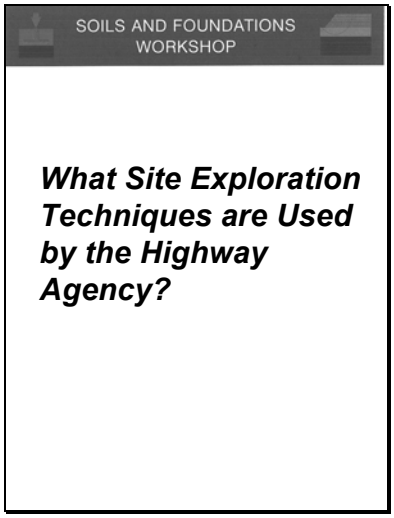
LESSON 2

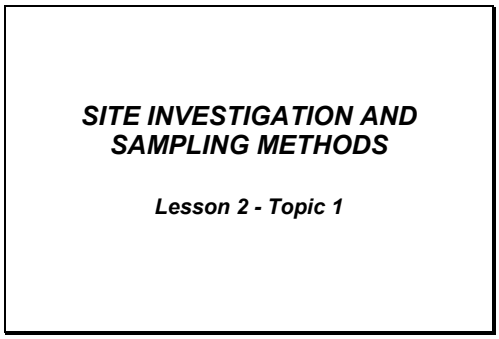
TOPIC 1

Site Investigation and Sampling Methods



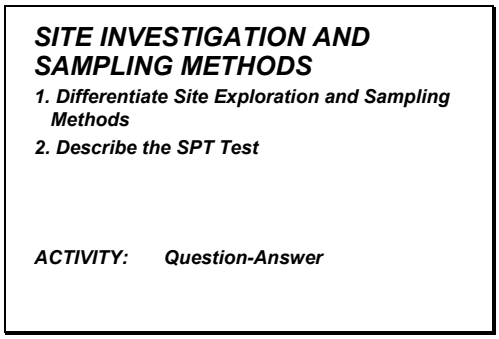
Slide 2-1-1

Begin lesson 2 topic 1 by asking the group to name the site exploration techniques that the agency now uses for highway projects. The instructor should write the responses on a flip chart sheet. At the end of lesson 2 (after the DOT representative presentation), ask the group to add to the list from what was just presented.



Slide 2-1-2

Ask for a show of hands on who has seen subsurface explorations in the field. Note that this lesson contain very basic material which may be known by some in class but is needed to insure that all students have the proper basis for more advanced concepts presented later in the course.



Slide 2-1-3

State objectives.

The Six Stages of a Project

1. *Enthusiasm*
2. *Disillusionment*
3. *Panic*
4. *Search for the Guilty*
5. *Punishment of the Innocent, and*
6. *Honor and Praise for the Non-Participants*

Slide 2-1-4

Funny slide relating geotechnical investigation to what can happen. Punch line is that after blaming the geotechnical engineers, the governor shows up to cut the ribbon and take credit for the new road (honor and praise to the non-participants)

Purpose of a Site Investigation

- ***Assess Suitability of Site for Proposed Project***
- ***Enable Adequate and Economic Design***
  - ***No Failures - No Conservatism***
- ***Foresee and Provide for Construction Problems that may Arise (Reduce Claims)***

Slide 2-1-5

General concepts

Foundation Engineer

Slide 2-1-6

Funny slide

Communicate and Coordinate

Selection, Design and Construction of a Safe, Cost-effective Foundation Requires Good Communication and Coordination Among Engineers, Geologists, Drillers, Structural Engineers, Roadway Engineers, and Construction Engineers

Slide 2-1-7

Reinforce concept from previous lecture and how this applies to site investigation.

Site Investigation Phases

- ***Site Reconnaissance***
- ***Detailed Investigation***
- ***Construction Observation and Monitoring***

Slide 2-1-8

Phases to be covered in lecture.

Site Reconnaissance

- ***Where Site Located***
- ***Geologic Maps-Topographic Maps-Well Logs***
- ***Air Photos***
- ***Nearby Boring Data***
- ***Site Inspection (With Bridge Designer)***

Slide 2-1-9

Emphasize site recon is both office and field related activity.

Site Reconnaissance (Cont'd)

- ***Equipment Needed to Access Site***
- ***Basic Design Decisions***
- ***Prepare Site Reconnaissance Report***

Slide 2-1-10

Stress need for geotechnical engineer to do recon.

Slide 2-1-11

What do you see in this picture which should be noted in the site investigation report?

Answer is the boulders in the pile alongside the excavation. Mention that borings can miss boulders

Slide 2-1-12

Ask what should be noted here. (Answer is settlement of approach)

"If you do not know what you are looking for in site investigation, you are not likely to find much of value."

R. Glossop-8th Rankine Lecture

Slide 2-1-13

Read quote and explain importance.

