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FOREWARD

Enclosed is Gestra Engineering's laboratory procedure manual for soil testing. The intent of this manual is to standardize the techniques used by our staff to complete geotechnical tests. This manual provides the properly trained laboratory technician with a written procedure in a step-by-step method which utilizes the equipment and methods specific to our laboratory. All test procedures are intended to follow ASTM methods where applicable. While ASTM is to be followed the ASTM language often allows for several different ways to accomplish a single task. This manual provides more specific relevant detail for the equipment and methods used by Gestra Engineering.

It is emphasized that all personnel using this manual require proper training in the test procedure. A separate record is maintained for equipment calibration and employee training records.

Sincerely,
GESTRA Engineering, Inc.

Doug Bath, P.E.
Senior Engineer

Laboratory Test Procedure Index

TEST DESCRIPTION

The moisture content of a soil is the percentage of the weight of water or "moisture" in a soil to the total weight of organics and dry soil together. This value is a valuable index property in clays and organic soils and is sometimes used in conjunction with other index properties to approximate settlement of a soil layer. Moisture contents have been known to vary in stiff clays from 10% to 18% and from 20% to 150% in soft clays. Peat soils which are highly organic can have moisture contents in excess of 300%.

APPLICABLE STANDARDS:

- ASTM D 2216-98 (AASHTO T 265) – Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock By Mass
- ASTM D 4220-95 – Practice for Preserving and Transporting Soil Samples

APPLICABLE FORMS:

- Moisture Content, Dry Density, and Organic Content Form

EQUIPMENT:

- Moisture cans
- Oven with accurate temperature control
- Balance

PROCEDURE:

Step 1: Choose a representative portion of the sample to be tested. Make sure the minimum moist sample weight coincides with the table shown below.

Maximum Particle Size	Standard Sieve Size	Minimum Mass of Moist Specimen for Reporting Water Content to ±0.1%	Minimum Mass of Moist Specimen for Reporting Water Content to ±1%
2 mm or less	No. 10	20 g	20 g
4.75 mm	No. 4	100 g	20 g
9.5 mm	$^{3}/_{8}$ in	500 g	50 g
19.0 mm	¾ in.	2.5 kg	250 g
37.5 mm	1 ½ in.	10 kg	1 kg
75.0 mm	3 in.	50 kg	5 kg

Step 2: Intact samples such as block, tube, split barrel, and the like obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample. Using a knife, wire saw, or other sharp cutting device, trim the outside portion of the sample a sufficient distance to see if the material is layered and to remove material that appears more dry or more wet than the main portion of the sample. See table below for sample selection depending on the existence of layers.

Layered (Y/N)	Sampling Methods
Not layered	Take all or ½ the specimen
	Trimming a representative slice.
	Trimming the exposed surface of ½ or the interval being tested.
Layered	Select an average specimen
	Select an individual specimen
	Both, an average and individual specimens

Step 3. Record the container number on the form and the weight of the sample container to the nearest 0.01 grams. If doing proctor tests, record pan weight to the nearest 0.1 grams.

Step 4. Place representative portion of sample in the container, weigh, and record "Wet weight of soil and cup".

Step 5. After all moisture contents have been prepared as above, place tray of moisture samples in the oven with the temperature not to exceed 230^{o}F. Dry the samples overnight (12-16 hours). Specimens of sand may often be dried to constant mass in a period of 4 hours. For soils with organic matter such as topsoil or peat, set the oven temperature 140° F and dry for a longer period of time. (Refer to ASTM D 2974). If results are required faster, after at least 6 hours weigh the sample, place back in oven and wait 1 hour. If the percentage of the moisture content does not change by more than 0.1%, the sample is dry.

Step 6. Remove sample container from the oven. Allow to cool to room temperature or until the container can be handled comfortably with bare hands. Weigh and record the dry sample and can (Dry Weight of soil and cup).

Calculations

1) **Weight of Dry Soil:**
- Dry Wt. of Soil and Cup - Wt. of Cup = Wt. of Dry Soil

2) **Weight of Moisture**
- Wet Wt. of soil and cup - Dry Wt. of soil and cup = Wt. of Moisture

3) **Moisture Content**
- $\frac{Wt.ofMoisture}{Wt.ofDrySoil} \times 100 = \%Moisture$ (Report to the nearest 0.1%)

SAFETY PRECAUTIONS:

- When placing samples in oven, removing, and weighing the samples always wear hot pad gloves or use tongs to handle the specimens
- Do not keep warm samples on the balances any longer than required to record accurate weight. Prolonged exposure will cause the balance plate to warp.

TEST DESCRIPTION
The organic content of a soil is the percentage of the weight of organic material, which ignites at 440^{o}C in a soil to the weight of dry soil. This value is a valuable index property in organic soils and is sometimes used in conjunction with other index properties to approximate settlement of a soil layer. Organic contents have been known to vary in lacustrine clays from 5% to 25% and from 50% to 75% in peat soils.

APPLICABLE STANDARDS:
- ASTM D 2974-00 – Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
- ASTM D 4220-95 – Practice for Preserving and Transporting Soil Samples

APPLICABLE FORMS:
- Moisture Content, Dry Density, and Organic Content Form

EQUIPMENT:
- White Furnace Jars
- Muffle Furnace with accurate temperature control
- Balance

PROCEDURE: for manual muffle furnace

Step 1: If an organic content is to be completed, the original soil must be put in a white furnace jar instead of the normal aluminum moisture content cans.

Step 2: After the moisture content is completed following Lab Procedure Soil-01 place the white furnace jar with the organic soil in the furnace and set the dial to 1.8. This temperature coincides with 440^{o}C. If the furnace is already turned on, tongs must be used to place specimen in the furnace.

Step 3: After at least 6 hours, turn dial to off, remove the jar from the furnace and allow cooling to room temperature. Put the specimen in a safe location so no one touches it. Weigh and record the dry sample and can (Organic Weight of soil and cup).

PROCEDURE: for digital muffle furnace

Step 1: If an organic content is to be completed, the original soil must be put in a white furnace jar instead of the normal aluminum moisture content cans.

Step 2: After the moisture content is completed following Lab Procedure Soil-01 place the white furnace jar with the organic soil in the furnace. Press the enter button, then number 4, followed by the enter button several times until display reads -On-. The furnace program will run for approximately 6 hours.

Step 3: When display reads CPLt, remove the jar from the furnace and allow cooling to room temperature. Put the specimen in a safe location so no one touches it. Weigh and record the dry sample and can (Organic Weight of soil and cup).

*Note – If you plan to use both furnaces at the same time make sure the large Oven is turned off to prevent tripping the circuit breaker.

CALCULATIONS:

1) **Weight of Dry Soil:**
   - Dry Wt. of Soil and Cup - Wt. of Cup = Wt. of Dry Soil

2) **Weight of Organics**
   - Dry Wt. of soil and cup – Wt. of soil and cup After Burn = Wt. of Organics

3) **Organic Content**
   - $\frac{Wt.of Organics}{Wt.of Dry Soil} \times 100 = \% Organic$ (Report to the nearest 0.1%)

SAFETY PRECAUTIONS:

- When placing samples in furnace, removing and weighing the samples, always use tongs to handle the specimens. The hot gloves will not protect your hands at these temperatures.
- Do not keep hot samples on the balances any longer than required to record accurate temperature. Prolonged exposure will cause the balance plate to warp.

TEST DESCRIPTION

The dry density of the soil is used to determine the % compaction of fill materials and the relative density of natural soils. It is determined by first determining the wet weight of a known volume of soil and the moisture content of that soil. A simple calculation is performed to determine the dry density.

APPLICABLE STANDARDS:

- ASTM D 2216-98 (AASHTO T 265) – Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock By Mass
- ASTM D 4220-95 – Practice for Preserving and Transporting Soil Samples

APPLICABLE FORMS:

- Moisture Content, Dry Density, and Organic Content Form

EQUIPMENT:

- Calipers
- Moisture Cans
- Oven with accurate temperature control
- Balance
- Cutting mold
- Knife
- Spatula

PROCEDURE:

Step 1: Take the geotechnical sample obtained by split barrel or Shelby Tube and place in the cutting mold. Cut each end off to be even with the edge of the mold assembly. Fill in voids with cuttings if need be.

Step 2: Take 3 readings of the length and average, Take 3 readings of the diameter and average. Enter averages into worksheet. These readings should be converted into feet.

Step 3: Weigh and record the wet weight of the soil in pounds.

Step 4: Determine the moisture content of the soil according to lab procedure Soil-01.

CALCULATIONS:

1) **Wet Density of Soil**

$$\frac{WetWeight}{Height \times \pi\left(\frac{Diameter}{2}\right)^2} = WetDensity$$

2) **Dry Density of Soil**

$$\frac{WetDensity}{1 + MoistureContent} = DryDensity$$

SAFETY PRECAUTIONS:

- When placing samples in oven, removing and weighing the samples, always wear hot pad gloves or use tongs to handle the specimens
- Do not keep hot samples on the balances any longer than required to record accurate temperature. Prolonged exposure will cause the balance plate to warp.

TEST DESCRIPTION

This test is usually performed to test the material, usually an aggregate, for percentages passing individual sieve sizes. In general, the material is broken down into individual sizes and weighed to determine the percentage of the soil retained and passing a certain sieve size. In the case of aggregates, these values can be compared to state and municipal specifications to determine if the material is suitable for use as an engineered fill.

APPLICABLE STANDARDS:

- ASTM C 136-96a (AASHTO T 27)– Standard Test Method for Sieve Analysis of Fine & Coarse Aggregate
- ASTM C 117-95 (AASHTO T 11) – Standard Test Method for Material Finer than No. 200 Sieve in Mineral Aggregates by Washing
- ASTM D 75 – Practice for Sampling Aggregates
- ASTM C 702 (AASHTO T 248) – Practice for Reducing Field Samples of Aggregate to Testing Size

APPLICABLE FORMS:

- Mechanical Analysis and Hydrometer Form

EQUIPMENT:

- Balance (sensitive to 0.1 g)
- Series of sieves
- Sieve shaker
- Oven or burner
- 2- round bowls or flat cake pans
- Sample splitting apparatus
- Dust pan
- Scoop
- Brush

PROCEDURE:

<u>Coarse Aggregate</u>

Step 1: Obtain a representative sample of the coarse aggregate. Refer to standard practice for sampling aggregates Field Procedure Soil-10.

Step 2: Split the sample into an appropriate test sample size. Refer to the standard practice for splitting samples (Laboratory Test Procedure, SOIL - 11). For the coarse aggregate, the minimum weight is directly related to the nominal maximum size of the aggregate, and should conform as follows:

Nominal Max. Size (in.)	Minimum Weight of Sample, kg (lb.)
3/8”	1 (2)
½”	2 (4)
¾”	5 (11)
1”	10 (22)
1 ½”	15 (33)
2”	20 (44)

Step 3: Dry the aggregate sample to a constant weight and record.

Step 4: Obtain the appropriate sieve sizes for the coarse aggregates as required by the specifications for each specific project. Additional sieves may be necessary between the specified sieves to avoid clogging or overloading the sieves. Place the sieves in a stack with the largest opening on top and the pan on the bottom.

