LONE STAR GEOTECHNICAL & TESTING SERVICES, L.P.

LSGS

P.O. BOX 820125 • HOUSTON, TEXAS 77282-0125
(281) 441-1462 • FAX: (281) 441-2367
Texas Registered Engineering Firm F-2615

July 7, 2015

Steve Epps Custom Homes, Inc.
6513 Mert Lane
Katy, Texas 77493

Attn: Steve Epps, Owner

Re: Soil Foundation Investigation
Residence at 30627 Lower Oxbow Trace
Lot 6, Block 1, Section 3C
Fulbrook Subdivision
Fort Bend County, Texas

Project No.: 1506-041
Report No.: 1506041-1

Dear Steve,

We are pleased to submit this report on the soil foundation investigation made recently at the site referred to above.

This investigation reveals high plasticity clay, with an intermediate layer of medium plasticity silty clay in borings B-2 & B-3, for the surface and shallow formations, underlain by medium plasticity sandy clay in borings B-1 & B-3, for the deeper formation explored. This soil is suitable for slab-on-ground/fill floor slabs with considerations as addressed in the report.

For a pier & beam design, the structural loads should be supported on drilled piers founded at 12 feet of depth below existing grade, and proportioned for 4500 PSF for total dead and live loads. Parameters for shallow foundations such as continuous footings in conjunction with the design of an FHA Type III waffle slab or an engineered post-tensioned slab are addressed in the report.

It has been a pleasure being of service to you on this project. If we may be of any further assistance, please call us.

Respectfully,

James L Hickey

James L. Hickey, P. E.

7-7-15
JAMES L. HICKEY
30518

5815 BENDER ROAD • HUMBLE, TEXAS 77396

Report No.: 1506041-1

TABLE OF CONTENTS

Page

SCOPE AND PURPOSE.................................. 1
PROCEDURES..
    Field.. 1
    Laboratory................................... 2
PROJECT DESCRIPTION AND AUTHORIZATION.............. 2
GEOLOGY.. 2
SITE DESCRIPTION................................... 3
VARIATIONS... 3
SOIL STRATIGRAPHY.................................. 3
ENGINEERING ANALYSIS............................... 4
SITE PREPARATION................................... 5
FOUNDATION CONSIDERATIONS.......................... 6
SHALLOW FOUNDATIONS................................ 6
DRILLED PIERS...................................... 6
EXPANSIVE CLAYS.................................... 7
SUPPLEMENTAL DATA.................................. 8

PLATES AND CHARTS

LOCATION OF TEST BORINGS........................... 1
LOGS OF BORINGS.................................... 2-4
KEY TO SOIL SYMBOLS................................ 5
UNIFIED SOIL CLASSIFICATION SYSTEM................. 6

SUBJECT: REPORT OF SOIL FOUNDATION INVESTIGATION

RESIDENCE AT 30627 LOWER OXBOW TRACE
LOT 6, BLOCK 1, SECTION 3C
FULBROOK SUBDIVISION
FORT BEND COUNTY, TEXAS

TO: STEVE EPPS CUSTOM HOMES, INC.
6513 MERT LANE
KATY, TEXAS 77493

ATTN: STEVE EPPS, OWNER

SCOPE AND PURPOSE:

This report presents the results of the foundation investigation made recently at the subject site to determine the nature and condition of surface and sub-surface soil as affects the design of foundations. In particular, it was desirable to determine the feasibility of slab-on-ground/fill type first floor construction, depth to water table where encountered, optimum type and depth of structural foundations and safe soil bearing capacity. The investigation was made in accordance with your instructions.

PROCEDURES: FIELD

Two (2) borings were made to a depth of 15 feet each, and 1 boring was made to a depth of 20 feet, at the locations shown on the Location of Test Borings plate or Figure 1. The borings were made with aN ls-100 rotary drilling rig using no drilling water in order to secure unaffected soil samples and reliable data on groundwater levels. Cohesive soil was sampled by pushing thin-walled Shelby tube samplers into the soil in accordance with ASTM Procedure D 1587-74. The samples were taken by a geotechnical engineering aide who noted the consistency, color, composition, and classification of the soil as encountered.

The unconfined compressive strength of the cohesive soil was measured in the field by use of a Soiltest Cl-700 Penetrometer. This value is reported on the logs of borings.

