UNITED STATES MARINE CORPS
ENGINEER EQUIPMENT INSTRUCTION COMPANY
MARINE CORPS DETACHMENT
14813 EAST 8TH ST
FORT LEONARD WOOD, MISSOURI 65473

LESSON PLAN

SOILS

LESSON ID EAC-A02

ENGINEER ASSISTANT CHIEFS COURSE

CID- A16EAV1

REVISED 08/01/14

APPROVED BY ______________________________ **DATE AUG 2014**

INTRODUCTION **(5 Min)**

(ON CAG #1)

1. **GAIN ATTENTION**. All construction projects, whether they are horizontal, or vertical in design require a solid foundation. As engineers, you must be able to determine the capabilities of the soil on which the structure is to be built. As engineer assistant chiefs, you must also know how to improve the soil's capabilities to accomplish your mission. Installing a structure on soil that is incapable of carrying the loads that will be applied will lead to failure.

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2. **OVERVIEW**. The purpose of this period of instruction is to provide you with the knowledge on how to perform a field identification test, classify the soil, determine the California Bearing Ratio, determine the suitability of the soil, selecting a soil stabilization technique, determining the amount of admixture and applying proper mechanical stabilization to the soil as required to meet construction design requirements.

3. **LEARNING OBJECTIVES**.

INSTRUCTOR NOTE
Have students read learning objectives to themselves.

a. **TERMINAL LEARNING OBJECTIVES**.

(1) Given an unidentified soil sample, and SL-3 complete soil test kit and references, perform hasty soil analysis to determine a two letter Unified Soil Classification System (USCS) classification, California Bearing ratio (CBR), and moisture content. (1361-XENG-2001)

b. **ENABLING LEARNING OBJECTIVES**.

(1) With the aid of references, state the procedures used to classify soil per the MCRP 3-17.7G.(1361-XENG-2001a)

(2) Given a soil test kit, a training area, an unidentified soil sample, soils laboratory, and references, perform soil analysis using the (USCS) per the MCRP 3-17.7G. (1361-XENG-2001b)

(3) Given a soil test kit, a training area, an unidentified soil sample, and references, operate the Dual-Mass Dynamic Cone Penetrometer (DCP) to determine the (CBR) of soil per the MCRP 3-17G. (1361-XENG-2001c)

(4) Given a soil test kit, a training area, an unidentified soil sample, and references, determine the moisture content of soil using the speedy moisture tester and the (DCP) with the Soil Moisture Probe (SMP) per the MCRP 3-17.7G. (1361-XENG-2001d)

(5) Given a USCS classification and references, determine the suitability of the soil for the intended mission per the MCRP 3-17.7G. (1361-XENG-2001e)

(6) Given a completed field identification analysis, soil suitability, and references, apply proper soil stabilization techniques per the MCRP 3-17.7G. (1361-XENG-2001f)

(7) Given a mission to construct a horizontal or vertical facility requiring soil stabilization and references, determine compaction requirements per the MCRP 3-17.7I. (1361-XENG-2001g)

4. **METHOD/MEDIA**. This lesson will be taught by the lecture, demonstration and practical application method. I will be aided by the use of computer generated graphics.

INSTRUCTOR NOTE
Explain Instructional Rating Forms to the students.

5. **EVALUATION**. You will be evaluated by a performance and written examinations immediately following this period of instruction in accordance with the training schedule.

INSTRUCTOR NOTE
Refer to the training schedule to give the exact date of the exam.

6. **SAFETY/CEASE TRAINING (CT) BRIEF**. There are no safety or cease training requirements for this class.

TRANSITION: Are there any questions about what we will be covering, or how and when you will be evaluated? If there are no questions, let's begin by discussing how soil is formed.
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(ON CAG #2)

BODY **(7HR 40MIN)**

1. **SOIL FORMATION. (20 Min)**

The term "soil" refers to the entire unconsolidated material that overlies and is distinguishable from bedrock. Soil is composed principally of the disintegrated and decomposed particles of rock. It also contains air and water as well as organic matter derived from the decomposition of plants and animals. Soil is a heterogeneous accumulation of cemented or weakly cemented mineral grains enclosing voids of varying sizes. These mineral grains range in size from large boulders to single mineral crystals of microscopic size. Soil is created by the process of rock weathering and often the additional process of transportation.

(ON CAG #3)

a. **Weathering**. Weathering is the physical or chemical breakdown of rock. These physical and chemical processes will vary with the environmental conditions present.

(ON CAG #4)

(1) Physical Weathering. The disintegration of rock. It breaks rock masses into smaller pieces without altering the chemical composition of the pieces. Processes that produce physical weathering include:

(ON CAG #5)

(a) Unloading. Extensive fracturing that results from the relief of pressure on a rock unit due to the removal of overlying material.

(ON CAG #6)

(b) Frost Action. Is the fracturing that occurs when trapped moisture in rocks freeze. This moisture can expand up to one tenth of its original volume, creating pressure of up to 4000 pound per square inch (psi).

(ON CAG #7)

(c) Organism Growth. Trees and plants readily grow in the joints of rock masses near the surface. The wedging action caused by root growth hastens the disintegration process.

(ON CAG #8)

(d) Abrasion. Sediments suspended in wind or fast-moving water can act as abrasives to physically weather rock masses. Rock particles carried by glacial ice can also be very abrasive.

(ON CAG #9)

(2) Chemical Weathering. The decomposition of rock through the chemical reactions that take place between minerals of the rock and the air, water or dissolved chemicals in the atmosphere. Chemical weathering processes include:

(ON CAG #10)

(a) Oxidation. The chemical union of a compound with oxygen. An example is rusting, which is the chemical reaction of oxygen, water and the iron mineral pyrite which forms ferrous sulfate.

(ON CAG #11)

(b) Hydration. The chemical union of a compound with water.

(ON CAG #12)

(c) Carbonation. The chemical process in which carbon dioxide from the air unites with various minerals to form carbonates.

(ON CAG #13)

b. **Formation Methods**.