Step 5: Pass the coarse aggregate sample through the stack of sieves. Put lid on the stack and place in shaker for at least 10 minutes.

Step 6: Weigh and record the amount retained on each of the sieves used. Cumulative weights are necessary; therefore keep adding the contents of the each sieve to the cumulative contents of the previous sieves and record weight.

Step 7: Perform a weight check on sample. If the summed total of the tested material differs from the original sample weight by more than 0.3%, the results should not be used and the test should be run again.

Fine Aggregate

Step 1: Obtain a representative sample of the fine aggregate. Refer to standard practice for sampling aggregates Soil-10 and splitting samples Soil-11. For the fine aggregate, the minimum weight is directly related to the nominal maximum size of the aggregate, and should conform as follows:

Nominal Maximum Size	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
9.5 mm (3/8 in)	1000
19.0 mm (3/4 in)	2500
37.5 mm (1 ½ in) or larger	5000

Step 2: Dry the fine aggregate to a constant weight, using the oven or the burner.

Step 3: Obtain the appropriate sieve sizes for the fine aggregate as required by the specifications for the specific project. Additional sieves may be necessary between the specified sieves to avoid clogging or overloading the sieves. Ideally, only 1 layer of the tested material should be on the sieve screen. The maximum amount of material on the #200 sieve should be limited to 385 grams.

Step 4: Once the fine aggregate has dried to a constant weight, record this as the original weight, and allow it to cool to room temperature.

Step 5: Wash the aggregate through a # 200 sieve. Do not place the sample directly on the #200 wash sieve. The wash should be performed by saturating the sample in the pan and pouring the dirty water out over the screen. Continue washing until the wash water is no longer cloudy or discolored. Be careful not to lose any particles that are retained on the #200 sieve in this process! Use a wash bottle to put retained material on the wash #200 sieve back into the sample.

Step 6: Again, dry the fine aggregate to a constant weight, record the weight, and allow it to cool to room temperature.

Step 7: Stack the appropriate sieves in order with the largest sieve size at the top, and pour the entire sample into the top sieve. Use a brush to clean the pan and get all of the particles into the sieves. Place the lid on the stack of sieves.

Step 8: Place the sieves in the mechanical shaker, and turn it on for 7 minutes.

Step 9: Remove the sieves once the shaker has stopped. Empty the sieves one at a time into a pan or bowl, and weigh the amount retained on each sieve. Record the weight as a cumulative total, including the material retained on the previous sieves.

Step 10: Perform a weight check on sample. If the summed total of the tested material differs from the original sample weight by more than 0.3%, the results should not be used. The sample should be discarded and the test should be run again.

CALCULATIONS

Percent passing No. 200 sieve by washing

$$\frac{(B-C)}{B}\times 100 = A$$ Where,

A=Percent Passing #200.

B=original dry mass, in g.

C=dry mass of sample after washing, in g.

TEST DESCRIPTION

This test is usually chosen by the geotechnical engineer when the percentage of material passing the #200 sieve or "fine content" is of particular importance. In general, the material is broken down into individual sizes and weighed to determine the percentage of the soil retained and passing the #10 sieve. A weighed portion of material passing the #10 sieve is made into a slurry and the specific gravity of the slurry is tested at timed intervals. In a geotechnical project, the fine content is correlated to the frost susceptibility of a soil and can provide us with important information pertaining to the stability of the soil during construction. In the case of aggregates, these values can be compared to state and municipal specifications to determine if the material is suitable for use as an engineered fill.

APPLICABLE STANDARDS:

- ASTM D 422-63 (AASHTO T 88) - Standard Test Method for Particle-Size Analysis of Soils

APPLICABLE FORMS:

- Mechanical Analysis and Hydrometer Worksheet

EQUIPMENT:

- #10 Sieve and Pan
- Glass Thermometer accurate to 1^{o}F
- Water bath
- Graduated Cylinder (250 ml)
- Timing device with a second hand
- ASTM hydrometer 152H
- Sedimentation cylinder with a volume marked at 1000 ml
- Balance readable to 0.01 g
- Blender with cup
- Plastic bowl approximately 4 inches in diameter with lid

PROCEDURE:

Step 1: Make sure you have enough 4 % sodium hexametaphosphate to perform the test. You will need at least 125 mL for one test. If not mix 40g of dry sodium hexametaphosphate with enough water to produce 1000 ml of solution. Solution can be used for a period of up to one month.

Step 2: Refer to ASTM D422 (AASHTO T 88) for the minimum sample size required for both sieve and hydrometer analysis. Then record and weigh a pan and place sample in the pan. Dry sample to within 1 gram of loss over ½ hour time. Weigh and record dry weight of total sample.

Step 3: Pulverize the oven-dried sample and pass it through the # 10 sieve. Portions that are retained on the #10 sieve after 2 pulverizing sequences should be wet sieved through the #10. Material that has washed through the #10 sieve should be recombined with the dry material previously recovered and placed in the oven to dry. Material retained on the #10 should be recombined with previous like material and placed in oven to dry. The material retained on the #10 sieve should be tested according to GESTRA Lab Procedure for

Mechanical Analysis of Soil, Soil -04. After the soil material passing the #10 sieve has dried proceed to next step.

Step 4: Material may be crusty due to drying and require further pulverizing by hand. Make sure all sample used in this test has passed the #10 sieve. Weigh and record weight of a test sample. If the soil is mostly of clay and silt sizes, weigh out approximately 65g. If it is mostly sand the sample should be approximately 110g.

Step 5: Place the sample the plastic bowl and measure out 125 ml of the sodium hexametaphosphate solution. Stir until all particles are dispersed and cover.

Step 6: Cover the bowl or pan with a damp paper towel to prevent evaporation, and allow the mixture to soak for at least 16 hours.

Step 7: Near the end of the 16-hour period, prepare a control sedimentation cylinder for the test. Place 125 ml of sodium hexametaphosphate solution into a 1000 ml sedimentation cylinder. Fill the cylinder to the 1000 ml line using distilled water that is approximately the same temperature as the bath. Place the rubber cap and mix at least 10 times by turning the cylinder upside down, etc.

Step 8: At the end of the 16 hour period, pour the entire soil mixture into the dispersion cup. Using a water bottle with distilled water, wash all of the particles from the pan or bowl into the cup. Be careful not to lose any particles in transferring the mixture!

Step 9: Add distilled water to the dispersion cup so that it is approximately 3/4 full. Stir the mixture under the blender for 1 minute.

Step 10: Immediately after blending, transfer the mixture to the sedimentation cylinder, and again use a water bottle to wash all of the particles from the cup into the sedimentation cylinder. Add distilled water so that the cylinder is filled to the 1000 ml mark.

Step 11: Cap the end of the cylinder with a rubber stopper and turn the cylinder upside down and back 30 times, making sure that none of the soil remains settled at the bottom.

Step 12: At the end of this dispersion process, set the cylinder into the water bath and immediately begin timing. Remove the rubber stopper and wash soil off of the stopper with the same water bottle.

Step 13: Record readings using hydrometer 152H and thermometer for each the control cylinder and sedimentation cylinder with the sample. Required time intervals are listed on the form. About 20 seconds before the reading time, insert the hydrometer into the sedimentation cylinder. Remove the hydrometer and the thermometer from the cylinder and rinse clean. (Note: All readings should be taken at the top of the meniscus).

Step 14: Record all readings on the Hydrometer Analysis worksheet. Record the hydrometer reading of the sample cylinder as (Ra) in column 5, the sample cylinder temperature as (Ts) in column 4, the hydrometer reading of the control cylinder as (Cr) in column 7, and control cylinder temperature as (Tc) in column 6.

Step 15: At the completion of the test procedure all necessary data including the % passing the #10 sieve should be input into the computer program to generate the required particle size distribution curve.

SAFETY PRECAUTIONS:

- When mixing or using Sodium Hexametaphosphate, be sure that you are in a well-ventilated area. Do not breathe in the vapors, mist or dust from the Sodium Hexametaphosphate.
- Wash your hands thoroughly after using the solution or powder form of this substance.
- Do not place hands in the dispersion cup while operating the blender.

TEST DESCRIPTION

A Modified Proctor test is completed in conjunction with a dry density test to determine the suitability of fill material on site or used for preliminary site information. The test is completed by compacting a soil sample in a mold of known volume at varying degrees of moisture content. By completing this test, a "compaction curve" will be generated showing dry densities achieved at varying moisture contents. The apex of this curve is known as the optimum moisture content and maximum dry density of the soil.

APPLICABLE STANDARDS:

- ASTM D D1557-00 (AASHTO T 180) - Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort
- ASTM D 2216 (AASHTO T 265)- Test Method for Laboratory Determination of Water Content of Soil and Rock
- ASTM D 4718 - Practice for Correction of Unit Weight and Water Content of Soils Containing Oversized Particles

APPLICABLE FORMS:

- Proctor Worksheet

EQUIPMENT:

- 4" or 6" cylindrical mold
- Metal straightedge
- 10 lbf. proctor hammer
- 3/4", 3/8", #4 sieves rocker sieves
- Drying oven or stove
- Balance
- Sample bowls
- Mixing equipment (spatula, spoon)
- Water Bottle
- Sample extruder

PROCEDURE:

Step 1: Perform a sieve analysis on a representative sample of approximately 20 pounds of the material (or enough to perform the proctor test) using the rocker sieve set. Determine the individual weight retained on the, ¾", 3/8", and #4 sieves. Record these weights in the gravel content area of the proctor worksheet.

Step 2: Determine which proctor procedure to use (A, B or C) depending on the percentage of gravel retained on each of the sieves

- Procedure A: 20% or less by weight retained on the #4 sieve
- Procedure B: 20% or more by weight retained on the #4 sieve and 20% or less retained on the 3/8"sieve
- Procedure C: 20% or more by weight retained on the 3/8" sieve and 30% or less retained on the 3/4"sieve. If more than 30% by weight is retained on the ¾" sieve see ASTM D 4718 for corrections.

Step 3: When you have determined which proctor to run (A, B, or C) it is necessary to discard a certain portion of the sample before preparing the sample for the test.

- Procedure A: Your sample for testing will contain only material that passed the #4 sieve.
- Procedure B: Your sample for testing will contain only material that passed the 3/8" sieve.
- Procedure C: Your sample for testing will contain only material that passed the ¾" sieve.

Step 4: If the material is an A or B proctor, split the remaining material into 3 sections weighing no less than 6 pounds each. If it is a (C) proctor, split the remaining material into 3 sections, each weighing no less than 14 lbs.

Step 5: Determine if your sample is wet or dry of optimum. Until experience in this test is established, have an engineer or senior technician set up your moisture points for you. Ask the engineer what he/she is looking for when determining the right amount of moisture.

Step 6: Prepare your proctor sample at three different moisture levels that are 2% apart. Your first sample or point should be approximately 2% dry of optimum. The second point should be at optimum and your third should be over optimum. Assuming your first point is 2% dryer than optimum you add water to your second point. The third point moisture content should be 4% higher than the first point. The 3 points should be covered with a plastic bag and left for at least 16 hours to allow for even distribution of water throughout the sample, if time allows.