The samples were examined and classified in accordance with the Unified Soil Classification System. They were then sealed to prevent moisture loss and transported to the laboratory for subsequent testing.

PROCEDURES: LABORATORY

In the laboratory, the samples were tested for moisture contents, density, unconfined compressive strength, and Atterberg limits. The final logs of borings were prepared by a geotechnical engineer after examining the samples, and reviewing the results of tests. The results of these tests are shown on the Logs of Borings.

PROJECT DESCRIPTION AND AUTHORIZATION:

The project consists of a 6,053 square foot, 1-1/2 story residence, with attached garage, on a concrete slab with wood frame and with stone veneer, and hardi plank siding. Wall loads are not known at this time, but are not expected to exceed 2 kips per foot. The pier loads are not expected to exceed 40 kips. The soil investigation was requested by Steve Epps, Owner, with Steve Epps Custom Homes, Inc., the builder.

GEOLOGY:

The surficial soil at this site is underlain by the Beaumont Formation of the Pleistocene era. This formation consists of overconsolidated clays, silts, and sands with fragments of shell, calcium carbonates, and ferrous nodules. These formations extend to a depth of about 200 feet, and are quite strong; although the surface has been weakened somewhat by the weathering process.

A fault study is beyond the scope of this investigation. For information on area faulting, it is recommended that a professional geologist be consulted.

SITE DESCRIPTION:

The residence site consists of a grassy area on a grassy lot, lightly wooded, fronting at 30627 Lower Oxbow Trace in the Fulbrook subdivision in Fort Bend County, Texas. The lot slopes toward the pond & the road, and was drained at the time of the investigation.

VARIATIONS:

The recommendations contained in this report are based on data gained from the test boring at the location shown on the Location of Test Boring plate, Figure 1, a reasonable volume of laboratory tests, and professional interpretation and evaluation of this data in view of the project information provided this firm. Should soil conditions differing from those described in this report be encountered at other locations in the course of construction, or should the design data change significantly, this firm should be notified immediately so that the conditions and their effect may be evaluated.

SOIL STRATIGRAPHY:

The surface soil consists of hard to very stiff reddish brown high plasticity clay (CH) to depths of 9 to 15 feet, with an intermediate layer of hard reddish brown & reddish tan medium plasticity silty clay (Cl) from 2 to 4 feet of depth in boring B-1, and from 9 to 13 feet of depth in boring B-3. The high plasticity clay is underlain by hard reddish tan medium plasticity sandy clay (CL) extending to the maximum depth of the borings at 20 feet. A more detailed stratigraphy can be seen on the logs of borings.

No ground water was encountered during the boring operations. However, it should be noted that ground water levels are subject to the influence of seasonal variations as well as other factors and should be checked prior to the initiation of any construction that could be affected.

ENGINEERING ANALYSIS:

The expansive potential of the surface and shallow formations was determined by comparison of the natural moisture content of the soil with the results of Atterberg limit tests. Experience has shown that plastic soil having moisture contents equal to or less than the plastic limit of the soil is potentially expansive with the expansion pressure varying directly with the plasticity index and inversely with the moisture content. On the other hand, soil having low or moderate plasticity indices and moisture content above the plastic limit is essentially non-expansive. Soil with high plasticity indices is practically always subject to volume changes regardless of the moisture.

Safe soil bearing pressures for cohesive formations are calculated from the depth and undrained shear strength of the soil determined by unconfined compression tests and field penetrometer values. Safe soil bearing pressures for cohesionless soil are determined from the values established by the Standard Penetration Test and interpretation of these values. A safety factor of two (2) is used for total dead and live load. A safety factor of three (3) is used for dead load and sustained live load. The most suitable type of foundation is determined by review of the job requirements, the logs of borings, and the test results. The most suitable depth is selected as the minimum depth below the zone of seasonal moisture fluctuations affording reasonably uniform footing support, reasonably high safe bearing capacities, and adequate vertical clearance with physical features of the proposed structures.

Surficial soil is studied for the ease of compactability and manipulation in the field during construction. Also, should the site have poor soil or should drainage conditions be restricted, consideration is given to the alternatives for stabilization or removal and replacement of the surficial soil with select compactible soil. These are some of the considerations given to pavement design.

