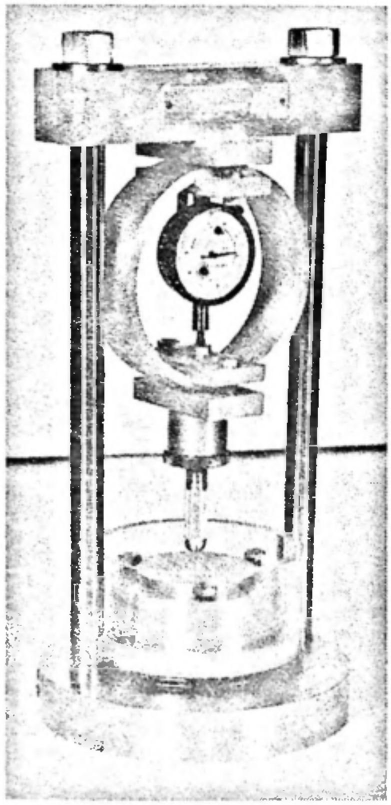

GUIDE TO USE OF THE FHA SOIL PVC METER

Including results of nationwide soil tests and correlation with climatic factors

A Technical Studies Publication
Prepared Under the
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GUIDE TO USE OF THE FHA SOIL PVC METER

Including Results of Nationwide Soil Tests and Correlation With Climatic Factors

A Technical Studies Publication

by

Elvin F. Henry

and

Mary C. Dragoo

January, 1965

PREFACE

Since 1960, when the FHA Soil PVC Meter was developed under the Federal Housing Administration Technical Studies Program, the technical studies staff has developed numerous ways to improve operation of the device. This guide presents these techniques in concise, simple form. It also presents a condensed explanation of the relationship between environment and moisture conditions and their effects on expansive soils.

In addition, Chief Architect Stanley T. Radenz of the San Diego, California, FHA Insuring Office has developed a mechanism for the meter which makes the compaction process easier. This attachable mechanism will become a part of FHA meters; however, it is possible to use the meter without this improvement. Instructions are given for both methods of compaction.

This guide also contains the significant, hitherto unpublished results of over 100 FHA Soil PVC Meter tests which were made from samples taken in selected locations in 15 states. Although these locations were primarily in areas of known highly expansive soils, the test results reflect general characteristics of expansive soils throughout the United States.

Any comments concerning this meter should be addressed to Neil A. Connor, Director, Architectural Standards Division, Federal Housing Administration, 811 Vermont Avenue, N.W., Washington, D. C. 20411.

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GUIDE TO USE OF THE FHA SOIL PVC METER
Including Results of Nationwide
Soil Tests and Correlation
With Climatic Factors

I. INTRODUCTION

Severe damage to building foundations can result from "swelling" or "expansive" soils. These soils, usually cohesive clays, can swell or shrink as they go from the dry to the wet state or vice versa. This alteration in moisture can cause a volume change which creates large differential movements within the structure and thus causes excessive cracking of floors, walls, and foundations.

Soils with expansive characteristics must be recognized in order to evaluate properly their stability as foundation material. The maximum potential volume change that a soil can undergo due to shrinking or swelling is known as Potential Volume Change or PVC. PVC cannot always be determined accurately by visual inspection. For this reason, a relatively simple device was needed which could be used by soil engineers as well as others less familiar with soil problems to provide quick identification of expansive soils. Therefore, the Federal Housing Administration, through its Technical Studies Program, contracted with Dr. T. William Lambe of the Massachusetts Institute of Technology to design such an instrument. This guide presents a simplified explanation of the instrument, which is known as the FHA Soil PVC Meter.

This meter is used to test volume change caused by moisture changes and their effects upon inherent clay minerals. Some soils, however, contain significant amounts of alkalies, salts, or soil chemicals in a free state. These free chemicals can also cause soils to swell upon the addition of water. For example, some of the soils containing free chemicals which are located in the western section of the United States become unstable upon the addition of moisture. This type of volume change cannot be determined through the use of the FHA Soil PVC Meter.

II. ENVIRONMENT AND MOISTURE CONDITIONS

Environment affects volume changes by influencing the moisture condition of the soil. In order to predict trends of volume change, one must ascertain which elements of the overall physical environment around a soil mass are most important to the moisture conditions in the soil. It is only when the usual climate is inconsistent and the moisture condition goes from wet to dry or vice versa that significant volume change occurs.

A. General

The principal environmental factors which affect the moisture conditions of soil are:

1. Climate -- Wind, rain, temperature, drought.

2. Pedology -- Inherent chemical and physical characteristics of soils.

3. Hydrology -- Location of water table, natural drainage, and conditions of seepage.

4. Man-placed structures.

Man-placed structures affect moisture conditions by such changes as artificially introducing water into the soil from lawn watering and increasing capillary activity by covering the soil.

B. Environment and Shrinkage

The principal cause of soil shrinkage is evaporation of water from the soil pores. Thus, periods of warm weather with relatively little rainfall favor shrinkage. During such periods, the situation may be aggravated by the presence of vegetation. This affects the moisture condition by modification of the drainage pattern and by transpiration of water from plants, which extract water from the soil. On the other hand, large amounts of rainfall and/or low temperatures will not favor shrinkage. Hence, it can be misleading to attempt to judge whether a soil is expansive after considering only mean temperatures or average yearly rainfall. One must consider the net effect of all climatic factors over long periods of time.

C. Environment and Swelling

The swelling of dry soil occurs when a change in environment results in a supply of water which can be absorbed by the clay. There are many ways that water can enter and move through soil:

1. Seepage, or the flow of water due to the force of gravity. Seepage may result from natural phenomena such as infiltration of rainfall or as a result of man-made phenomena; for example, irrigation ditches or faulty water mains.

2. Capillarity, or the movement of water into or through soils due to attractive forces between two unlike molecules. Capillarity is regulated by such factors as grain size of soil, water supply and depth, and temperature changes. The capillary movement of water in soils above the water table is often a contributing cause of soil instability.

3. Vapor transfer, or the flow of water in vapor form through air voids in soils. This is caused by differences in water vapor pressure.

The vapor pressure of water in air voids increases with increased temperature and water content of the soil. Thus, water vapor will flow from soil of high temperature or high water content or both to soil of low temperature or low water content or both. However, this method of moisture movement is usually only of concern in soils at low degrees of saturation (usually below 80 per cent) under high temperature gradients. Vapor flow through air voids can also contribute to the shrinkage of soil, but this is usually of secondary importance since most of the volume decrease of wet soil occurs at a high degree of saturation.

