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THE PORTALAB MANUAL:
Low-Cost Soil-Engineering Tests for Constructing Earthen Buildings

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Earth Lab Systems
Alamogordo, New Mexico

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NEW MEXICO APPROPRIATE TECHNOLOGY PROGRAM

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Chapter I

PROSPECTING FOR RAW MATERIALS

A. Locating a Sampling Area. Sampling material is the most important procedure in PORTALAB'S process: *A poorly taken sample can destroy or substantially alter every single test conducted in the testing sequence.* A methodical observation of the following "rules" of sample collection will produce usable samples 90 percent of the time.

1. Topography. Obvious features of terrain narrow the sampler's task in collection. Avoid outcrops of rock, limestone shelfs, caliche, alkali and gypsum sands. Alluvial fans, built by the action of watercourses over time, are excellent places to begin. Gently rolling to flat land is another promising indicator. Examine the banks of streams, gullies, and roadcuts for "profiles" or strata of sand, clay, and rock. Such profiles can be sampled directly and indicate the depth at which the matetial can be relocated in surrounding terrain. Dry stream beds ought to be sampled when available, with particular attention paid to bends and turns in the course opposite the bank most sharply cut, for this is where sand and sandy loam accumulate.

2. Color. Everyone is aware of the prevailing colors of earth in a given locality. Materials such as iron, for instance, impart a vivid red or dull rust hue. Areas with high organic content have a black to dark grey "greasy" color. Alkali and gypsum given the surrounding terrain a white, chalky appearance. White, chalky, and black colors tell the prospector that those materials should be avoided, for the chemistry of these acid and alkaline soils does not make good earth—building material. Look for the buff, "sandy" areas where sandy loams and fine clay loams have been laid down. These are the materials to be sought.

3. Vegetation. There is a direct relation between the composition of soils and vegetation that stands upon

them. Black soils, heavy in clay and organic compounds, support slow—growing hardwoods, woody vines, and a dense understory of shrubs and grass. This soil is dense and deep; water stands for long periods after a rain, and during prolonged dry periods the ground has pronounced effects of cracking. Red, rusty soils are shallow and the vegetation is much less dense than black soils; the trees are likely to be, conifers, mixed with cedar and post oak. Grasses are clumped with a network of bare spaces. Sandy loams vary in depth, from a few inches to many feet. Trees are generally found along the intermittent water courses, or they are of the deep—rooted variety, such as mesquite. If the area has escaped overgrazing, there may be a heavy cover of complex prairie grasses. Generally the grass complex has been overgrazed and mesquite, ironweed and woody plants such as tumbleweed are present. Heavy alkali and soluble salts are indicated by creosote bush, salt—wood, yucca, and cactus.

4. Summary. Soils suitable for use in adobe and rammed-earth Csoil— cement) are sandy loam and light clay loam (Fig. 1). These materials can be found in almost any locality in the Southwestern United States. However, the magnitude of these materials may vary enormously within a few acres to scores of miles of a building site. From 60 to 100,000 lbs of processed earth are required to build a 1500—1800 sq ft •house, and the resulting transport of the earthen mass should be kept to a minimum. Few earthen houses are sited today upon a source of materials because of urban restrictions. It is, therefore, very important to locate a raw matetial source with a minimum of time and expense. Following the general guide set out in the preceding paragraphs, the prospector can locate a suitable sampling area.

P. Taking a Soil Sample. Choose an area 18—24 inches in diameter, preferably bare of vegetation. If no bare area exists, then carefullyremove the grass to ground level. The sample material will be found in the “C” horizon (see Fig.

2). The depth of the topsoil will vary from an inch to a foot more, depending on locality. This •is the “A” horizon; it contains organic debris, leaves,

mold, twigs, etc. Use a “sharp—shooter” shovel or hand—pick.. Remove the dirt in small amounts and measure the depth of this strata. The “B” horizon may be a foot or more deep. Roots of plants present radiate in this band.

Practically speaking, the “B” horizon plays out about 14—18 inches down in the majority of Western.soils. At the point where organic debris and roots thin out, the “C” horizon begins and it is in this area that the sample is taken. By now, the prospector has removed, in excavator’s parlance, the “overburden.” Material in the A&B horizon (“overburden”) is not suitable for use in earth—building components.

1. Remove approximately 50 lbs of material from the “C” horizon. A five—gallon wide—mouth paint can is an excellent. container for transport and storage. Drive a stake next to the sample hole with an identification number; put the I.D. number on a tag and attach it to the container. This is important, especially if you are collecting several samples.

2. The prospector is now ready to perform the following preliminary field tests.:

    a. Agitation jar

    b. Ribbon extrusion

    c. Drop—ball

    Apparatus and procedure for the tests are described in; detail <in the testing section of this manual.

3. Results of the tests in the preceding paragraph will determine the extent to which this area should be sampled. If the results are negative or marginal, the prospector should move into another site and repeat the sampling procedure.

4. Presence of small rock (3/4” and smaller) will not effect the sample for testing purposes *if* it constitutes less than 20 percent of the sample, If 20 percent or more of the sample is rock 3/4” and larger, then removal becomes a serious economic problem.

C. Estimating the Tonnage of Material Present at a Given Site. Assuming that a sample produces good results in the preliminary field tests (B,2, above), an estimate of excavation for both usable and discarded material is made.