(1) Residual Soils. Residual soils are formed where the rock material has been weathered in place. While mechanical (physical) weathering may occur, chemical weathering is the dominant factor.

(2) Transported Soils. By far, most soils that we encounter are materials that have been transported and deposited at a new location. Three major forces - glacial ice, water and wind - are the transporting agents; hence, these soils can be divided into glacial deposits, sedimentary (water-laid) deposits and eolian (wind-laid) deposits.

(ON CAG #14)

TRANSITION: Now that we have discussed weathering, the different types of weathering and how soil is formed, are they any questions? If there are no questions I have some questions for you. (a) What are the two types of weathering called? **Physical and Chemical** (b) What are the two types of soil formation methods? **Residual and Transported** Now that we have covered weathering, the different types of weathering and how soil is formed let's take a look at soil characteristics.
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(ON CAG #15)

2. **SOIL CHARACTERISTICS**. **(25 Min)**

The physical characteristics of a soil aid in determining the engineering characteristics. These properties form the basis for the system of soil classification used to identify soil types. The physical characteristics of soil particles are size and shape.

(ON CAG #16)

a. **Grain (Particle) Size**. Soils are divided into groups based on the size of the particle grains in the soil mass. Particle size is determined through the use of sieves. A sieve is a screen attached to a metal frame. There are two types of sieves, inch and numbered.

(1) Inch Sieves. These sieves range in size from 3" to 1/4" and are measured by the clear distance between the wires.

(2) Numbered Sieves. These sieves are numbered from #4 to #200 and are measured by the number of openings per linear inch.

(3) Passing or Retained. If a particle will not pass through a screen of a certain size opening, it is said to be "retained on" that sieve. The following table lists size groups within the Unified Soils Classification System:

(ON CAG #17)

Size Groups	Sieve size	
	Passing	**Retained on**
Cobbles	No Maximum Size	3 inch
Gravels	3 inch	Number 4
Sands	Number 4	Number 200
Fines	Number 200	No Minimum Size

(ON CAG #18)

b. **Particle Shape**. Two general shapes are normally recognized: bulky and platy. The bulky shapes include particles which are relatively equal in all three dimensions. In platy shapes, one dimension is very small compared to the other two; for example, a thick book would be considered bulky, but a page of a book would be platy.

(1) Bulky Shapes. Bulky shapes are subdivided depending on the amount of weathering that has acted on them.

(a) Angular. Particles that have recently been broken up are angular. They are characterized by jagged projections, sharp ridges and flat surfaces. The interlocking characteristics of angular gravels and sands generally make them the best materials for construction. These particles are seldom found in nature because the weathering processes normally wear them down in a relatively short time.

(b) Sub-angular. Particles that have been weathered until the sharper points and ridges of their original angular shape have been worn off. The particles are still very irregular in shape and are excellent for construction.

(c) Sub-rounded. Is the Particles on which weathering has progressed even further. Still somewhat irregular in shape, they have no sharp corners and few flat areas. They are still adequate for construction.

(d) Rounded. Particles in which all projections have been removed and few irregularities remain. The particles approach spheres of varying sizes. They are not desirable in construction unless the rounded shape can be altered by crushing.

(ON CAG #19)

(2) Platy Shapes. As previously stated, platy particles are extremely thin compared to their length and width. Only fine grained material of the clay variety has this characteristic shape. It is generally

accepted that platy grains are responsible for the plasticity of clay. Platy particles are highly compressible under static load. Several phenomena are associated with platy shapes.

(a) Clays frequently undergo very large volume changes with variations in moisture content. Evidence of this can be seen in the shrinkage cracks that develop in a lake bed as it dries.

(b) Unpaved clay roads, although often hard when sun baked, lose stability and turn to mud during rainstorms.

(c) In general, the higher the moisture content of a clay or silt, the less its strength and hence it's bearing capacity.

(ON CAG #20)

c. **Gradation**. The distribution of particle sizes within a soil mass is known as its gradation. Gradation is described by two main headings.

(1) Well-Graded Soil. A well-graded soil is defined as having a good representation of all particle sizes from the largest to the smallest. Additionally, the shape of the grain size distribution curve is smooth, the coefficient of curvature is between 1-3, and the coefficient of uniformity must be >4 for gravel and >6 for sand.

(2) Poorly-Graded Soil. There are two types of poorly-graded soil.

(a) Uniformly graded soil consists primarily of particles of nearly the same size.

(b) Gap Graded soil contains both large and small particles, but the gradation continuity is broken by the absence of some particle sizes.

(ON CAG #21)

TRANSITION: Now that we have discussed soil characteristics, the different types of particle sizes and shapes, and gradation, are they any questions? If they are no questions I have some questions for you. (a) How is particle size determined? **Using a sieve** (b) What are the two types of poorly graded soil? **Uniformly and Gap Graded**
Now that we have covered soil characteristics, the different types of particle sizes, shapes and gradation, let's take a ten minute break and then we will take a look at the Unified Soil Classification System (USCS).

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(BREAK 10 Min)

TRANSITION: Before the break we covered **SOIL CHARACTERISTICS.** Do you have any questions? If not, let's talk about **UNIFIED SOIL CLASSIFICATION SYSTEM (USCS).**

(ON CAG #22)

3. **UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)**. **(15 Min)**

Soils seldom exist separately as sand, gravel, or any other single component in nature. They are usually mixtures with varying proportions of different sized particles. Each component contributes to the characteristics of the mixture. The USCS is based on the characteristics which indicate how a soil will behave as a construction material. These characteristics include the percent of gravel, sand and fines; gradation; and plasticity. The physical properties determined by field identification techniques are used to classify the soil. Once an accurate classification is obtained, the potential behavior of the soil under traffic or foundation loads can be determined.

(ON CAG #23)

a. **Categories**. In the USCS, all soils are divided into three major categories: Coarse grained, fine grained, and peat. The first two are differentiated by grain size, whereas the third is identified by the presence of large amounts of organic material.

