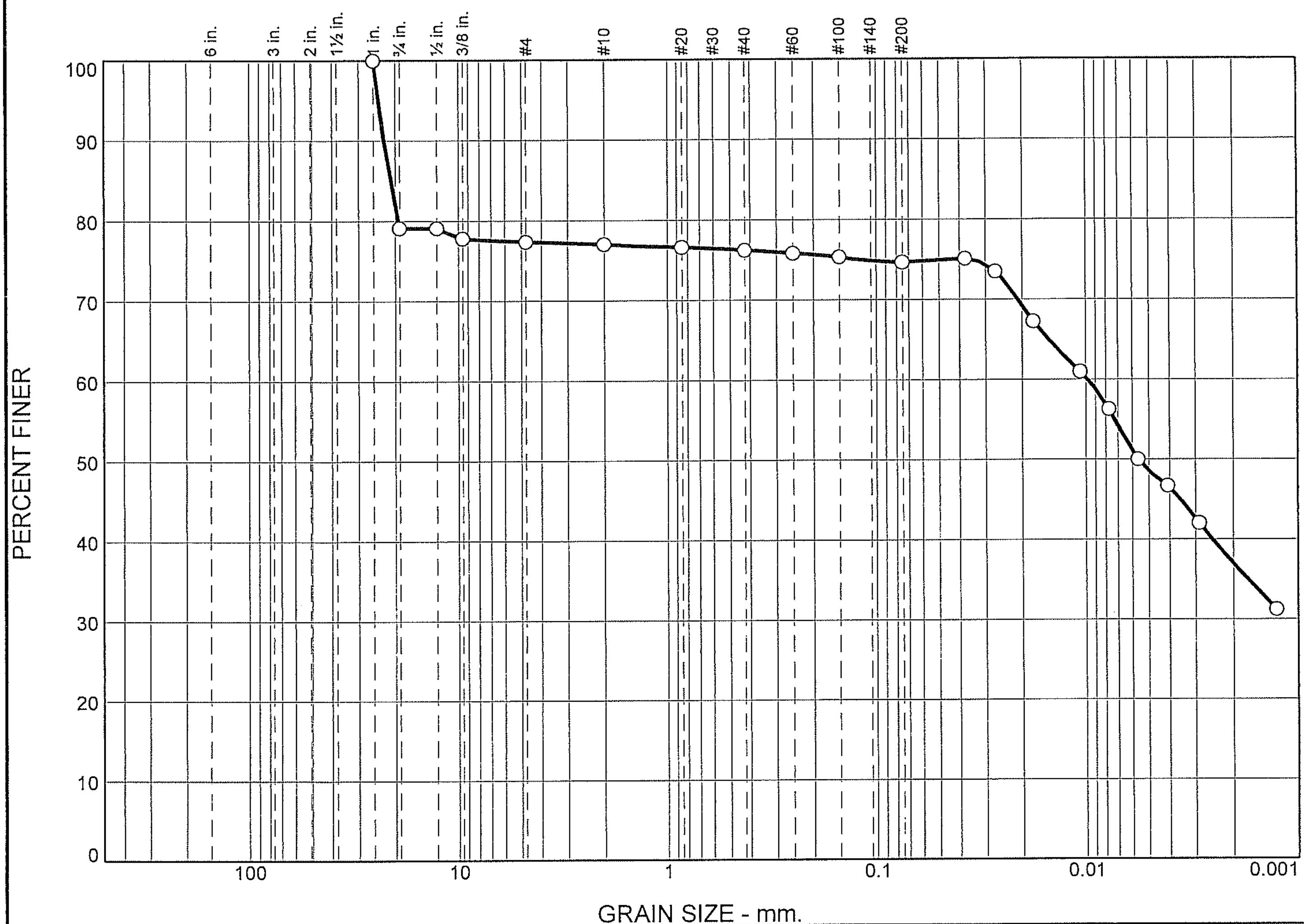
○ **Location:** Boring 001-0-07 **Depth:** 1.0'-2.5' **Sample Number:** 1A

Remarks:
○ As Received
Moisture Content: 5.2%
ODOT Class: A-1-b(0)

BOWSER-MORNER, INC.