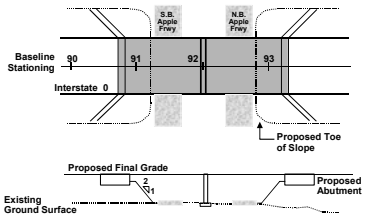
Detailed Investigation

- ***Boring → Sampling → Testing***
- ***Develop Soil Profile***
- ***Get Parameters for Final Design***
  - ***Embankments***
  - ***Foundations***
- ***Data for Construction***

Slide 2-1-14

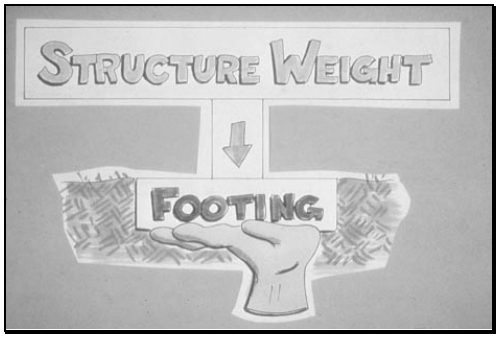
The work done is a site investigation must provide an adequate amount of information for both design and construction. The planning of this work should be done by an engineer who is familiar with design and construction uses of the subsurface data. Coordination with others involved in the design process will produce the proper amount of relevant site information.

Preliminary Bridge Layout



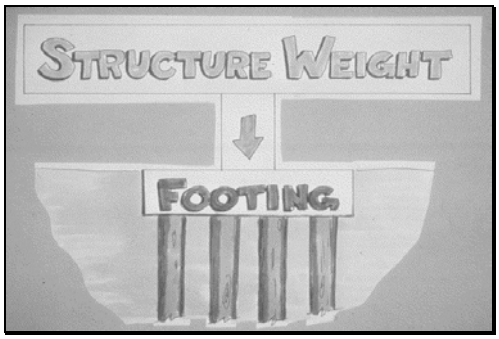
Slide 2-1-15

Show initial typical plan which would be used to layout a site investigation for a proposed structure. Note that receipt of such a plan is usually the first step in beginning a detailed site investigation. This layout usually provides information about critical locations to be explored, site access, available survey lines, and rough dimensions of the embankment.



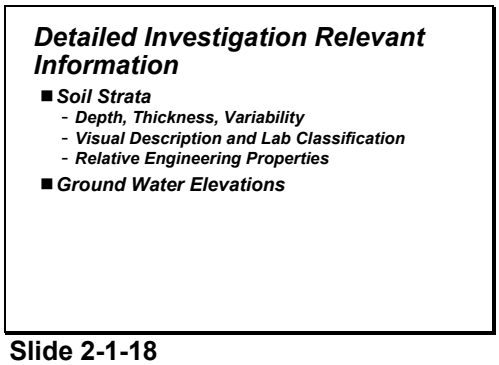
Slide 2-1-16

Relate possible use of shallow foundations to investigation requirements. Mention that the bearing capacity of spread footings is controlled primarily by the soils located a short distance below the footing. Therefore continuous samples are usually taken for the top 15' to better define the bearing conditions.



Slide 2-1-17

Relate possible deep foundation to investigation requirements. Stress that coordination with other units such as the hydraulics unit in the case of potential scour situations, is necessary to insure that boring depth are adequate for foundation design.



Slide 2-1-18

Describe data to be collected.

Detailed Investigation Relevant Information (Cont'd)

- ***Rock***
  - ***Depth to Rock***
  - ***Rock Type***
  - ***Rock Quality (RQD, Weathering, Jointing, Joint In-filling)***
  - ***Compressive Strength***

Slide 2-1-19

Describe data to be collected.

Exploration Methods and Equipment

Slide 2-1-20

Header slide to introduce discussion on equipment.

Instructor should substitute slides of local equipment if possible.

The objective of showing the wide variety of equipment, which follows, is that there is no excuse not to take borings at any site; equipment exists for all sites and conditions.

Slide 2-1-21

Hand auger or other shallow work

Slide 2-1-22

Tripod rig moved by hand or by helicopter.

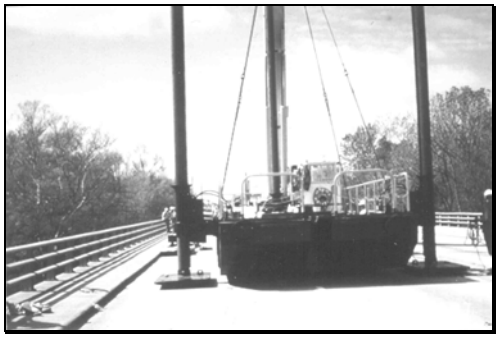
(Funny slide. ask who is geotechnical engineer. Answer is man on right)

Slide 2-1-23

Minuteman rig can be backpacked into remote site. Able to bore to 200’ depth.