Step 7: Assemble the proctor mold* that you will be using. If the proctor is an (A) or (B), assemble a 4" mold. If it is a (C), assemble a 6" mold. Weigh this assembly (without the upper collar) and record the weight on the proctor worksheet (lbs.). Also record the mold number and the mold volume. The volume of the mold is located on the proctor worksheet.

Step 8: Starting with the first or driest point, fill the mold assembly, with the collar on, approximately 1/5 full. Before compacting, level the layer of soil and lightly tamp it to eliminate the fluffiness. Using the 10 LB hammer, compact the layer with 25 blows for an (A) or (B) proctor, and 56 blows for a (C) proctor. When dropping the hammer, the hammer should drop the full 12 inches. After compacting the first layer, repeat the process 2 more times. Your third and final layer, the material should extend approximately ¼" over the top of the mold so that when the collar is removed there is material to strike off even with the top of the mold.

Step 9: Take the collar off and use a beveled bar to scrape the material flush with the top of the mold. Make sure to get a smooth and even surface. Remove excess soil from the exterior of the mold. Weigh and record the soil and the mold in pounds on the proctor worksheet under section (a)*.

Step 10: If the sample is clay, extract the specimen from the mold by using the hand jack. If the sample is a sand or gravel hold the mold and tap the sides with a hammer.

Step 11: Take the middle portion of the extruded sample and test for moisture content using at least 500 grams of soil.

Step 12: Repeat the process on the next 2 points of the proctor. The next point can be started while the previous point is drying.

Step 13: The weight of the last proctor point should be equal to or less than the previous point. At this point you will know the moisture content has passed the optimum moisture. If the weights are still rising, you should prepare and compact another point.

Step 14: Once the worksheet is completed, enter the data in the computer program.

CALCULATIONS

1) Moist density

$$\rho_m = \frac{(M_t - M_m)}{1000 \times V}$$ Where,

M_t = mass of moist specimen and mold
M_m = mass of mold
V = volume of mold

2) Dry Density

$$\rho_D = \frac{\rho_m}{1 + \frac{w}{100}}$$ Where,

w = water content, %

3) Dry Unit Weight

$$\gamma_D = 62.43\rho_D$$

SAFETY PRECAUTIONS:

- While drying the samples, always wear hot/hazardous substance gloves when handling sample bowls on the open-flame burner or in the oven.
- Be very careful to move your hand away from the top of the hammer when it is falling.

TEST DESCRIPTION

Three values are obtained by completing the Atterberg Limits: the liquid limit, plastic limit, and plasticity index. The liquid limit is performed by obtaining a clayey or silty specimen which has been dried and ground to pass through a #40 sieve and adding water to make a "mud". This mud is then placed in a liquid limit machine and subjected to blow counts which are recorded. The "moisture" of the mud is then varied 2 more times in order to chart the relationship between blow counts and moisture content. The moisture content of the soil at 25 blows is referred to as the "liquid limit" of the soil.

The plastic limit is performed by again using the same soil that has passed through #40 sieve and water has been added to it. However, the moisture content of this soil is kept lower than before. The soil will form a ball which is rolled into "worms" of soil. When cracking is observed in the skin of the worm at 1/8" diameter, the moisture content of the soil at this point is the "plastic limit".

The plasticity index is the difference between the liquid limit and the plastic limit

APPLICABLE STANDARDS:

- ASTM D 4318-00 (AASHTO T 89 & T 90) – Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soil

APPLICABLE FORMS:

- Atterberg Limits Worksheet

EQUIPMENT:

- #40 sieve
- mixing dish
- Spatula
- Liquid limit Machine
- Glass plate
- 5 moisture cups
- Drying oven set at 220° f

SAMPLE PREPERATION

Step 1: Prepare a sample of approximately 200 grams (use more if available) by breaking it into small pieces. Place the material in a pan and air dry sample (do not use oven).

Step 2: Remove the sample from the pan and place into a mortar bowl pulverize using the ceramic hammer. Remove any shells, concretions, or other fragile pieces by hand.

Step 3: Take the sample after being ground and sieve through the #40. The material passing the #40 is what you will use to run the test. Place this material into a mixing dish. You will need a minimum of 150g of material to run the test.

Step 4: Get 5 moisture cups and weigh them. Record the weights and cup numbers down in the appropriate areas of the Atterberg worksheet. 3 cups are used for the liquid limit and 2 are used for the plastic limit sections of the worksheet.

LIQUID LIMIT DETERMINATION

Step 1: Use a plastic squirt bottle to add water to the sample in the Petri dish. **Before all the water is added** and not thoroughly mixed take approximately 20 grams and knead and roll it into a ball. You want to take this sample for the plastic limit part of the test. If you wait till all the water is added the sample will be too wet to roll into a ball. Set this aside on the glass plate. Mix the sample with a spatula until the moisture is consistent throughout the sample. Add just enough water so that the groove in the sample, when it is in the Liquid limit machine, will close in 30 to 35 blows.

Step 2: Use the spatula to place the material into the cup on the Liquid limit machine. Make sure the cup is resting on the base. Push and squeeze the material into the cup so that it is about 10 mm deep at its deepest point and forms an approximately horizontal surface.

Step 3: Use the grooving tool, with the beveled edge facing you, to make a groove in the sample. Start from the back and pull it toward you keeping the tool perpendicular to the cup throughout the movement. The beveled "wings" of the grooving tool should scrape just a little of the material. Make sure the base and the sides of the cup are clean.

Step 4: Once the groove is in, turn the handle on the Liquid limit machine fast enough so that the cup hits the base at a rate of 2 drops per second until the 2 halves of the soil come together in 30 to 35 blows. The length of the 2 touching halves should be approximately 13 mm. Make sure that an air bubble has not caused a pre-mature closure. If the two halves did not come together evenly an air bubble probably caused it. If this happens, you can add material to the cup to make up for what the grooving tool took out, re-shape the material in the cup and repeat the groove closure process.

Step 5: Once the groove has closed properly take a moisture sample from the cup. Do this by using the spatula to scrape across the sample perpendicular to the groove in 2 places to obtain approximately 15g of material. (ie. front and back of the groove closure).

Step 6: Place the 2 scoops in the sample cup that you previously designated for your 1st of 3 points for the liquid limit section of the worksheet. Record the number of blows, N, required to close the groove. Weigh the cup and the sample and record it in the "mass of wet soil + can" section on the worksheet. Don't waste any time between sampling and weighing the sample. A little unaccounted weight loss makes a big difference in such a small sample.

Step 7: Remove the sample that is left in the cup on the Liquid limit machine and place back in the Petri dish. Make sure the cup on the Liquid limit machine is clean.

Step 8: Repeat steps 1 through 7 two more times. Each time adding a little more water to obtain the groove closure at the required number of blows.

- You should have 3 samples and cups in the oven at the following groove closures. **Groove closures:**
    a. **First point:** 25-35 blows
    b. **Second point:** 20-30 blows
    c. **Third point:** 10-25 blows

Step 9: Allow the samples to dry in the oven for at least 6 hours, record and weigh the dry mass of the soil and cup. Input values into the computer program for calculation.

PROCEDURE FOR PLASTIC LIMIT

Step 1: From step 1 of the liquid limit, set aside a portion for the plastic limit. Select approximately 2 grams of that material and roll it on the glass plate into a thread that is 1/8th inch in diameter and approximately 3" long. When it has reached 1/8th inch and not broken into any pieces, reform the material into a ball and re-roll into a thread. Repeat this process until the moisture has dropped enough and the thread crumbles under the pressure required to roll it.

If the length of the thread breaks before it has reached 1/8th inch it is not necessarily at its plastic limit. Roll each of the shorter threads until it is 1/8th inch. If it does not break or crumble reform it with the rest of the sample and repeat the process.

If the soil crumbles and breaks before it has been rolled to 1/8th inch, the soil has reached its plastic limit and this is a satisfactory end point.

Step 2: Place the crumbled pieces into the numbered aluminum cup that you had designated for your 1st of 2 trials in the plastic limit portion of the worksheet. A minimum of 6 grams is required, so it is necessary to cover the cup of sampled material to prevent moisture loss while you roll more of the soil to its plastic limit. Repeat the process until a minimum of 6 grams is in the cup.

Step 3: Weigh the soil and cup and record this weight on the worksheet. Place the sample in the oven.

Step 4: Repeat this process to make another cup containing at least 6 grams of soil.

Step 5: Weigh all the samples periodically (liquid limit and plastic limit). When they have stopped losing weight record the final weight on the worksheet.

SAFETY PRECAUTIONS

- Use hot gloves or tongs when handling samples within the oven

TEST DESCRIPTION

The unconfined compression test is completed by imparting an axial load to a clayey soil at a specified rate until the sample deforms at least 15% of its original length or fails by fissure. The maximum load applied to the sample is then divided by the area of the sample to obtain the unconfined compressive strength of the soil. This value is often used in calculating soil bearing capacity.

APPLICABLE STANDARDS:

- ASTM D 2166-00 (AASHTO T 208) – Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
- ASTM D 2216-98 (AASHTO T 265) – Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock By Mass

EQUIPMENT NEEDED:

multiloader with deformation and load dial indicators
mold for trimming soil sample
balance readable to 0.1 g
oven
sample extruder (for thin wall tube samples)
timing device
calipers

APPLICABLE FORMS:

Unconfined Compressive Strength of Soil

PROCEDURE:

<u>Split Spoon Sample Preparation</u>

Step 1: If the sample to be tested is from a thin wall tube (Shelby Tube) then the sample will have to be pushed out of the tube with the sample extruder, additional information on the preparation of thin-wall tube samples is given in the next section. For unconfined compressive strength testing, the sample should be prepared so that the height to diameter ratio is between 2 and 2.5.

Step 2: Most samples tested will be split spoon samples. These are prepared by placing the sample in the mold and trimming the sample with a lab spatula so it is at the correct length and has flat ends. If the sample has some minor voids on the ends of the sample, they can be filled with trimmings from sample material. Measure the sample length and diameter in 3 separate locations and record the average length. Weigh and record the wet weight of the specimen in lbs.

Step 3: If a sample shows distress and/or holes attributed to hand penetrometer readings, the portion of the sample showing the distress cannot be used for the test.

<u>Shelby Tube Sample</u>

Step 1: Determine the necessary sample length, the sample should be prepared so that the height to diameter ratio is between 2 and 2.5.

Step 2: Place the tube in the extractor and secure to the frame making sure the top and bottom of the pipe are aligned correctly. Carefully push the sample out of the tube, the sample should be disturbed as little as possible. If the end of the tube is damaged, it may not be possible to extrude without cutting the end of the tube

Step 3: Place in the larger split mold and trim each end. If the sample has some minor voids on the ends of the sample, they can be filled with trimmings from sample material. Measure the sample length and diameter in three places and record.

Step 4: Weigh and record the wet weight of the soil sample before beginning the loading portion of the test.