Dayton, Ohio

GRAIN SIZE DISTRIBUTION REPORT



	% Boulders	% +3"	% Gravel		% Sand		% Fines	
			Coarse	Fine	Coarse	Fine	Silt	Clay
○	0.0	0.0	20.9	2.0	0.8	1.6	26.1	48.6

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	50	28	21.1896	0.0098	0.0056					

Material Description	USCS	AASHTO
○ brown CLAY, some silt, some gravel, trace sand	CH	A-7-6(17)

Project No. 142304 **Client:** Brown County Engineer Office

Project: Soil Study for Proposed Bridge Replacement Project

○ **Location:** Boring 001-0-07 **Depth:** 3.5'-5.0' **Sample Number:** 2A

BOWSER-MORNER, INC.

Dayton, Ohio

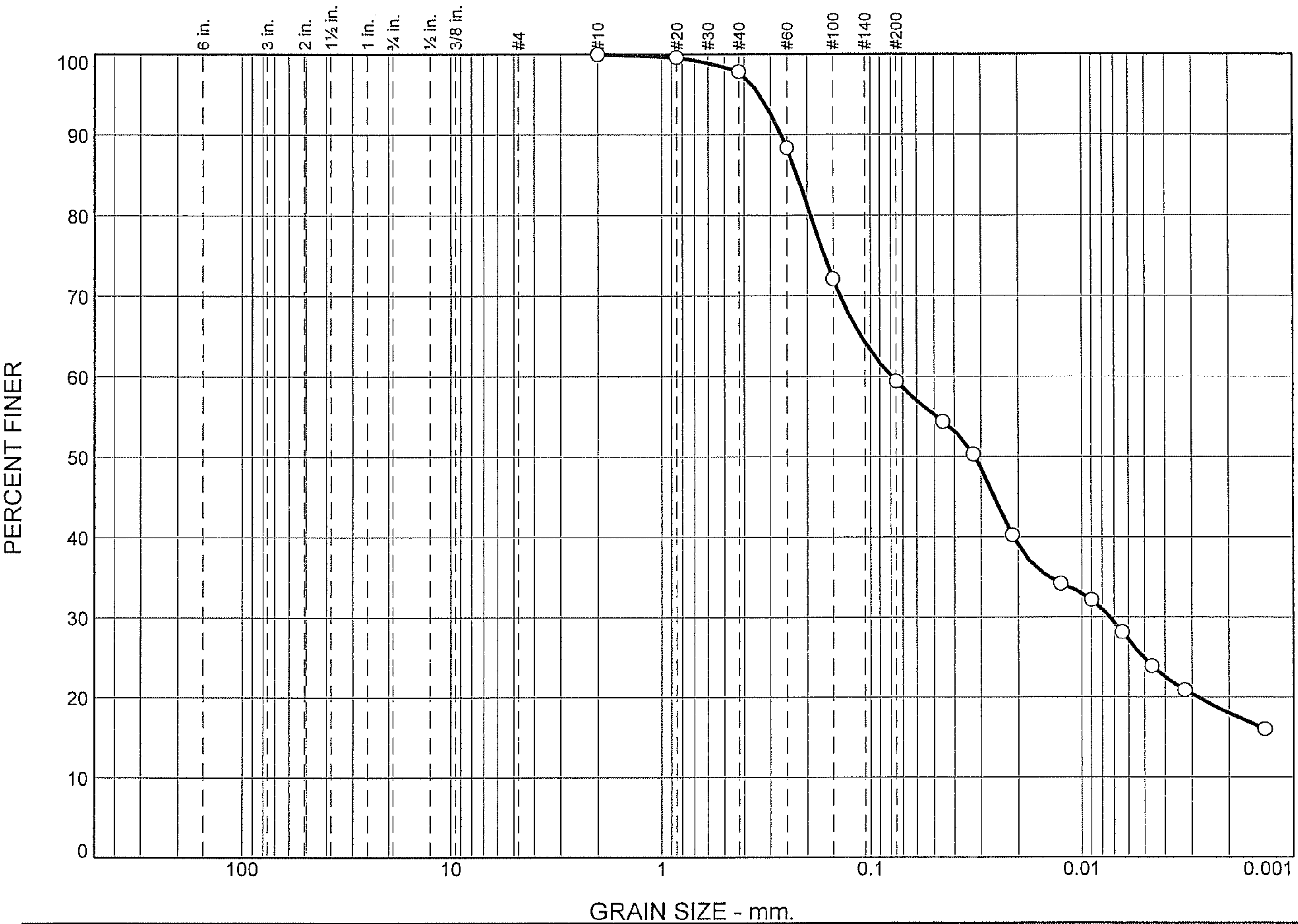
Remarks:

○ As Received

Moisture Content: 18.9%

ODOT Class: A-7-6(15)

GRAIN SIZE DISTRIBUTION REPORT



	% Boulders	% +3"	% Gravel Coarse	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines Silt	% Fines Clay
○	0.0	0.0	0.0	0.0	2.1	38.5	34.5	24.9

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	36	20	0.2232	0.0786	0.0319	0.0073				

Material Description	USCS	AASHTO
○ brown silty CLAY, and sand	CL	A-6(7)

Project No. 142304 **Client:** Brown County Engineer Office

Project: Soil Study for Proposed Bridge Replacement Project

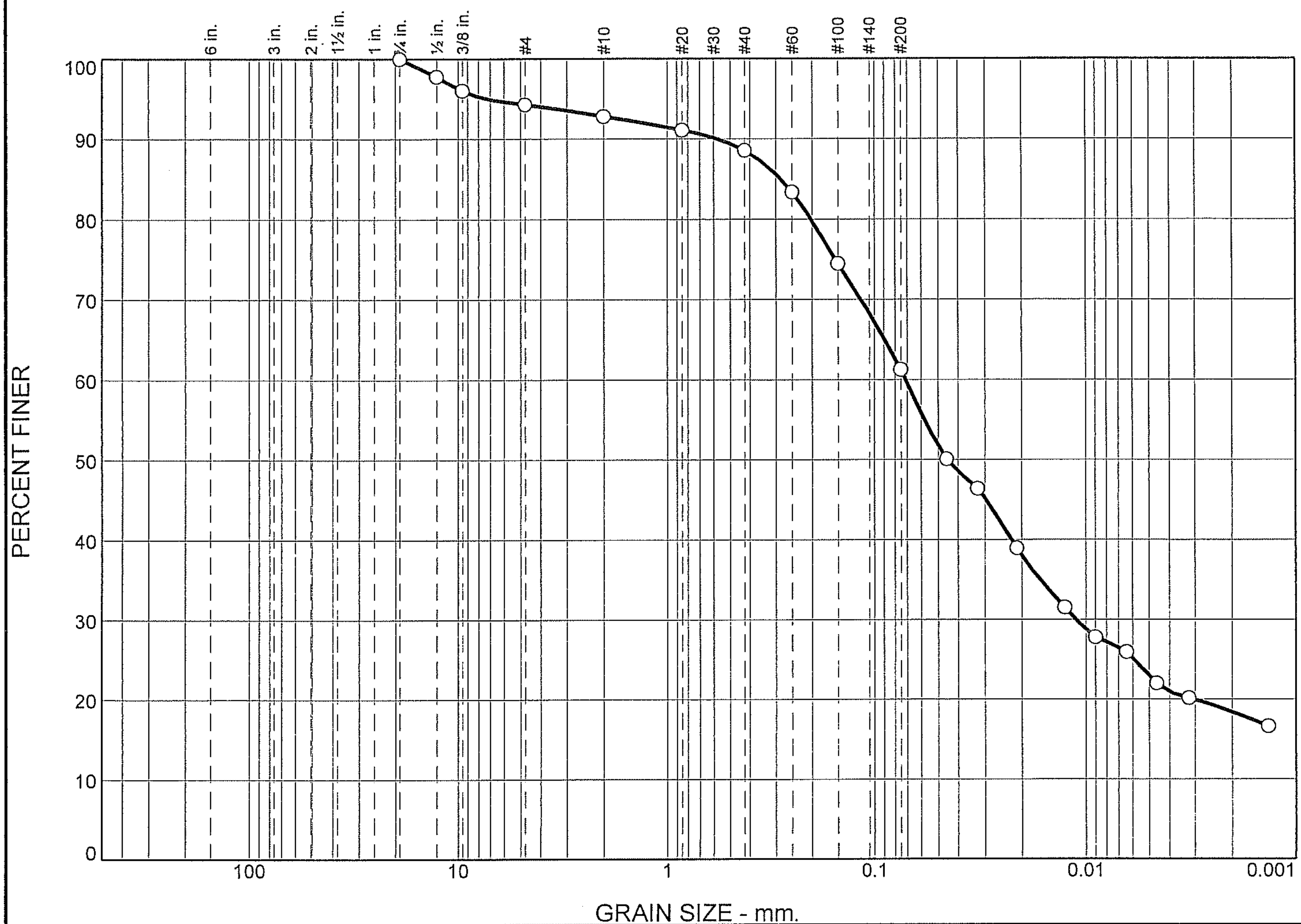
○ **Location:** Boring 001-0-07 **Depth:** 8.5'-10.0' **Sample Number:** 4A