Certain tests are performed for building conditions in which certain characteristics of the soil are critical to the design of the structure. When long-term settlement analysis is required, consolidation tests are performed. Triaxial tests are performed to measure shear strength and pore pressure in sandier soil. Permeability tests are performed when the loss of fluids through the soil is critical. However, these are not critical tests for this project.

SITE PREPARATION:

The potential vertical rise (PVR) when determined in accordance with the Texas Department of Transportation Test Method Test 124-E was found to be 1.45 inch at the time of the investigation. The maximum swell pressure potential of the soil at the time of the investigation was 1600 PSF. PVR is not a design parameter, but, rather, an indication of the swell potential of the soil at the time of the investigation. It is recommended that the following procedures be implemented in preparation of the site for construction:

1) Strip and scarify the surface soil to a minimum depth of six (6) inches and remove all surface organics, trash, debris, and other deleterious materials. If trees are to be removed, the root system should be removed to a minimum depth of 2 feet or to a depth where the maximum root size is less than 1/2 inch.

2) Provide positive drainage by sloping, and directing the runoff away from the building. This includes all roof drain downspouts after construction extending the outfall of the same beyond the residence pad.

3) Proof-roll the prepared soil with a loaded dump truck to locate any wet or pumping area and treat the same with the proper stabilizing agents. Compact the soil to 100 percent of natural density (No ruts when proof-rolled with a loaded dump truck or equivalent).

4) Any fill required under floor slabs in the building area should be a select soil consisting of sandy and/or silty clay free of any organics, trash, or other deleterious materials with a minimum liquid limit of 25. The plasticity index (PI) should range from 10 to 20. Compact the select fill in 6 inch lifts to 95 percent of Standard Proctor Density, in conformance with the standard procedure, ASTM D 698, at or within 3 percent of optimum moisture.

5) The building pad should consist of a minimum of 30 inches of compacted select fill, or more if necessary to elevate the site for proper drainage. The pad should extend a minimum of 5 feet beyond the periphery of the building, if possible. The height of the pad can be controlled by the removal of the surface soil & replacement of the same with compacted select fill. The placement of the fill should be monitored by this firm or another approved geotechnical engineering firm.

FOUNDATION CONSIDERATIONS:

NOTE: The surface soil is an active clay. The least affected design would be a structurally isolated slab, and is recommended for this site. However, this system may be impractical or cost prohibitive. Pre-wetting the soil, preferably by water or lime slurry injection during a drought period, will aid in reducing the swell potential of the soil. For a pier & beam design, or a column supported structure, drilled and under-reamed (bell bottom) piers are recommended for the support of the structural loads as addressed below. Parameters for a shallow foundation such as a floating waffle slab with stiffener interior beams or post-tensioned slab are included for the use of your designer. The effective PI = 37. The climatic rating, Cw = 25. The pier shafts should be designed to withstand an uplift pressure of 1600 PSF. The steel reinforcement of the pier shafts should be a minimum of 1 percent of the shaft area.

The following are Post-Tensioning Institute, Inc. parameters for the DESIGN AND CONSTRUCTION OF POST-TENSIONED SLABS-ON-GROUND, 3rd Edition:
Boring #: B-3   Depth: 0' to 2'   Description: Reddish brown clay
Liquid Limit: 57   Plastic Limit: 20   Plasticity Index: 37
Clay Content: 50 Percent   Thornwaite Index: 18
Depth to constant suction: 9 feet
Soil Suction: pF = 3.5   Activity Ratio, Ac: 0.74
Cation Exchange Ratio, CEAc: 0.67   Clay Type: Montmorillonite
Velocity of Moisture Flow, v: 0.7 inches/month
Edge Moisture Variation Distance, Em: Center Lift = 9.0 Ft.
Edge Lift = 5.0 Ft.
Differential Swell, Ym: Center Lift = 0.49 inch
Edge Lift = 0.53 inch

SHALLOW FOUNDATIONS:
After proper site preparation, continuous footings founded at the 1/2 to 2-1/2 foot depth below existing grade should be proportioned for a safe bearing capacity of 2000 PSF incorporating a minimum safety factor of 3.