D. Climate Studies

In order to understand the relationship between climatic factors and volume changes in the United States, studies have been made for FHA of United States Weather Bureau data (1). These studies indicate at least five variables affecting consistency of climate:

1. Yearly annual precipitation;

2. Degree of uniformity in distribution of precipitation through the year;

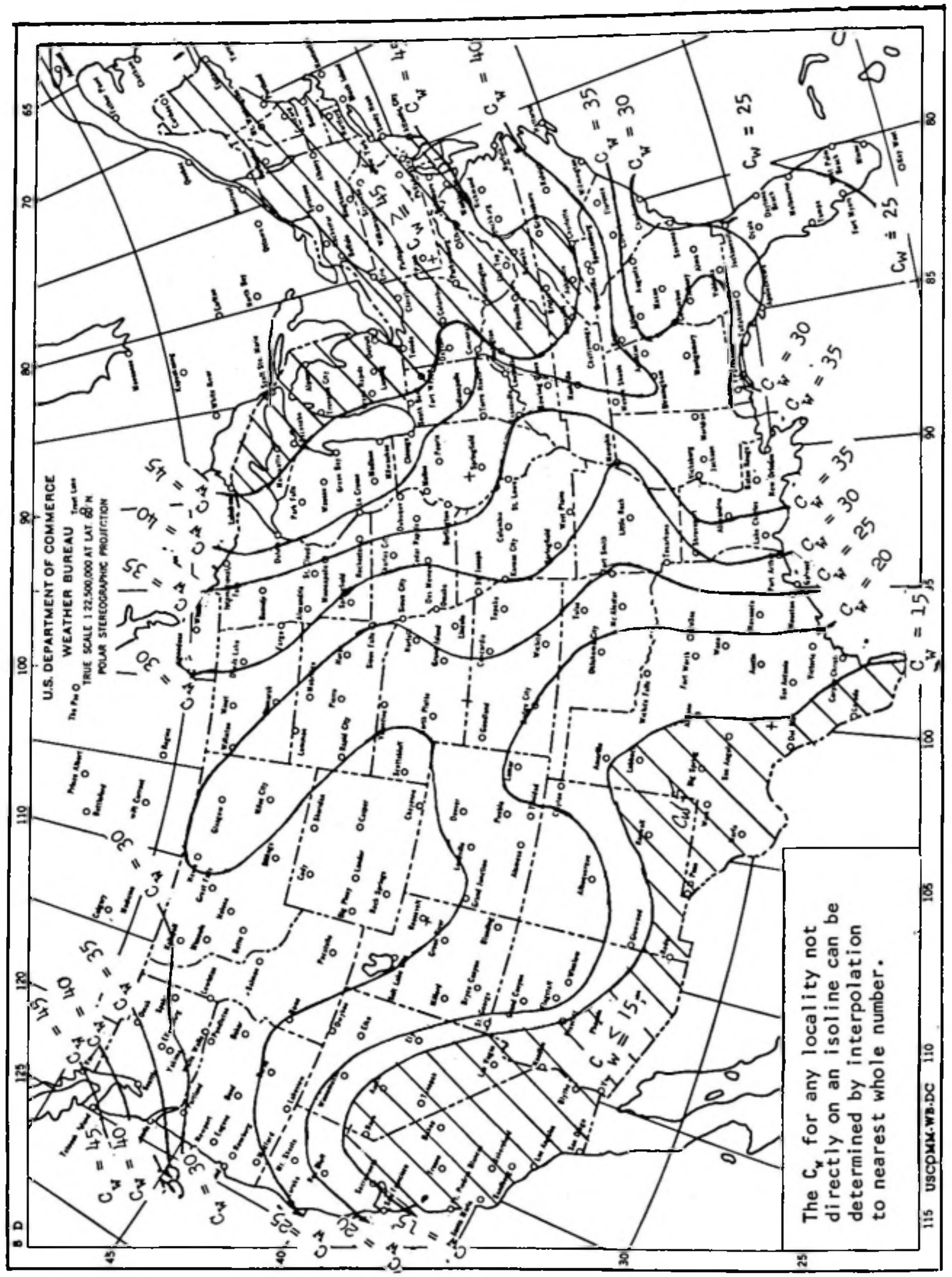
3. Number of times precipitation occurs;

4. Duration of each occurrence;

5. Amount of precipitation at each occurrence.

FIGURE 1

UNITED STATES WEATHER BUREAU SOIL-CLIMATE RATING MAP



From "Design Criteria for Residential Slabs-on-Ground,"
National Academy of Sciences Publication No. 1077

The United States Weather Bureau studies have further disclosed that the amount of rainfall during any particular period cannot be directly correlated with the number of rains during that period. Without going into a detailed explanation, for this guide it suffices to say that the frequency function provides an excellent measure of the potential for soil activity by giving a sound indication of the likelihood of extended periods during which soil-moisture balance may be upset either through a small amount of rainfall and evaporation or through a great amount of rainfall in fewer-than-normal occurrences. In any instance, cohesive soils can be expected to shrink with loss of moisture and swell with moisture gain.

The rate at which moisture is lost or gained by soils is not at this time thoroughly understood. It is generally accepted, however, that air movement accelerates loss of soil moisture. Since air movement is independent of rainfall, it can be assumed that air movement increases loss of soil moisture especially during extended periods of little or no precipitation.

Using the variables mentioned above, the U.S.W.B. developed a climatic rating (C_w) for all points in the continental United States (Figure 1). These climatic ratings range from a numerical value of 15, which signifies those areas where the climate exerts the most severe adverse influence on the soils, to 45, which signifies those areas where the climate is least influential on the soils. The C_w for any particular locality not directly on an isoline can be determined simply by interpolation to the nearest whole number; for example, Columbia, Missouri, would be about 33.

The climatic rating chart can be used to indicate potential problem areas where climatic variations are significant; however, to determine the potential volume change of any particular soil sample, a swell index test using the FHA Soil PVC Meter can be made.

III. USING THE FHA SOIL PVC METER

A. General

The FHA Soil PVC Meter is used to perform a swell index test. This test is essentially a measurement of the pressure exerted by a sample of compacted soil when it swells against a restraining force after being wetted. The FHA Soil PVC Meter, in addition to yielding PVC values, can be used to estimate the plasticity index and shrinkage behavior of soils. These values are determined by comparing the results of the swell index test with appropriate values contained in Figures 3, 4, 5, and 6 in this guide and reading the corresponding extrapolations.

The following categories of PVC have been established:

PVC Rating	Category
Less than 2	Noncritical
2 to 4	Marginal
4 to 6	Critical
Greater than 6	Very critical

These ratings were established on the basis of the swelling and shrinking behavior of the soil.