(1) Coarse-Grained Soils. A coarse-grained soil is classified as a gravel if more than half the coarse fraction, by weight, is larger than a No. 4 sieve. It is a sand if more than half the coarse fraction, by weight, is smaller than a No. 4 sieve. In general, there is no clear-cut boundary between gravelly and sandy soils. As far as behavior is concerned, the exact point of division is relatively unimportant. Where a mixture occurs, the primary name is the predominant fraction, in percent by weight, and the minor fraction is used as an adjective. For example, a sandy gravel would be a mixture containing more gravel than sand, by weight. Coarse grained soils have better internal drainage than fine-grained soils. Observations of the soil should be made in both disturbed and undisturbed conditions.

NOTE: If fines interfere with free-draining properties (as may occur with plastic fines), use the double symbol (GW-GM, GW-GC, and so on)indicating that such soils will be classed with soils having from 5 to 12 percent fines.

(a) Subdivided into two divisions:

1 Gravels and gravelly soils (G).

2 Sands and sandy soils (S).

b. **Groups**. Each of the major categories is further subdivided into groups and a letter symbol is assigned to each group. The primary letter of a classification relates to the soil group, while the secondary letter is descriptive of the soil's characteristics. The following symbols are combined to describe the soil mixture:

(ON CAG #24)

SOIL GROUPS	SYMBOL
Gravel	G
Sand	S
Silt	M
Clay	C
Organic	O

(ON CAG #25)

SOIL CHARACTERISTICS	SYMBOL
Well Graded	W
Poorly Graded	P
High Compressibility	H
Low Compressibility	L

*M and C are also used as secondary letters of the USCS

(ON CAG #26)

TRANSITION: Now that we have discussed the Unified Soil Classification System (USCS), and the group characteristics, are they any questions? If they are no questions I have some questions for you. (a) What is the USCS based on? **The characteristics which indicate how a soil will behave as a construction material** (b) What is the symbol for gravel based of the USCS? **G** Now that we have covered the Unified Soil Classification System (USCS), and the group characteristics, take a look at the Field Identification of Soil.

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(ON CAG #27)

4. **FIELD IDENTIFICATION OF SOIL**. **(50 Min)**

The soil types of an area are an important factor in selecting the exact location of airfields and roads. The military engineer, construction foreman, and members of engineer reconnaissance parties must be able to identify soils in the field so that the engineering characteristics of the various soil types encountered can be compared. Several simple field identification tests are described below. Each test may be performed with a minimum of time and equipment, although seldom will all of them be required to identify a given soil. The number of tests required depends on the type of soil and the experience of the individual performing them. By using these tests, soil properties can be estimated and materials can be classified. Such classifications are approximations and should not be used for designing permanent or semi-permanent construction.

a. **Soil Surveys**. The survey of soil conditions at the site of proposed military construction provides information about the nature, extent and condition of soil layers. It is vital to both the planning and execution of military construction operations.

(1) Sources Useful in Planning Soil Surveys. Any of the following sources of information can be useful to the Marine engineer:

(a) Intelligence Reports. Intelligence reports which include maps and studies of soil conditions usually are available for areas in which military operations have been planned. These reports are a source of information on geology, topography, terrain conditions, climate, and weather conditions.

(b) Local Inhabitants. Local inhabitants may provide information to supplement Intel reports or provide information about areas for which Intel reports are unavailable. Data obtained from this source could include possible locations of borrow pits, sand and gravel deposits, and peat or highly organic soils.

(c) Maps and Aerial Photographs. Thorough inspection of maps provide information about topography that can be useful to the trained soils analyst such as locations of hills, mountains, ridges, levees, sand dunes and alluvial fans. Aerial photographs allow the trained observer to identify landforms, slopes, drainage patterns, erosion characteristics and land use.

(2) Soil Exploration. Soil exploration, or soil boring, is nothing more than gathering soil samples for examining, testing and classifying. Three methods of obtaining samples are available to the military engineer: taking samples from the surface, from excavations already in existence or digging a test hole. Regardless of the method employed, a quantity of soil that will fit in a sandbag is required for analysis. When digging a test hole or conducting a soil boring, the following procedures should be followed:

(a) Locate soil borings at or adjacent to the point of interest.

(b) Ensure that the bore- hole is deep enough to penetrate the topsoil layer.

(c) Observe the color, moisture and number of layers exposed within the bore hole.

(d) On large scale horizontal projects (roads or airfields), conduct multiple borings and compare data as required.

(ON CAG #28 - 29)

b. **Soils Test Kit**. The soils test kit is an invaluable tool for classifying the soil types and strength of soil on or near your project site. The kit contains three field deployable cases equipped with the essential items to conduct a series of field identification tests to determine important characteristics of the soil. Case one contains equipment to complete the field identification. Case two contains the Dynamic Cone Penetrometer (DCP) to test the California Bearing Ratio test. Case three contains various tools from the data acquisition system to the speedy moisture tester.

(1) Requires a small amount of soil to conduct these field tests.

(2) The field tests can be conducted in a reasonably short period of time compared to a full laboratory analysis. Time to complete the field identification tests should be 15-20 minutes approximately.

(3) From this series of field tests, the properties of the soil can be estimated with reasonable accuracy.

(4) Procedures. An approximate identification of coarse grained soil can be made by spreading a dry sample on a flat surface and examining it, noting particularly, grain size, gradation, grain shape and particle hardness. All lumps in the sample must be thoroughly pulverized to expose

individual grains and to obtain a uniform mixture when water is added to the fine grain portion. A rubber-faced or wooden pestle and a mixing bowl are recommended for pulverizing. Lumps can also be pulverized by placing a portion of the sample on a firm, smooth surface and using the foot to mash it. If an iron pestle is used for pulverizing, it will break up the mineral grains and change the character of the soil; therefore, using an iron pestle is discouraged. Tests for identification of the fine grained portion of any soil are performed on the portion of the material that passes a Number 40 sieve. This is the same soil fraction used in the laboratory for Atterberg limits tests, such as plasticity. If the sieve is not available, a rough separation may be made by spreading the material on a flat surface and removing the gravel and larger sand particles. Fine grained soils are examined primarily for characteristics related to plasticity.

c. **Equipment**. Practically all the tests to be described can be performed with no equipment or accessories other than a small amount of water. However, the accuracy and uniformity of results is greatly increased by the proper use of certain equipment. The following equipment is available in nearly all engineer units (or may be improvised) and is easily transported:

(1) A Number 40 US standard sieve. Any screen with about 40 openings per lineal inch could be used, or an approximate separation may be used by sorting the materials by hand. Number 4 and Number 200 sieves are useful for separating gravels, sands, and fines.