DRILLED PIERS:
Drilled and under-reamed piers should be founded at the 12 foot depth below existing grade, and be proportioned for a safe bearing capacity of 4500 PSF for total dead and live loads incorporating a minimum safety factor of 2. For total dead and sustained live loads, the safe bearing capacity is 3000 PSF incorporating a minimum safety factor of 3. If sloughing occurs, a 1:2 shaft to bell ratio is recommended. If sloughing persists, straight-sided piers will be required.

EXPANSIVE CLAYS:

Significant volume changes are experienced by highly plastic clays with changes in moisture content. During dry weather, the clays shrink. During wet weather, the clays swell. These shrink/swell tendencies can produce considerable stress on structures, especially slabs.

As water evaporates, it is replaced through capillary action by water from below. When a slab is constructed, the evaporation is effectively cut off from the surface. However, the moisture continues to be drawn upward until a balanced condition is attained. Along the edges, the moisture can evaporate, but not toward the middle of the slab. The difference in moisture content can cause differential volume change and can induce stress that will produce cracking in the slab.

There are several approaches to minimizing moisture loss around the edges due to evaporation. Deep beams can be effective. Flower beds kept continually wet around the periphery of the slab have been found to be effective. Extending the periphery of drying area beyond the slab by lime stabilizing and/or paving a five (5) foot strip around the slab can be beneficial.

Trees draw quite a bit of moisture through the roots. They should be planted a fair distance away from the structure or the foundation of the structure should extend beyond the root system to not be affected.

SUPPLEMENTAL DATA:

The shrink/swell potential of high plasticity clay can have detrimental effects on a slab, and the safest system in this situation, is a structurally isolated slab, with crawl space or void forms. Void boxes are used under grade beams to isolate the slab from the effects of the soil transferring the support to the drilled piers, where drilled piers are used. However, some designers believe that the voids allow water to migrate through the natural soil or through porous fill and backfill for utilities, and affect the slab. A completely isolated slab, grade beams and slab, is the safest system, but can be cost prohibitive.

PVR (Potential Vertical Rise) is the theoretical possible movement in a swelling situation being more substantial in high plasticity clay. Since the PVR curves are based on the soil index, Liquid Limit, and the moisture content of the soil, this value can vary with changes in moisture content. The largest range is from a "bone dry" state to a wet (saturated) state. This value is not a design parameter, but, rather a "red flag" that can indicate the possibility of swell in dry soil. In a high plasticity clay with a high moisture content, the PVR is low when compared to the dry condition.

As a preventative to slab movement and cracking in the floor tiles and walls, both interior sheet rock and outside veneer walls, a structurally isolated slab is recommended with a deep enough foundation that will not be affected by moisture changes.