B. Equipment (See Figure 2 for Pictures of Equipment)

1. PVC Meter
2. Spacers, plate, and clamp for alternate compaction method
3. No. 10 Sieve
4. Teaspoon
5. Compaction Hammer and Sleeve
6. Two Dry Porous Stones
7. Knife, (preferably serated)
8. Straight Edge
9. Water in Squirt Bottle with Pointed End
10. Wrenches

C. Preparation of Sample

For the test sample, take about a pint of soil from the soil layer in which the foundation member will rest. Although samples can be tested at three relative water contents (dry, moist, or wet), it is suggested that those being tested for FHA purposes be tested in the air dried condition only. The samples can be sufficiently air dried by breaking the soil into small lumps and leaving it in the sun for a few hours. The following procedures

are for soil in the air dried condition. For information about soil in other conditions, see Bibliography reference (2).

D. Preparation for Compaction

Disassemble the PVC Meter with exception of the rods which can remain screwed into the base. Place proving ring and top bar where it will not be jarred during compaction. Wipe equipment with clean cloth.

E. Compaction

Definitions:

Compaction ring -- largest ring; identified by letter "c" etched on outside periphery.

Spacer ring -- smallest ring; identified by letter "s" etched on outside periphery.

1. To assemble meter for compaction, fit compaction ring on base so that "c" is backwards and at the top. Align bolt holes with those in base. Place spacer ring on compaction ring so that "s" is at the top (radial grooves are at top). Align bolt holes with those in base. Insert the 3 bolts through both the rings and the base and tighten firmly to base.

2. The soil sample is to be placed in the ring assembly in 3 layers of equal amounts. Each layer is to be compacted separately. Compaction is accomplished by use of the hammer, which is a tamping device encased in a metal sleeve.

3. Compact each layer of the sample in the following manner:

    a. Place 3 heaping teaspoonsfull of sample in ring assembly and smooth lightly with hammer to firm up the surface before applying the blows (This reduces the amount of soil "jumping" out of the mold during compaction.). Place apparatus on a solid level floor.

b. Before each blow, lift sleeve 1/8 inch from soil and hold firmly against the inside of the spacer ring. Make sure sleeve of hammer rests inside rings so that hammer does not damage them in falling. Be sure to hold sleeve and hammer perpendicular and in line with supporting rods. Raise hammer to top of sleeve and let it fall free (not striking sides of sleeve). Space blows evenly over surface of sample by shifting hammer after each blow. Compact the first two layers with 7 blows each of the compaction hammer and the last with 8 blows. Repeat this process for each layer. (See F for Alternate Compaction Method.)

4. At completion of the compaction of both the first and second layers, scratch the top surface of the layer with a knife to assure proper bond with the next layer. After compaction, the last layer should extend approximately 1/4 inch into the spacer ring. If it is significantly below this point, remove entire sample and recompact.

5. Put assembly on table and remove the 3 bolts. Rotate spacer ring (to break bond between ring and soil) and remove carefully from base. Remove compaction ring containing sample in same way. Do not tilt compaction ring or spill soil.

6. Trim top of the sample with a knife. Hold knife against the compaction ring at all times during trimming to avoid dislodging sample. Trim in a sawing motion taking off only a small amount of soil at a time. Rotate the ring as you trim. Work from the edge toward the center. When sample is almost level, do final leveling by drawing a metal straight edge over sample.

7. The final surface of the soil sample should be firm and smooth. Any voids should be filled by pressing additional soil into them with the knife or spoon.

8. Clean soil from base and from all holes in rings and base. Remove soil in the groove of the spacer ring and from the holes in the spacer ring and the compaction ring with a toothpick or paperclip.

F. Alternate Compaction Method

1. After fitting rings to base as explained in E, paragraph 1, place one spacer on each rod, then set the plate on the spacers. Bolt these securely to the rods. Attach the clamp to the sleeve so that the sleeve extends about 1/4 inch inside the spacer ring. Place the soil sample in the ring assembly in the same manner as explained in E, paragraphs 2 and 3a.

2. Before each blow, turn the "foot" of the clamp so that it points in the direction of the spot to be compacted. The sleeve and hammer must be held perpendicular and in line with the supporting rods. To assure this, the sleeve should be held firmly against the inside of the plate and the spacer ring. Raise hammer to top of sleeve and let it fall free (not striking sides of sleeve). Space blows evenly over surface of sample by shifting hammer after each blow. Compact the first two layers with 7 blows each of the compaction hammer and the last with 8 blows. Repeat this process for each layer.

3. The remaining compaction process is the same as E, paragraphs 4 through 8.

G. Swelling

1. Place spacer ring on base with "s" (and radial grooves) on top. Align bolt holes with those on base. Place thoroughly dry porous stone in spacer ring. Move assembled base to edge of working table. Place thumb under base and other fingers over spacer ring and stone, holding them firmly in place. Turn base upside-down retaining firm hold on stone and spacer ring. Pick up compaction ring containing sample -- trimmed side up -- and place flush against porous stone in spacer ring aligning bolt holes in the two rings. Move compaction ring with as little disturbance of sample as possible. Turn base with rings, stone, and sample rightside-up. Bolt rings tightly to base.

2. Place a dry porous stone on top of sample inside compaction ring. Place the rubber O-ring on the base and screw the lucite container onto it tightly to insure water seal. Place metal cover on porous stone with the center indentation at the top.

3. Place top bar with proving ring on the steel rods (Be sure that the adjustable rod which extends down from the proving ring dial does not strike the cover.). Add washers and nuts and tighten firmly.

4. Set proving ring dial to zero by moving the band around the dial. Tighten dial with the screw on band. Push up on proving ring dial to see that it appears to work properly. Turn adjustable rod exactly into the center of the indentation on top of the cover. Be sure that the cover is centered exactly over the stone. Tighten lock nut on adjustable rod firmly. Be sure adjustable rod does not stick in cover (receptable for adjustable rod may require slight enlargement). Turn adjustable rod until dial reads one division past zero. Tighten lock nut firmly again until adjustable rod has no play.

5. Record the time and the proving ring reading. Add water to sample by squeezing from squirt bottle into the holes located at the top of compaction ring until water level in lucite container has covered the spacer ring and tops of the bolts. (This procedure is used to reduce the amount of air entrapped in the ring assembly and thus insures that the sample has uniform access to water over its entire top and bottom surfaces.)

H. Reading

1. Allow soil to expand until completely stabilized or for a maximum of 2 hours, then read dial to obtain PVC swell index value. On the dial the number 1 equals 10 divisions, the number 2 equals 20, etc.