1. Step off a ten foot square. Mark each corner. Locate the center of the grid at the intersection of diagonals from the corners. Mark the intersection. Four corners *and* the intersection produce five sample spots. Dig each, measuring the depth of the A&B horizons (“overburden”). If there is little variation of depth of these materials, then the ten foot grid as a whole will require removal of 800—900 lbs per inch to remove the overburden. For example, if one foot has to be removed from the grid, a total of 9600—1100 lbs of material (3—4 cu yd)~ is involved,

2. Now the usable material may be estimated with the following procedure:

a. End—product is assumed to be 1000 adobe block at 33# each or 330 sq ft of rammed earth wall.

100 cu ft at 95# per cube = 287 block or 100 sq ft of R-~E wall x 3 ft excavated material = 861 block or 300 sq ft R—E wall

b. The ten—foot grid t.iould now require a hole l0’xlO’xY’ plus overburden depth. An average 1500 sq ft house would require an excavation 30’x30’x9’ plus. The area can be increased, with the depth lessened for ease of excavation but the constant of 95~f per cu ft will be the constant.

c. Now it. is necessary to gauge the depth of usable material to determine the ultimate grid size. Shallow strata will require a large area: extend the grid and dig sample holes.

d. Do not assume that sufficient materials exist in a given locality. This can be an expensive and laborious error to overcome. Dig the test holes.

D. Excavating Raw Earth. The following information regarding excavation should be considered, with comparisons based upon the basic lO’xlo’ grid (100 sq ft).

1. Excavation of 1 ft of cover and overburden

   a. Manual labor – 8—12 manhours

   b. Machine – 1 hour

2. Excavation and loading of usable material., per 10,000 lbs (3.7 cu yd) a.. Manual labor – 8—10 manhours

   b. Machine – 1 hour

3. Processing of material into block .or ramme&~arth~*R~EWwall_fgrms varies with procedure used by builder; i.e., “labor intensive,” machinery, or combination.

4. Machinery, whilessaving enormously on.labor time, includes charges for delivery of equipment. to site, minimum charges regardless of time employed, etc.

E. Sources of Partially—Proce~sed Earth Materials. Those prospecting .for earth materials may elect to bypass the labor and expense of locating, excavating, and removing raw materials to the building site. There are many areas where this can be done at substantial savings in time and money. It must be borne in mind that testing of the material, from whatever source, cannot be ignored. Do not naively accept a contractor’s opinion that his material is what you are looking for. Check it out before you buy.

1. Commercial gravel and sand operations.

   a. "Crusher—fines" or "crusher—waste" is material that passes

      a 3/8" or 1/4" screen. This material is left over from

      operations that produce "base—course,",crushed rock of

      3 /4" to 3/8". The fines or waste will consist of small gravel, sand, and clay.

   b. Depending upon granular size, percentage of sand and clay, and parent source (granite, flint, limestone, etc.), this material may be usable as is or blended with additional sand or clay.

   c. Do not accept materials based upon limestone or caliche for adobe or rammed earth.

2. Paving Contractors and Asphalt Plants,

   a. Crusher—fines constitute a small percentage of blended asphalt. Producers of asphalt maintain stocks of "fines" and usually offer surplus stock for sale.

   b. In addition, asphalt plants are also possible sources for water—based emulsions, such as 55—1 and CSS—lH.

3. Bank Sand and Fill Haul.

a. In many locations bank and fill sand is available for builders and landscaping. This material is not washed

and contains clay. Often the clay is no more than 15— 20 percent of the total and is usable in adobe and rammed earth. Washed sand (masonry and plaster) is not usable unless reblended.

b. “Dirty” or “arroyo” sand is commonly available in the western U.S. In most cases dirty sand can be easily blended and used as primary material. (Care must be taken to test thr material for alkali and soluble salts.)

1—6

U.S. Department of Agriculture Textural Clasuiflcatlons Chart

100% clay
(2 microns)
90
N
80
cv
07~

C.
Q)
Co

andy clay loam

20

Loam

A

10

Sandy loam

Sand Loamy sand

100% sand

0 **cp** *0*

.. [1]*Earth Manual,* U.S. Department of the Interior, 20402. 1868. P. 93.

Silt loam

'I

Silt

a U' **P'**

o ~ 100%silt

Per cent sand

Bureau of Reclamation. U.S. Government Printing Office: Washington,

20.

1—7

70

CHAPTER II

PORTALAB

The PortaLab apparatus consists of an array of analytical instruments, some fabricated in—house and others purchased off—the—shelf from suppliers of scientific

equipment. A complete equipment list reflecting manufacturer appears on pages 2—4 and 2—5. This package (PortaLab) is brokendown into three smaller units: 1) the Field

Unit, for use at the point of prospecting, 2) the Lab Unit, used in enclosed space of approx. 100 sq ft, and 3) the Quality Control package, used in the production phase of making building components.

A. Field Unit Inventory Excavation Kit, consisting of—— one long—handle flat—nose shovel

one combination pick ("grubbing hoe") one long—nose, short—handle shovel ("sharpshooter") five—gallon plastic paint buckets with lids (quantity sufficient to identify and transport samples to lab)

wooden stakes for sample markers, bundle of 10

Analysis Kit, consisting of—— one—quart mason jars with lids, two each five—gallon container of water, one bOX field scope

portatle pH meter

8” USS screens (one each of #10, #50, #200)

pan and cover 12” ruler, one

Tests Performed in the Field

a. Agitating Jar. Place approx. 6” of material from the “C” level into

a one—quart mason jar. Add water slowly until soil is saturated, then fill until water level is 2” from mouth of jar. Screw lid on until tight. Then shake the

- jar with a circular motion, reversing ends up and down at least 50 times. Do not use a fast, frantic twist, as a slow, even motion produces the best result.

