

Drilling and Sampling for Laboratory Testing

1. Drilling equipment/procedures
2. Soil sampling equipment & procedures

Focus primarily on:

- terrestrial applications
- fine grained soils



What is Purpose of Samples?

Key issues are purpose of samples and sample quality required

Purpose of samples??:

- general soil profile
- soil classification
- soil classification + index tests
- soil classification + index tests + engineering properties



Sample Disturbance

1. physical disturbance during sampling
2. changes in water content
3. changes in temperature
4. changes in pore liquid and gas pressure
5. handling, sampling and storage

**Full sample recovery often does not imply
an undisturbed sample was collected**

Soil Sampling Equipment

1. Hand tools
2. Split spoon barrel
3. California barrel
4. Thin walled tube
5. Fixed piston
6. Denison/Pitcher
7. Continuous tube
8. Internal sleeve with wireline
9. Block Sampling



Sample Disturbance - Ranking

Most disturbed → least disturbed

1. cuttings from hand holes or drill string
2. drive samples – SPT
3. push samples with thin walled tube
4. push samples with fixed piston
5. block samples

Summary of Sampling Methods

Sampler	State	Soil Types	Penetration	% use
Split Barrel	D	Sand, silts, clays	Hammer	85
Thin-walled Shelby Tube	U	Clays, silts, fine-grained soils, clayey sands	Mechanical push	6
Continuous Push	D/U	Sands, silts, clays	Hydraulic push	4
Piston	U	Silts and clays	Hydraulic push	1
Pitcher	U	Stiff to hard clay, silt, sand and partially weathered rock	Rotation and hydraulic pressure	<1
Denison	U	Stiff to hard clay, silt, sand and partially weathered rock	Rotation and hydraulic pressure	<1
Bulk	D	All	hand	<1
Block	U	Cohesive soils	Hand/special sampler	<1



D = disturbed; U = undisturbed

After FHWA NHI-01-031; see also ASTM 4700

Truck/Rig Mounted Test Borings

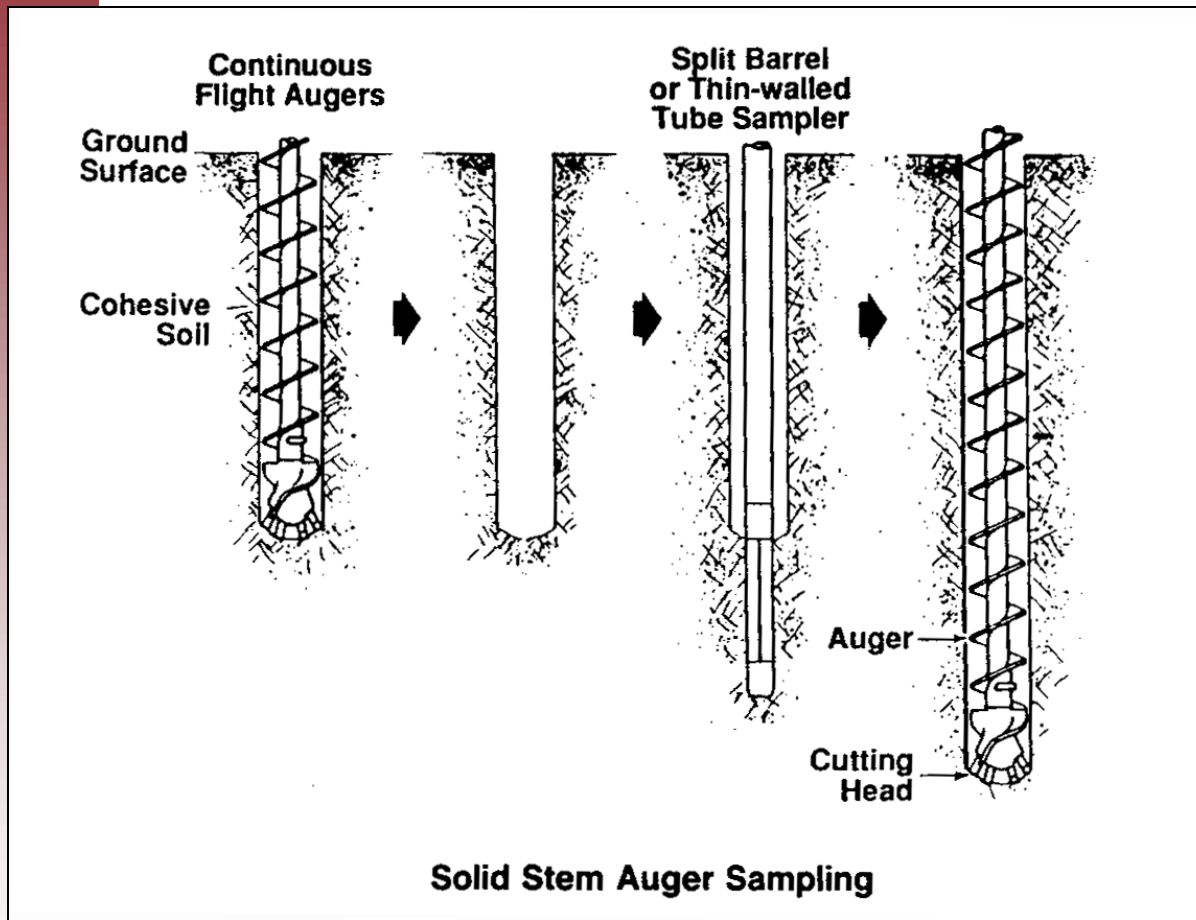
1. Solid-Stem Continuous Flight Augers
2. Hollow-Stem Augers
3. Open Hole Mud Rotary Drilling
4. Drive Casing Mud Rotary Drilling
5. Air-Rotary Drilling
6. Wireline/Cable tooling

Key Drilling Procedures

1. Vertical alignment and stability of drill string
2. Cleaning of borehole prior to sampling
3. Stabilization of borehole with drilling mud – critical for collection of undisturbed samples
4. Patience