2. Next, find the number corresponding to the prooving ring dial reading on Figure 3 and subtract the one division that registered on the dial prior to swell. Read horizontally to intersection with sloping line. From point of intersection, read downward to baseline which indicates pressure in lbs./sq. ft.

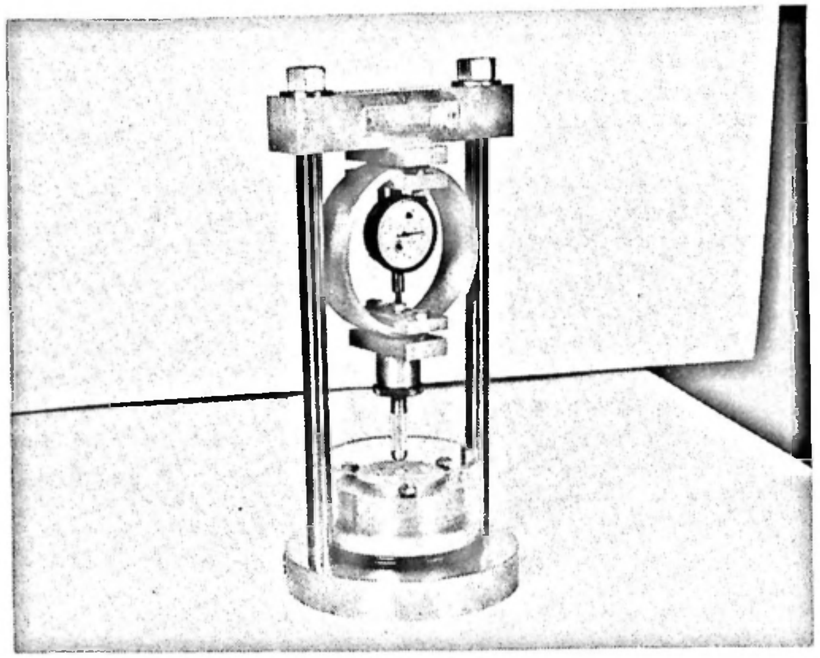
3. Take this figure to Figure 4. Find the number corresponding to it on left hand side of the chart. Read horizontally to intersection with the sloping line marked "Dry and Moist." From point of intersection, read downward to the baseline, which indicates PVC category.

4. Take the reading in lbs./sq. ft. to Figure 5 to determine the plasticity index.

5. It is also possible to obtain the approximate PVC category and plasticity index by taking the reading from the proving ring dial directly to Figure 6.