(2) A pick and shovel or a set of entrenching tools for obtaining samples. A hand earth auger is useful if samples are desired a few feet below the surface.

(3) A spoon issued as part of mess equipment for obtaining samples and for mixing materials with water to the desired consistency.

(4) A bayonet or pocket knife for obtaining samples and trimming them to the desired size. A small mixing bowl with a rubber faced or wooden pestle for pulverizing the fine grained portion of the soil. Both may be improvised by using a canteen cup and a wooden dowel.

(5) Several sheets of nonabsorbent paper for rolling samples.

(6) A pan and a heating element for drying samples.

d. **Testing**. The procedures outlined below will result in a USCS classification. Many of the tests listed are not in sequential order. Utilize the wire diagram on page 12 to determine required tests and the order in which they should be performed. This wire diagram is an extract from FM 5-472, "Materials Testing".

(ON CAG #30)

INTERIM TRANSITION: Now that we have discussed conducting a field identification of soils and all the necessary equipment needed to do so, let's take a break then we will move outside for a demonstration of the field identification of soils.

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(BREAK 10 Min)

TRANSITION: Before the break we covered **FIELD IDENTIFICATION OF SOIL**. Do you have any questions? If not, let's start the demonstration.

INSTRUCTOR NOTE:
Move students to the outside Southwest corner of Brown Hall and assign them into 2-4 man teams

(CAG # 31)

DEMONSTRATION. **(1 Hr)** Have the students gather around the test table for a demonstration of a field identification of a soil samples.

STUDENT ROLE: Observe field identification of soil demonstration utilizing the proper steps taught.

INSTRUCTOR(s) ROLE: Demonstrate a field identification of soil making sure to assign the correct two letter identification symbol according to the Unified Soils Classification System (USCS).

1. SAFETY BRIEF: No safety concerns with this class.

2. SUPERVISION & GUIDANCE: Be sure to have students follow along in their student outline along with the instructor's supervision.

DEBRIEF: Now that I have demonstrated a field identification of soil, assigned a two letter symbol designator according to the USCS, you will now be able to properly conduct your own field identification test.

INSTRUCTOR DEMONSTRATION:

(1) Select a random but typical sample of soil.

(2) Perform visual examination, noting color, particle shape, and maximum size aggregate.

(3) Separate the gravel.

(a) Remove from the sample all particles retained on the #4 sieve.

(b) Estimate the percent of gravel.

(4) Odor test

(a) Heat the sample with a match or open flame.

(b) If the odor is musty or foul smelling, there is a strong indication that organic material is present.

(5) Sedimentation test

(**Both methods use -4 materials only**)

CANTEEN CUP METHOD

(a) Place the sample in a canteen cup, mark the soil depth, and fill it with water.

(b) Shake the mixture vigorously.

(c) Allow the mixture to stand for 30 seconds to settle out.

(d) Pour the water containing the suspended fines into another container.

(e) Repeat steps (b) through (d) until the water poured off is clear.

(f) Dry the soil left in the cup (sand).

(g) Estimate the percent of sand.

MASON JAR METHOD

(a) Place approximately 1” of soil into a mason jar. Draw a line on the Mason jar to represent 100% of material to be tested.

(b) Add water to within 1” from top of jar (about 5” of water).

(c) Shake mixture vigorously for 4 minutes.

(d) Place jar on flat, undisturbed surface and allow settling for 30 seconds.

(e) Mark settlement line on Mason jar. This represents % settled.

(f) Estimate % settled in relation to the original 100% line.

(g) Determine % sand using the following equation:

$$\frac{\%\ \text{settled}}{100} \times \%\ \text{sand \& fines} = \%S$$

(6) Compare the gravels, sands, and fines.

(a) The gravels have been estimated in test (3) step (b).

(b) The sands have been estimated in test (5) step (g).

(c) Estimate the percent of fines. 100 - (%G + %S) = %F

(7) Grit or Bite test

(a) Place a pinch of the sample between teeth and bite.

(b) If the sample feels gritty, the sample is silt (ML) or sand (S).

(c) If the sample feels floury, the sample is clay (C).

(8) Feel test

(a) Rub a portion of dry soil over a sensitive portion of the skin, such as the inside of the wrist.

(b) If the feel is harsh and irritating, the sample is silt (ML) or sand (S).

(c) If the feel is smooth and floury, the sample is clay (C).

(9) Wet Shaking test

(a) Place the pat of moist (not sticky) soil in the palm of the hand (the volume is about ½ inch)

(b) Shake the hand vigorously and strike it against the other hand.

(c) Observe how rapidly water rises to the surface.

(d) If it is fast, the sample is silty (M). If there is no reaction, the sample is clayey (C).

(10) Thread test

(a) Form a ball of moist soil (marble size).

(b) Attempt to roll the ball into a thread 1/8 inch in diameter.

(c) If thread is easily obtained, it is clay (C).

(d) If thread cannot be obtained, it is silt (M).

(11) Ribbon test

(a) Form a cylinder of soil that is approximately the size and shape of a cigar.

(b) Flatten the cylinder over the index finger with the thumb, attempting to form a ribbon 8 to 9 inches long, 1/8 to ¼ inch thick, and 1 inch wide.

(c) If 8 to 9 inches is obtained, it is (CH); if less than 8 inches is obtained, it is (CL); if there is no ribbon (less than 3”), it is silt (M).

(12) Shine test

(a) Draw a smooth surface, such as a knife blade or thumbnail, over a pat of slightly moist soil.