Slide 2-1-24

Skid rigs are compact, full size drill rigs which are used at numerous off road sites. These rigs require transport to the project site but can be winched to locations that are not accessible to truck mounted rigs.



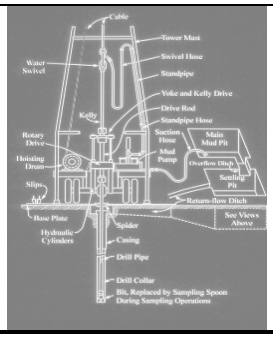
Slide 2-1-25

Jack up barge and rig used by North Carolina DOT for over water work. The legs of this barge are about 40' long and are deployed after the barge has been moved into position over a borehole location.

Slide 2-1-26

Jack-barge and rig deployed in a river. Note that rig is now stationary and will not be affected by currents of tides. A stationary position greatly simplifies the procedure for qualify undisturbed sampling and in-situ testing.

Drill Rig Schematic



Slide 2-1-27

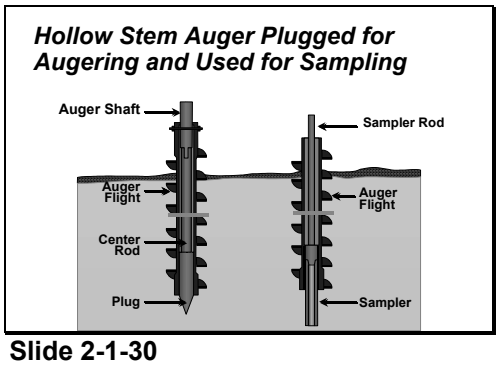
Schematic only shown to illustrate the complexity of the mechanical workings of a drill rig. Bottom line: the drillers must qualified to be an equipment operator as well as a soils technician. Stress the difficulties of the drilling job.

Driven casing hole advancement.

Slide 2-1-28

Hollow stem auger hole advancement.

Slide 2-1-29



Schematic of hollow stem process.

Slide 2-1-30

Soil Sampling and Testing Methods

Slide 2-1-31

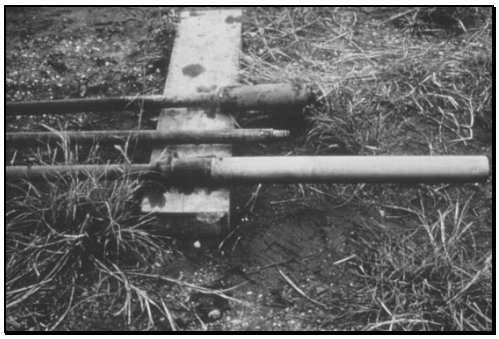
Introduce soil sampling and field testing; the key point in this section is to stress that the procedures used in this field work are controlled by standards developed by groups such as AASHTO or ASTM. Adhering to these standard procedures is time-consuming but absolutely necessary to insure the results of soil sampling and testing are valid. Shortcuts or improper techniques can result in site information that will lead to poor design. The DOT can insure the quality of site work down by in-house staff through periodic training. However the capabilities of site investigation contractors is more difficult to assess and their work requires the use of qualified inspectors by the DOT.

Cohesive Soils

"Undisturbed" Tube Samples (Shelby or Piston Sampler)

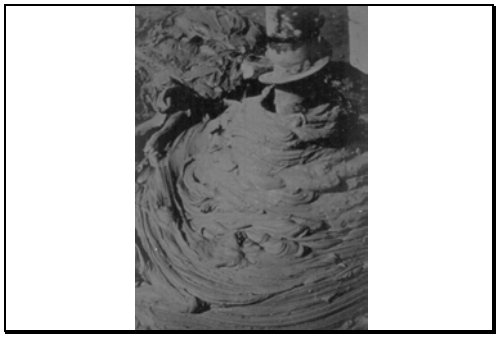
Slide 2-1-32

Cohesive sampling techniques.



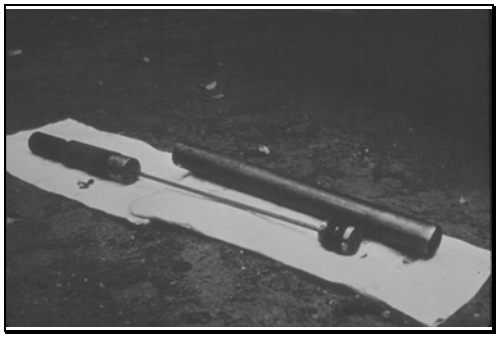
Slide 2-1-33

Explain basic equipment for sampling cohesive soils with a Shelby tube. Important items to note are preparation of the hole prior to insertion of the tube, the need for a slow, steady press of the tube, and the proper length of the press. Note in this slide that the top of the tube typically is connected to the drill rod by a head which extends into the tube about 4". Therefore the maximum length of press must be at least 4" less than the tube length to prevent sample disturbance.