FIGURE 2

PICTURES OF EQUIPMENT



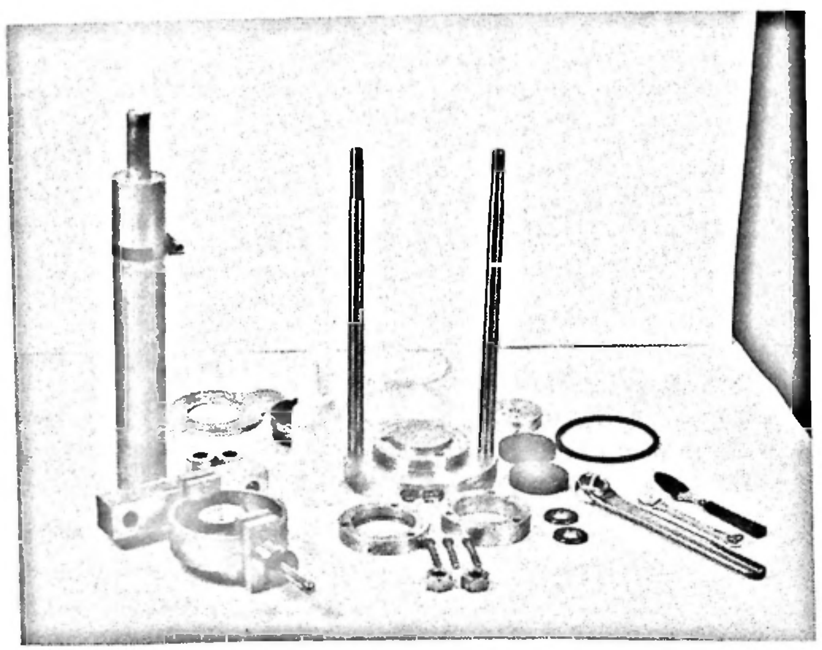
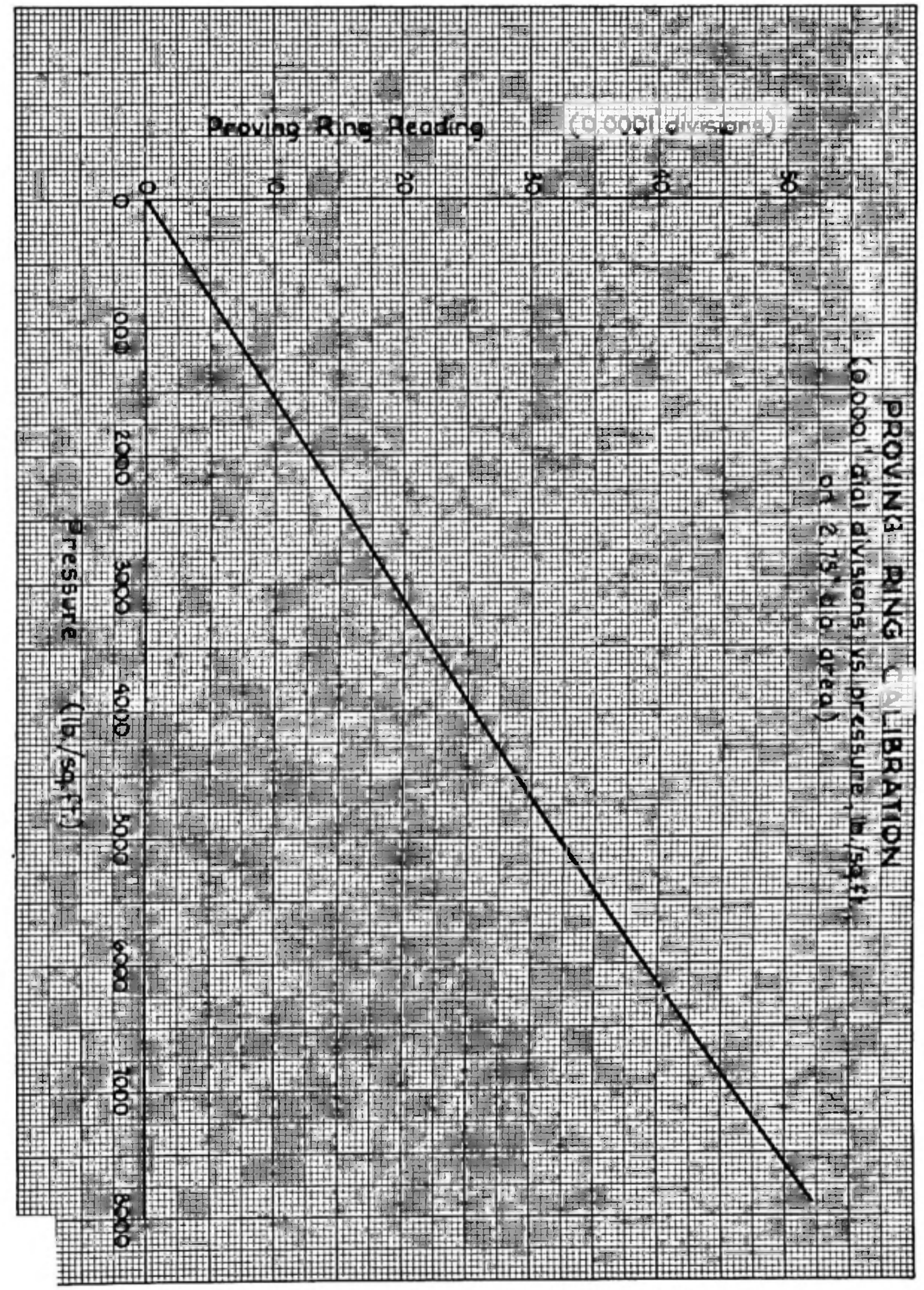
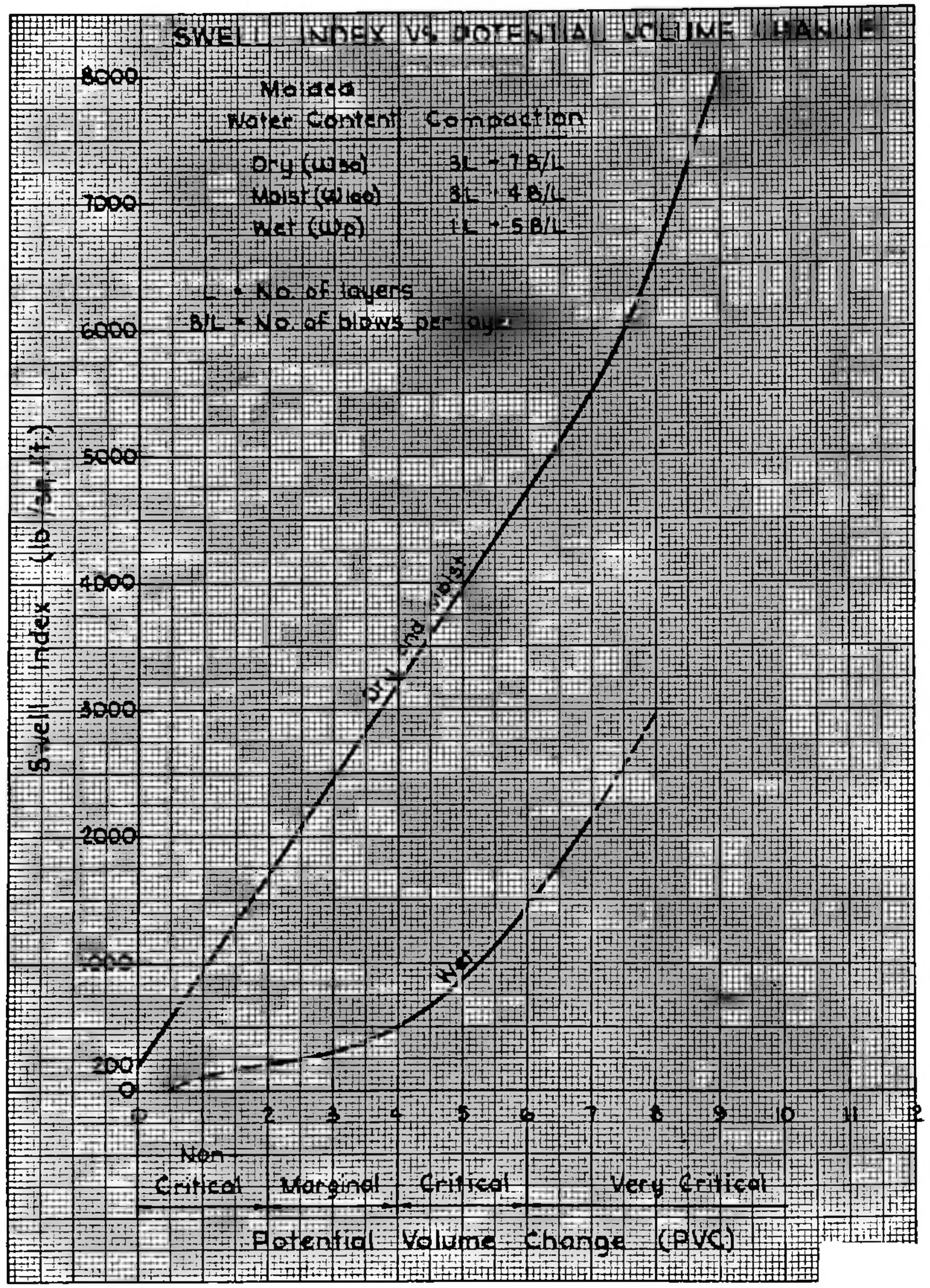


FIGURE 3



From "FHA Soil PVC Meter Publication," Federal Housing Administration Publication No. 701.