(b) If the surface becomes shiny and lighter in texture, the sample is highly plastic compressible clay (CH).

(c) If the surface remains dull, the sample is low plasticity compressible clay (CL).

(d) If the surface remains very dull or granular, the sample is silt (M).

(13) Dry Strength test

(a) Form a moist pat 2 inches in diameter by ½ inch thick.

(b) Allow it to dry with low heat.

(c) Place the dry pat between the thumbs and index fingers only and attempt to break it.

(d) If breakage is easy, it is slightly plastic silt (ML).

(e) If breakage is difficult, it is medium plastic and medium compressible clay (CL) or highly compressible silt (MH).

(f) If breakage is impossible, it is highly plastic and highly compressible clay (CH).

(1) Select a random but typical sample of soil.

(2) Perform visual examination, noting color, particle shape, and maximum size aggregate.

(3) Separate the gravel.

(a) Remove from the sample all particles retained on the #4 sieve.

(b) Estimate the percent of gravel.

(4) Odor test.

(a) Heat the sample with a match or open flame.

(b) If the odor is musty or foul smelling, there is a strong indication that organic material is present.

(5) Sedimentation test.

(**Both methods use -4 materials only**)

CANTEEN CUP METHOD

(a) Place the sample in a canteen cup, mark the soil depth, and fill it with water.

(b) Shake the mixture vigorously.

(c) Allow the mixture to stand for 30 seconds to settle out.

(d) Pour the water containing the suspended fines into another container.

(e) Repeat steps (b) through (d) until the water poured off is clear.

(f) Dry the soil left in the cup (sand).

(g) Estimate the percent of sand.

MASON JAR METHOD

(a) Place approximately 1" of soil into a mason jar. Draw a line on the Mason jar to represent 100% of material to be tested.

(b) Add water to within 1" from top of jar (about 5" of water).

(c) Shake mixture vigorously for 4 minutes.

(d) Place jar on flat, undisturbed surface and allow settling for 30 seconds.

(e) Mark settlement line on Mason jar. This represents % settled.

(f) Estimate % settled in relation to the original 100% line.

(g) Determine % sand using the following equation:

$$\frac{\%\ \text{settled}}{100} \times \%\ \text{sand \& fines} = \%S$$

(6) Compare the gravels, sands, and fines.

(a) The gravels have been estimated in test (3) step (b).

(b) The sands have been estimated in test (5) step (g).

(c) Estimate the percent of fines. $100 - (\%G + \%S) = \%F$

(7) Grit or Bite test

(a) Place a pinch of the sample between teeth and bite.

(b) If the sample feels gritty, the sample is silt (ML) or sand (S).

(c) If the sample feels floury, the sample is clay (C).

(8) Feel test

(a) Rub a portion of dry soil over a sensitive portion of the skin, such as the inside of the wrist.

(b) If the feel is harsh and irritating, the sample is silt (ML) or sand (S).

(c) If the feel is smooth and floury, the sample is clay (C).

(9) Wet Shaking test

(a) Place the pat of moist (not sticky) soil in the palm of the hand (the volume is about ½ inch)

(b) Shake the hand vigorously and strike it against the other hand.

(c) Observe how rapidly water rises to the surface.

(d) If it is fast, the sample is silty (M). If there is no reaction, the sample is clayey (C).

(10) Thread test

(a) Form a ball of moist soil (marble size).

(b) Attempt to roll the ball into a thread 1/8 inch in diameter.

(c) If thread is easily obtained, it is clay (C).

(d) If thread cannot be obtained, it is silt (M).

(11) Ribbon test

(a) Form a cylinder of soil that is approximately the size and shape of a cigar.

(b) Flatten the cylinder over the index finger with the thumb, attempting to form a ribbon 8 to 9 inches long, 1/8 to ¼ inch thick, and 1 inch wide.

(c) If 8 to 9 inches is obtained, it is (CH); if less than 8 inches is obtained, it is (CL); if there is no ribbon (less than 3”), it is silt (M).

(12) Shine test

(a) Draw a smooth surface, such as a knife blade or thumbnail, over a pat of slightly moist soil.

(b) If the surface becomes shiny and lighter in texture, the sample is highly plastic compressible clay (CH).

(c) If the surface remains dull, the sample is low plasticity compressible clay (CL).

(d) If the surface remains very dull or granular, the sample is silt (M).

(13) Dry Strength test

(a) Form a moist pat 2 inches in diameter by ½ inch thick.