Solid stem augers

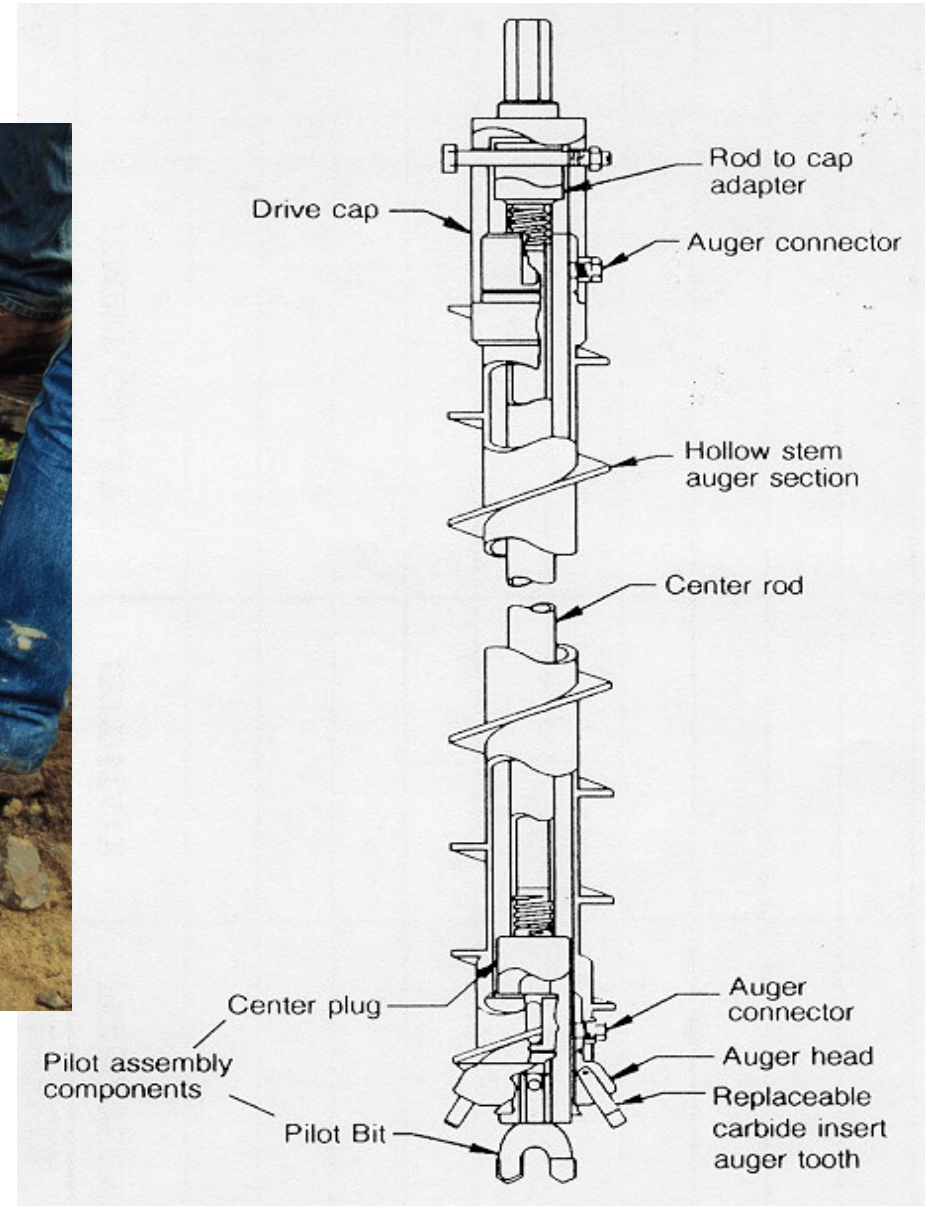


Soil sampling is performed by removing augers and introducing sampling tools (i.e., open hole); augers are then reinserted to advance the borehole