Set the jar on an even surface and do not disturb until contents have settled. Settling has not occurred until the water over the soil has cleared;. this takes from 10—45 minutes.

After settling is complete, carefully examine the layering of materials, beginning at the bottom. Rock and gravel, if present, will lie upon the jars s bottom, followed by coarse and medium sand as inspection nears the top of the jar. You will recognize the grainy appearance of sand and color. Near the top of the sample, a band of dense, fine material is clay and silt. The density and color will be different from the ring of sand below. Study the entire sample visually——do not move the jar——although the coloration may not alter in a dramatic fashion at the boundaries, a few moments of observation will reveal the separation points.

Now lay the 12” ruler against the jar. Note the depth of the soil sample from top to bottom. If the depth is 5”, then note the depth of the rock and gravel ring, the depth of the sand up to the clay and silt boundary, and finally, the clay and silt itself. There is a distinct possibility that the clay and silt ring will appear to be ttfloatinglt as a ‘~greasy” slick between the soil and water. This is normal; do not wait until it appears solid. If the water is clear, or nearly so, take the measurement.

Estimate the percentages present. If the total depth of the soil sample is 4—1/2”, then assume that 7/S’s of an inch equals approx. 20 percent. If the clay and silt ring measures over one inch, the clay/silt fraction is too heavy for consideration as unblended raw material. (Do not make snap assumptions about the blending materials until you have read Chapter III.) If, on the other hand, the clay/silt fraction is 5—10 percent and the sand fraction is 85—90 percent, ten blending is an economical possibility.

b. The Ribbon Ektrusidt Test. Assume tests with the agitating jar indicate a mixture of sand/clay to be in the vicinity of 15—20 percent clay. Mechanical confirmation can be obtained via the ribbon extrusion technique.

1. Scoop up a handful of loose material in one hand, and with, the other add water carefully until the soil is damp enough to work into a tight ball about 1—1/2 to 2” in diameter. The ball should be tight with a greasy, slippery feel.

2. Place the ball on the palm of one hand, held parallel to the ground.

- With the other hand, palm down, work the ball into a ribbon by rolling the ball

back and forth. As the ribbon forms, extrude it out and over one edge of the bottom hand. The ribbon will droop, elongate, and finally break. If the diameter of the ribbon is worked to 3/8—1/4” and breaks at a length of 1—1/4 to 1—3/4”, then you have mechanical proof of a clay content between 15—20 percent. If the ribbon is longer than 1—3/4” at break, the percentage of clay is 25 percent or higher; if the break occurs at 1” or less, the clay is 10 percent, or less.

c. The Dtop—Ball Test. Work up a ball of damp material identical to the one used in the ribbon extrusion test. When the ball is complete, drop the ball onto a flat surface of wood,. stone, or concrete. The height of the drop should be from 35—40”. Repeat this process three times.

If the moisture content is right and the clay content is 15—20 percent, the

• ball will impact and break with 90percent of the “scatter” located within a 2” diameter circle. Shattering, with material spread out •to a 3—4” circle, indicates 1) less than 10 percent clay, or 2) a “dry” sample. If the ball merely deforms with occasional cracking, then the clay content is 25 percent or more.

d. MiscellaUeous Field Tests for Special Problems.

1. If the prospector suspects that alkaline salts contaminate the sample, v then he should test the pH of a sample.with the portable meter. A reading of 7.8 or above will indicate the magnitude of such concentrations. Operation of the meter varies slightly, depending upon make, but an operator[1] s manual in the kit will describe its operation in detail.

2. Three 8” 1155 screens, #10, #50, and #200, are carried into the field and operated by hand to facilitate examination of small samples of sand and clay. The #10 screen will exclude most rock. Material remaining on the #50 will produce samples of coarse and medium—fine sand. Material remaining on the #200 screen will produce fine sand; material passing the #200 will produce clay/silt.

These samples must be small——about 200 grams. Before screening, the sample should be thinly spread on a flat surface• and dried by sun and wind as thoroughly as possible. Each sample should be placed in a plastic “Ziploc” bag and labelled.

3. Sand samples from the screen procedure are now examined with the 100X inspection scope. Place an amount equal to an area 1/4” in diameter on aluminum foil (dull side up), set on a flat surface and place the inspection scope over it. Vary the focal length as the crystals are seen. Look for sharp, angular sand with a mixture of flakes and variety of size. Round, subangular sand is worn down and

generally too fine to have any strength. Such sand is often described as “blow—sand”

~ and, as the name implies, has~ been worn down by eons of wind action. Avoid this

type of sand.

e. Summary and Interpretation of Field Tests.

Locate suitable sampling area. Sink test hole and recover fifty pounds of sample for test procedures.

Prior to digging complete sample, conduct the following procedures: 1) agitating jar, 2) ribbon—extrusion, and 3) drop—ball. If tests are favorable or thought to be marginally promising, take the full bucket sample. If the sample is heavy in clay (20 percent or more), move to a different location and repeat procedure.

If the site indicates heavy alkali or salt content, test with meter. Reading

• of 7.8—8.0 is the high acceptable limit; if 8.1 or more, move to a new location. If the sand present appears to be mostly fine and powdery, screen and inspect

with scope. Heavy concentrations of rounded, subangular sand render the material useless. If this is indeed the case, discard the sample and move to another location.