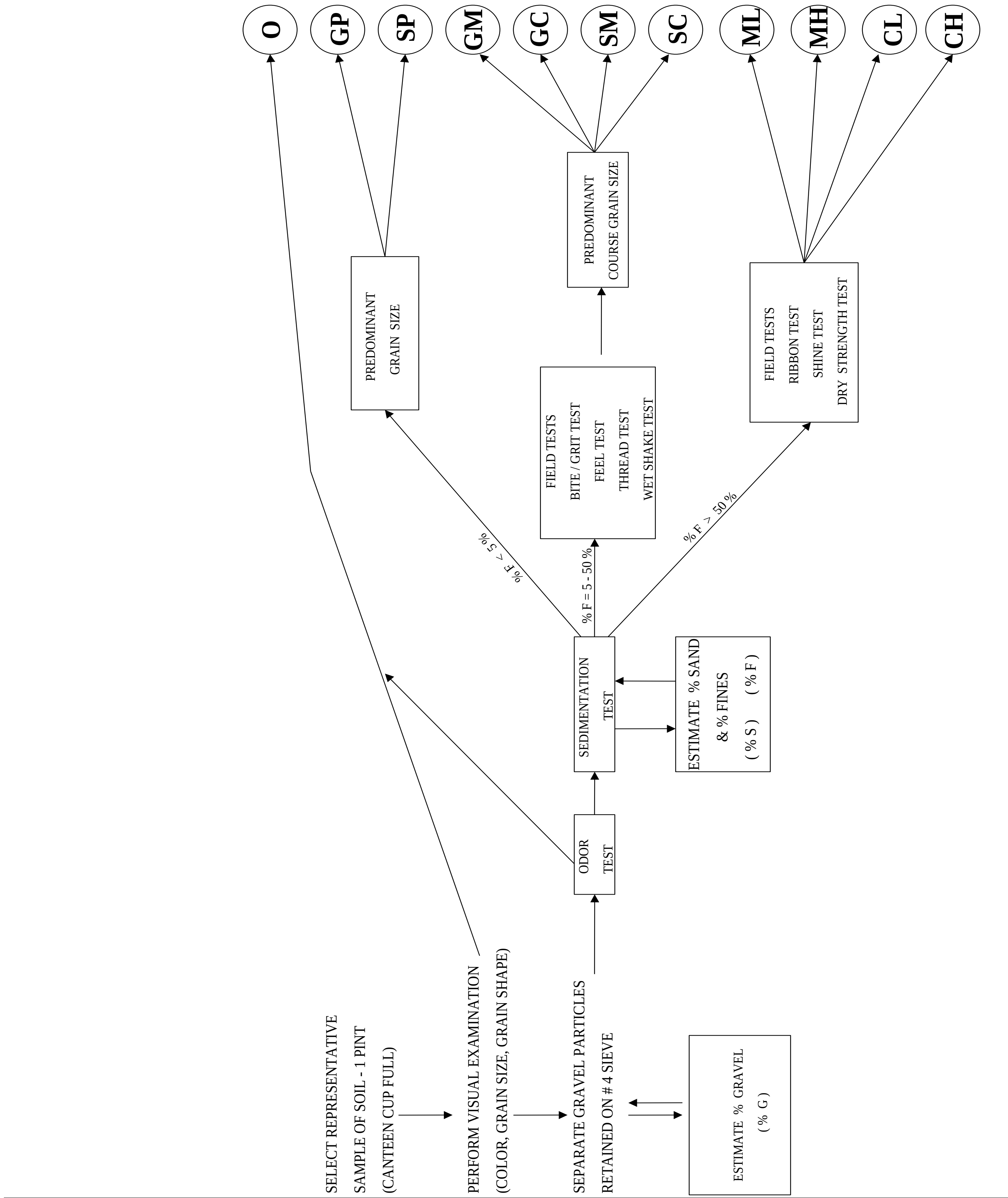
(b) Allow it to dry with low heat.

(c) Place the dry pat between the thumbs and index fingers only and attempt to break it.

(d) If breakage is easy, it is slightly plastic silt (ML).

(e) If breakage is difficult, it is medium plastic and medium compressible clay (CL) or highly compressible silt (MH).

(f) If breakage is impossible, it is highly plastic and highly compressible clay (CH).


SELECT REPRESENTATIVE
SAMPLE OF SOIL - 1 PINT
(CANTEEN CUP FULL)
PERFORM VISUAL EXAMINATION
(COLOR, GRAIN SIZE, GRAIN SHAPE)
SEPARATE GRAVEL PARTICLES
RETAINED ON # 4 SIEVE
ESTIMATE % GRAVEL
(% G)
ODOR
TEST
SEDIMENTATION
TEST
ESTIMATE % SAND
& % FINES
(% S) (% F)
% F < 5 %
% F = 5 - 50 %
% F > 50 %
PREDOMINANT
GRAIN SIZE
FIELD TESTS
BITE / GRIT TEST
FEEL TEST
THREAD TEST
WET SHAKE TEST
PREDOMINANT
COURSE GRAIN SIZE
FIELD TESTS
RIBBON TEST
SHINE TEST
DRY STRENGTH TEST
O
GP
SP
GM
GC
SM
SC
ML
MH
CL
CH

(CAG # 32)

INTERIM TRANSITION: Now that we have seen a demonstration of the field identification of soil, how to classify it according to the Unified Soil Classification System (USCS), let's move into the practical application portion in which we will conduct a field identification of soil to include assigning a two letter designator according to the USCS. Please proceed to your assigned sites outside.

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INSTRUCTOR NOTE:
Perform the following practical application

PRACTICAL APPLICATION: (1.5 Hrs) Have the students conduct multiple field identification of various soil samples.

PRACTICE: Conduct field identification of soil utilizing the proper steps taught

PROVIDE-HELP: Walk around the classroom and aid the students in their interpretation of the field tests along with making sure they assign the correct two letter identification symbol according to the Unified Soils Classification System (USCS).

SAFETY BRIEF: No safety concerns with this class.

SUPERVISION & GUIDANCE: Be sure to follow the step by step directions covered in your student outline along with the instructor's supervision.

DEBRIEF: Now that we have conducted a field identification of soil, assigned a two letter symbol designator according to the USCS, you will now be able to properly test and identify any area in order to keep within proper construction design requirements.

INSTRUCTOR NOTE:

Upon completion of the Soil Field Identification practical application, move students back to the classroom.

(ON CAG #33-36)

e. Bearing Capacity. The above soil characteristics are a measure of the soil's suitability to serve some intended purpose. Generally, a dense soil will withstand greater applied loads (have greater bearing capacity) than a loose soil. Particle size has a definite relation to this capacity. Empirical tests show that well-graded, coarse grained soils generally can be compacted to a greater density than fine grained soils because the smaller particles tend to fill the spaces between the larger ones. The shape of the grains also affects the bearing capacity. Angular particles tend to interlock and form a denser mass, and are more stable than rounded particles, which can roll or slide past one another. Poorly-graded soils, with their lack of one or more sizes, leave more or greater voids and therefore a less dense mass.

(ON CAG #37, 38)

(1) California Bearing Ratio (CBR). This system of determining soil density was developed by the California Department of Transportation in 1929. This system compares the density of the soil being tested to the density and strength of crushed limestone. CBR is expressed as a percentage. i.e. a soil which has a CBR value of 50 means it is 50% the strength of crushed limestone.