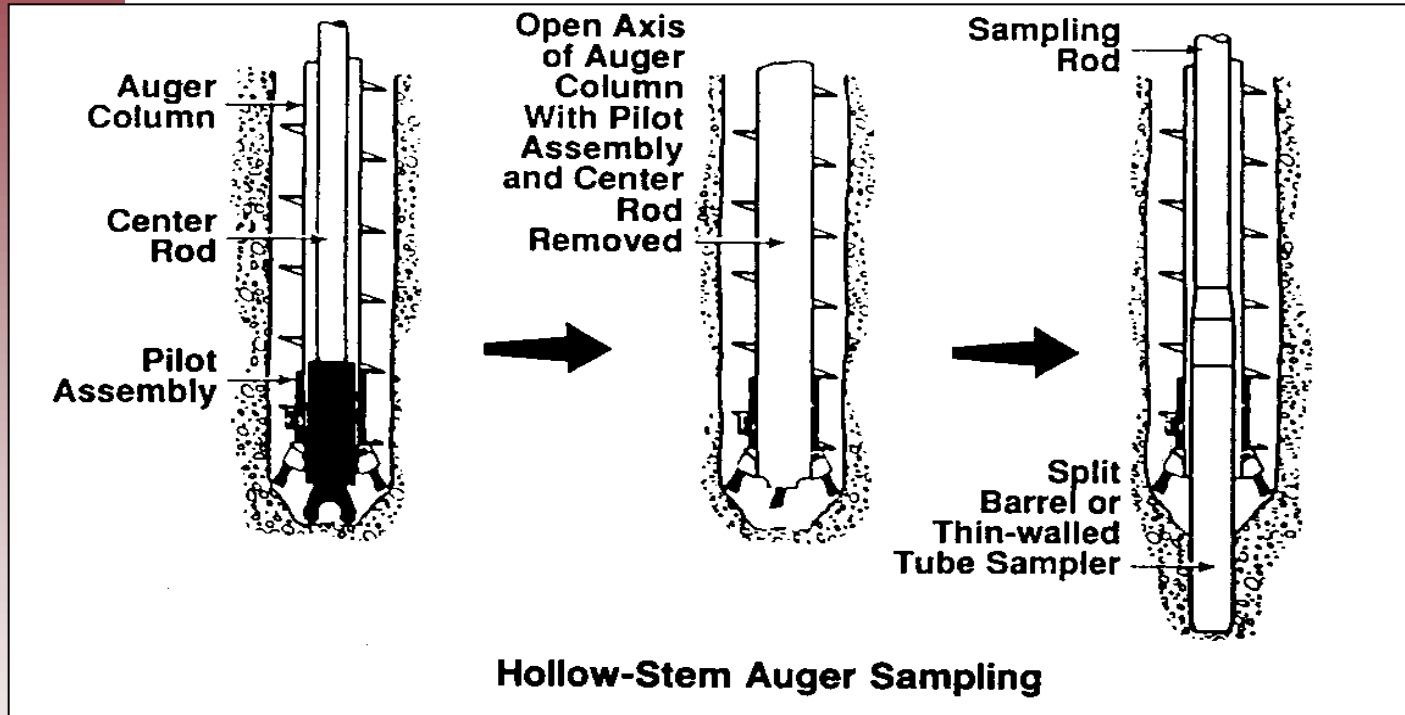
Hollow-Stem Augers



Augers act as a casing



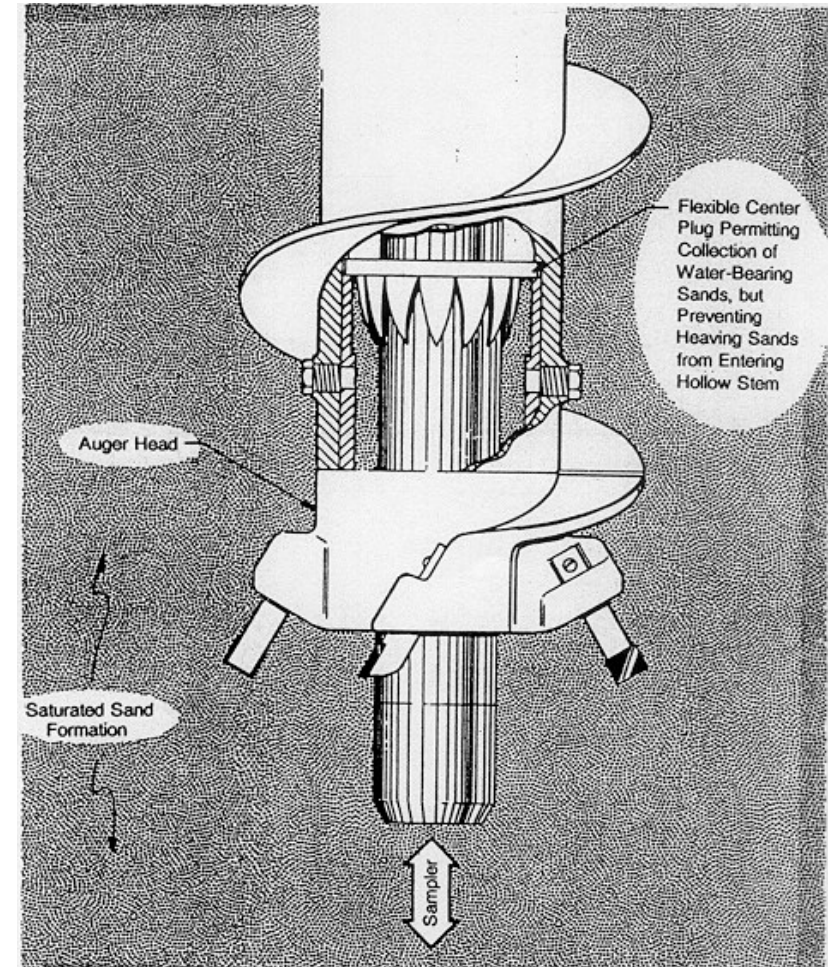
Sampling with Hollow Stem Augers



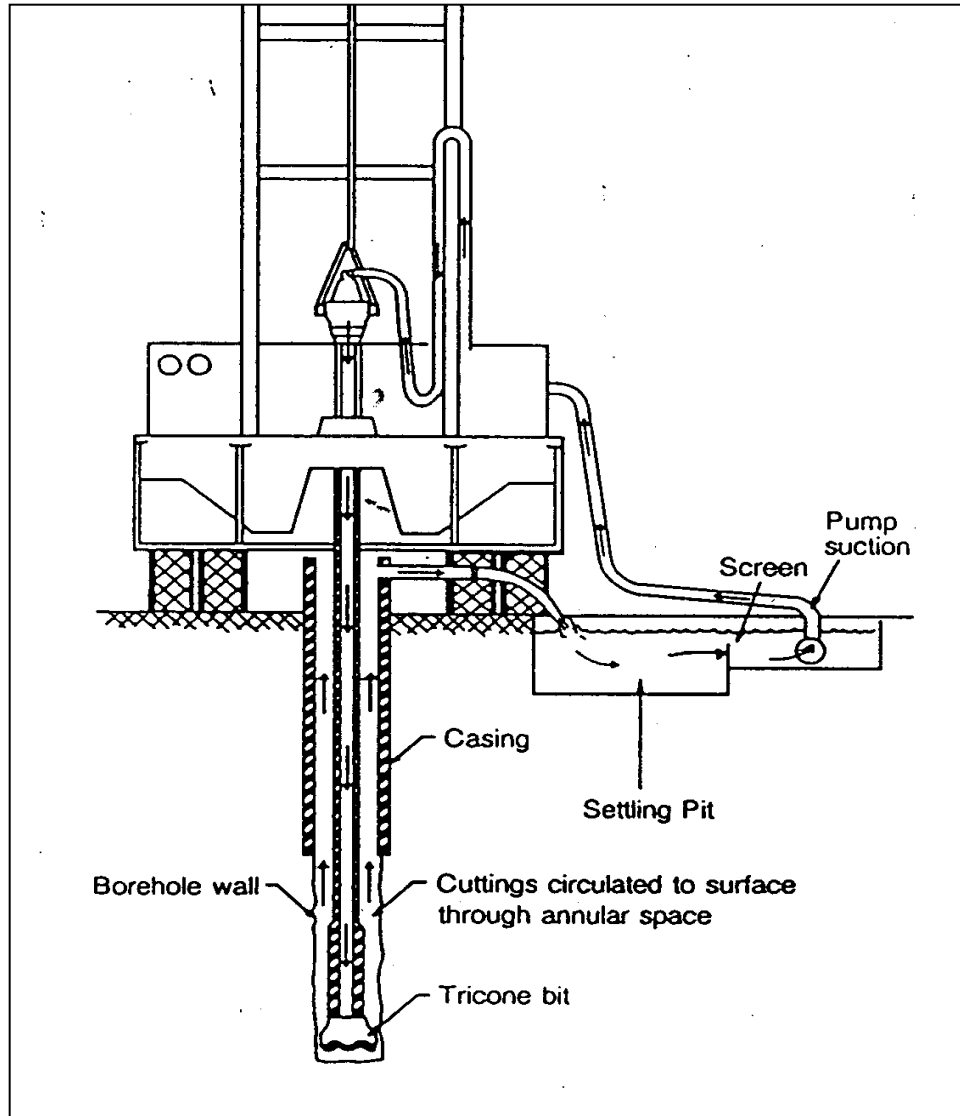
ASTM D 6151 “Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling”