Testing the Sample

Step 1: Adjust the rate for the loading so that the test will be complete at approximately 10 minutes from the start of loading. The test is complete when the sample deforms 15% of its length or when the specimen fails. To set the load rate for split spoon samples, set the strain dial to zero, start the machine, and time it for one minute. The load dial should read approximately 42 in one minute. That =.042 inches per minute. Record this on the lab sheet. Multiply the length of the sample by 15%. For a split spoon this should equal .42" (2.8"x.15). Return the loading plate to lowest position.

Step 2: Place the sample in the center of the loading plate and adjust it so that the upper plate is just making contact with the top of the sample. Start the loading cycle. When the load dial is first making a reading turn off the loading machine and make sure that both dials are zeroed.

Step 3: Begin loading the sample. Record the load and deformation dial readings at the given intervals up to 15% strain or when the load values begin decreasing.

Step 4: When the test is complete, record a moisture content on the middle third of the sample. The dry density will be back calculated based on the wet density and moisture content.

CALCULATIONS

1) Axial Strain

$$\varepsilon_1 = \frac{\Delta L}{L_0}$$ Where,

ΔL = length change of specimen
L_0 = initial length of specimen

2) Average cross-section area for given load

$$A = \frac{A_0}{(1-\varepsilon_1)}$$ Where,

A_0 = initaial average cross-section area

3) Compressive Stress

$$\sigma_C = \frac{P}{A}$$ Where,

P = given applied load

TEST DESCRIPTION
To determine the California Bearing Ratio (CBR) value of base course and subgrade soils. This is done in order to determine the suitability of the soils for structural support, mainly for roadways and pavement systems.

APPLICABLE FORMS:

- DCP Field Form

EQUIPMENT:

- DCP Case (including): DCP (hammer, top rod & handle, bottom rod & anvil, scale, tips, etc.)
- Shovel
- Hand Auger
- Bucket Auger
- Sample Jars

PROCEDURE: (Two person procedure)

Step 1. Assemble the DCP by sliding the hammer onto the top rod with the large diameter portion of the hammer near the handle. Next, thread the top rod into the anvil portion of the bottom rod. Tighten the two (2) set screws located in the handle and anvil. Apply Lock-Tite to the threads of the reusable tip or the disposable tip adapter and thread into the end of the bottom rod. Tighten the tip or adapter with the channel locks. If disposable tips are being used, push a disposable tip onto the adapter till snug. Disposable tips should be used when sand, silt or gravelly soils are being tested, and the reusable tip should be used for clay or organic soils.

Step 2. Hold the DCP in a vertical position and place it in the location to be tested. Let the hammer rest on top of the anvil, but do not drop the hammer yet.

Step 3. Place the scale on the ground next to the DCP with the numbers increasing downward. Record the initial position of the bottom of the anvil, in millimeters, in column 2 (Accumulative Penetration) adjacent to the “0” reading in column 1 (No. of Blows) of the DCP field form.

Step 4. While holding the DCP steady and perpendicular to the ground, slide the hammer to the top of the rod until it touches the handle. DO NOT STRIKE THE HANDLE FORCEFULLY. Hold the hammer against the handle, and then let the hammer free-fall to the anvil. Be sure to keep the DCP perpendicular at all times.

Step 5. Record the new position of the anvil and the number of blows (hammer drops) incurred since the previous reading. It is recommended that readings be taken for every 10 mm of penetration, however, it is usually easier to take a scale reading after a set number of blows. This means that the DCP operators must qualitatively observe the DCP penetration rate and adjust the number of blows incurred between readings accordingly.

Step 6. Continue steps 4 & 5 until the anvil surpasses the 1000mm mark.*****

***** Discontinue the DCP test if the DCP departs from perpendicularity or if the penetration rate becomes less than 3mm/blow. At 3mm per blow the CBR value is approximately 100. Attempting to penetrate soils with higher CBR values can and have bent the DCP.

Step 7. Remove the DCP by forcefully striking the handle with the hammer. BE CAREFUL TO KEEP THE DCP PERPENDICULAR WHILE DOING THIS.

SAFETY PRECAUTIONS

- Keep your hands away from anvil when performing test. Serious injury can occur.
- Also when moving the DCP, hold the weight so it will not slid into your hands

TEST DESCRIPTION

This procedure is used to gain a representative sample from a field stockpile of material for laboratory testing.

APPLICABLE STANDARDS:
ASTM D 75-03 – Standard Practice for Sampling Aggregates
ASTM D 3665-02 – Standard Practice for Random Sampling of Construction Materials

APPLICABLE FORMS:

1. Project Soil Summary Sheet - This sheet lists all the prior samples obtained for a project along with the tests performed. The forms for on-going testing projects are listed alphabetically in the files in the lab. If it is the first visit to a project, check with the project manager. A new form may have to be filled out in the field. It is imperative that this form be with the technician in the field to avoid repeating sample numbers.

EQUIPMENT REQUIRED:

1. Shovel
2. Sample Bags/Bucket
3. Sample Tag
4. Belt template and Brush for belt samples

PROCEDURE:

Determine the necessary sample size based on the type of aggregate. Clay for proctor tests shall be a minimum sample size of 25 lbs. A full 5 gallon bucket is preferable.

Fine Aggregate

Maximum Specified Sieve Size	Minimum Sample Size (lb.)
#8	25
#4	25

Coarse Aggregate

Maximum Specified Sieve Size	Minimum Sample Size (lb.)
3/8”	25
1/2”	35
3/4”	55
1”	110
1 1/2”	165
2”	220
2 1/2”	275
3”	330
3 1/2”	385

CHOOSING A LOCATION:
Materials to be sampled are often not homogeneous. It is important to understand how material segregates and to study the material on-site prior to taking the sample in order to obtain as representative a sample as possible. Things to look out for:

- Water erodes material, carrying smaller particles downhill.
- Gravity carries larger particles downhill, so the outside bottom of a stockpile will typically be coarser than the inside.

NON-RANDOM SAMPLING:
If true random sampling is not specifically required, the sample locations shall be taken based on the person's judgment in an effort to obtain a representative sample.

RANDOM SAMPLING:
The determination of random locations and/or times at which samples of construction materials may be required, especially on government QA/QC projects. This is done in order to eliminate any intentional or minimize any unintentional bias from the person taking the sample.

Sampling from a belt or flowing stream of material:
Step 1: Determine the length of time needed in minutes for the lot of material to pass by the sampling point. Call this number "t."
Step 2: Determine the number of samples to be taken from the lot. Call this number "n."
Step 3. Using Table 1 pick "n" numbers randomly as follows.

A. Point without looking to one number on one page (alternating pages).
B. Using the number pointed to in A above, use the first two digits to designate the row to be used in finding the sought after number.
C. Point to another number without looking and use the first digit to find the correct column of which to find the sought after number.
D. Using steps B and C find the intersection of the two numbers and use the intersection number as one of your random numbers.
E. Repeat steps A through D "n" times.

Step 4: Decimals and any numbers over "t" should be discarded and another chosen.
Step 5: Arrange the numbers chosen in chronological order and proceed to take samples at these times.

Sampling from a windrow of material.
Step 1. Determine the total length of one windrow in feet or meters of the lot of which samples need to be taken.
Step 2. Determine the number of samples "n" to be taken from the windrow.
Step 3. Using Table 1 pick "n" numbers randomly as in steps A through F above.
Step 4. Multiply the numbers chosen by the total length of the windrow found in step 1 and round to the nearest foot or meter. These numbers indicate the distance from the beginning of the windrow of which to sample.

Sampling in-place paving material.
Step 1. Determine the length "l" of one pavement representing a lot of material
Step 2. Determine the width of pavement "w."
Step 3. Determine the number of samples needed for each lot "n."
Step 4. Using Table 1 choose two sets of "n" numbers using steps A through F above.

Step 5. Multiply the numbers chosen by the total length "l" of the pavement to determine the distance from the beginning of the pavement of which a sample should be taken.

Step 6. Multiply the numbers chosen by the total width "w" of the pavement to determine the distance from the edge of the pavement.

Sampling from a loaded truck.

Step 1. Determine the number of truckloads that represent the lot of material to be sampled.

Step 2. Determine the number of samples "n" to be taken.

Step 3. Using Table 1 pick "n" numbers using steps A through F above.

Step 4. Multiply the random numbers chosen by the number of trucks in the lot.

Step 5. Determine the quadrant in each truck by choosing "n" numbers from Table 1 and multiplying by 4. (Quadrant locations are shown below.) All numbers should of course be rounded to the nearest whole number.

SAMPLING PROCEDURES

STOCKPILE SAMPLING:

For sites where there is machinery and working faces available (where material is actively being removed for construction use) the following shall apply:

1. The working face of the stockpile should be sampled using excavating equipment by removing three buckets full of material from the quarter points of the working face and placing them in separate piles on the ground.
2. Flatten the piles using the equipment in a back dragging motion.
3. Obtain the previously determined amount of sample by retrieving material from 1 to 3 separate locations on each pile. When sampling coarse aggregate, it is usually necessary to fill more than one sample container.

If no equipment is available, gather a representative sample from the stockpile in 3 different locations. This should be done by removing the outer surface of the stockpile at each location prior to taking the sample, as the outside is often segregated or altered by weather. A board or other device may be necessary to prevent stones from rolling into the sample from above the sample location. Refer to the WISDOT AGGTECH 1PP MANUAL for further information.

WINDROW SAMPLING:

1. Have the grading equipment on-site form a windrow (a long narrow pile 1' to 2' high).
2. With a flat shovel, scrape the outer surface of the windrow to remove segregated particles.
3. Pass the shovel completely through the windrow, taking a full cross section of material.
4. Do this in three locations to make a composite sample.

BELT SAMPLING:

1. Have the production facility stop the belt.
2. Using a template or a scoop, isolate a section of material on the belt large enough for a sample.
3. Completely remove the sample from the belt, including using a brush to get all the fines.

PRODUCTION SAMPLING: (for a stream of moving aggregates, where there is safe access to falling material at the end of a belt.

1. Using a suitable container such as a bucket or a catcher with a strong handle, pass the container completely through the stream of falling material.
2. Empty the material into the transport container.
3. Repeat steps 1 and 2 until the desired quantity is obtained.

AS PLACED SAMPLING: (for material already placed in a subgrade, road base, trench, etc)
1. Dig a hole, clearly defining the borders of the hole using a circular template or the shovel. Be sure to completely remove all the material from the hole, including the fines at the bottom. In the case of base course material, the hole shall extend to the subgrade material.
2. Do this in 3 locations, and form a composite sample.

SAFETY PRECAUTIONS:
- When obtaining a sample from a gravel pit, always wear a hard hat.
- Be very cautious when sampling from aggregate stockpiles. The slopes on these piles are often very steep, and the side of a stockpile may slide at any time.
- Be cautious while driving in gravel pits. There are usually numerous pieces of heavy machinery and trucks operating in pits.

TEST DESCRIPTION

This procedure is done in order to accurately reduce a large sample into a representative portion that can be accurately tested in a shorter amount of time compared to testing the entire sample.