Slide 2-1-34

Explain that very soft soils require special sampling techniques to prevent the sample from falling out of the tube during withdrawal. Ask if anyone knows how to perform this operation.



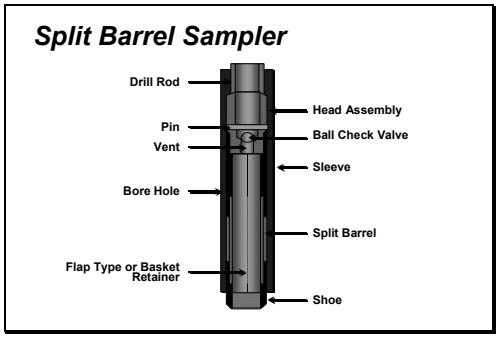
Slide 2-1-35

Show stationary piston sampler, which is used to sample very soft soils. Briefly explain that the sampler has separate rods, which are connected to the piston (inner rod) and the tube (outer rod). The sampler is lowered into the hole with the piston at the bottom of the tube. The outer rod is used to advance the tube as the piston remains stationary on the top of the soil sample. After the press is complete the piston is locked and the tube is withdrawn. The piston provides a vacuum to hold the soft material in the tube during withdrawal.

"Sampling of Granular Soils
Use Split Barrel Sampler"

Slide 2-1-36

Introduce sampling of granular soils



Slide 2-1-37

Explain how split barrel sampler works and possible problems to watch out for during inspection of drilling operations such as; damaged drive shoe which would cause artificially high blow counts or removal of the ball check valve which would cause softening of the soils to be sampled or poor recovery of soil in the sampler which could be due to clogging of the shoe and result in high blow counts.

Slide 2-1-38

Show how sample retained in spoon. Mention that the sample is then transferred into a plastic bag and placed in a jar or other container, which is labeled and sealed to prevent loss of moisture.

Slide 2-1-39

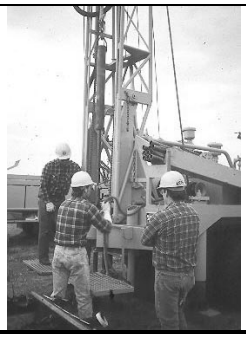
Show care and transportation of samples to preserve properties.

The Standard Penetration Test (AASHTO T-206, ASTM D-1586)

The Standard Penetration Test (SPT)
2" O.D. Sampler
140# Hammer/30" Drop
N = Blows/Foot

Slide 2-1-40

Explain the SPT standard test.



Slide 2-1-41

Picture of safety hammer with cathead and rope drop. Explain that automatic hammer systems are also available.

Use of SPT "N" Values

- ***Granular Soils***
  - *Estimate Friction Angle ϕ*
  - *Estimate Settlement*
- ***Cohesive Soils***
  - *Only Crude Estimate of Cohesive Strength*
  - *Do Not Use for Final Design*

Slide 2-1-42

Describe use of N values

Relative Density of Sand Based on SPT N -Values

Slide 2-1-43

Relate granular soil density to N.

Consistency of Cohesive Soils Based on SPT N-Values

N Blows/Foot	*Consistency*
Below 2	*Very Soft*
2 – 4	*Soft*
5 – 8	*Medium*
9 – 15	*Stiff*
16 – 30	*Very Stiff*
Over 30	*Hard*

Slide 2-1-44

Relate cohesive soil consistency to N. Mention that N. values in cohesive soils are not a good indicator of soil strength. Then before showing the next slide, ask what are some sources of error in the SPT test?

SPT Test - Common Errors

- *Damaged Drive Shoe*
- *Variation in Hammer Fall*
- *Effect of Overburden Pressure*
- *Plugging End of Sampler*
- *Hollow Stem Auger Quick Condition*
- *Careless Work by Drill Crew*

Slide 2-1-45

Do not explain obvious errors. Focus on need for competent drillers to perform test and the Po effect.

Advantage of SPT Test

- *Very Economical Test*
- *Provides Sample for Soil Classification*
- *Long Service Life of Equipment*
- *Vast SPT Data Base*
- *Numerous Empirical Correlations with SPT*

Slide 2-1-46

Review the need for competent drillers to perform test. At this point the instructor should encourage the DOT to provide training to their field staff on a routine basis.

Gravels - What to do?