Dealing With Heaving Conditions - HSA

1. Add water to drill string
2. Use drilling mud
3. Internal reverse augers
4. Knock-out plate
5. Flexible center plug



Mud Rotary (Wash Boring) Drilling



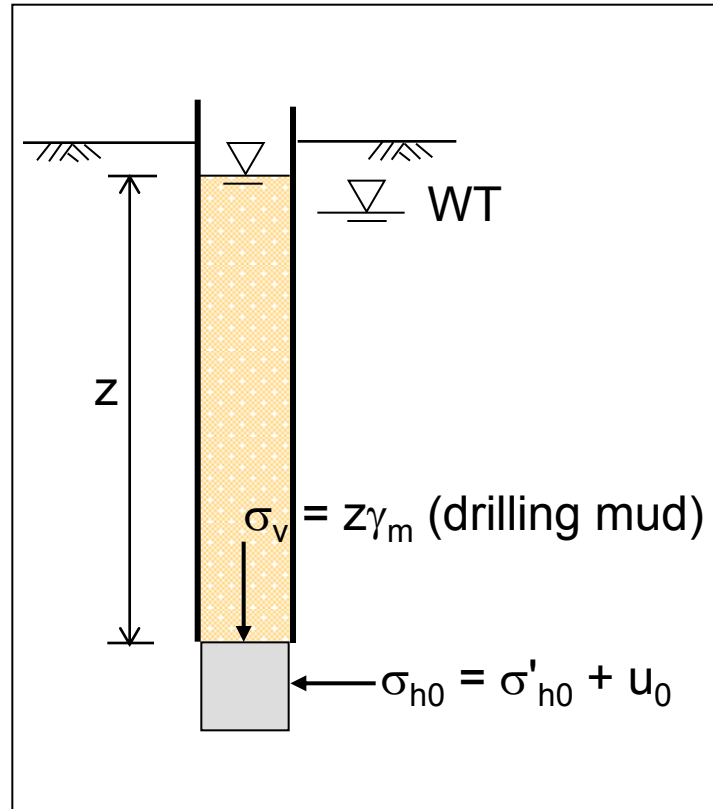
ASTM D 5783 “Guide for Use of Direct Rotary Drilling With Water-Based Drilling Fluid for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices”



Only way to conduct open hole drilling in fine grained soils for collection of "undisturbed" soil samples – used of weighted drilling mud keeps borehole stable.



Drilling Mud



Recommendations:

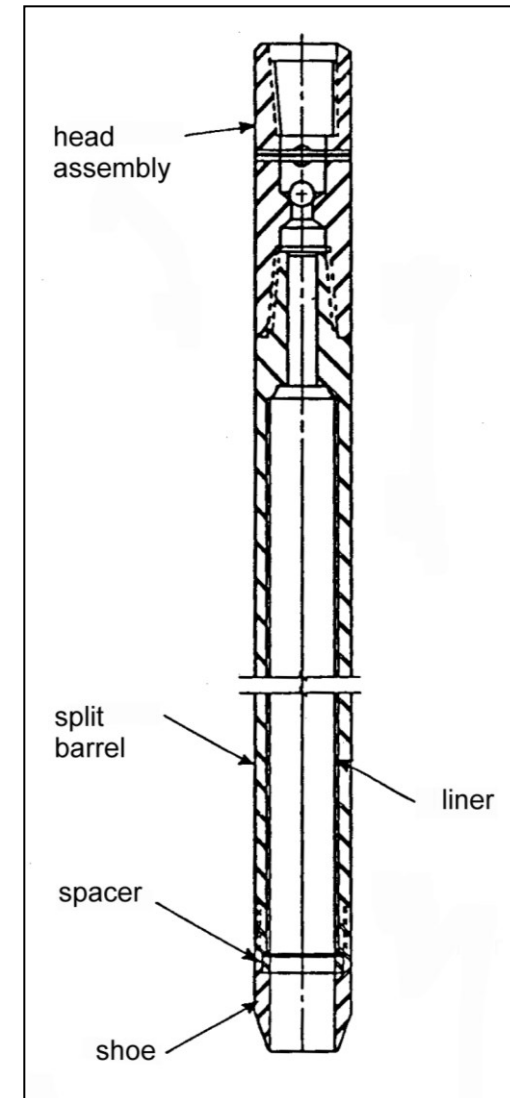
- maintain $\sigma_v = z\gamma_m$ high enough to avoid significant stress relief
- z at top of casing + N vs A rods
- $\gamma_m \approx (1.2 - 1.3)\gamma_w$