APPLICABLE STANDARDS:

- ASTM C702-98 (AASHTO T 248) – Standard Practice for Reducing Samples of Aggregates to Testing Size

EQUIPMENT:

- Original Sample Container-bucket or bag
- Additional pans or containers
- Flat Shovel or Flat Scoop
- Broom or brush
- Mechanical splitter with two receptacles and hopper

SAMPLE PREPARATION:

For Cohesive soils (clay) sample must be prepared as follows; for others, go directly to Procedure

Step 1: Place the sample on a hard, clean, level surface. The concrete floor of the lab, out of the way of traffic, works well.
Step 2: Spread out the sample and break it up using a shovel. Dry the sample using a fan until the pieces are brittle enough to pulverize.
Step 3: Pulverize the pieces using foot action or mechanical means until the whole sample will pass through a #4 sieve.
Step 4: Split the sample as noted below.

PROCEDURE: Quartering Method

Step 1: Place the sample on a hard, clean, level surface. Leave enough room around the area to allow splitting without loss of material or addition of other foreign materials.
Step 2: Place the entire sample in the middle of the area.
Step 3: Thoroughly mix the material by turning the entire sample over three times using the scoop or shovel.
Step 4: With the final turn, shape the sample into a conical pile.
Step 5: Flatten the pile to a uniform thickness and diameter.
Step 6: Divide the flattened mass into four quarters using the flat edge of the scoop or shovel, separating each quarter distinctly.
Step 7: Remove two opposing quarters completely, using a brush to recover all the fine material. Place these quarters in the original container with the sample tag.
Step 8: Remix remaining sample, and repeat steps 4-7 until the desired size is attained.

PROCEDURE: Mechanical Splitter

Step 1: Determine if large or small splitter should be used depending on the size of the largest aggregate. Do not use a mechanical splitter if largest size aggregate is over 1 ½”.

Step 2: Place the sample in the hopper or pan and uniformly distribute it from edge to edge, so that when introduced to the chutes it will distribute uniformly.

Step 3: Introduce the sample at a rate so as to allow free flowing through the chutes into the receptacles below.

Step 4: Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test.

Step 5: Reserve the portion of material collected in the other receptacle for reduction in size for other tests, when required.

SAFETY PRECAUTIONS:

- Use proper lifting techniques when lifting heavy buckets of soil

TEST DESCRIPTION

A Standard Proctor test is completed in conjunction with a dry density test to determine the suitability of fill material on site or used for preliminary site information. The test is completed by compacting a soil sample in a mold of known volume at varying degrees of moisture content. By completing this test, a "compaction curve" will be generated showing dry densities achieved at varying moisture contents. The apex of this curve is known as the optimum moisture content and maximum dry density of the soil.

APPLICABLE STANDARDS:

- ASTM D D698-00a (AASHTO T 99) - Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort
- ASTM D 2216 (AASHTO T 265) - Test Method for Laboratory Determination of Water Content of Soil and Rock
- ASTM D 4718 - Practice for Correction of Unit Weight and Water Content of Soils Containing Oversized Particles

APPLICABLE FORMS:

- Proctor Worksheet

EQUIPMENT:

- 4" or 6" cylindrical mold
- Metal straightedge
- 5.5 lbf. proctor hammer
- 3/4", 3/8", #4 sieves rocker sieves
- Drying oven or stove
- Balance
- Sample bowls
- Mixing equipment (spatula, spoon)
- Water Bottle
- Sample extruder

PROCEDURE:

Step 1: Perform a sieve analysis on a representative sample of approximately 20 pounds of the material (or enough to perform the proctor test) using the rocker sieve set. Determine the individual weight retained on the, ¾", 3/8", and #4 sieves. Record these weights in the gravel content area of the proctor worksheet.

Step 2: Determine which proctor procedure to use (A, B or C) depending on the percentage of gravel retained on each of the sieves

- Procedure A: 20% or less by weight retained on the #4 sieve
- Procedure B: 20% or more by weight retained on the #4 sieve and 20% or less retained on the 3/8"sieve
- Procedure C: 20% or more by weight retained on the 3/8" sieve and 30% or less retained on the 3/4"sieve. If more than 30% by weight is retained on the ¾", sieve see ASTM D 4718 for corrections.

Step 3: When you have determined which proctor to run (A, B, or C) it is necessary to discard a certain portion of the sample before preparing the sample for the test.

- Procedure A: Your sample for testing will contain only material that passed the #4 sieve.
- Procedure B: Your sample for testing will contain only material that passed the 3/8" sieve.
- Procedure C: Discard the ¾" material. Your sample will contain only material that passed the ¾" sieve.

Step 4: If the material is an A or B proctor, split the testable material into 3 sections weighing no less than 6 pounds each. If it is a (C) proctor, split the testable material into 3 sections, each weighing no less than 14 lbs.

Step 5: Determine if your sample is wet or dry of optimum. Until experience in this test is established, have an engineer or senior technician set up your moisture points for you. Ask the engineer what he/she is looking for when determining the right amount of moisture.

Step 6: Prepare your proctor sample at three different moisture levels that are 2% apart. Your first sample or point should be approximately 2% dry of optimum. The second point should be at optimum and your third should be over optimum. Assuming your first point is 2% dryer than optimum you add water to your second point. The third point moisture content should be 4% higher than the first point. The 3 points should be covered with a plastic bag and left for at least 16 hours to allow for even distribution of water throughout the sample if time allows.

Step 7: Assemble the proctor mold* that you will be using. If the proctor is an (A) or (B), assemble a 4" mold. If it is a (C), assemble a 6" mold. Weigh this assembly (without the upper collar) and record the weight on the proctor worksheet (lbs.). Also record the mold number and the mold volume. The volume of the mold is located on the proctor worksheet.

Step 8: Starting with the first or driest point, fill the mold assembly, with the collar on, approximately 1/3 full. Before compacting, level the layer of soil and lightly tamp it to eliminate the fluffiness. Using the 5.5 LB hammer, compact the layer with 25 blows for an (A) or (B) proctor, and 56 blows for a (C) proctor. When dropping the hammer, the hammer should drop the full 12 inches. After compacting the first layer, repeat the process 2 more times. Your third and final layer, the material should extend approximately ¼" over the top of the mold so that when the collar is removed there is material to strike off even with the top of the mold.

Step 9: Take the collar off and use a beveled bar to scrape the material flush with the top of the mold. Make sure to get a smooth and even surface. Remove excess soil from the exterior of the mold. Weigh and record the soil and the mold in pounds on the proctor worksheet under section (a)*.

Step 10: If the sample is clay, extract the specimen from the mold by using the hand jack. If the sample is a sand or gravel hold the mold and tap the sides with a hammer.

Step 11: Take the middle portion of the extruded sample and test for moisture content using at least 500 grams of soil.

Step 12: Repeat the process on the next 2 points of the proctor. The next point can be started while the previous point is drying.

Step 13: The weight of the last proctor point should be equal to or less than the previous point. At this point you will know the moisture content has passed the optimum moisture. If the weights are still rising, you should prepare and compact another point.

Step 14: Once the worksheet is completed, enter the data in the computer program.

CALCULATIONS

1) Moist density

$$\rho_m = \frac{(M_t - M_m)}{1000 \times V}$$ Where,

M_t = mass of moist specimen and mold
M_m = mass of mold
V = volume of mold

2) Dry Density

$$\rho_D = \frac{\rho_m}{1 + \frac{w}{100}}$$ Where,

w = water content, %

3) Dry Unit Weight

$$\gamma_D = 62.43\rho_D$$

SAFETY PRECAUTIONS:

- While drying the samples, always wear hot/hazardous substance gloves when handling sample bowls on the open-flame burner or in the oven.

- Be very careful to move your hand away from the top of the hammer when it is falling.

TEST DESCRIPTION

This test is completed in the field to test the compaction of engineered fill by testing the dry density and moisture content of the soil. These values are then compared to the maximum dry density and optimum moisture content as determined by the standard or modified proctor test to determine the % compaction of the material.

APPLICABLE STANDARDS:

- ASTM D2922 (AASHTO T 238) -Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

APPLICABLE FORMS:

- Field Nuclear Density Worksheet
- Report Template for Moisture-Density Relationship of Soil (Proctor)

EQUIPMENT:

- Nuclear Density/Moisture gauge (Troxler 3440 or 3430) with accompanying documentation (Bill of Lading, Emergency Procedures, NRC License, and Latest Leak Test Data).
- Troxler Case Should Have: an operations manual, drill rod, scraper plate, the gauge itself, emergency battery pack, extraction tool, standard count log, standard count block, and a 4-lb sledge hammer.
- Tape Measure
- Calculator
- Hand Level
- Gloves
- Hard Hat
- Radiation Dosimeter

PROCEDURE:

Transportation

Step 1: Inspect nuclear density/moisture gauge and verify that all listed equipment above is in the nuclear case itself. Turn on the gauge to make sure it is operational. Secure the gauge in the back of the truck with supplied cable and lock.

Step 2: Sign out the gauge on the “Nuclear Gauge Utilization Log”

Step 3: Make sure Bill of Lading Packet is in cab of truck while driving

Standard Count

Step 1: After arriving at the site, remove the gauge from the case and find an area at least 15 ft. away from any large pieces of metal (including the truck) or other large objects. Remove the safety lock from the handle of the gauge.

Step 2: Set the base of the nuclear gauge securely on the ridged side of the white standard count block. Place the gauge so that the end farthest from the rod/handle is resting firmly against the raised metal flange on the block.

Step 3: Turn on the nuclear gauge

Step 4: Wait until the internal diagnostic test is complete

Step 5: After it is warmed up, press STD.CNT. button

Step 6: Display should read New Standard Count? Press ON/YES button.

Step 7: Step 3 ft. away from gauge while standard count is being performed. After the standard count is completed, record the density and moisture counts in the gauge logbook or standard count log. Compare these values to the average of the previous four tests. The new density and moisture counts should not be more than 1% and 2%, respectively from the average of the last 4 standard counts.

Step 8: If the standard count is out of the above tolerances, additional standard counts should be completed in order to establish a new average. Do this a maximum of 4 times. If still out of tolerance, the gauge is in need of repair and should be returned to the laboratory immediately. Contact an engineer or lab manager to make the necessary arrangements.

Site Preparation

Step 1: For the Troxler Gauge, the drill rod, extraction tool, scraper plate, gauge, in place nuclear density form, sledge hammer, and gloves will be used. If the test area is within 2 feet of a wall or in a trench, the white standard count block will be needed as well.

Step 2: Place the preparation plate on the testing surface. Put the stake through the hole of the stake handle, and place the tip of the stake through the elevated hole on the preparation plate. Keeping the plate in place, pound in the stake to a depth of approximately 12 inches and remove the stake.

Step 3: Outline the edge of the preparation plate

Test Procedure

Step 1: Line up the edge of the gauge bottom with the outlined edge of the preparation plate and lower the rod into the hole. Pull trigger on handle and push the rod into the hole. If feeling resistance, move the gauge around until the rod goes in.

Step 2: Verify that the time, depth, and density are correctly input into the gauge (See operations manual for procedure). A one-minute test is considered standard.