- *SPT may not be Dependable*
- *Can Use Oversize Sample Spoon*
- *Can Use Dynamic Cone for Correlation to SPT Test*

Slide 2-1-47

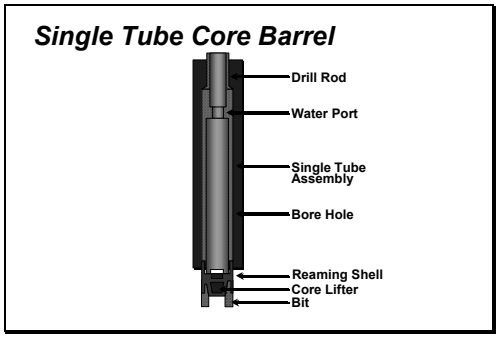
Show special issues in gravels.

Rock Sampling

Slide 2-1-48

Introduce rock-sampling techniques.

Stress that new developments in equipment have vastly improved our ability to obtain high quality rock samples.



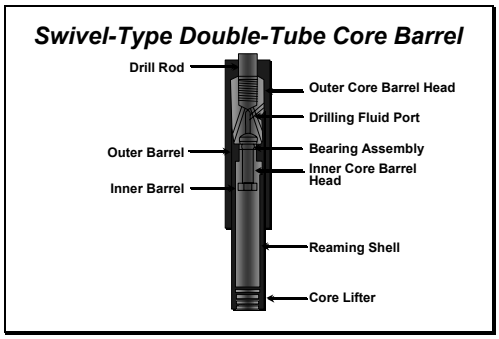
Slide 2-1-49

Describe old type barrel, how the drilling fluid passes between the core and inside of the barrel, the problems with loss of core due to the wash water, and what was considered good recovery; i.e. 50%. Also recommend that only double tube or better core barrels be used for DOT work to provide adequate rock information.

Slide 2-1-50

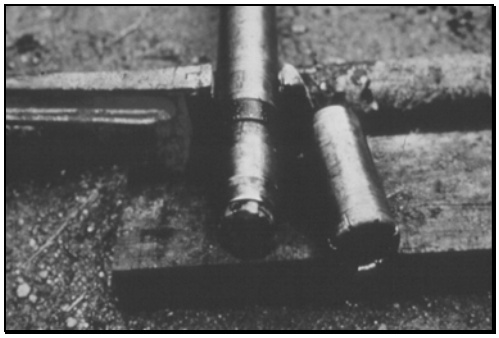
What is wrong with this method of removing rock core from the sampler?

Answer is that core is usually fragmented and any attempt to remove from barrel should be made into a core box so the sample is retained intact as possible.



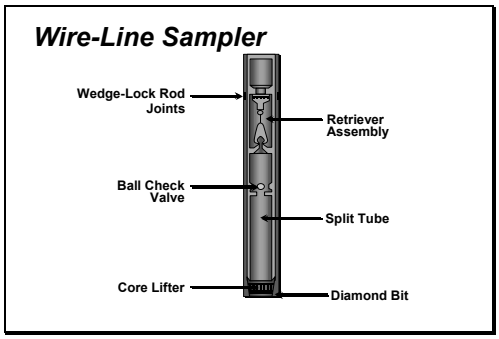
Slide 2-1-51

Explain the workings of a double tube core barrel. Note that the swivel type barrel shown here is preferred over a rigid barrel, as the swivel type permits the inner barrel to remain stationary while the outer barrel rotates. This design minimizes any abrasion of the core due to the rotation of the inner barrel.



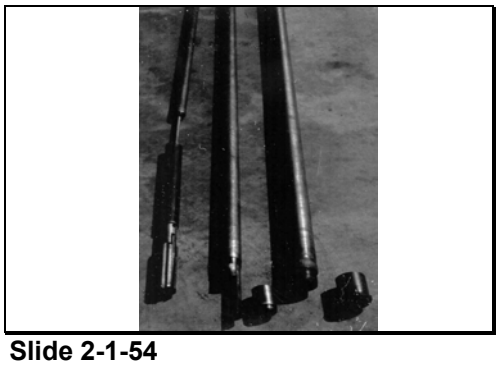
Slide 2-1-52

Show the component equipment for the double tube barrel and mention that industrial diamonds are used on the bit. Also mention that more sophisticated rock coring equipment such as triple barrels now exist.



Slide 2-1-53

Describe a wire line device and how time is saved in core extraction.



Slide 2-1-54

Show the wire line equipment.

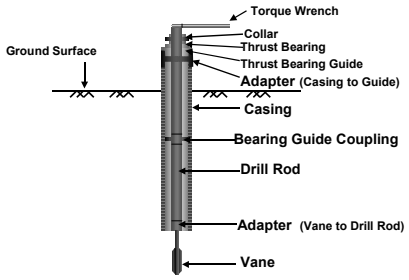
In-Situ Testing

- ***Vane Shear Test***
  - ***Clays, Silts, Peats***
- ***Static Cone Penetrometer***
  - ***Clays, Silts, Sands***
- ***Pressuremeter***
  - ***Clay, Weak Rock, Sand***

Slide 2-1-55

Introduce insitu testing.