Note: displacement type samplers (e.g., NGI type) do not need drilling mud

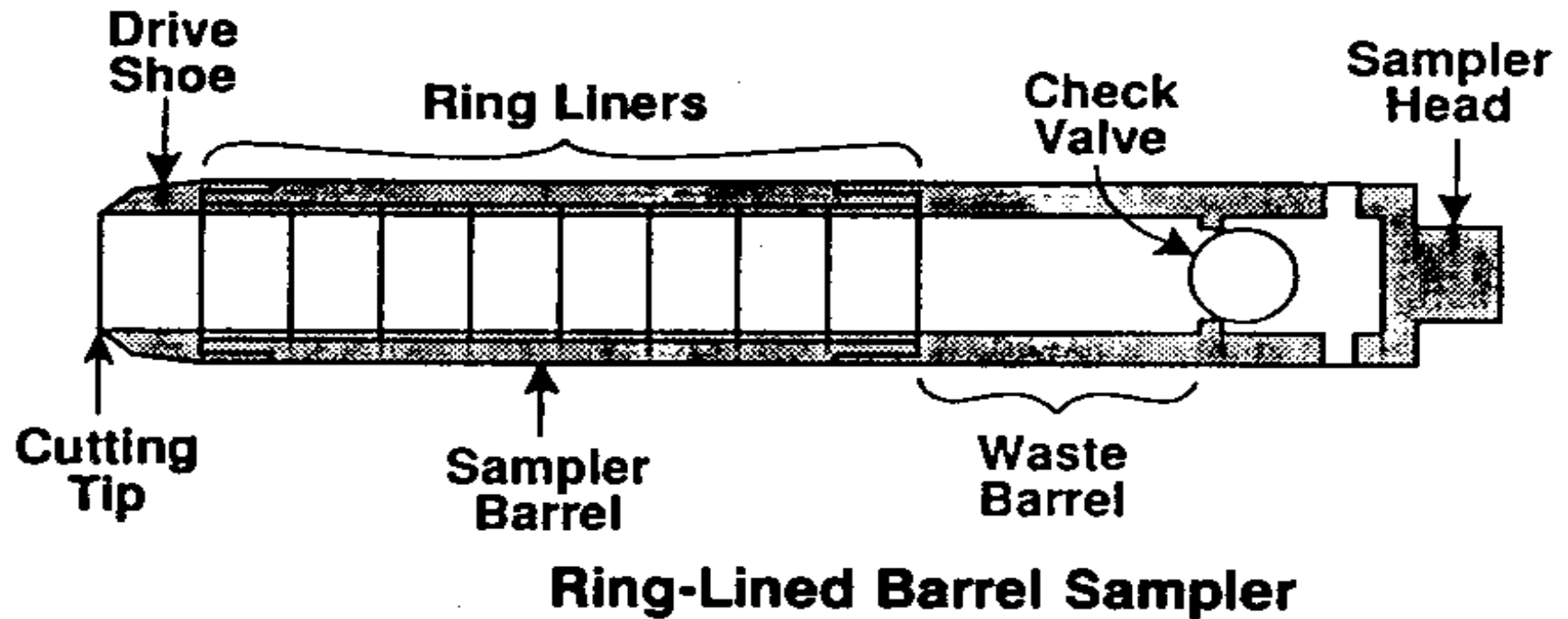
Drive Samples - SPT

1. ASTM 1586 Standard Test Method for *Penetration Test and Split-Barrel Sampling of Soils*
2. Good for soil classification and index tests (grain size, Atterberg Limits, etc.)
3. Disturbed samples that cannot be used for engineering properties
4. Measure recovery, determine soil units, presence of water, bag or jar samples for water content, classification tests, etc.

HSA with SPT hammer and split spoon sampler

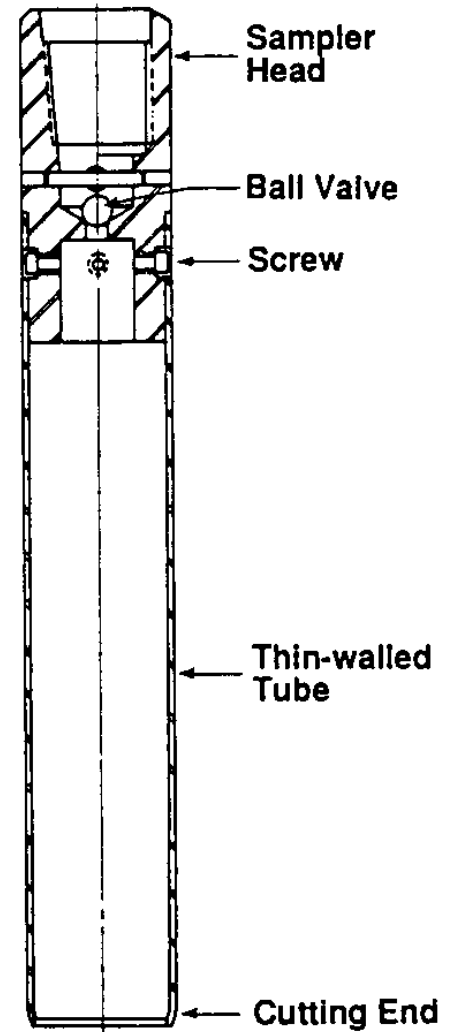


Ring Barrel Sampler – California Sampler



Push Samples – Thin Walled Tube Sampling

1. ASTM 1587 *Standard Practice for Thin Walled Tube Sampling of Soils*
2. Fixed piston better than push
3. Actuating rod vs hydraulic piston sampler
4. NW rods vs AW rods