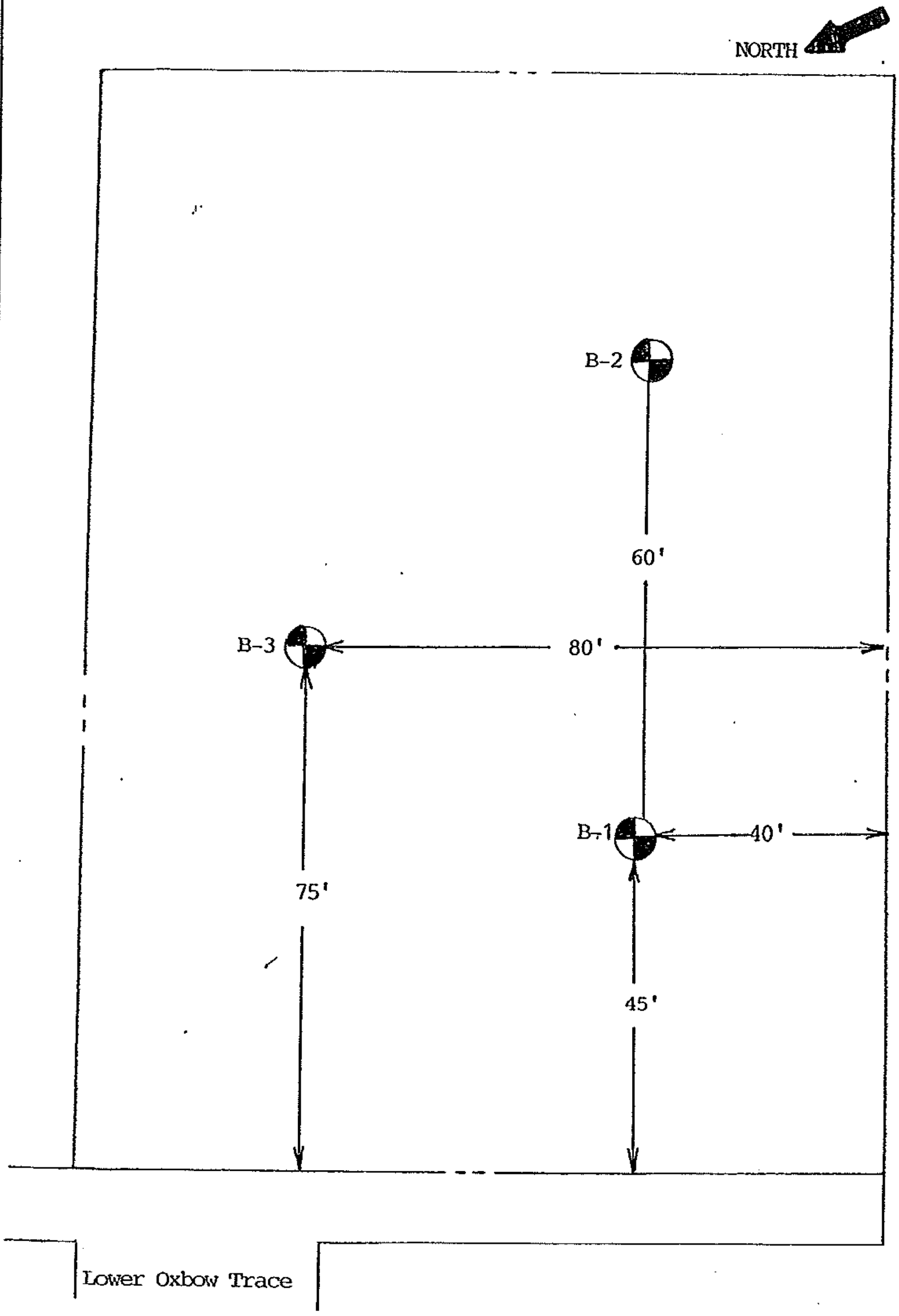
The addition of select fill is a rational attempt to reduce the effective plasticity index of the soil, thereby, reducing the shrink/swell potential, where the cost of a structurally isolated slab is not practical or beyond the limits of the budget, or financing of the project.

All drain spouts should be extended, and hose connections & sprinkler systems placed, at a distance that is substantially away from the building to prevent spillage that may infiltrate the soil.

Where trees are removed, the voids should be wetted in the areas of high plasticity clay, pre-swelling the soil, and should be backfilled as addressed under site preparation.

All trees should be planted at a minimum distance equivalent to the height of the tree, and the drip line should be kept at a minimal distance of 10 feet away from the structure, if space allows. Plants that require constant watering should not be planted next to the structure.

LOCATION OF TEST BORINGS



Project No: 1506-041
Report No.: 1506041-1

Not to Scale

Figure 1

LONE STAR GEOTECHNICAL SERVICES

LOG OF BORING

BORING NO: B-1

PROJECT: Residence @ 30627 Lower Oxbow Trace
FOR: Steve Epps Custom Homes
DATE: 6-30-2015
DRILLER: MG Drilling

JOB NO: 1506-041
BORING METHOD: Core
AUGER: X
WASH:
GROUND ELEV: Existing

Depth (Feet)	Sample Method	Water Levels	Penetrometer or Blow Count	Compressive Strength Tons/Sq. Ft.	Moisture Content (%)	Dry Density Lbs./Cu. Ft.	Liquid Limit %	Plasticity Index	■ Shelby Tube ☒ Standard Penetration Test ▨ No Recovery ▽ Initial Water Level ▼ Water Level After
	■		4.5		27		57	37	Hard, reddish brown clay (CH), with sand seams
	■		4.5	2.6	22	98			...very stiff
5	■		4.5		21		51	32	...hard
	■		4.5		26				...with sand partings
	■		4.5		24				...same
10									
	■		4.5		13				Hard, reddish tan sandy clay (CL)
15									
									Boring terminated at 15' No water encountered