Vane Shear Device



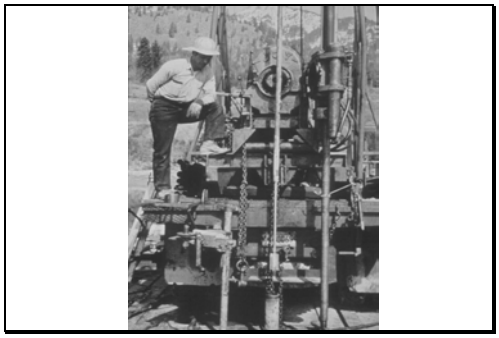
Slide 2-1-56

Describe vane shear concept.

Slide 2-1-57

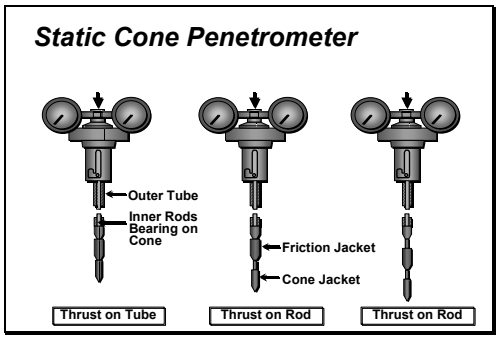
Show vane shear blades.

Ask students if large blade used in soft or hard soils.



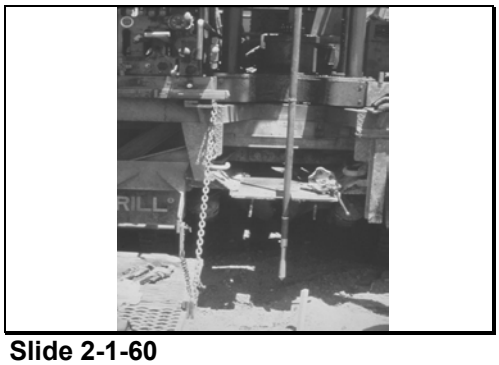
Slide 2-1-58

Show vane being inserted into the borehole. Note that the vane is extended down a defined distance below the bottom of the drilled hole and the test performed. The vane is then removed, the hole drilled deeper, and the vane test repeated at the new depth.



Slide 2-1-59

Show a basic cone penetrometer schematic and explain concept. Note that cone testing has evolved in the past decade to include special devices to measure pore pressure or soil dynamic properties. Refer students to the FHWA Site Investigation course for detail.



Slide 2-1-60

Show cone insertion into ground and importance of reaction force to cause cone penetration.

Minimum Exploration Program for Structure Sites

- ***How Much Exploration?***
- ***How Many Borings?***
- ***How Deep Should Borings Penetrate?***
- ***How Often to Sample?***
- ***When to Measure Water Levels?***
- ***Driller's Responsibilities?***

Slide 2-1-61

Introduce questions for discussion. Ask students to consider these items which will be covered later; both in general by the instructor and specific to agency policy by the guest speaker from the agency.

Subsurface Exploration by Drilling Contractors

- ***Clearly Define Boring Procedures, Location and Depth Criteria***
- ***Assign a Driller from the Highway Agency to Inspect Field Drilling and Sampling Operations***

Slide 2-1-62

Reinforce the need to obtain quality work from drilling contractors by controlling the operation.

SOILS AND FOUNDATIONS WORKSHOP

How Much Exploration?

Points to remember

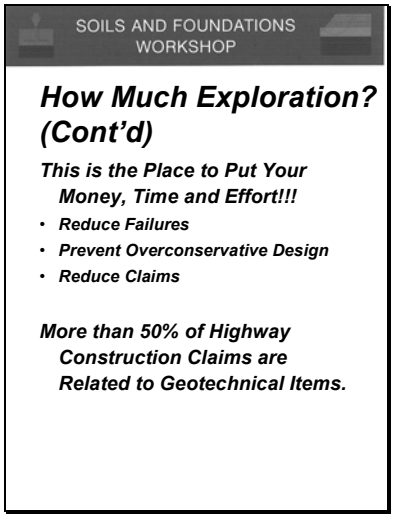
- ***Boring Cost <<< Bridge Cost***
- ***2.5″ Diameter Boring ≅ $ 12″ Diameter Pile***

Rule of Thumb

- ***Cost of Adequate Site Investigation is 1% to 2% of Construction Costs***

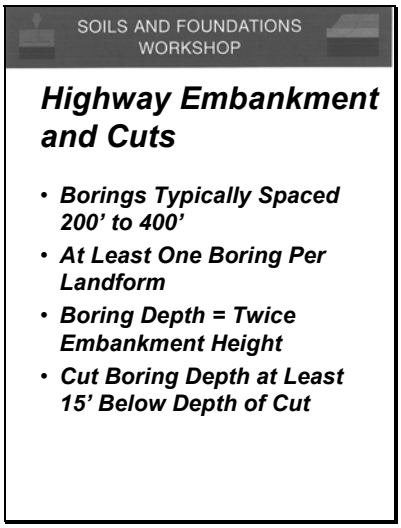
Slide 2-1-63

"How Much" transparencies used to convince students of the need to get enough data for a good design.