Remarks:
○ As Received
Moisture Content: 20.3%
ODOT Class: A-6-b(7)

BOWSER-MORNER, INC.

Dayton, Ohio

GRAIN SIZE DISTRIBUTION REPORT



	% Boulders	% +3"	% Gravel Coarse	% Gravel Fine	% Sand Coarse	% Sand Fine	% Fines Silt	% Fines Clay
o	0.0	0.0	0.0	7.2	4.2	27.3	38.3	23.0

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
o	24	16	0.2826	0.0710	0.0450	0.0111				

Material Description	USCS	AASHTO
o brown sandy SILT, some clay, trace gravel	CL	A-4(2)

Project No. 142304 **Client:** Brown County Engineer Office
Project: Soil Study for Proposed Bridge Replacement Project

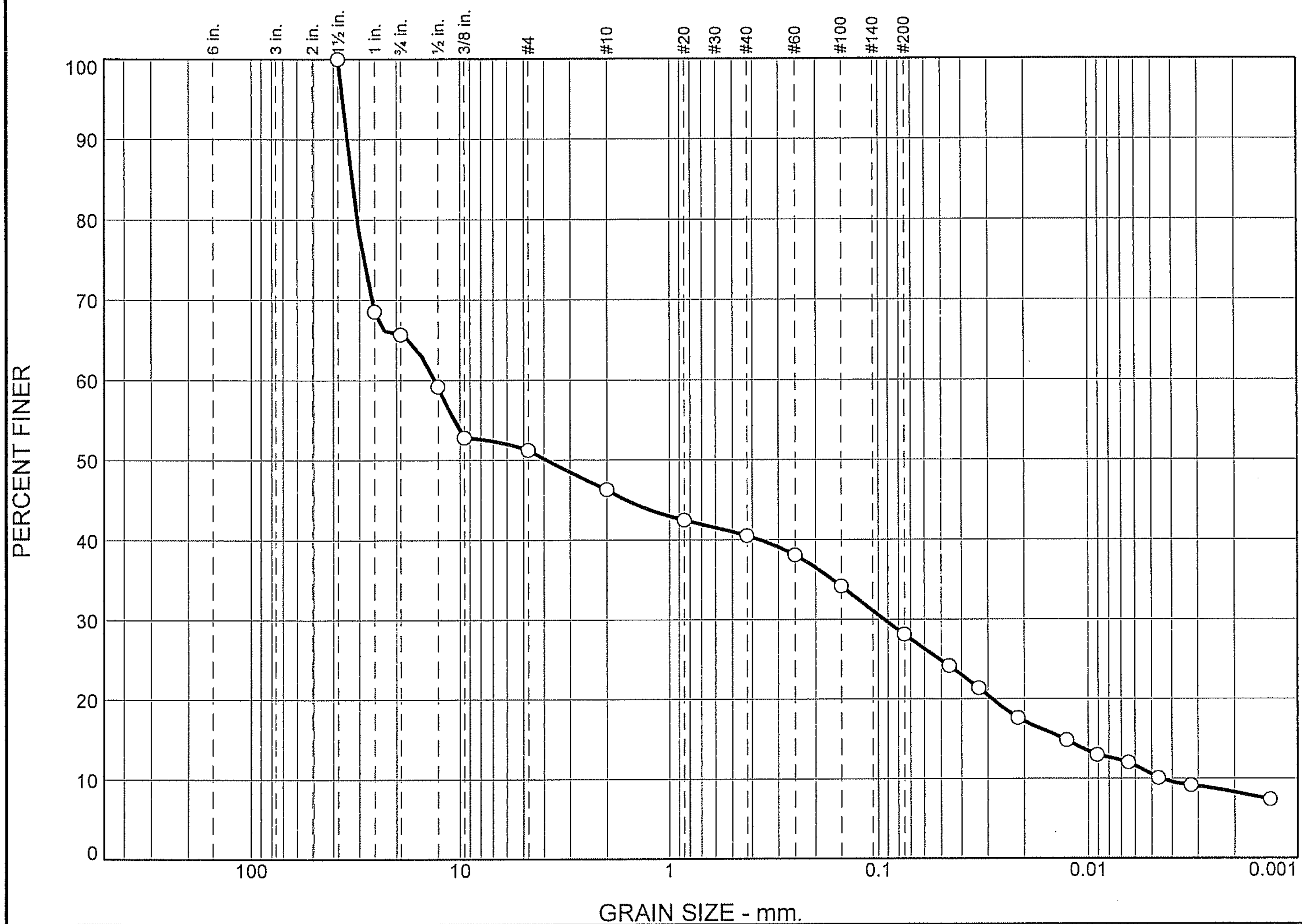
o **Location:** Boring 002-0-07 **Depth:** 1.0'-2.5' **Sample Number:** 1A

BOWSER-MORNER, INC.

Dayton, Ohio

Remarks:
o As Received
Moisture Content: 13.0%
Odot Class: A-4a(5)

GRAIN SIZE DISTRIBUTION REPORT



	% Boulders	% +3"	% Gravel		% Sand		% Fines	
			Coarse	Fine	Coarse	Fine	Silt	Clay
○	0.0	0.0	34.3	19.4	5.8	12.4	17.6	10.5