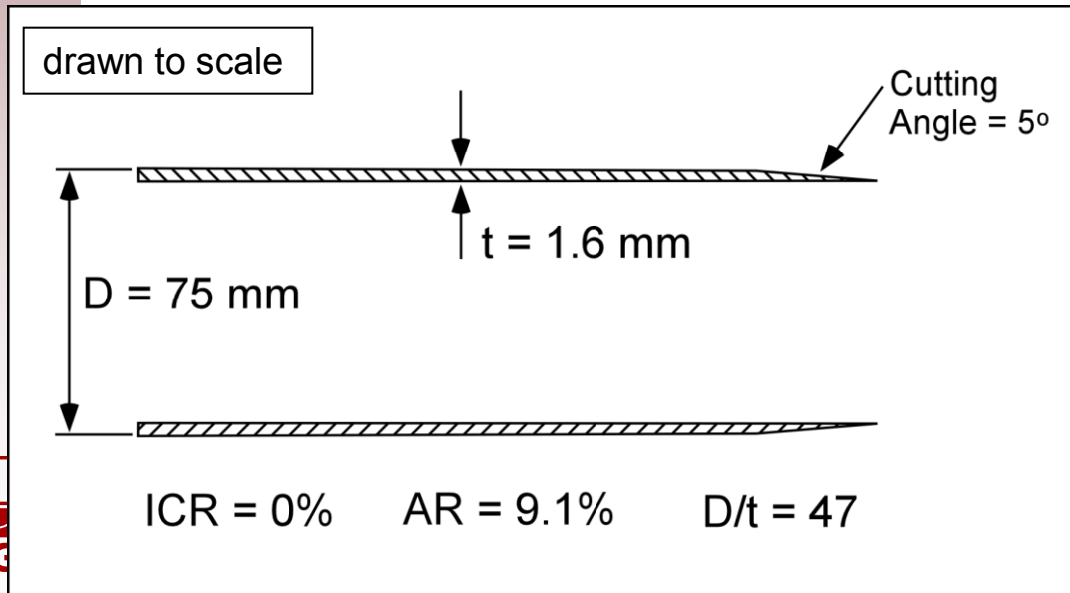


Thin Walled Sampling Tubes

Focus on:

- Area Ratio (AR)
- Inside Clearance Ratio (ICR)
- Cutting angle

- Diameter $D \geq 75$ mm, $AR < 10\%$
- Diameter/thickness ratio, $D/t \geq 45$
- Inside Clearance Ratio, $ICR \approx 0$
- Sharp cutting angle, $\approx 5^\circ$
- JPN sampler (Tanaka et al. 1996)

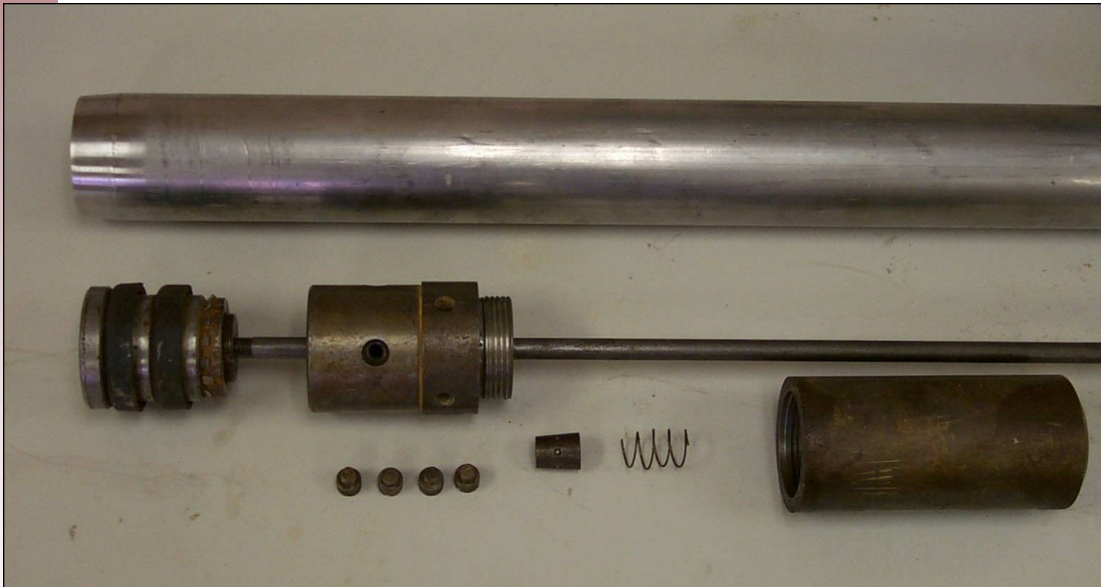


Modified
thin-walled
(Shelby) tube

Piston Sampling

Recommendation:

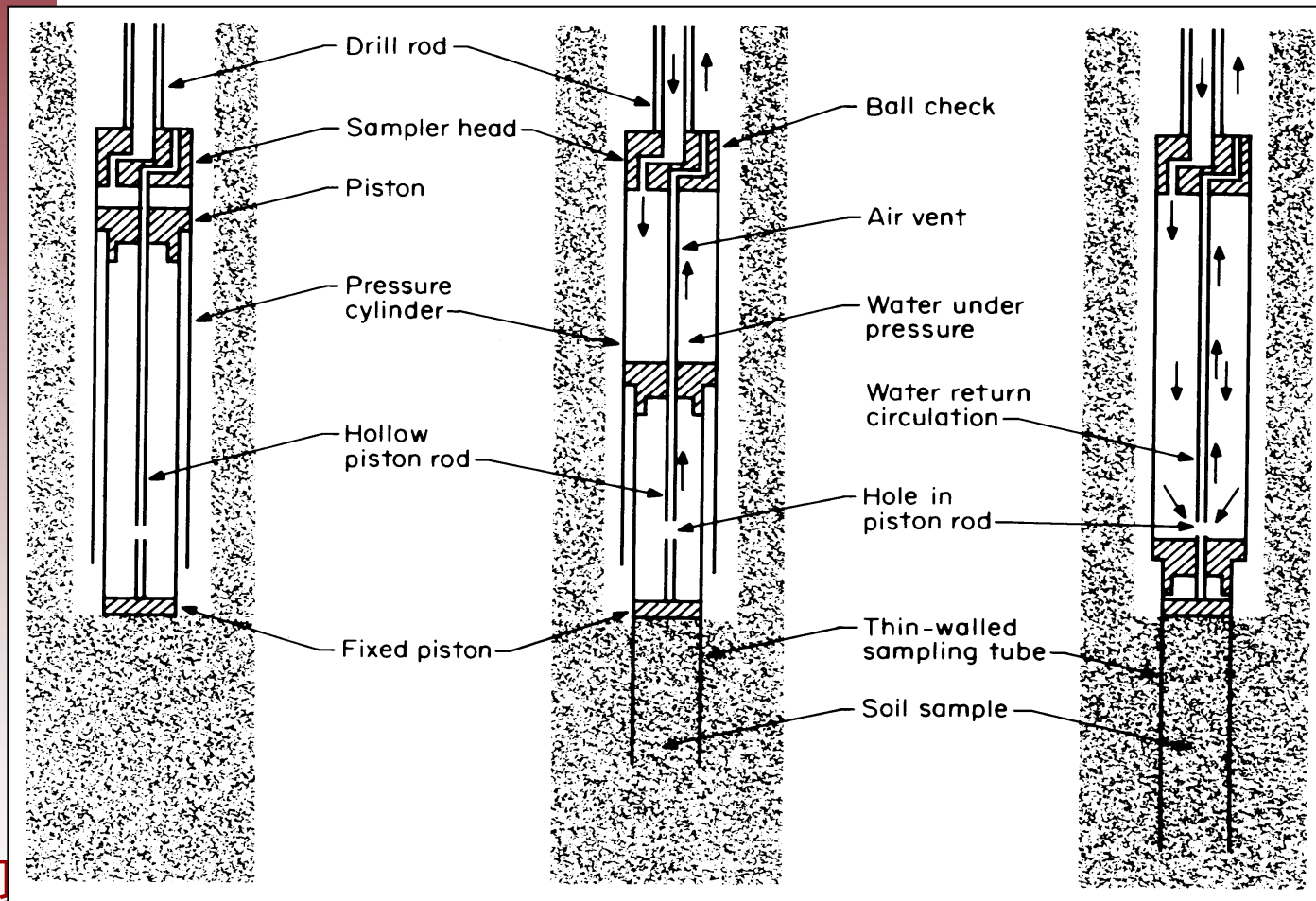
Use fixed piston - better control of entering soil + better recovery