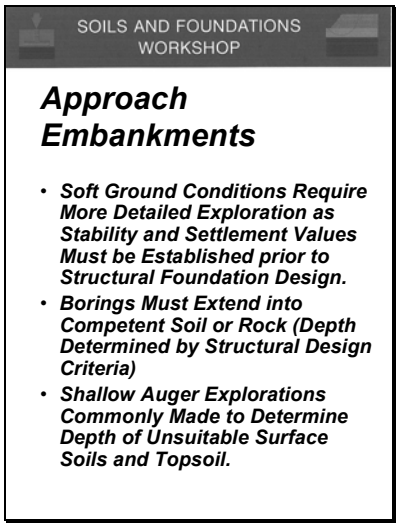
Slide 2-1-64

"How Much" transparencies used to convince students of the need to get enough data for a good design.



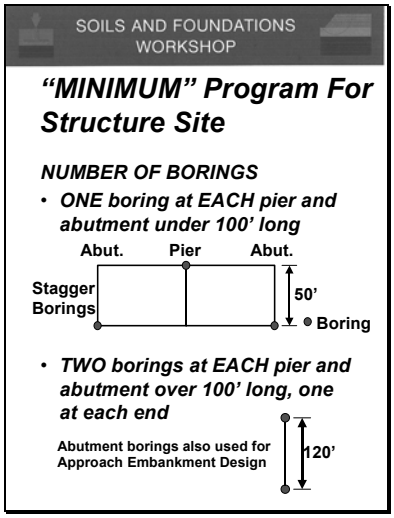
Slide 2-1-65

Begin minimum guidelines for boring and sampling. Note that the depth of cut refers to the elevation at the lowest ditch line of the cut section and not the centerline grade.



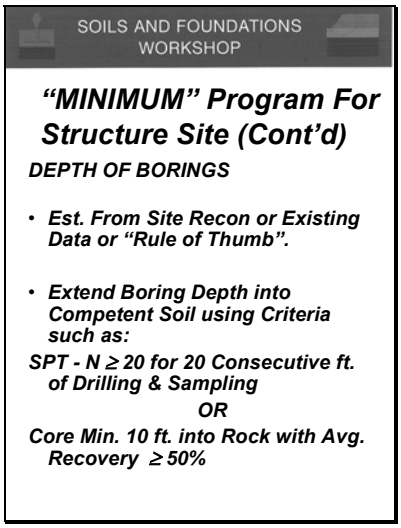
Slide 2-1-66

Carefully explain the difference between approach embankment needs and routine highway embankment needs.



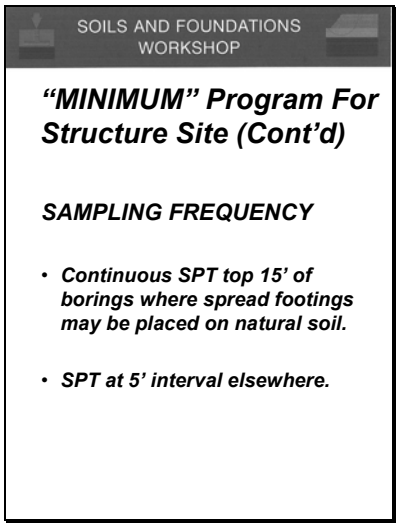
Slide 2-1-67

Explain the reasons for staggering the single borings is to obtain an indication of lateral variation of subsurface conditions. Also stress the need for coordination of highway and structure borings so the both groups do not take duplicative borings. In general the borings for approach embankment should be detailed enough to meet the needs of the structure design.



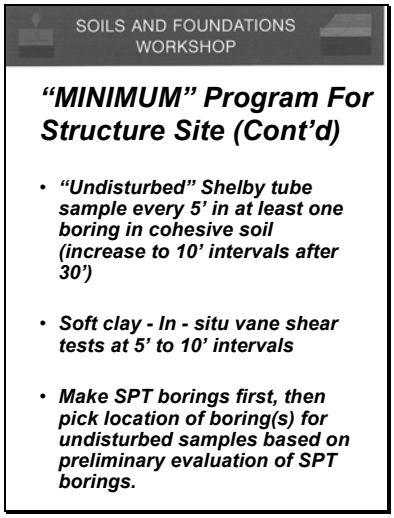
Slide 2-1-68

Contrast the criteria for the structure design needs with the embankment criteria. Note that the depth of a proposed boring is difficult to determine if no existing information is available at the site. Agencies should establish blow count criteria for boring minimum depth rather than simply asking drillers to drill to predetermined depth at all locations.