LOG OF BORING

BORING NO: B-2

PROJECT: Residence @ 30627 Lower Oxbow Trace
FOR: Steve Epps Custom Homes

DATE: 6-30-2015
DRILLER: MG Drilling

JOB NO: 1506-041
BORING METHOD: Core
AUGER: X
WASH:
GROUND ELEV: Existing

■ Shelby Tube
☒ Standard Penetration Test
▨ No Recovery
▽ Initial Water Level
▼ Water Level After

Depth (Feet)	Sample Method	Water Levels	Penetrometer or Blow Count	Compressive Strength Tons/Sq. Ft.	Moisture Content (%)	Dry Density Lbs./Cu. Ft.	Liquid Limit %	Plasticity Index	
	■		4.5		27				Hard, reddish brown clay (CH), with sand seams
	■		4.5	5.7	19	108	36	19	Hard, reddish brown silty clay (CL)
5	■		4.5		24				Hard, reddish brown clay (CH)
	■		4.5		26		66	45	...with sand partings
	■		4.5		21				...same
10									
	■		4.5		23				...with sand seams
15									
									Boring terminated at 15' No water encountered

LOG OF BORING
BORING NO: B-3

PROJECT: Residence @ 30627 Lower Oxbow Trace
FOR: Steve Epps Custom Homes

DATE: 6-30-2015
DRILLER: MG Drilling

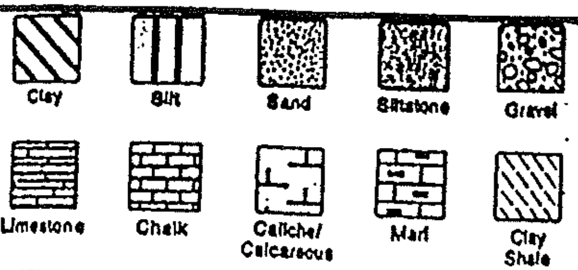
JOB NO: 1506-041
BORING METHOD: Core
AUGER: X
WASH:
GROUND ELEV: Existing

■ Shelby Tube
☒ Standard Penetration Test
▨ No Recovery
▽ Initial Water Level
▼ Water Level After

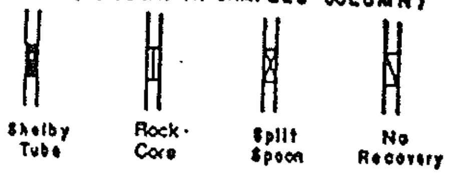
Depth (Feet)	Sample Method	Water Levels	Penetrometer or Blow Count	Compressive Strength Tons/Sq. Ft.	Moisture Content (%)	Dry Density Lbs./Cu. Ft.	Liquid Limit %	Plasticity Index	
	■		4.2		30		57	37	Hard, reddish brown clay (CH)
	■		4.5		23		51	32	...with sand partings
5	■		4.5		27				...jointed
	■		4.5	5.9	20	107			...with sand seams
	■		4.5		17		39	22	Hard, reddish tan silty clay (CL)
10									
15	■		4.5		18				Hard, reddish brown clay (CH), with sand seams
20	■		4.5		10				Hard, reddish tan sandy clay (CL)

Boring terminated at 20'
No water encountered

SYMBOLS AND TERMS USED ON BORING LOGS



SAMPLER TYPES
(SHOWN IN SAMPLES COLUMN)



TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (Major Portion Retained on No.200 Sieve): Includes (1) clean gravels and sands, and (2) silty or clayey gravels and sands. Condition is rated according to relative density, as determined by laboratory tests.

Descriptive Term	Standard Penetration, Resistance, Blows/Ft.	Relative Density
Loose	0 - 10	0 to 40%
Medium dense	10 - 30	40 to 70%
Dense	30 - 50	70 to 100%

FINE GRAINED SOILS (Major portion passing No. 200 sieve): Includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests.

DESCRIPTIVE TERM	UNCONFINED COMPRESSIVE STRENGTH TONS / Sq. Ft.
Very soft	less than 0.25
Soft	0.25 to 0.50
Firm	0.50 to 1.00
Stiff	1.00 to 2.00
Very Stiff	2.00 to 4.00
Hard	4.00 and higher

Note: Slickensided and fissured clays may have lower unconfined compressive strengths than shown above, because of planes of weakness or cracks in the soil. The consistency ratings of such soils are based on penetrometer readings.