Buckets of material that pass the preliminary tests are tagged, noted in the

• field book, and removed to the lab testing area.

B. Base Lab Equipment

The following list describes major• components of the Base Lab. Some items on this list have been itemized in the Field Lab inventory but included here because of their dual use.

Alcock “Shrink” Boxes (Fig. 1) – Fabricated in—house. Wooden forms with a cavity of 1—1/2” by 1—1/2” by 24”. A minimum of ten boxes should be made; pilot lab used 60 to handle large sample runs.

Splitter Box (Fig. 2) – Steel—veined mixing box with 4 trays. 8” USS Screens (Fig. 3) – Pilot lab used #3/8, #1/4, #10, #16, #40, #50, #100, #200 with p•an and lid. Mechanical shaking machines are available that hold up to ten screens. Triple Beau Balance Scale (Fig. 4) – 2610 g capacity with scoop. Liquid Limit Machine (Fig. 4)

1000 mm Graduated Flask (Fig. 4)

- 500 mm Beakers – 6 each

One—Quatt Mason Jars With Lids – 6 each

Stationary Mixer – Adjustable speed with dual mixer head and stainless steel mixer bowl. (This mixer is of the type sold in appliance stores for home use.)

Miscellaneous Plastic Buckets and Trays – 1/2 to one—gallon capacity

Pocket Pentometer (Fig. 5) – Soiltest Mfg. Co. Model CL700 Portable pH Meter (Fig. 6)

Portable Conductivity Meter (Fig. 7)

Ionexchanger Cartridge. – Used in producing lab grade deionized water

Soil Hydrometers (Fig. 4) – Types ASTM 15111 and 1521-1 5” Diameter Plastic Funnel (Fig, 7) – With detachable spout Whatman Filter Paper, #5 – Package of 100 circles Unconfined Testing Machine (Fig, 8) – Soiltest Model 11—560, with calibrated strain gauge limit of 1100 psi.

Cylinder Molds, 2” Diameter (ID) by 4” – Fabricated from 2” PCV pipe. Minimum of 4 required

Plastic Tray – 12”x6”x24” with wire standoff

Camp Stove – 2—burner with portable oven (Coleman stove or similar)

12” Aluminum Pie ‘Pan – Or equivalent

Log Book – Spiral or hardcover notebook

20# Water Regular Valve – With shower head and needed fittings

and pipe

lOOX Field Inspection Scope (Fig. 9)

Soil CheniisttyKit (Fig. 10)

C. ·LAb Testing Procedure,

Arrival at the lab of material from the field requires careful organization to produce accurate results. The following organization of tests is designed to eliminate marginalsamples at each step. Why? Because time spent in this phase must be directed to those materials most likely to be useful in the building process.

1. Shrink Box

– Step 1 – Remove 10 lbs from sample bucket and place in a clean container—— plastic, pan, bucket, etc. This sample is then processed 5 lbs at a time through the splitter box. Each 5 lb increment is “split’ six times and the total sample replaced in the clean container. (Fig. 1)

Step 2 – Add clean water slowly to the sample. Stir contents with wooden paddle or large spoon until the soil reaches the consistency of soft ice cream. Do not let water content get too high.. Do proceed slowly, adding water finally by the ounce, until the material reaches a soft but still plastic state. Set aside.

Step 3 – Set up four shrink boxes. Coat each box now with a thin layer of lard. Lard can be brought to a liquid state. in a double—boiler on a low flame,and applied with brush. The cavity of these boxes is 1—1/2” x 1—1/2” x 24”. Each box will hold 2 – 2—1/2 lbs of the material prepared in Steps 1 and 2. (Fig. 2)

Step 4 – Place soil sample in boxes with small trowel, layering the material thinly the length of the box. Work for a solid pack, try to avoid air pockets. Then filled, level the box with the edge of the trowel——try to get a smooth, slick finish devoid of scratches and grooves. Fill all four boxes and label with sample identification.

Step 5 – Sat these boxes in a shady dry area., Do not disturb them for 2—5 days. At the end of the curing period, the visual appearance will indicate:

1) shrinkage from 0 to one inch or more, 2) possible cracking, from a few to many cracks, and 3) in some cases, swelling with noticeable uplifting of the core from the box itself.

Step 6 – If swelling of cores is present, waste no more time testing sample material. If no swelling is indicated, insert a thin—bladed spatula into one end of the box and push sample as far towards the opposite end as it will go. Measure the void, from the inside of the ‘box to the core face.

Conclusion: If the length of the void is from 0 to 3/4”, the material has allowable plastic limits’ if the void is 1” or more, the material will have to be blended; if more than 1—1/2”, the material is to be avoided.

2. Screen Test.

Granule size and percentage of particles of a given size in the total sample is important for three principal reasons: 1) Soil components are easily determined

by their size and shape. 2) Major soil types are classified by the gross percentage of particle size present, as well as geochemical origin (see Table 1). 3) Blending of soil components is based upon manipulation of component size and percentage.