Step 3: Move the gauge toward the testing surface to bring the rod into intimate contact with the sides of the hole. Press start and move 3ft. away.

Step 4: After test completion, pull the rod up into the safe position and record the test results.

SAFETY PRECAUTIONS:

- Always wear your own radiation dosimetry badge when working with a nuclear gauge.
- Maintain a minimum distance of 3' from the nuclear gauge while performing a test. The maximum distance is 6'.
- Return the gauge rod to the safe mode immediately after performing a test.
- Never expose the gauge source while the gauge is not on the soil or asphalt that is to be tested. A common mistake made is the practice of exposing the source in order to guide the source into the test hole. This is unsafe, and should not be done at any time.
- Refer to the nuclear gauge manuals for other specific safety precautions.

TEST DESCRIPTION

This test is completed to determine the percent passing the #200 sieve which is also referred to as the "fine" content of soil or aggregate. This is done by running water over the soil and pouring the dirty water over a #200 sieve. After the water is clean, you're done.

APPLICABLE STANDARDS:

- ASTM D 75 – Practice for Sampling Aggregates
- ASTM C 117-95 (AASHTO T 11) – Standard Test Method for Materials Finer than 75-µm (#200 sieve) in Mineral Aggregates by Washing
- ASTM C 702 (AASHTO T 248) – Practice for Reducing Field Samples of Aggregate to Testing Size

APPLICABLE FORMS:

- Percent Passing #200 Sieve Wash Form

EQUIPMENT:

- Balance accurate to 0.1 grams
- Sieves #200 & #16 (ASTM) or # 8 (AASHTO)
- Pan large enough for the sample to be covered by water
- Oven: 230° +/- 9° F.
- Bulb syringe
- Water

PROCEDURE:

Step 1. Obtain a field sample of fine aggregate according to ASTM D 75.

Step 2. Obtain a laboratory sample in accordance with ASTM C-702 (AASHTO T 248). The minimum mass when dry shall be determined as follows:

Nominal Maximum Size	Minimum Mass (g).
#8	100
#4	500
3/8"	1000
3/4"	2500
1-1/2" or Larger	5000

Step 3. Dry the sample to a constant mass and record.

Step 4. Place the sample in the pan and cover with water.

Step 5. Agitate the sample to thoroughly mix the sample and water.

Step 6. Immediately pour the wash water through the sieves taking care not to lose any sample.

Step 7. Cover the sample again with water and repeat agitation and sieving.

Step 8. Repeat the process until the wash water is clear.

Step 9. Wash the material on the sieves back into the sample pan using a water bottle.

Step 10. Using a bulb syringe; draw the excess water from the pan, being careful not to draw any soil particles into the syringe.

Step 11. Place the sample in the oven, and dry it to a constant mass.

Step 12. Weigh the dry sample and record the mass.

Calculations:

-Amount of material passing the #200 Sieve

$$C=[(A-B)/A]*100$$

A= Original mass of dry sample (g).
B= Mass of dry sample after washing (g).
C= % Passing the #200

-Report the % of material passing the #200 sieve to the nearest 0.1% except if the result is 10% or more, in this case report it to the nearest 1%.

TEST DESCRIPTION
This test is used to determine the bulk specific gravity to use in calculation of volume occupied by the aggregate in different mixtures. Determine the change in weight of aggregate due to the presence of water in the pore spaces.

APPLICABLE STANDARDS:

- ASTM D 75 – Practice for Sampling Aggregates
- ASTM C 702 (AASHTO T 248) – Practice for Reducing Field Samples of Aggregate to Testing Size
- ASTM C 136 (AASHTO T 27) – Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM C 127-01 (AASHTO T 85) – Standard Test Method for Specific Gravity and Absorption of Coarse Aggregates

APPLICABLE FORMS:

- Concrete Aggregate Tests Form

EQUIPMENT:

- Balance
- Water tank below scale
- Sample basket suspended from the scale in the water tank
- Sample pans

PROCEDURE:

Step 1: Obtain a sample of coarse aggregate.

Step 2: Split the sample using either the splitter method or quartering method outlined in the gradation procedure. Reduce it to the appropriate test sample size as described below, and place it in a large sample pan.

Nominal Max. Size (in.)	Minimum Weight of Test Sample, kg (lb.)
1/2 or less	2 (4.4)
3/4	3 (6.6)
1	4 (8.8)
1 1/2	5 (11)
2	8 (18)

Step 3: Dry the test sample to a constant weight in the oven (already pre-heated to a temperature of 230 +/- 9 degrees F).

Step 4: Remove the sample and cool it to room temperature for 1 to 3 hours (longer for test samples of 2” nominal maximum size or larger). The sample should be cool enough that it is comfortable to handle. Record the oven dry weight (A).

Step 5: Immerse the sample in water at room temperature for 24 +/- 4 hours. Make sure that all particles are completely covered.

Step 6: Once the 24 +/- 4 hours have passed, drain all of the water that is possible from the sample pan, without losing any of the aggregate particles.

Step 7: Lay a bath towel out on a clean spot on the concrete floor, and place the sample onto the towel.

Step 8: Roll the sample around in the bath towel, and use another towel to pat-dry the sample. Dry it to a saturated surface-dry condition. (All visible films of water should be removed from the surface).

Step 9: Immediately place the sample back into the sample pan. Make sure that you get all of the particles back into the pan by shaking the towel into the pan.

Step 10: Weigh the test sample, and record the weight as the saturated surface-dry weight (B).

Step 11: Return the sample into the wire basket, and suspend the basket from the scale into the water tank. Record this as the weight in water (C) (make sure to tare the scale with the basket hanging in the water.

Step 12: Dry the test sample to a constant mass at a temperature of 230^{0}F, cool in air at room temperature, and record the mass to check with initial dry mass.

CALCULATIONS

Specific Gravity Calculations:

Specific Gravity (oven dry) : SG_{OD}

$SG_{OD} = \frac{A}{(B-C)}$ Where; *Report to the nearest 0.01 grams.

A=oven dry weight
B=Saturated surface-dry weight
C=Saturated weight in water

Bulk Specific Gravity (sat. surface dry) : SG_{SSD}

$SG_{SSD} = \frac{B}{(B-C)}$ *Report to the nearest 0.01 grams.

Absorption Calculation:

Percent Absorption : a%

$\% = \frac{B-A}{A} \times 100$ *Report to the nearest 0.1%.

TEST DESCRIPTION

The California Bearing Ratio, CBR test is used to evaluate the potential strength of subgrade, subbase and base course material for use in road and airfield pavements. This test performed on three samples prepared from three different compactive efforts at one water content. Each sample is subjected to penetration by a cylindrical road after soaking in water. Results of stress (Load) vs depth of penetration are plotted to determine the CBR.

APPLICABLE STANDARDS

- ASTM D 1883-99 (AASHTO T 193) - Test Method CBR (California Bearing Ratio) of Laboratory Compacted Soils.
- ASTM D 422 (AASHTO T 88) - Test Method for Particle-Size Analysis of Soils
- ASTM D 698 (AASHTO T 99) - Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.
- ASTM D 1557 (AASHTO T 180) - Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort.
- ASTM D 2168 - Test Methods for Calibration of Laboratory Mechanical- Rammer Soil Compactors.
- ASTM D 2216 (AASHTO T 265) - Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock.
- ASTM D 4318 (AASHTO T 89 & T 90) - Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils.

EQUIPMENT:

- Loading Machine - the S5830 Multiloader in the lab
- Molds (3 nos.) with perforated base plate and extension collars (inside diameter of 6 +/-0.026 ins. and height of 7+/- 0.018 ins. without collar), extension collar height is 2 ins.
- Spacer Disk - minimum outside diameter of 5 - 15/16 inch
- Rammer - As specified in either standard (D698) or modified (D1557)
- Expansion measuring Apparatus - perforated plate and metal tripod stand
- Weights – Annular metal weights 5 lbs, usually two per mold
- Penetration Piston with attached proving ring
- Gages - 2 deformation dials
- Miscellaneous Equipment - soaking tank, scale, oven, bowls, straightedge, filter paper, sieves

SAMPLE PREPARATION

Step 1 :Prior to performing a CBR test, a modified or Standard proctor, as per project specification should be performed for the material.

Step 2 : Pass the samples through ¾ inch. Take about 13 lb of samples for each specimen (mold).

Step 3 :Prepare the three test specimen at different densities, two methods can be used to compact the samples in the mold.

a. Preparation of three specimens at the same water content with different efforts. If the CBR at 95% compaction is desired, it is typical to have one mold compacted with 10 blows per layer, a second mold with 25 blows per layer, and a third with 56 blows per layer. If a density is specified at or near 100%, it maybe necessary to include a compactive effort greater than 56 blows per layer. All the specimens should be all prepared at the same moisture content, typically within 0.5% of the optimum moisture content. To ensure that they are all at the same moisture, mix the material for all three molds at once and then split them. Clay samples should be allowed to set up over night. Make sure to cover the samples to prevent the loss of moisture.

a. Preparation of specimens at different moisture contents and then compacting each sample with the same effort. The moisture contents will most likely be specified and will be a certain percentage away from optimum. It is recommended by ASTM that each moisture contents have points at 10, 25, and 56 blows per layer.

COMPACTING SAMPLES

Step 1: Take a portion of sample for moisture content determination, if the sample is to be soaked after it is compacted. If it not soaked, take the moisture content in a similar manner as proctor points.

Step 2: Follow the same basic procedure for each mold or point of the test,. Weigh the mold (lb) without the spacer disk, extension collar, or base plate. Record this on the CBR Data sheet.

Step 3: Clamp the mold and extension collar to the perforated base plate with the spacer disk in place at the bottom of the mold. Place a piece of filter paper on top of the spacer disk. Compact the samples in the specified number of lifts and effort. This is performed in the same manner as compacting a proctor (described in Laboratory Test procedure, Soil-06 or Soil–12).

Step 4: After the material is compacted, remove the extension collar and level the upper surface, fill the voids (if any)

Step 5: Remove the base plate and spacer disk. Weigh the mold with compacted sample and record it on the data sheet. Place another piece of filter paper in the center of the base plate, and set the upper surface of the compacted soil on the filter paper. Secure the mold and extension collar to the base plate.

Step 6: Place the perforated plate and stem in the mold and check to see if the deformation dial end will be touching the top of the stem when it is in place. Make sure the stem is secure. Mark the location where the stands for the deformation dial will sit; this will ensure the stand and dial to the same spot for each reading.

Step 7: Remove the perforated plate and stem. Add the specified amount of surcharge weight (10 lb.) and carefully lower the weight and perforated plate back into the mold. Take the mold and the surcharge and place it in the soaking tank. The mold should be sitting level and water should be able to freely enter the upper and lower portions of the mold.

Step 8: Record the starting time of soaking, the date, and the surcharge load. Take the initial deformation dial reading. Suggested times for Expansion readings are 0, 1, 2, 4, 8, 12, 24, 36, 48, 72, and 96 hours. The soaking can be stopped at 96 hours or when the readings indicate that the expansion has stopped.