TERMS CHARACTERIZING SOIL STRUCTURE

Parting: -paper thin in size   Seam: -1/8"-3" thick   Layer: -greater than 3"

Slickensided - having inclined planes of weakness that are slick and glossy in appearance.

Fissured - containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical.

Laminated - composed of thin layers of varying color and texture.

Interbedded - composed of alternate layers of different soil types.

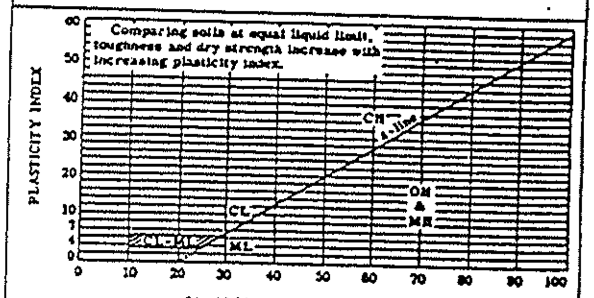
Calcareous - containing appreciable quantities of calcium carbonate.

Well graded - having wide range in grain sizes and substantial amounts of all intermediate particle sizes.

Poorly graded - predominantly of one grain size, or having a range of sizes with some intermediate size missing.

Flocculated - pertaining to cohesive soils that exhibit a loose knit or flakey structure.