╳	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	23	17	32.5509	13.1148	3.8567	0.0934	0.0130	0.0045	0.15	2890.68

Material Description	USCS	AASHTO
○ brown GRAVEL and/or STONE FRAGMENTS with SAND and SILT, little clay	GC-GM	A-2-4(0)

Project No. 142304 **Client:** Brown County Engineer Office

Project: Soil Study for Proposed Bridge Replacement Project

○ **Location:** Boring 002-0-07 **Depth:** 3.5'-4.0' **Sample Number:** 2A

Remarks:

○ As Received

Moisture Content: 5.6%

ODOT Class: A-2-4(0)

BOWSER-MORNER, INC.

Dayton, Ohio

MOISTURE CONTENTS OF SOILS (ASTM D2216)

BOWSER MORNER®

Client: Brown County Engineer Office
Project: Soil Study for Proposed Bridge Replacement Project
Work Order No.: 142304
Date: 11/07/07

Boring Number	Sample Number	Depth, (ft)	Depth, (m)	Moisture Content, (%)
B-001-0-07	1 A	1.0 - 2.5	0.3 - 0.8	5.2
	2 A	3.5 - 5.0	1.1 - 1.5	18.9
	3 A	6.0 - 7.5	1.8 - 2.3	24.4
	4 A	8.5 - 10.0	2.6 - 3.0	20.3
	5 A	11.0 - 12.5	3.4 - 3.8	8.9
B-002-0-07	1 A	1.0 - 2.5	0.3 - 0.8	13.0
	2 A	2.5 - 4.0	0.8 - 1.2	5.6