Mechanical or hydraulic piston



Osterberg Piston Sampler



- use fluid pressure to active sampler

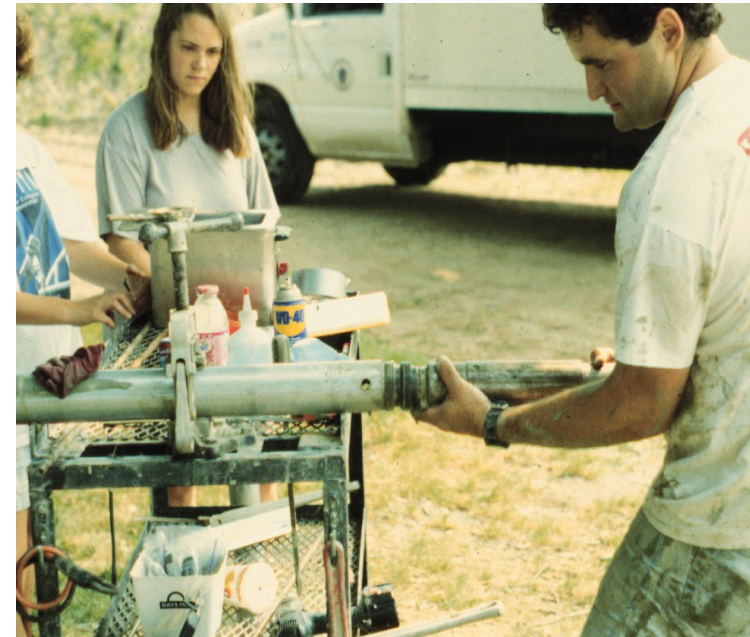
- easier to operated than mechanical system

- but cannot see movement of piston head

- rely on drop in pressure and/or return of bubbles in drill fluid to see if full push complete

Tube Walled Tube Sample Field Inspection

1. Remove loose material from ends
2. Measure recovery
3. Conduct index tests, e.g., TV, PP, LV, etc.
4. Remove sample for water content and field classification
5. Seal ends with 50:50 mix paraffin wax and petroleum jelly and mechanical O-ring packer



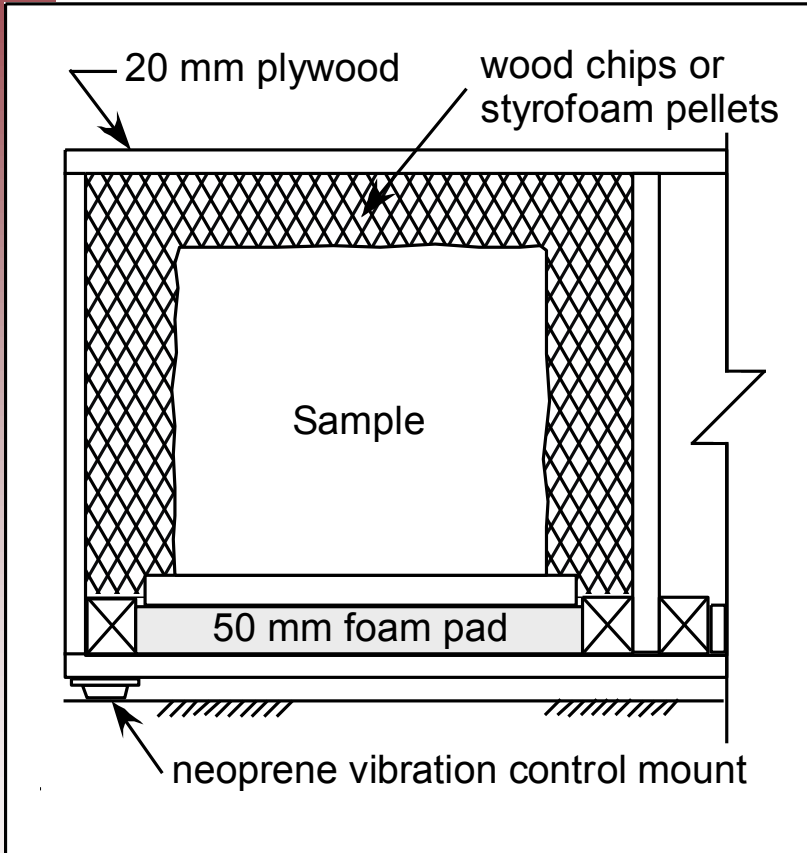
Undisturbed Tube Sample Shipping and Storage