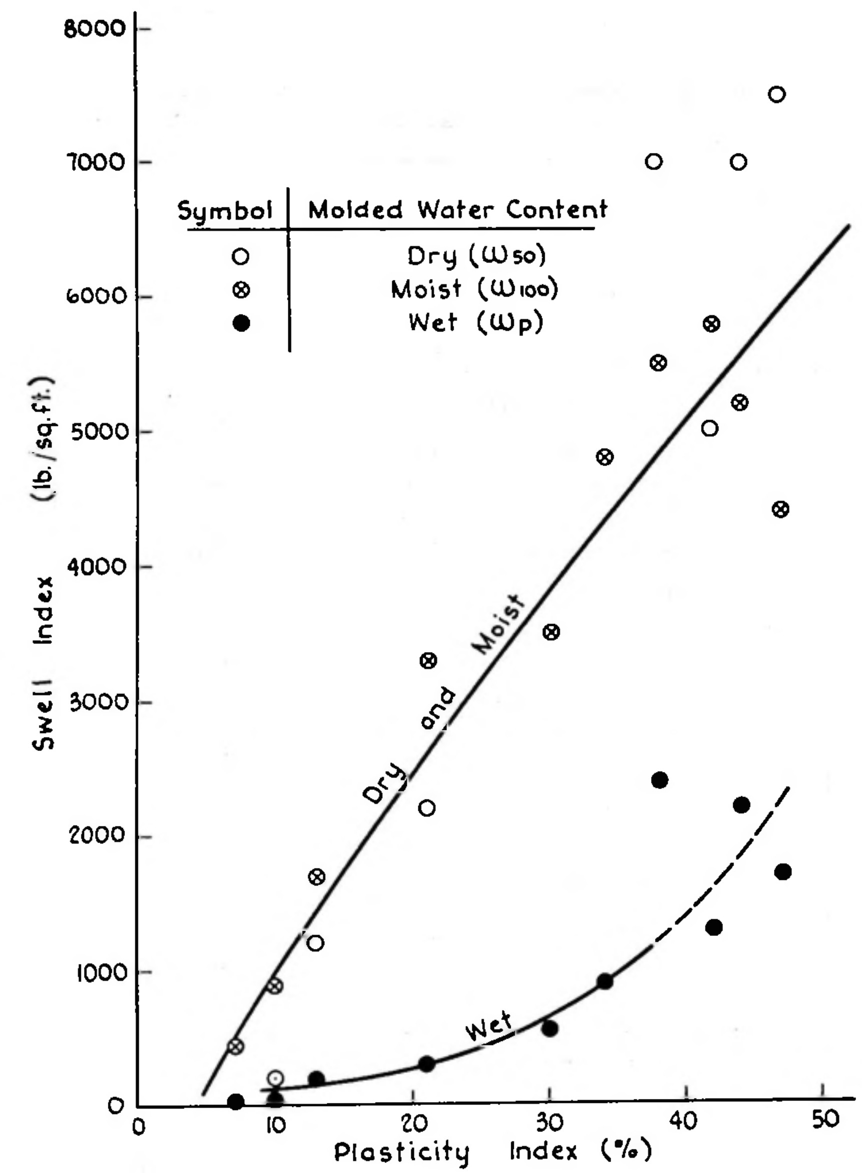
FIGURE 4



From "FHA Soil PVC Meter Publication," Federal Housing Administration Publication No. 701.

FIGURE 5

SWELL INDEX VS. PLASTICITY INDEX



From "FHA Soil PVC Meter Publication," Federal Housing Administration Publication No. 701.

FIGURE 6

TABLE FOR CONVERTING PROVING RING READINGS TO PVC CATEGORY AND APPROXIMATE PLASTICITY INDEX

Proving Ring Reading	Swell Index (#/SF)	PVC Category	Plasticity Index (%)
5	775	0.8	8.5
6	925	1.0	9.5
7	1075	1.2	10.7
8	1250	1.4	11.7
9	1375	1.6	12.7
10	1550	1.8	13.8
10.8	1675	2.0	14.6
11	1700	2.0	14.8
12	1875	2.2	15.8
13	2025	2.4	17.0
14	2175	2.65	18.0
15	2350	2.85	19.0
16	2500	3.05	20.0
17	2675	3.3	21.5
18	2800	3.45	22.5
19	2975	3.7	23.8
20	3150	3.9	25.0
20.3	3200	4.0	25.5
21	3300	4.1	26.0
22	3450	4.3	27.5
23	3600	4.5	28.5
24	3775	4.75	29.8
25	3925	4.95	30.8
26	4075	5.15	31.8
27	4225	5.4	33.0
28	4375	5.55	34.0
29	4525	5.75	35.3
30	4700	5.95	37.0
30.2	4725	6.00	37.1
31	4850	6.2	38.0
32	4975	6.35	39.0
33	5125	6.5	40.4
34	5275	6.7	41.7
35	5425	6.9	43.4
36	5575	7.1	44.2
37	5725	7.25	45.5
38	5850	7.4	46.6
39	6000	7.5	48.0
40	6150	7.65	49.5
40.5	6225	7.7	50.0

Prepared by
the Architectural Section,
Federal Housing Administration Insuring Office
San Antonio, Texas

IV. FHA SOIL PVC METER SWELL INDEX TEST RESULTS FROM SELECTED LOCATIONS IN THE UNITED STATES

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
ALABAMA			
1. Houston clay, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	8300	Very Critical	65
2. Houston clay, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	6400	Very Critical	53
3. Houston clay, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	1400	Non-Critical	13
4. Eroded Sumpter clay mixture of subsoil and chalky soil material, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	3700	Critical	29
5. Sumpter clay, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	9000	Very Critical	67
6. Sumpter clay, Montgomery, Alabama (sampled and tested by Elvin F. Henry).	5700	Very Critical	45
7. Vaiden soil overlying Selma chalk, Montgomery, Alabama (sampled by Elvin F. Henry and Ray Dawson).	4000	Critical	31
ARIZONA			
1. Clay soil, Holbrook, Arizona (sampled by Lloyd Leslie).	4800	Critical	38
ARKANSAS			
1. Soil, Fayettsville, Arkansas (sampled and tested by Elvin F. Henry).	2025	Marginal	17

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
CALIFORNIA			
1. Soil, Brawley, California (sampled and tested by Ray Sherman).	3200	Marginal	25
2. Soil, Silty clay, Calexico, California (sampled and tested by Elvin F. Henry).	4075	Critical	32
3. Soil, El Cajon, California (sampled and tested by Ray Sherman).	500	Non-Critical	8
4. Soil, El Cajon, California (sampled and tested by Ray Sherman).	1200	Non-Critical	12
5. Soil, El Cajon, California (sampled and tested by Ray Sherman).	500	Non-Critical	8
6. Soil, El Cajon, California (sampled and tested by Ray Sherman).	500	Non-Critical	8
7. Soil, El Centro, California (sampled and tested by Ray Sherman).	4100	Critical	32
8. Soil, El Centro, California (sampled and tested by Ray Sherman).	2800	Marginal	21
9. Soil, El Centro, California (sampled and tested by Ray Sherman).	4800	Very Critical	38
10. Soil, El Centro, California (sampled and tested by Ray Sherman).	2500	Marginal	20
11. Soil, El Centro, California (sampled and tested by Ray Sherman).	3200	Marginal	25
12. Soil, Poway, California (sampled and tested by Ray Sherman).	2250	Marginal	18
13. Soil, Poway, California (sampled and tested by Ray Sherman).	600	Non-Critical	8
14. Soil, Poway, California (sampled and tested by Ray Sherman).	100	Non-Critical	5