Step 1 – Extract approx. one lb of raw sample and process through splitter box (5—S passes). Place the processed material in a 12” aluminum pan. Spread

soil evenly over bottom of the pan. The soil material must be carefully dried before screening. There is a simple way to accomplish this, outlined as follows:

a. Set up a Coleman camp stove with portable oven. Temperature gauge on oven door should register llO~120o before pan and contents are placed within.

b. “Bake” the sample 30—45 mm. Remove and cool.

c. Weigh out sample in triple—beam balance scale. One thousand grams is a good working sample and simplifies figuring the percentage by weight as each 10 grams equals one percent of the total sample.

d. Pour weighed sample into top screen, secure the lid and begin the. shakedown..

e. If a mechanical shaker is used, ten minutes of shaking will treat the average sample. If the screens are shaken by hand, double the time for shaking to 20 minutes. A gentle up—and—down movement at the rate of 30 shakes per minute works well.

f. Weigh the material remaining on each screen and record. Recorded weight divided by 10 will result in the percentage of that particular size as part of the total.

g. As the #200 screen is examined, both the material remaining on the screen and material passing into the pan are weighed.

Step 2 – Interpretation of sample.

a. Material remaining on #10 screen and above is recorded as gravel.

b. Material remaining on #50 to #16 screen is recorded as medium—to— coarse sand.

c. Material remaining on #2004100 screens is recorded as fine sand.

d. Material passing #200 screen is recorded as clay/silt.

e. There is a built—in error in this procedure; that is, in practice a small percentage of clay/silt will be present in the gravel and sand fractions. The combination of thorough drying and mechanical separation of sandy loams will consistently produce less than three percent of entrapped clay/silt, well within the limits for these purposes.

2—7
Step 3 _

a.
___Percentages and applications.

1—7% gravel, 65—80% sand, 20—18% sand/clay will generally produce good to excellent material for adobe block.

b. 5—15% gravel, 60—75% sand, 20—30% clay is suitable for soil— cement and rammed earth.

c. Gravel above 3/8", heavy percent~ges of fine sand (above 25%), and large percentages of clay/silt (above 30%) present formidable blending problems and should be considered impractical for use.

3. Color Significance

Color is an important aspect of soil sampling.

a. Red to sandy—buff indicates that the geochemistry of the material is stable and can be stabilized (by asphaltic emulsions or cement).

b. Chalky white to light grey almost always requires cement for stabilization.

c. Black to greasy—grey indicates a high organic/carbon content, which is impractical to stabilize for building use.

4. Summary of Testing Procedures (Shrink Box, Granular Percentage, and Color). Shrink Box Test

a. Shrinkage within acceptable limits; proceed.

b. Shrinkage marginall~r acceptable:

1 – Check granular analysis——blending may change behavior to acceptable limits; reblend and make new shrink sample.

ii— Begin the blend by increasing the ratio of coarse sand/ fine gravel; in some instances, where the clay/silt fraction is high (20—30%), lowering the clay content to 15% may produce good results.

c. Sample swells over lip of the box or “humps.” Do not consider using this soil for any building purpose.

Granular Percentages often fall into acceptable limits if good field samples are located. More often, blending from two or more locations is called for. Careful correlation between the percentages and the shrink—box tests will yield good results. Problems are indicated by:

a. Large amounts and size of gravel, generally above 10 percent and above 3/8” in size.

b. Large percentages of fine sand (25 percent or more).

c. Large amounts of clay/silt (more than 20 percent for adobe and 30 percent for soil—cement and rammed earth).

Color – Soil color indicates choice of stabilizers. Black clay. ‘soils are to be entirely avoided.

Assuming that shrinkage limits are achieved, percentages in granular size are acceptable, and color indications are good, the second stage of lab tests are begun.

D. Base Lab Tests, Phase ‘1.1

1. pH Reading of Soil—water Extract. Study the operating instructions of

the pH meter carefully. Pay particular attention to the adjustment of the meter with the ionized solutions that come with the kit. Preparing the solution is very simple:

a. Weigh a 100 gram sample that has passed the #3/8 screen; run through the splitter box 5—10 times; place sample in one—quart mason jar.

b. Weigh 500 mm flask, record. Set scale to total weight of beaker plus 500 grams. Place beaker on scales and add distilled water until scale balances.

c. Add water to mason jar containing soil sample. Seal jar and shake for 2—3 minutes, rotating jar end—for—end several times. Set jar aside until contents settle.

d. Insert p1-i meter probe, and take reading. If pI-i meter reads:

1 – Below 7.0 – Soil is acid, indicating ‘organic contamination

ii— Above 8.2 – Soil is alkaline, indicating gypsum, lime or metallic salt contamination

iii—pH levels and stabilizer reaction:

Asphaltic emulsions do not work well at pH 7.2 or below;

nor do they work well above 8.2. Cement is adversely

affented in pH levels below 7.0; readings as high as 8.5 give good results..

2. Conductivity Meter (Salt Determination). The conductivity meter offers a quick and accurate indication of a soil's salt content. Again, study the operating instructions carefully. Prepare the soil/water extract ratios according to the meter's capacity as given in the operating instructions.

Salt content above .5—.8 percent is to be avoided for asphalt stabilizers; 1.0 percent is the practical limit for use with cement.

3. Salt Determination by Filter Apparatus. Soluble salts can be extracted from soil samples and percentages calculated by ratio of weight to that of the total sample.

a.

b.