Step 9: Repeat this process for each point for the CBR.

LOADING THE SPECIMEN

Step 1: Place the proving ring for the CBR test on the loading machine and adjust the setup so the penetration piston and attached deformation dial can be set for the test. The penetration piston will be set directly on the soil, and the deformation dial will rest on the edge of the mold.

Step 2: Adjust the specified loading rate to 0.05 in/min.

Step 3: Remove the specimen from the soaking tank when it has been determined to be complete. Allow the specimen to drain for 15 minutes. It may be necessary to tip the specimen to remove any surface water, be careful not to disturb the surface during this process.

Step 4: After 15 minutes, remove the weights, perforated plate, and filter paper and weigh the mold. Place the weights (without the perforated plate) on the top of the sample.

Step 5: Place the mold on the loading machine and seat the penetration piston on the surface of the soil with the lowest possible load in no case exceeding 10 lb. Reset the deformation dial to 0 and secure the deformation dial and reset it to 0.

Step 6: Begin loading the sample and record the load readings at penetrations of 0.025, 0.05, 0.075, 0.1, 0.125, 0.15, 0.175, 0.2, 0.3, 0.4, and 0.5 in. If the maximum load occurs at a penetration less than 0.5 inch record it on the lab form. When the test is complete, measure the indentation left to see if it is close to the deformation dial reading.

Step 7: Determine the moisture content from the top 1”, the middle, and bottom 1” of the sample.

CALCULATIONS

1. The calculations can be completed using an Excel spreadsheet located under: CBR-optimum moisture.xls. (Note: It is advisable before entering the data, copy the file to the proper project directory, this will prevent the original from being lost).

2. Enter the proper information in appropriate boxes.

TEST DESCRIPTION

This test is done to determine the unit weight in a compacted or loose condition and calculated voids in fine, coarse, or mixed aggregates based on the same determination. This test is applicable to aggregates not exceeding 6 in. in nominal maximum size.

APPLICABLE STANDARDS:

- ASTM C 29/ C 29M- 97 (AASHTO T 19) – Standard Test Method for Unit Weight and Voids in Aggregate
- ASTM C127 (AASHTO T 85) – Test Method for Specific Gravity and Absorption of Coarse Aggregate.
- ASTM C128 (AASHTO T 84) – Test Method for Specific Gravity and Absorption of Fine Aggregate.
- ASTM D 75 – Practice for Sampling Aggregates
- ASTM C 702 (AASHTO T 248) – Practice for Reducing Samples of Aggregate to Testing Size

EQUIPMENT:

- A cylindrical metal measure- preferably with handle
- Tamping rod from concrete slump test set
- Balance/scale
- Shovel or Scoop

PROCEDURE:

Step 1: Obtain a sample of coarse aggregate (approximately a 5 gallon bucket full). Refer to standard practice for sampling Soil and Aggregate, GESTRA Soil-10.

Step 2: If the sample is not already dry, place it in the oven and dry it to a constant weight. Remove the sample from the oven and allow it to cool to room temperature.

Step 3. Take the weight of empty measure. Record this weight as **"T".** To determine which measure to use and which compaction procedure the following table shall be used.

Nominal Maximum Size of Aggregate (in)	Capacity of Measure ft^3	Compaction Procedure
½	1/10	Rodding
1 to 1 ½	1/2	Rodding
Larger than 1 ½	1 (unavailable)	Jigging

Rodding Procedure

Step 1. Fill one-third of the measure with aggregate. Rod the layer of aggregate 25 times with the tamping rod, do not strike the bottom of the measure.

Step 2. Fill two third of the measure and rod the layer 25 times with tamping rod. Do not penetrate to the previous layer.

Step 3. Fill the measure to over-flowing and again rod the layer 25 times with tamping rod. Do not penetrate to the previous layer.

Step 4. Level the surface with your fingers so that the particles projecting above the top surface of the measure approximately balance the voids in the surface below the top of the measure.

Step 5. Take the weight of measure filled with aggregate. Record this weight as **"G"**

Step 6. Record known volume of measure (**V**) determined during yearly calibration.

Jigging Procedure

Step 1. Fill one-third of the measure with aggregate. Raise the opposite sides alternately about 2 inches and allow the measure to drop. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side.

Step 2. Level the surface with your fingers so that the particles projecting above the top surface of the measure approximately balance the voids in the surface below the top of the measure.

Step 3. Take the weight of measure filled with aggregate. Record this weight as **"G"**

Step 4. Record known volume of measure (**V**) determined during yearly calibration.

CALCULATIONS

Dry Unit Weight

Measurements required:

Weight of measure (T)
Weight of measure and aggregate (G)
Volume of measure (V)

Dry unit weight (M)

$$M = \frac{G - T}{V}$$

Report to the nearest 1 lb/ft^3

Saturated Surface Dry Unit Weight

Measurements required:

Dry unit weight (M)
Percent Adsorption (A)
For procedure in determining percent adsorption follow the following standard:
C 127- Standard Test Method for Specific Gravity and Adsorption of Coarse Aggregate
C 128- Standard Test Method for Specific Gravity and Adsorption of Fine Aggregate

Saturated surface dry unit weight (M_{SSD})

$$M_{SSD} = M\left[1 + \frac{A}{100}\right]$$

Report to the nearest 1 lb/ft^3

Void Content Calculation:

Measurements required:

Dry unit weight (M)

Bulk specific gravity, Dry basis(S), determined in accordance with ASTM C 127 (AASHTO T 85) or ASTM C 128 (AASHTO T 84)

Void content (% Voids)

$$\%VOID = 100 \times \left[\frac{(S \times W) - M}{S \times W} \right]$$

Report to nearest 1%

Where,

W = Density of water, 62.3 lb/ft^3

Precision:

Single Operator

--Fine Aggregate -- 2.5 lb/ft^3

--Coarse Aggregate -- 2.5 lb/ft^3

Multiple Operators

--Fine Aggregate --7.8 lb/ft^3

--Coarse Aggregate -- 5.3 lb/ft^3

TEST DESCRIPTION
This test method is used to determine the density of the essentially solid portion of a large number of aggregate particles and provides and average value representing the sample.

APPLICABLE STANDARDS:

- ASTM D 75 – Practice for Sampling Aggregates
- ASTM C 702 (AASHTO T 248) – Practice for Reducing Field Samples of Aggregate to Testing Size
- ASTM C 136 (AASHTO T 27) – Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM C 128-01 (AASHTO T 84) – Standard Test Method for Density, Relative Density, and Absorption of Fine Aggregates

APPLICABLE FORMS:

- Specific Gravity Fine Aggregates

EQUIPMENT:

- Balance

Find following in drawer labeled "Fine Aggregate Testing Supplies"
- Pycnometer (Large Mason Jar with copper fitting)
- Mold (3" copper mold)
- Tamper (6" tamper)

PROCEDURE:

Step 1: Obtain a sample of aggregate.

Step 2: Split the sample using either the splitter method or quartering method outlined in the gradation procedure. Reduce it to the appropriate test sample size of approximately 1 kg passing the #4 sieve, and place it in a large sample pan.

Step 3: Dry the test sample to a constant weight in the oven (already pre-heated to a temperature of 230 +/- 9 degrees F). Remove the sample and cool it to room temperature for 1 to 3 hours (longer for test samples of 2" nominal maximum size or larger). The sample should be cool enough that it is comfortable to handle.

Step 4: Add approximately 100 grams of water cover, mix the sample, and cover with plastic wrap for 24 +/- 4 hours. Once the 24 +/- 4 hours have passed, drain all of the water that is possible from the sample pan, without losing any of the aggregate particles.

Step 5: Weigh Pycnometer dry (P). Weigh Pycnometer filled to its calibrated capacity with water (800 mL). (B)

Step 6: Place flat pan near heated fan, put sample in pan and stir frequently until sample reaches saturated surface dry. See step 7 to determine when at saturated surface dry level.

Step 7: Hold the mold firmly on glass plate with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling it to overflowing and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the aggregate into the mold with 25 light drops of the tamper. Start each drop approximately 5 mm above the top surface of the fine aggregate. Remove loose sand from base and lift the mold vertically. Slight slumping of the molded aggregate indicates that it has reached a surface-dry condition. If aggregate retains shape return to drying in step 7. If sample is too dry mix a few milliliters of water with the aggregate and restart the drying process.

Note: If sample compacts to quickly the following procedure may be used.
Alternate Step 7: Fill the mold as described above except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using 3 and 2 drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base; and lift the mold vertically. Slight slumping of the molded aggregate indicates that it has reached a surface-dry condition. If aggregate retains shape return to drying in step 7. If sample is too dry mix a few milliliters of water with the aggregate and restart the drying process.

Step 8: Partially fill the pycnometer with distilled water. Introduce into the pycnometer 500 g of surface-dry material. Weigh actual SSD sample used (S). Fill with additional distilled water to approximately 600 mL mark. Agitate the pycnometer by rolling, inverting and agitating to eliminate the air bubbles. (This can take 15 to 20 minutes) Add water to 800 mL mark.

Step 9: Weigh the pycnometer with soil and water when air bubbles are removed (A). Remove the aggregate from pycnometer and dry to constant weight (temperature 230).

Step 10: Remove sample from oven cool in air at room temperature. Record oven dry weight (E).

CALCULATIONS

Specific Gravity Calculations:

Specific Gravity (oven dry) : SG_{OD}

$$SG_{OD} = \frac{A}{(B+S-C)}$$ Where; *Report to the nearest 0.01 grams.

A=oven dry weight
B=Mass Pycnometer + water
C=Mass Pycnometer + water + sample
S=Mass surface dry sample

Bulk Specific Gravity (sat. surface dry) : SG_{SSD}

$$SG_{SSD} = \frac{S}{(B+S-C)}$$ *Report to the nearest 0.01 grams.

Apparent Specific Gravity : SG_A

$$SG_A = \frac{A}{(A+B-C)}$$

Absorption Calculation:

Percent Absorption : a%

$$\% = \frac{S-A}{A} \times 100$$

*Report to the nearest 0.1%.

Masud Alam, Ph.D., P.E.

PRINCIPAL ENGINEER

Education

- Ph.D. in Civil Engineering, Oklahoma State University, July 1993
- M.S. in Construction Eng. & Project Management, Oklahoma State University, Dec. 1989
- B.S. in Civil Engineering, BUET, Bangladesh, August 1984

Areas of Expertise

Geotechnical Exploration and Analysis
Shallow and Deep Foundation
Soil Improvement
Soil Retention Systems
Slope Stability Analysis
Flexible and Rigid Pavement

Selected Project Experience

- STH 11 Bypass (Burlington, WI)- Geotechnical Engineering
- Soil improvement work design, preloading with prefabricated vertical drain, for Butterfield Road Improvement project, Libertyville, IL
- Lake Andrea Shoreline Protection design, Pleasant Prairie, WI
- Tobin Creek Embankment Stability Restoration, Pleasant Prairie, WI
- Performed vibro-replacement and vacuum consolidation design and construction.
- Geotechnical Engineering for Power Plant Addition – Pleasant Prairie, WI
- Sub-surface drainage design for the 40,000 sq. m. podium (20 m. below existing ground surface) for the Kuala Lumpur City Center, currently the tallest building in the world.
- Managed the detail design of a 16km-six lane expressway in Kuala Lumpur, Malaysia
- Designed foundation for an eighty (80) story office building.