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
CALIFORNIA (Continued)			
15. Soil, Poway, California (sampled and tested by Ray Sherman).	100	Non-Critical	5
16. Soil, Poway, California (sampled and tested by Ray Sherman).	650	Non-Critical	9
17. Clay, San Diego, California (sampled and tested by Elvin F. Henry).	6000	Very Critical	48
18. Soil, San Diego, California (sampled and tested by Ray Sherman).	2750	Marginal	21
19. Soil, San Diego, California (sampled and tested by Ray Sherman).	5500	Very Critical	43
20. Soil, San Diego, California (sampled and tested by Ray Sherman).	4000	Critical	31
21. Soil, San Diego, California (sampled and tested by Ray Sherman).	5500	Very Critical	45
22. Soil, San Diego, California (sampled and tested by Ray Sherman).	1400	Non-Critical	13
23. Soil, San Diego, California (sampled and tested by Ray Sherman).	2500	Marginal	20
24. Soil, San Diego, California (sampled and tested by Ray Sherman).	4000	Critical	31
25. Soil, San Diego, California (sampled and tested by Ray Sherman).	2200	Marginal	18
26. Soil, Spring Valley, California (sampled and tested by Ray Sherman).	650	Non-Critical	8
27. Soil, Spring Valley, California (sampled and tested by Ray Sherman).	750	Non-Critical	9
28. Soil, Spring Valley, California (sampled and tested by Ray Sherman).	2500	Marginal	20
29. Soil, Spring Valley, California (sampled and tested by Ray Sherman).	3000	Marginal	20

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
COLORADO			
1. Clay, Denver, Colorado (sampled by Charles Bigler).	7600	Very Critical	55
2. Clay, Denver, Colorado (sampled by Charles Bigler).	3950	Critical	31
3. Silty clay, Denver, Colorado (sampled by Charles Bigler).	2350	Marginal	19
4. Silty clay, Denver, Colorado (sampled by Charles Bigler).	2400	Marginal	19
5. Silty clay, Denver, Colorado (sampled by Charles Bigler).	450	Non-Critical	6
6. Silty clay, Northwest Pueblo, Colorado (sampled by Charles Bigler).	900	Non-Critical	9
HAWAII			
1. Dark clay Foam basalt, Manilani, Oahu, Hawaii (sampled and tested by Elvin F. Henry).	5500	Very Critical	43
2. Soil sample, (fill area), Aikahi Hillside, Oahu, Hawaii (sampled and tested by Elvin F. Henry).	7400	Very Critical	56
3. Soil sample, Halawa Hill, Oahu, Hawaii (sampled and tested by Elvin F. Henry).	2200	Marginal	18
4. Soil sample, (subsoil), (Kalihi) Wilson Tract, Oahu, Hawaii (sampled and tested by Elvin F. Henry).	8000	Very Critical	63
5. Soil Sample, (fill area), Waiolu Subdivision, Oahu, Hawaii (sampled and tested by Elvin F. Henry).	3400	Marginal	27

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
LOUISIANA			
1. Colfax soil, Olla, Louisiana (sampled and tested by Elvin F. Henry).	1550	Non-Critical	14
2. Clay, Shreveport, Louisiana (sampled and tested by Elvin F. Henry).	5725	Very Critical	45
3. Clay, Shreveport, Louisiana (sampled and tested by Elvin F. Henry).	4075	Critical	32
4. Clay, Shreveport, Louisiana (sampled and tested by Elvin F. Henry).	3000	Marginal	24
5. Bladen clay, St. Joseph, Louisiana (sampled and tested by Elvin F. Henry).	4700	Critical	37
MARYLAND			
1. Montalto silty clay (Experimental House), Rockville, Maryland (sampled by Ralph Johnson, NAHB).	2675	Marginal	21
MISSISSIPPI			
1. Yazoo clay, Jackson, Mississippi (sampled and tested by Elvin F. Henry).	9500	Very Critical	68
OKLAHOMA			
1. Parsons clay, Tulsa County, Oklahoma (sampled and tested by Elvin F. Henry).	2000	Marginal	17
2. Summit clay, Tulsa County, Oklahoma (sampled and tested by Elvin F. Henry).	2400	Marginal	19
TEXAS			
1. Soil, NE of San Antonio, Bexar County, Texas (sampled by John Turner).	3300	Critical	26
2. Soil, NE of San Antonio, Bexar County, Texas (sampled by John Turner).	2175	Marginal	18

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
3. Soil, NE of San Antonio, Bexar County, Texas (sampled by John Turner).	10,000+	Very Critical	70
4. Soil, NW of San Antonio, Bexar County, Texas (sampled by John Turner).	775	Non-Critical	8
5. Soil, E of San Antonio, Bexar County, Texas (sampled by John Turner).	6550	Very Critical	54
6. Soil, S. of San Antonio, Interstate Highway, Bexar County, Texas (sampled by John Turner).	2500	Marginal	20
7. Soil, S. of San Antonio, Texas, Bexar County, Texas (sampled by John Turner).	1700	Marginal	15
8. Soil, SW of San Antonio, Bexar County, Texas (sampled by John Turner).	450	Non-Critical	4
9. Soil, SW of San Antonio, Bexar County, Texas (sampled by John Turner).	5575	Very Critical	44
10. Soil, W. of San Antonio, Bexar County, Texas (sampled by John Turner).	2025	Marginal	17
11. Soil, W. of San Antonio, Bexar County, Texas (sampled by John Turner).	8425	Very Critical	66
12. Soil, W. of San Antonio, Bexar County, Texas (sampled by John Turner).	4975	Very Critical	39
13. Soil, W. of San Antonio, Bexar County, Texas (sampled by John Turner).	2500	Marginal	20
14. Soil, Cavaca, Texas (sampled by John Turner).	4525	Critical	35
15. Denton clay, Dallas, Texas (sampled and tested by Elvin F. Henry).	3800	Critical	30
16. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	5050	Very Critical	39

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
17. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	2800	Marginal	22
18. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	5200	Very Critical	42
19. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4050	Critical	32
20. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4400	Critical	34
21. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	5450	Very Critical	43
22. Soil, Dallas, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	900	Non-Critical	9
23. Soil, Denton, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	700	Non-Critical	8
24. Soil, Duncanville, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	2200	Marginal	18
25. Soil, Duncanville, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	1400	Non-Critical	13
26. Soil, Eagle Pass, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	1875	Marginal	16
27. Soil, Eagle Pass, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	1250	Non-Critical	12