Prepare 100 gram soil sample as in pH test. Place soil sample in 1/2 gallon container. Flood with 1000 grams of distilled water. Agitate with plastic paddle 3—5 minutes. Let stand until contents settle and water clears (approx. 30 —45 minutes).

c. Carefully siphon water into another container. Avoid, as much as possible, contaminating the extract with soil in bottom of jug.

d. Insert #5 Whatford paper filter into plastic funnel floor. Place funnel into one—quart mason jar. Fill funnel 4/5 full until extract is exhausted; This may be a slow procedure, taking as long as 2—3 hours.

e. Place contents into two 500 mm beakers, weighing and labelling each beaker before contents are added.

f. Place beakers on 1/4" steel plate, which is placed upon the camp stove grill.

g. Adjust flame to low level. Do not allow solution to boil; slow evaporation will exhaust the liquid, leaving a salt scale in the beaker bottom. Weigh the beakers, subtradt the beakers weight and the results will be the salts weight in grams. Calculate the ratio of the salts weight to the 100 grams total of the soil sample. This will produce the percentage of salt.

4. Liquid Limit Determinations. The point at which moisture content of a soil dissolves the chemical and mechanical bond is generally known as the liquid limit. Moist soils can be very plastic when saturated but this is not a liquid limit; a mudf low or quicksand bog, for instance, is composed of soil beyond the liquid limit. There are practical uses involving knowledge of liquid limits:

a. The quantity of water needed to mix soil material can be deduced from liquid limit tests.

b. Moisture concentration of soil stockpiles can be deduced from liquid limit tests if other means are not available.

c. The presence of superplastic clays can be deduced from the test.

d. If properly utilized, the liquid limit machine can be used to determine boundaries between soil margins, such as between sandy loam and clay—loam, if sufficient samples are taken in the field.

The Liquid Limit Machine requires considerable practice to develop operator skill. Instructions are usually furnished with the unit and are based upon the American Society of Testing Materials (ASPI) standards.

Hydrometer Testing. Use of the hydrometer in establishing extremely accurate clay measurements is accepted as the ultimate gauge by soil scientists. Use of the hydrometer by ncvices is possible and practical. Much practice is necessary and instructions are carefully desdribed in several of the technical books listed in the reference section of this report.

5. 100X Field Scope (Monocular). The field scope is extremely useful for visual examination of soil particles, such as:

a. geometry of sand——sharp, rounded, subangular, etc.

b. mineral intrusion in clays

c. hydration formation in soil—cement samples

d. distribution of asphalt—emulsions in adobe samples

6... Summary of Phase II Base Lab Tests

a. pH and salt measurements establish quantities present in soil and provide guidelines for most effective stabilization techniques (hydrocarbons, cement, etc.) to be used. in fabrication of building materials.

b. Liquid limit determination provides information about soil behavior at the point of saturation, and

i – provides a guide fpr water ratios needed to mix soil and stabilizers

ii— can provide quick identification of superplastic clays, if present

iii—can be used in surveying boundaries between some soil types

c. Visual examination by field scope provides information about geometry of soil particles, especially sand, and the mineral intrusion of clays.

E. Quality Control Testing

Quality control testing is the climax of the testing sequences first described in Chapter I and includes both phases of the Base Lab procedures described in Chapter II. Tests described in this section will reveal whether or not the material being tested will meet minimum specifications, or whether the quality of lab work has been accurate enough to establish——in a consistent, reproducible form——the materials' inherent potential.

It is necessary to stress two important facts about quality control

– measurement: 1) Results from lab procedures do not automatically reproduce at the production level, and 2) Frequent quality control tests must be made from the production run to establish the mean deviation from standards set by lab specifications. If these procedures are ignored the quality of material produced predictably will be inferior, and the best workmanship won't provide a remedy.

1. <u>Moisture Content of Cured SpecitheUMatetial</u>

a. Adobe, stabilized (See Chapter III for imformation on stabilizers.)

i —Fill five 2" diameter x 4" length cylinders withadobe

material. DO NOT PACK OR COMPRESS. Fill slowly with a

large spoon, avoiding air pockets and shake to settle.

ii —Set cylinders on 3" felt squares on a flat surface. Do not disturb sample for 48 hours.

iii —Carefully remove samples from cylinders with a 1—15/16 diameter wooden rod, 8" in length. Allow the cylinders

to air cure for 48 hours.

iv —At the end of 48 hour—air cure, place the soil cylinders in 12" aluminum pan and set in camp stove oven. Regulate heat to llO^{0}F on oven gauge. Bake for 2 hours.

v —Remove .from oven and allow to cool to handling comfort. Mark each cylinder with felt pen, 1 through 5. Weigh

each cylinder and record in log book.

vi —A square tray, plastic or metal, at least 12” square and 6” deep, is prepared as follows: Place an 11—1/2” xll—l/2”x314” clay floor tile in the tray; place a felt square 12—l/2”x12—l/2” or larger, if space permits, upon the tile with edges touching the bottom of the tray. Flood the tray with water until level is 1/4” from the top of the tile.

vii —Stand the cylinders on the felt liner. The felt will conduct water to the cylinder base. Place a close fitting lid over the tray (aluminum foil works well).

viii—Cylinders will remain in the tray for 72 hours. Check water level once per 24 hours and maintain water level at 1/4” from top of tile.

ix —At end of 72 hours remove cylinders and weigh. A weight gain of more than 2.5% of the cylinder’s dry weight indicates insdfficient stabilizer and the sample DOES NOT meet specifications for stabilized adolie.

x —If cylinders show moisture gain of less than 2.5%, they are “stabilized.” Prepare immediately to test these cylinders in the Unconfined Compression Device (tests described later in this section). Destruction of these cylinders must occur at pounds per square inch of not less than 20 percent of dry cylinders of the same batch.