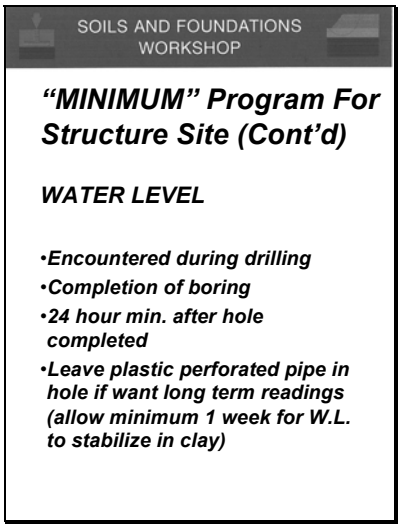
Slide 2-1-69

Note that shallow foundations place high stresses on the soil near the base of the footings. Then layers of poor materials can present major problems for the use of shallow foundations. Continuous samples taken near the footing elevation provide the necessary information for confident design.



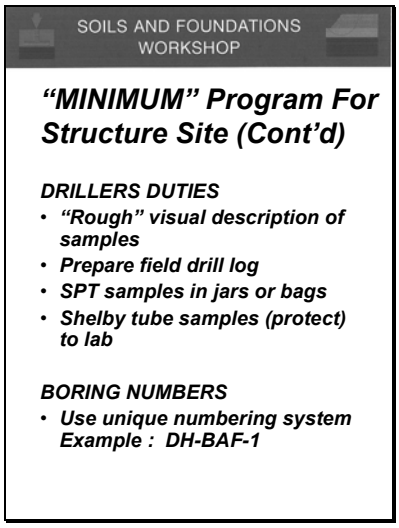
Slide 2-1-70

Note that the cost of undisturbed sampling and in-situ testing is much greater than the cost of an SPT sample. A good practice is to perform the SPT sample holes first and then decide if more expensive exploration are needed and if so where is the best location.



Slide 2-1-71

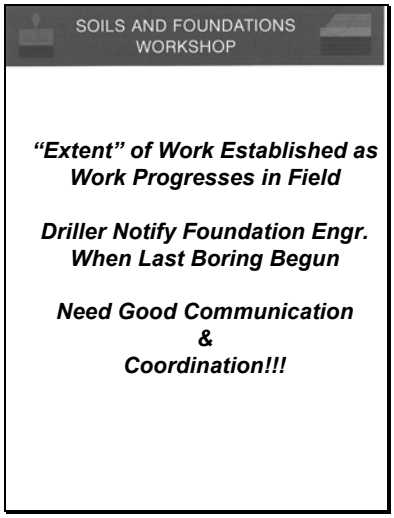
Water level is very important to determine both for embankment and structure design considerations. Additional information about water level is available from other sources such as local well records or ground water resources bulletins which can help to define the seasonal fluctuation of the area water levels.



Slide 2-1-72

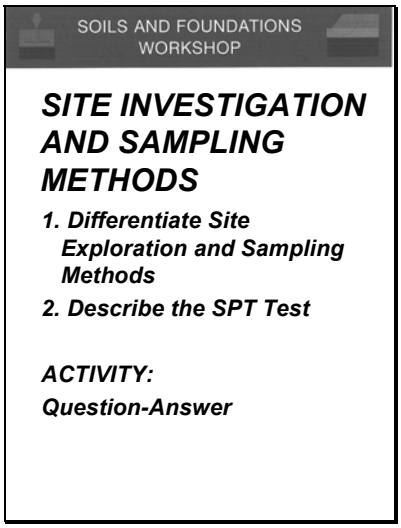
The drillers duties may be shared by a field geologist who is assigned to the rig. Students should be aware that the drillers primary duties include running the rig and doing all the operations associated with the ASTM standards for drilling and sampling.

Also the boring number issue is more important than the casual observer would guess because the duplication of boring numbers can cause major confusion in project design and construction.



Slide 2-1-73

Good communication between field crews and design can pay big dividends in getting the right amount of information with the least time and effort expended. No drill crew wants to move out of a difficult site and then be asked to return a short time later because enough data was not obtained the first time.



Slide 2-1-74

Repeat objectives.

Introduce the state representative who will present agency-specific information on site investigation. After the presentation is complete, thank the presenter then show the following overhead.

Slide 2-1-75

SHOW THIS OVERHEAD AFTER THE STATE PRESENTATION

Ask the group to add other site investigation techniques to the flip chart prepared at the beginning of the topic.