(CAG #39-54)

(2) Dynamic Cone Penetrometer (DCP). This instrument is used to assess the in situ strength of undisturbed soil and/or compacted materials. The penetration rate of the DCP can be used to estimate in situ CBR, shear strength of strata, and identify strata thickness. This instrument is typically used to assess material properties down to a depth of 1 meter (39.4 inches) below the surface. The DCP can be used to estimate the strength of fines and coarse grained soils, granular construction materials and weak stabilized or modified materials however should never be used in highly stabilized soil or materials containing a large percentage of aggregates greater than 2 inches.

(a) Basic Operation. The operator holds the device by the handle in a vertical or plumb position and lifts and releases the hammer from the standard drop height. The recorder measures and records the total penetration for a given number of blows or the penetration per blow.

(b) Initial Reading. The DCP is held vertically and the tip is so seated such that the top of the widest part of the tip is flush with the material to be tested. An initial reading is obtained from the vertical scale. The distance is measured to the nearest 1 mm.

(c) Termination of Test. The test should be terminated if the handle deviates 3" or more from the vertical or after 5 blows; the device has not advanced more than 2 mm. A new test location should be a minimum of 12" from the prior location.

(d) Extraction. Following completion of the test, the device should be removed by driving the hammer upwards against the handle.

(ON CAG #55)

f. **Quality Control**. Can be accomplished by several different means and is the project manager’s single best way to ensure standards throughout the project.

(1) Test Strip. Is the “full dress rehearsal” of a construction project. It allows the project manager to test his plans against the actual conditions as they exist on the project site.

(2) Speedy Moisture Tester. Allows accurate gauge of the soils moisture content on site. A portable system used for measuring the moisture content of a wide range of materials including soils, aggregates, dust and powders, and liquids. The procedures are as follows:

(a) Ensure the vessel is clean prior to using.

(b) Select and prepare the sample. Some material may need to be ground prior to testing or pulverized during the test.

(c) Weigh the sample by placing the empty measuring beaker on the scale and zero the scale. Add small amounts of sample until the correct sample weight of 20 grams has been reached.

(d) Add sample to the speedy vessel along with pulverizing balls if needed.

(e) Add a minimum of two scoops of calcium carbide to the cap cavity.

(f) While holding the speedy vessel horizontally, replace the cap and secure the top screw to seal the vessel.

(g) Mix the sample and calcium carbide together by holding the speedy vertically with the pressure gauge facing the ground and shake vigorously for 5 seconds. Rotate the speedy so the pressure gauge is facing the sky. Tap the sides to ensure the sample falls into the cap cavity and hold this position for 1 – 2 minutes.

(h) Alternatively, if the pulverizing balls are being used, hold the speedy horizontally and shake it in an orbital motion to make the balls spin around the inside of the vessel. Do this for 20 seconds and then rest for 20 seconds. Repeat this process two or three times.

(i) Take the reading by holding the speedy horizontally and at eye level and determine the moisture content reading directly from the pressure gauge. If it is believed that the sample contains greater than 20% moisture, repeat the entire process, only this time reduce the sample size to 10 grams and double the reading taken from the dial.

(j) Release the pressure in the vessel by slowly unscrewing the cap.

(k) Remove the sample from the vessel by pouring the contents into a clean dry open container and dispose of in accordance with the MSDS.

(l) Clean the vessel and all tools and components used.

(3) DCP with Attachments. Allows proper testing of the entire in place characteristics of soils CBR and moisture and allows it to be graphed.

(CAG # 56)

TRANSITION: We have just discussed the California Bearing Ratio (CBR) in conjunction with Dynamic Cone Penetrometer. Do you have any questions? If not, let's start the demonstration in which we will use the DCP outside on typical Fort Leonard Wood clayey soil.

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INSTRUCTOR NOTE:

Perform the following demonstration

DEMONSTRATION: (1 Hr) Have the students gather around the DCP for a demonstration on how to use it to get a CBR rating.

STUDENT ROLE: Observe DCP demonstration utilizing the proper steps taught.

INSTRUCTOR ROLE: Demonstrate the DCP to also include the how to utilize the Soil Moisture Probe.

- -Setup of DCP
- -Manual CBR test(s)
- -Automated CBR tests
- -SMP tests
- -Speedy Moisture test

1. SAFETY BRIEF: Give Safety brief concerning DCP handling/set-up and SMP testing safety procedures.

2. SUPERVISION & GUIDANCE: Be sure to have students follow along in their student outline along with the instructor's supervision.

DEBRIEF: N/A

INTERIM TRANSITION: You have just seen a demonstration of the Dynamic Cone Penetrometer (DCP) and the Speedy Moisture Tests, let's move into the practical application portion.

INSTRUCTOR NOTE:

Perform the following practical application

PRACTICAL APPLICATION: (1.5 Hrs) Give students a training/project scenario (HLZ, airfield, etc.) where a training lane or distance intervals are given enabling the use of the DCP and the SMP.

INSTRUCTOR ROLE: Ensure students set up the DCP properly to receive readings.

STUDENT ROLE: Conduct field CBR rating soil utilizing the proper steps taught.

- -Setup of DCP
- -Manual CBR test(s)
- -Automated CBR tests
- -SMP tests
- -Speedy Moisture test

SAFETY BRIEF: Ensure class has received safety brief prior to conduct.

SUPERVISION & GUIDANCE: Be sure to follow the step by step directions covered in your student outline along with the instructor's supervision.

INSTRUCTOR NOTE:

Upon completion of the DCP practical application, move students back to the classroom.

(ON CAG #57)

TRANSITION: Today we have conducted a field identification of soil, classified it according to the Unified Soil Classification System (USCS), and discussed California Bearing Ratio (CBR) in conjunction with Dynamic Cone Penetrometer, are they any questions? If they are no questions I have some questions for you. (a) What two methods are used for the sedimentation test? **Canteen Cup and Mason jar method.** (b) What is California Bearing Ratio use to determine? **Soil density.** Lets take a ten min break and then we will talk about soil stabilization.