In any case, destruction must not occur at pressures of

less than 200 psi.

b. Soil—Cement (See Chapter lIt, Stabilizers.)

i —Prepare soil—cement batch, as described:in Chapter III.

ii —Lubricate cylinder molds (2” diameter x 4” length) with light coat of wheel—bearing grease. Fill molds with soil—cement, tamping gently until mold is full.

iii —Remove “cores” in 24 hours with tool described in (iii) of adobe section immediately preceding.

iv —Air cure core.s for 72 hours. Mark, weigh, and record in log book.

v —Prepare saturation tray and core samples as in steps (vi) through (viii) of the adobe section.

vi —After 72 hours remove the cores from the tray, weigh, and record.

vii —If the moisture gain equals 12 percent of the core’s dry weight (original weight plus 12 percent), the soil cement is unstabilized.

viii—If the weight gain is less than 12 percent, the sample is stabilized. Prepare immediately for Unconfined Compression

Test. Destruction point of less than 350 psi indicates

failure of cementaceous structure despite acceptable stabailization specifications.

2. Unconfined Compression Tests. In this writer’s opinion, great accuracy is needed when testing the destruction limits of soil—building compnents. The device used in the procedures described below is manufactured by Soiltest, Inc., and identified as Model 11—560, Unconfined Testing Device.

a. Description of the machine

i —manual operation via rotating screw

ii —calibrated strain ring of 1000 lbs per sq in capacity

iii—nomograph provided with strain ring for interpretation of readings

iv —two dial indicators record destruct point and deformation of sample simultaneously

b. Preparation of test cylinders

i —Prepare 5 each2” diameter x 4” length test cores.

ii —Test and record, following procedures in machine manual.

iii—Average the five readings for average psi point; spread between lowest reading and highest will estimate the

mean deviation

3. Spray/Erosion Test. The most practical and economical means of testing earthen blocks employs a spray device which duplicates the action~of driven rain.

The equipment required for this test is listed as follows:

a. Adjustable water regulator valve that can be set for 20—25 lbs pressure

b. Standard shower head with pattern control capable of being set to a 12” circle at 18” distance frpm the head

c. Pipes, connections, and fitting to plumb the regulator and shower head to a standard 1/2” or 3/4” water line

The test is conducted in the following sequence:

a. Place the test specimen 18” from the shower head.

b. Check the regulator for a setting of 20—22 lbs pressure. Turn on water to regulator and shower head. Measure the diameter of the water pattern against the block. This pattern should be between 8—12” in diameter.

c. Monitor the test visually. Expose the test block for 20 minutes. Turn off the water and examine the block.

d. If the surface is pitted (eroded) up to depths of 1/4”, the probable durability of the material is poor. If there is erosion no deeper than 1/16—1/8”, the durability is probably.good. Repeat the 20—minute cycle in both cases. Erosion of more than 1/4” at the end of the second cycle indicates material cannot be left exposed in the building and will require a plaster weather coat. If less than 1/4” erosion at end of second cycle, then the material is sufficiently durable for exposed use in areas of less than 25” annual rainfall. A minimum.of three samples of the same batch should be tested and compared for uniformity of results.

e. Water consumption in this test procedure is heavy——approx.

150—180 gal per sample. Recycling of the water used would be very useful. In any cast, provisions must be made to dispose of the water into drains or storage, etc.

4. Freeze/Thaw Stress Test. The action of water entrapped in earthen building materials that will be exposed to driving rain and sudden freeze can be duplicated in the laboratory. The procedure is as follows:

a. Mold five 2” diameter by 4” cylinders of material for testing. Dry specimens as described in the section

on saturation testing.

b. Submerge the cylinders in a tray of water for 5 minutes.

c. Place the cylinders in a dry tray after removing surface moisture with a paper towel or dry clean cloth.

d. Place the tray with cylinders in any freezing compartment that operates in the 0^0F—10^0F range. Leave in freezer for 2 hours, then remove and examine for surface flaking or cracks. Thaw for 1 to 1—1/2 hrs, “rinse” the core for 20—30 •sec, remove loose moisture and replace in freezer for 2 hr. Repeat the process for a total of 8—10 times (‘cycles”). Acceptable materials will withstand 8—10 freeze/

thaw cycles without a serious flaking or cracking. (Minor

wear or surface sloughing will probably occur, such as a

gritty or grainy pass—off. This is not considered serious

or indicative of failure.)

5. Diagratttnatid Sequence of PortaLab Testing Procedure.

The diagrammatic model is illustrated on the following page.

SOIL SAMPLES

Agitating Jar Test
Ribbon Extrusion Test
Drop Ball Test

Screen Test for Particle Size

Field Scope

BASE LAB

Shrinl.t Box

LiquiJ Limit Machine
Screen Sizing

Color Coding

pH of Soil—Water Extract Soluble Salt Measurement

Hydroti~eter Test

Moistui2e Content
Conductivity Meter
Filter Appratus

Field Scope

QUALITY CONTROL TESTS
Unconfined Compression

Spray/Erosion

Freeze/Thaw Test

Completion

Diagrammatic Sequence of PortaLab Testing Procedure

pH Meter

Splitter Box and. Trays

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t -
tigure 1. Shrink Boxes

Figure 2.

1355 Standard Screens

Figure 4. Weight and. Volumetric Instruments

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Figure 3.