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
28. Soil, Garland, Texas (under the direction of Mr. Herschel Smith, the Dallas, Texas).	5400	Very Critical	43
29. Soil, Garland, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4700	Critical	37
30. Soil, Garland, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	5650	Very Critical	44
31. Houston clay (black), Houston, Texas (sampled and tested by Elvin F. Henry).	6000	Very Critical	48
32. Katy sandy clay, Houston, Texas (sampled and tested by Elvin F. Henry).	2400	Marginal	19
33. Lake Charles clay loam, Houston, Texas (sampled by Elvin F. Henry and Dr. M. M. Lemcoe).	3900	Critical	31
34. Sandy clay loam, Houston, Texas (sampled and tested by Elvin F. Henry).	500	Non-Critical	7
35. Soil, Irving, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	1550	Non-Critical	14
36. Soil, Kirby, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4850	Very Critical	38
37. Soil, Kirby, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	8025	Very Critical	63
38. Soil, Lancaster, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4700	Critical	37

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
39. Soil, Mesquite, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	2800	Marginal	22
40. Soil, Plano, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	6300	Very Critical	51
41. Soil, Richardson, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	5850	Very Critical	47
42. Black organic clay, overlying Taylor marl, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3300	Critical	26
43. Clay, San Antonio, Texas (sampled by Dr. M. M. Lemcoe).	6300	Very Critical	51
44. Clay, San Antonio, Texas (duplicate test sampled by Dr. M. M. Lemcoe and Elvin F. Henry).	6200	Very Critical	50
45. Clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5725	Very Critical	45
46. Clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5725	Very Critical	45
47. Clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5425	Very Critical	43
48. Clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5275	Very Critical	42
49. Clay, San Antonio, Texas (sampled by Elvin F. Henry and Dr. M. M. Lemcoe).	4900	Very Critical	39
50. Clay (Bentonitic), San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5575	Very Critical	44

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
51. Clay soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2500	Marginal	20
52. Clay soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	0	Non-Critical	0
53. Clay soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2175	Marginal	18
54. Clayey marl, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2300	Marginal	19
55. Dark Topsoil, silt loam, San Antonio, Texas (sampled by Dr. M. M. Lemcoe).	1400	Non-Critical	13
56. Marly Material, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	0	Non-Critical	0
57. Marly Material, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	925	Non-Critical	9
58. Sandy Clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	1700	Marginal	15
59. Silty clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	4225	Critical	33
60. Silty clay, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	1550	Non-Critical	14
61. Silty clay soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2350	Marginal	19

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
62. Soil, San Antonio, Texas (sampled by Elvin F. Henry and Dr. M. M. Lemcoe).	4800	Critical	38
63. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3150	Marginal	25
64. Soil, Woodlawn, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3950	Critical	31
65. Soil, Summertime, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	300	Non-Critical	4
66. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2025	Marginal	17
67. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2675	Marginal	21
68. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2800	Marginal	22
69. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	1875	Marginal	16
70. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2675	Marginal	21
71. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	1250	Non-Critical	12
72. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3775	Critical	30
73. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2675	Marginal	21
74. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5425	Very Critical	43

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
TEXAS (Continued)			
75. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	7425	Very Critical	52
76. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2350	Marginal	19
77. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2675	Marginal	21
78. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	1075	Non-Critical	11
79. Soil, W. of San Antonio, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3925	Critical	31
80. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3600	Critical	28
81. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2175	Marginal	18
82. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	4075	Critical	32
83. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	5775	Very Critical	46
84. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	2500	Marginal	20
85. Soil, San Antonio, Texas (sampled by Elvin F. Henry and John Turner).	3450	Critical	27
86. Soil, Universal, Texas (under the direction of Mr. Herschel Smith, Dallas, Texas).	4250	Critical	33

Soil Sample	Swell Index Pounds/sq. ft.	PVC Category	Approximate Plasticity Index
VIRGINIA			
1. Lenoir clay, Alexandria, Virginia (sampled and tested by Elvin F. Henry).	3900	Critical	31
2. Iredell sandy clay loam Roadbed material, Centerville, Virginia (sampled and tested by Elvin F. Henry).	800	Non-Critical	9
3. Iredell soil, Fairfax County, Virginia (sampled and tested by Elvin F. Henry, repeated 6 times, results ± 300 lbs. per square ft.).	5500	Very Critical	43
4. Iredell clay, Fairfax County, Virginia (sampled and tested by Elvin F. Henry).	6000	Very Critical	48
WYOMING			
1. Clay loam sample, Casper, Wyoming (sampled and tested by Elvin F. Henry).	2200	Marginal	18
2. Clay loam to loam sample, Casper, Wyoming (sampled and tested by Elvin F. Henry).	900	Non-Critical	9
3. Yellow-Bentonitic clay, Casper, Wyoming (sampled and tested by Elvin F. Henry).	6300	Very Critical	51

V. GLOSSARY

Atterberg limits: Limits of soil consistency named after a Swedish soils scientist. Used in the Unified Soil Classification System as the basis for laboratory differentiation between materials of appreciable plasticity (clays) and slightly plastic or non-plastic materials (silts).

Liquid limit: The water content in percentage of dry weight at which the soil passes from the liquid state to the plastic state.

Plastic limit: The water content of the soil at the boundary between the plastic state and the solid (or semisolid) state.

Plasticity index: The numerical difference of water contents between the liquid and plastic limits.

Clay: The term clay as used today carried with it three implications: (1) a natural material with plastic properties, (2) an essential composition of particles of very fine size grades, and (3) an essential composition of crystalline fragments of minerals that are essentially hydrous aluminum silicates or occasionally hydrous magnesium silicates.

Cohesion: The capacity of sticking or adhering together.

Liquid: Soil either in suspension or behaves like a viscous fluid.

Natural Drainage Classes:

Excessively Drained: Water is removed from the soil rapidly. Uniformily colored in surface and subsoil. Usually sandy, porous and has thin soil layers over parent materials.

Well Drained: Water is removed from the soil readily but not rapidly. Uniformily colored in surface and subsoil layers.

Moderately Well Drained: Water is removed from the soil somewhat slowly so that the profile is wet for a small but significant part of the time. Uniformily colored in surface and upper subsoil layers.

Somewhat Poorly Drained: Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Has mottled subsoil layers.

Poorly Drained: Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly near or at the surface for a considerable part of the year. Has gray or mottled colors in both surface and subsoil layers.

Very Poorly Drained: Water is removed from the soil so slowly that the water table remains at or near the surface most of the time. Has black, dark gray surface layers and dark or mottled subsoils.

Plastic: Soil can be rapidly deformed or molded without rebounding elastically, changing volume, cracking, or crumbing.

Solid: Soil will crack when deformed or will exhibit elastic rebound. The solid state is sometimes divided into the semisolid state and the solid state.

Transpo-evaporation: Movement or transfer of moisture or vapor from below ground or ground areas through vegetative media to the atmosphere.

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