Employment

- Gestra Engineering, Inc. - Oak Creek, WI 2003-
  President – Principal Engineer
- KTE Consultants, Inc. – Kenosha, WI 1998-2002
  Vice President – Chief Engineer
- Gamuda Berhad – Petaling Jaya, Malaysia 1995-1998
  Manager (Design and Technical Services)
- Ranhill Barsekutu Sdn Bhd – Kuala Lumpur, Malaysia 1993-1995
  Senior Engineer
- AARK Construction Corporation – Spring Valley, New York 1990-1991
  Assistant Project Manager
- Roads and Highways Department- Bangladesh 1984-1988
  Assistant Engineer

Professional Registration

- Professional Engineer, Wisconsin, Illinois, Michigan

Razaul Haque

SENIOR ENGINEER

Education

- B. S. in Civil Engineering, BUET, Dhaka, Bangladesh, October 1993

Areas of Expertise

Geotechnical exploration and analysis
Shallow and Deep Foundation
Reinforced Earth Walls/ Fills
Soil Retention Systems
Slope Stability Analysis
Soil Improvement

Selected Project Experience

- Soil improvement work design, preloading with prefabricated vertical drain, for Butterfield Road Improvement project, Libertyville, Illinois
- Lake Andrea Shoreline Protection design, Pleasant Prairie, WI
- Tobin Creek Embankment Stability Restoration, Pleasant Prairie, WI
- Geotechnical Engineering for Power Plant Addition – Pleasant Prairie, WI
- STH 20 Sewer Interceptor Soil Study – Town of Mount Pleasant, WI
- Soil Investigation for the 6 Mile Road Overpass, Oak Creek, WI
- Geotechnical Engineering for the Wilson Road-Nippersink Road Intersection, Fox Lake, IL
- Wadsworth Road Widening, Wadsworth, IL

Employment

- Gestra Engineering, Inc. - Oak Creek, WI — 2003-
  Senior Engineer
- KTE Consultants, Inc. – Kenosha, WI — 2001-2003
  Staff Engineer
- Jurutera Perunding Zaaba Sdn Bhd (JPZ) – Dhaka, Bangladesh — 1998-2001
  Assistant Project Manager
- Ranhill Barsekutu Sdn Bhd – Kuala Lumpur, Malaysia (RBSB) — 1995-1998
  Assistant Geotechnical Engineer
- South Asia Traders (STA) — 1993-1995
  Assistant Engineer

Douglas Bath, P.E.
SENIOR ENGINEER

Education

- B.S. in Geological Engineering, University of Wisconsin, May 1993

Areas of Expertise

Geotechnical Exploration and Analysis	Stormwater Infiltration
Shallow and Deep Foundation	Slope Stability Analysis
Landslide Investigation and Analysis	Reinforced Earth Walls/Fills

Selected Project Experience

- Community Memorial Hospital expansion – Menomonee Falls, WI
- Kramer Lifestyle Redevelopment – Milwaukee, WI
- City of Milwaukee Shops earthwork monitoring – Milwaukee, WI
- Rail Expansion at Elm Road Power Plant – Racine and Milwaukee Counties, WI
- Highway 11 Burlington Bypass – Racine & Walworth Counties, WI
- WisDOT review of bridge structure replacement - Wisconsin
- Railroad siding projects for Canadian National – Wisconsin
- Oak Creek South Interceptor Sewer (MMSD) – Oak Creek, WI
- Underwood Creek Confluence (MMSD) – Wauwatosa, WI
- Facility upgrades for Koch Petroleum Terminal– Milwaukee, WI
- Phase II - Butterfield Road Improvement project - Libertyville, IL
- Construction monitoring for mass grading projects with over 20 ft. fill depths – WA
- Investigations with landslide analysis and slope stabilization - WA
- Slope stability analysis for high-end residential lots – Bellevue, WA
- Construction monitoring for 80 ft. high reinforced road embankment – Clallam Co., WA
- Stormwater infiltration and mounding analysis – North Bend, WA

Employment

- Gestra Engineering, Inc. - Oak Creek, WI — 2004-
  Senior Engineer/Office Manager
- Maxim Technologies, Inc. – Milwaukee, WI — 2003-2004
  Project Engineer/Office Manager
- Cornerstone Geotechnical – Woodinville, WA — 2000-2003
  Project Engineer
- Nelson-Couvrette & Associates, Woodinville, WA — 1993-2000
  Staff Engineer/Project Engineer

Professional Registration

- Professional Engineer, Wisconsin, Washington

John Davies

MANAGER, CONSTRUCTION MATERIALS

Areas of Expertise

Construction Material Field Testing
Client Relations
Project Management
Office Management

Selected Project Experience

- Menard's Store – Milwaukee, WI
- Elm Road Generating Station – Oak Creek, WI
- Kenosha Transit Garage – Kenosha, WI
- Canal Street Soil Correction – Milwaukee, WI
- Stadium Business Center – Milwaukee, WI
- 14 Story Cardiac Care Addition to St. Lukes Hospital – Milwaukee, WI
- McShane In-Line Storage Tank – Muskego, WI
- Exposition Hall and Ag Village at State Fair Park – West Allis, WI
- Foglia YMCA – Chicago, IL
- Ash Storage Facility at the Oak Creek Power Plant – Oak Creek, WI
- 8,400,000 gallon Underground Storage Tank – Racine, WI
- Sewer Separation Project – City of St. Paul, MN
- 50 Acre Dynamic Compaction project – Roseville, MN
- 32 Story Aflac Hotel – Minneapolis, MN
- 52 Story City Center – Minneapolis, MN

Employment

- Gestra Engineering, Inc. – Oak Creek, WI 2003 –
  Construction Materials/Business Development Manager
- KTE Consultants, Inc. – Kenosha, WI 1999 – 2003
  Construction Materials Testing (CMT) Manager
- Braun Intertec – St. Paul, MN 1988 – 1999
  Business Development Representative
- STS Consultants – Minneapolis, MN 1981 – 1988
  Senior Engineering Technician

Dean Carlson

MANAGER, DRILLING SERVICES

Areas of Expertise

Drilling Management	Project Management
Client Relations	Equipment Management
Geotechnical Drilling	Environmental Drilling

Selected Project Experience

- Elm Road Generating Station – Oak Creek, WI
- 15 Interceptor Structures, MMSD – Milwaukee, WI
- Port Washington Relief Sewer, MMSD – Milwaukee, WI
- Miller Park – Milwaukee, WI
- IMAX Theater – Milwaukee, WI
- Deep Tunnel Well Installations – Milwaukee, WI
- Sussex Industrial Park – Sussex, WI
- Otis Air Force Base, JP-4 Remediation wells– Cape Cod, MA
- Warwick Manufacturing, superfund site – North Brunswick, NJ
- Snake Rive Dam, fill compaction verification – Jackson Hole, WY
- Deep Tunnel Rock Curing – Milwaukee, WI
- Milwaukee Harbor Breakwater Reconstruction – Milwaukee, WI

Employment

- Gestra Engineering, Inc. – Oak Creek, WI — 2003 –
  Drilling Services Manager
- KTE Consultants, Inc. – Kenosha, WI — 2002 – 2003
  Senior Driller
- Wisconsin Testing Labs – Menomonee Falls, WI — 1990 – 1999
  Drilling Department Supervisor
- Mathis & Associates – Groveport, OH — 1988 – 1990
  Senior Driller
- Exploration Technology – West Allis, WI — 1985 – 1988
  Drilling Technician

Stephanie Sward, E.I.T.

STAFF ENGINEER

Education

- B.S. in Civil Engineering, University of Wisconsin – Platteville, May 2002

Areas of Expertise

Geotechnical exploration and analysis
Laboratory Testing/ Quality Control
Flexible and Rigid Pavement
Soil Improvement
Shallow and Deep Foundation
Construction Material Testing

Selected Project Experience

- Racine County Law Enforcement Center, Racine, WI
- Spirit Life Church Addition, Milwaukee, WI
- Artic Place earthwork monitoring, St. Francis, WI
- Wisconsin Street Reconstruction (STH 67), Elkhorn, WI
- ALLOC warehouse addition earthwork monitoring, Racine, WI
- Milwaukee Mile Infield Building, within Wisconsin State Fair Grounds – West Allis, WI
- Johnson Bank Development – Franklin, WI
- Inspected the STH 20 Reconstruction in Woodbine, IL
- Inspected the 92nd Street Reconstruction for the City of West Allis and Wisconsin DOT
- Performed traffic analysis for Waukesha County DOT
- Utility Inspection for the City of Wauwatosa

Employment

- Gestra Engineering, Inc. – Oak Creek, WI — 2004 –
  Staff Engineer
- City of Kenosha, Department of Public Works – Kenosha, WI — May to Oct. 2004
  Civil Engineer I
- GESTRA Engineering, Inc. – Oak Creek, WI — 2003 – 2004
  Staff Engineer
- Purdue University – West Lafayette, IN — 2002 – 2003
  Research Assistant

Jorge L. Martinez

STAFF ENGINEER

Education

- B.S. in Civil Engineering, Universidad Autonoma de Guerrero-Chilpancingo, Gro, Mexico, 2003

Areas of Expertise

Geotechnical exploration and analysis   Construction Material Testing
Laboratory Testing

Selected Project Experience

- Menard's Store – Milwaukee, WI
- Elm Road Generating Station – Oak Creek, WI
- Kenosha Transit Garage – Kenosha, WI
- Canal Street Soil Correction – Milwaukee, WI
- Stadium Business Center – Milwaukee, WI
- Foglia YMCA – Chicago, IL
- Ash Storage Facility at the Oak Creek Power Plant – Oak Creek, WI
- Artic Place earthwork monitoring, St. Francis, WI

Employment

- Gestra Engineering, Inc. – Oak Creek, WI   2004 –
  Staff Engineer
- Manuel del Valle Contractors – Chilpancingo, Gro, Mexico
  Engineering Assistant

Effective Date: January 1, 2006
Expiration Date: December 31, 2006

WISCONSIN DEPARTMENT OF TRANSPORTATION

Wisconsin Department of Transportation

Certificate of Qualification

This is to signify that

GESTRA ENGINEERING, INC.

Laboratory and personnel have been found to be qualified to conduct acceptance sampling and testing of materials for WisDOT National Highway System projects and have met the requirements set forth by the Wisconsin Laboratory Qualification Program for the sampling and testing of:

Aggregate: T89, T90.

Concrete Mix: T141, T22, T231, T23, T152-Air Meter Calibration, T152-Air Content, T119, T24, T148, T309.
Soils: T206, T207, T89, T90, T99, T88, T93, T87, T92, T100, T180, T265, ASTM D422, ASTM D 1140.
General Items: M92, M231, T67, T310.

Donald J. Greuel

Chief Quality Management Engineer

Director Bureau of Technical Services