UNIFIED SOIL CLASSIFICATION SYSTEM

<table>
<tr><th colspan="3">Major Divisions</th><th>Group Symbols</th><th>Typical Names</th><th colspan="3">Field Identification Procedures (excluding particles larger than 3 in. and basing fractions on estimated weights)</th><th>Information Required for Describing Soils</th><th colspan="4">Laboratory Classification Criteria</th></tr>
<tr><th>(1)</th><th colspan="2">(2)</th><th>(3)</th><th>(4)</th><th colspan="3">(5)</th><th>(6)</th><th colspan="4">(7)</th></tr>
<tr><td rowspan="8">Coarse-grained Soils (More than half of material is <u>larger</u> than No. 200-sieve size.)</td><td rowspan="4">Gravels (More than half of coarse fraction is larger than No. 4-sieve size.)</td><td rowspan="2">Clean Gravels (Little or no fines)</td><td>GW</td><td>Well-graded gravels, gravel-sand mixtures, little or no fines</td><td colspan="3">Wide range in grain sizes and substantial amounts of all intermediate particle sizes</td><td rowspan="8">For undisturbed soils, add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.
Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
Example:
<u>Silty sand</u>, gravelly; about 20% hard, angular gravel; particles 1/2-in. maximum size; rounded and subangular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).</td><td rowspan="17">Use grain-size curve in identifying the fractions as given under field identification.</td><td rowspan="8">Determine percentages of gravel and sand from grain-size curve.
Depending on percentage of fines (fraction smaller than No. 200-sieve size), coarse-grained soils are classified as follows:
Less than 5% GW, GP, SW, SP
More than 12% GM, GC, SM, SC
5% to 12% <u>Borderline</u> cases requiring use of dual symbols.</td><td colspan="2">$C_u = \frac{D_{60}}{D_{10}}$ (greater than 6) $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ (between one and 3)</td></tr>
<tr><td>GP</td><td>Poorly graded gravels, gravel-sand mixtures, little or no fines</td><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td colspan="2">Not meeting all gradation requirements for GW</td></tr>
<tr><td rowspan="2">Gravels with Fines (Appreciable amount of fines)</td><td>GM</td><td>Silty gravels, gravel-sand-silt mixtures</td><td colspan="3">Nonplastic fines or fines with low plasticity (for identification procedures see ML below)</td><td>Atterberg limits below A-line or PI less than 4</td><td rowspan="2">Above A-line with PI between 4 and 7 are <u>borderline</u> cases, requiring use of dual symbols.</td></tr>
<tr><td>GC</td><td>Clayey gravels, gravel-sand-clay mixtures</td><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>Atterberg limits above A-line with PI greater than 7</td></tr>
<tr><td rowspan="4">Sands (More than half of coarse fraction is smaller than No. 4-sieve size.) (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4-sieve size.)</td><td rowspan="2">Clean Sands (Little or no fines)</td><td>SW</td><td>Well-graded sands, gravelly sands, little or no fines</td><td colspan="3">Wide range in grain size and substantial amounts of all intermediate particle sizes</td><td colspan="2">$C_u = \frac{D_{60}}{D_{10}}$ (greater than 4) $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ (between one and 3)</td></tr>
<tr><td>SP</td><td>Poorly graded sands, gravelly sands, little or no fines</td><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td colspan="2">Not meeting all gradation requirements for SW</td></tr>
<tr><td rowspan="2">Sands with Fines (Appreciable amount of fines)</td><td>SM</td><td>Silty sands, sand-silt mixtures</td><td colspan="3">Nonplastic fines or fines with low plasticity (for identification procedures see ML below)</td><td>Atterberg limits below A-line or PI less than 4</td><td rowspan="2">Limits plotting in hatched zone with PI between 4 and 7 are <u>borderline</u> cases requiring use of dual symbols.</td></tr>
<tr><td>SC</td><td>Clayey sands, sand-clay mixtures</td><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>Atterberg limits above A-line with PI greater than 7</td></tr>
<tr><td rowspan="8">Fine-grained Soils (More than half of material is <u>smaller</u> than No. 200-sieve size.) (The No. 200-sieve size is about the smallest particle visible to the naked eye.)</td><td colspan="2" rowspan="5">Silts and Clays (Liquid limit less than 50)</td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3">Identification Procedures on Fraction Smaller than No.40-Sieve Size</td><td rowspan="2"></td><td colspan="3" rowspan="2"></td></tr>
<tr><td>Dry Strength (Crushing characteristics)</td><td>Dilatancy (Reaction to shaking)</td><td>Toughness (Consistency near PL)</td></tr>
<tr><td>ML</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity</td><td>None to slight</td><td>Quick to slow</td><td>None</td><td rowspan="7">Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses.
For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.
Example:
<u>Clayey silt</u>, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).</td><td colspan="3" rowspan="7">
Liquid Limit Plasticity Chart
(for laboratory classification of fine-grained soils)</td></tr>
<tr><td>CL</td><td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td><td>Medium to high</td><td>None to very slow</td><td>Medium</td></tr>
<tr><td>OL</td><td>Organic silts and organic silty clays of low plasticity</td><td>Slight to medium</td><td>Slow</td><td>Slight</td></tr>
<tr><td colspan="2" rowspan="3">Silts and Clays (Liquid limit greater than 50)</td><td>MH</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td><td>Slight to medium</td><td>Slow to none</td><td>Slight to medium</td></tr>
<tr><td>CH</td><td>Inorganic clays of high plasticity, fat clays</td><td>High to very high</td><td>None</td><td>High</td></tr>
<tr><td>OH</td><td>Organic clays of medium to high plasticity, organic silts</td><td>Medium to high</td><td>None to very slow</td><td>Slight to medium</td></tr>
<tr><td colspan="3">Highly Organic Soils</td><td>Pt</td><td>Peat and other highly organic soils</td><td colspan="3">Readily identified by color, odor, spongy feel, and frequently by fibrous texture</td></tr>
</table>

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols, for example, *GW-GC*, well-graded gravel-sand mixture with clay binder.
(2) All sieve sizes on this chart are U. S. standard.

Field Identification Procedures for Fine-grained Soils or Fractions

These procedures are to be performed on the minus No. 40-sieve-size particles, approximately 1/64 in.
For field classification purposes, screening is not intended; simply remove
by hand the coarse particles that interfere with the tests.

<u>Dilatancy</u> (reaction to shaking)

After removing particles larger than No. 40-sieve size, prepare a pat of moist soil with a volume of about 1/2 cu. in. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat, which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction, whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

<u>Dry Strength</u> (crushing characteristics)

After removing particles larger than No. 40-sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling it between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty, whereas a typical silt has the smooth feel of flour.

<u>Toughness</u> (consistency near plastic limit)

After removing particles larger than the No. 40-sieve size, a specimen of soil about 1/2-in. cube in size is molded to the consistency of putty. If too dry, water must be added, and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about 1/8 in. in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

Adopted by Corps of Engineers and Bureau of Reclamation, January, 1952.