(BREAK - 10 min)

TRANSITION: are there any more questions before we talk about **soil stabilization.**

(ON CAG #58)

5. **SOIL STABILIZATION**. **(30 min)** Stabilized soils can often be adequate for airfields, traffic pavements, and parking and storage areas where an all-weather surface is required, yet traffic does not justify a higher-strength pavement. Surface treatments are also used to provide dust control. The most widely recognized form of stabilization is compaction, which improves the mechanical stability of virtually any soil. Compaction also preserves the construction strength of the soil by preventing the entry of surface water (waterproofing). However, compaction alone is often not enough. Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. The process may include blending

soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to cement the soil.

a. **Uses.** Pavement design is based on the premise that specified levels of quality will be achieved for each soil layer in the pavement system. Each layer must:

(1) Resist shearing within the layer.

(2) Avoid excessive elastic deflections that would result in fatigue cracking within the layer or in overlying layers.

(3) Prevent excessive permanent deformation through densification.

As the quality of a soil layer is increased, the ability of that layer to distribute the load over a greater area is generally increased enough to permit a reduction in the required thickness of the soil and surface layers.

(ON CAG #59)

b. **Methods of Stabilization**. The two general stabilization methods are mechanical and additive (chemical admixture). The effectiveness of stabilization depends on the ability to obtain uniformity in blending the various materials. Mixing in a stationary or traveling plant is preferred. However, other means of mixing (such as scarifiers, plows, disks, graders, and rotary mixers) have been satisfactory.

The soil-stabilization method is determined by the amount of stabilizing required and the conditions encountered on the project. An accurate soil description and classification are essential for selecting the correct materials and procedure. FM 5-410, Chapter 9, lists the most suitable treatments for various soil types to stabilize these soils for different objectives.

(ON CAG #60)

(1) Mechanical. Mechanical stabilization produces by compaction an interlocking of soil-aggregate particles. The grading of the soil-aggregate mixture must be such that a dense mass is produced when it is compacted. Mechanical stabilization can be accomplished by uniformly mixing the material and then compacting the mixture. As an alternative, additional fines or aggregates maybe blended before compaction to form a uniform, wellgraded, dense soil-aggregate mixture after compaction. The choice of methods should be based on the gradation of the material. In some instances, geotextiles can be used to improve a soil's engineering characteristics.

(ON CAG #61)

(2) Additive (Chemical Admixture). Additive refers to a manufactured commercial product that, when added to the soil in the proper quantities, will improve the quality of the soil layer. The two types of additive stabilization discussed mainly in are chemical and bituminous. Chemical stabilization is achieved by the addition of proper percentages of portland cement, lime, lime-cement-fly ash (LCF), or combinations of these materials to the soil. Bituminous stabilization is achieved by the addition

of proper percentages of bituminous material to the soil. Selecting and determining the percentage of additives depend on the soil classification and the degree of improvement in the soil quality desired. Smaller amounts of additives are usually required to alter soil properties (such as gradation, workability, and plasticity) than to improve the strength and durability sufficiently to permit a thickness-reduction design. After the additive has been mixed with the soil, spreading and compacting are achieved by conventional means.

(a) Types.

(ON CAG #62)

1 Cement. Portland cement can be used either to modify and improve the quality of the soil or to transform the soil into a cemented mass with increased strength and durability. Cement can be used effectively as a stabilizer for a wide range of materials; however, the soil should have a PI (Plasticity Index) less than 30. For coarse-grained soils, the amount passing the No. 4 sieve should be greater than 45 percent. The amount of cement used depends on whether the soil is to be modified or stabilized.

(ON CAG #63)

2 Lime. Experience shows that lime will react with many medium-, moderately fine-, and fine-grained soils to produce decreased plasticity, increased workability, reduced swell, and increased strength. Soils classified according to the USCS as CH, CL, MH, ML, OH, OL, SC, SM, GC, GM, SW-SC, SP-SC, SM-SC, GWGC, GP-GC, ML-CL, and GM-GC should be considered as potentially capable of being stabilized with lime. Lime should be considered with all soils having a PI greater than 10 and more than 25 percent of the soil passing the No. 200 sieve.

(ON CAG #64)

3 Fly Ash. Fly ash, when mixed with lime, can be used effectively to stabilize most coarse- and medium-grained soils; however, the PI should not be greater than 25. Soils classified by the USCS as SW, SP, SP-SC, SW-SC, SW-SM, GW, GP, GP-GC, GW-GC, GP-GM, GW-GM, GC-GM, and SC-SM can be stabilized with fly ash.

(ON CAG #65)

4 Bituminous. Most bituminous soil stabilization has been performed with asphalt cement, cutback asphalt, and asphalt emulsions. Soils that can be stabilized effectively with bituminous materials usually contain less than 30 percent passing the No. 200 sieve and have a PI less than 10. Soils classified by the USCS as SW, SP, SW-SM, SP-SM, SW-SC, SP-SC, SM, SC, SM-SC, GW, GP, SW-GM, SP-GM, SW-GC, GP-GC, GM, GC, and GM-GC can be effectively stabilized with bituminous materials, provided the above-mentioned gradation and plasticity requirements are met.

(ON CAG #66)

5 Combination. Combination stabilization is specifically defined as lime-cement, lime-asphalt, and LCF stabilization. Combinations of lime and cement are often acceptable expedient stabilizers.

Lime can be added to the soil to increase the soil's workability and mixing characteristics as well as to reduce its plasticity. Cement can then be mixed into the soil to provide rapid strength gain. Combinations of lime and asphalt are often acceptable stabilizers. The lime addition may prevent stripping at the asphalt-aggregate interface and increase the mixture's stability.

(CAG # 67)

SUMMARY **(5 MIN)**

During this period of instruction we have covered: how soil is formed, the composition of a soil mass, how to conduct a hasty field I.D. on a previously unknown soil, CBR test, and stabilization methods. Those students with the instructor rating forms fill them out, and turn them in. Take a Ten minute break.

(BREAK - 10 min)

REFERENCES:

Engineering Operations	MCWP 3-17
Engineering Field Data	MCRP 3-17A
Military Soils Engineering	MCRP 3-17.7G
Materials Testing	MCRP 3-17.7H
Earthmoving Operations	MCRP 3-17.7I