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Figure 5. Pocket Pentameter

Figure 6.

Conductivity and pH Meters

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Filter Apparatus

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Figure 8. Unconfined Compression Machine

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Figure 7~

Figure 9.

Figure 10.

Field Inspection Scope

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CHAPTER III

SOIL STABILIZERS

All soils are subject to mechanical and chemical action and resultant changes in density and/or chemical composition. "Stability" in the sense *of* using soils as building material is narrowly confined to such categories as ability to carry load, resist moisture, abrasion, and moderate thermal flow through its mass. Various chemical compounds improve a soil's inherent stability and are pertinent to PortaLab's use.

A. Asphalt Emulsion

The use of emulsified asphalt in the manufacture of adobe is well known and used on an international scale. A publication available from the University of California at Fresno, The Matiufacture of Asphalt Eitulsiofl Stabilized Brick, is considered the best study on the subject today. This book should be consulted by anyone wishing to use PortaLab; however, there are a number of points not

covered in the book that should be considered.

1. Asphalt Emulsion in Adobe Manufacture. The percentage of asphalt emulsion used to manufacture adobe block is measured by the blockà' ability to resist water penetration and can be established by laboratory testing.

a. The amount of asphalt emulsion needed to meet a maximum absorption of 2.5 percent will vary according to th~

physical and chemical composition of the soil being used.

b. The term "semi—stabilized," as used in the adobe industry today, is unquantifiable. Semi—stabilized block is designed to resist light rain during storage and must be plastered immediately in the construction process.

c. Asphalt emulsion contains a high percentage of the emulsifying vehicle, which performs no function as a stabilizer. The percentage of solids (asphalt) should be consideted as the weight factor in computing the ratio of asphalt to soil.

d. Asphalt emulsion cannot be used effectively in rammed earth or compressed Mock because of the percentage of additional water required to disperse the agent in the soil mixture. Tests on rammed—earth and pressed—block (Cinva—Ram and hydraulic press) show no additional strength or ability to resist moisture to the minimum required levels.

e. Asphalt emulsion adds no compressive strength to the material..

2. Types of Asphalt Emulsions Used iü Earthen Building Components.

a. Only ss (slow setting) emulsions are of practical use in adobe.

b. Road oil (RC 250 and similar) has a volatile vehicle——NAPA, and is potentially dangerous in storage and around machinery.

c. Serious students will consult ABasid Asphalt Emulsion Manual, Volumes 1 & 2, The Asphalt Institute, College Park, MD (1979).

B. Cement

Cement is the. material of choice for use in soil—cement, rammed—earth, and pressed block. Like asphalt, cement hydration results in a cementaceous infrastructure, which adds greatly to tite load—bearing ability of the soil material. Soil—cement mixtures are difficult to control during the mixing process (low water content), must be carefully mixed to disperse the cement throughout the soil or soft pockets will form with potential shattering of the component under load, and must be damp—cured for up to five days after manufacture or placement in form work.

Readers should consult the following publications for specific information on soil—cement in building usage.

— Portland Cement Association Soil Primer (1973)
— Portland Cement Association Cement—Soil Lab Manual (1974)
— Cement Modification of Clay Soils (1969)
— Soil Cement: Its Use in Building. United Nations Publication, 1972. Sales No. E—64—IV—6—ST/SOA/54.

Cement—soil mixtures have several special characteristics.

— Some alkaline soils, such as caliche and gypsum sands, can be stabilized only by cement.

Cement—soil must be compressed to reach high compressive strength.

— Cement—soil units require surface treatment to resist water penetration (plaster, paint, etc.)

— Speed of thermal transfer is greater in soils using cement stabilizer than in those soils using asphalt emulsion or polymer compounds.

C. Other Chemical Stabilizers

Beginning in the middle 1970's, numerous firms began sales campaigns for "new"[t] and "amazing" soil stabilizers. In fact, none of these products were new or substantially better than conventional asphalt or coment compounds. A partial listing of the "new" products, with a brief chemical description, is as follows:

a. Quarternary nines – Organic byproducts of meat—packing industry, based upon cationic compounds of ammonia

Ii. PDC – A mixture of Portland cement, hydrated lime, and casein

c. TERSC – Dow Chemical Company; chemical name is 4—tert—butylpy— rocatechol

d. Lignin liquor and lignin/cellulose compounds – byproducts of the paper industry

e. Phosphoric acid – Monsanto Chemical Company; found to be potentially hazardous to humans

f. Special limes – Hydraulic lime, derived from impure lime sources; waste lime, a byproduct of acetylene manufacture

g. Industrial waste – Flyash, "red—mud[11] from aluminum industry, etc.

For tn—depth information on this subject, the following publications should be consulted.

— Development and Evaluation of ChettiealSoil Stabilizers, Earl B. IKinter, rederal Highway Administration, Washington D.C. (1975). NTIS No. PB—242—556.

— Chemical Stabilization of Soils, Laboratory and Field Evaluation of Several Petrochemical Liquids for Soil Stabilization, W. R. Morrison, Bureau of Reclamation (1971). NTIS No. PB 205—800.

— The Soil—Polymer System. Army Construction Engineering Research Laboratory (1974). NTIS No. AD—775—812.

— State—of—the—Art Survey: Soil Stabilization, Vol. 1. Naval Air Engineering Center, Philadelphia, PA (1968). NTIS No. NAEC—ENC—7469.