1. ASTM 4220 *Standard Practice for Preserving and Transporting Soil Samples*
2. Shipping: wrap vertically in protective cushion materials inside rigid containers
3. Ship in coolers if necessary
4. Store tubes vertically in high humidity room and ideally at in situ temperature
5. Cut tubes for extruding samples – especially if stored for long durations

Transportation

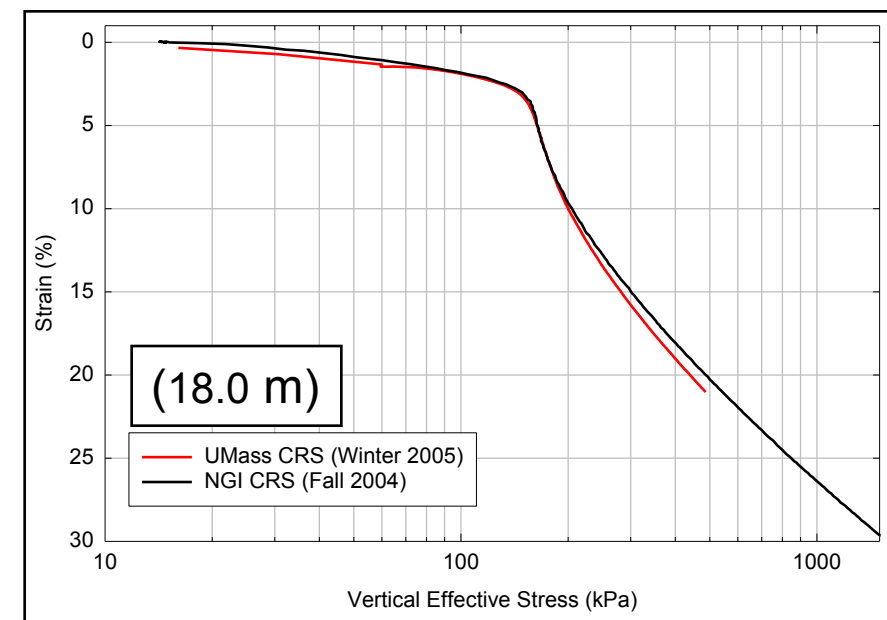
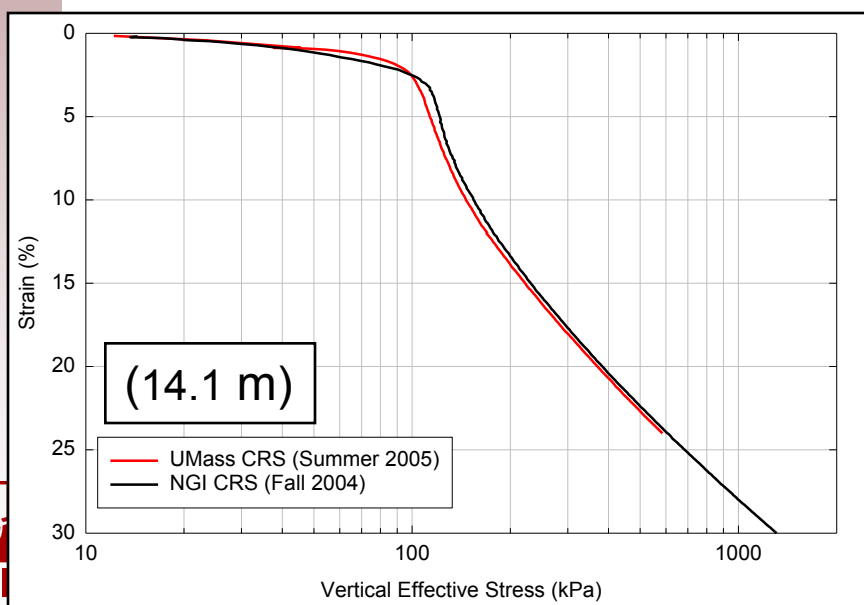
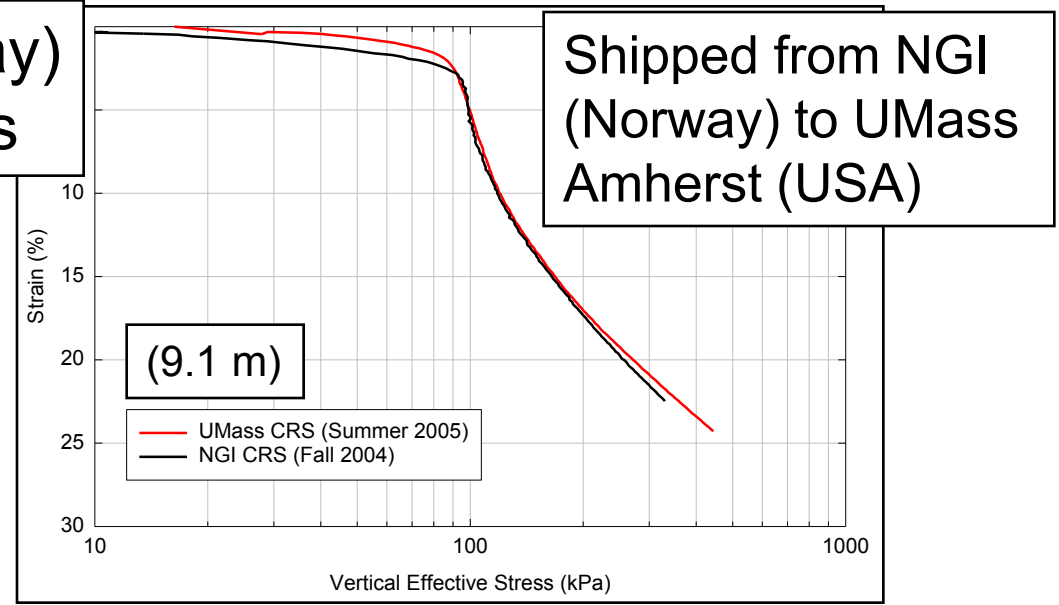
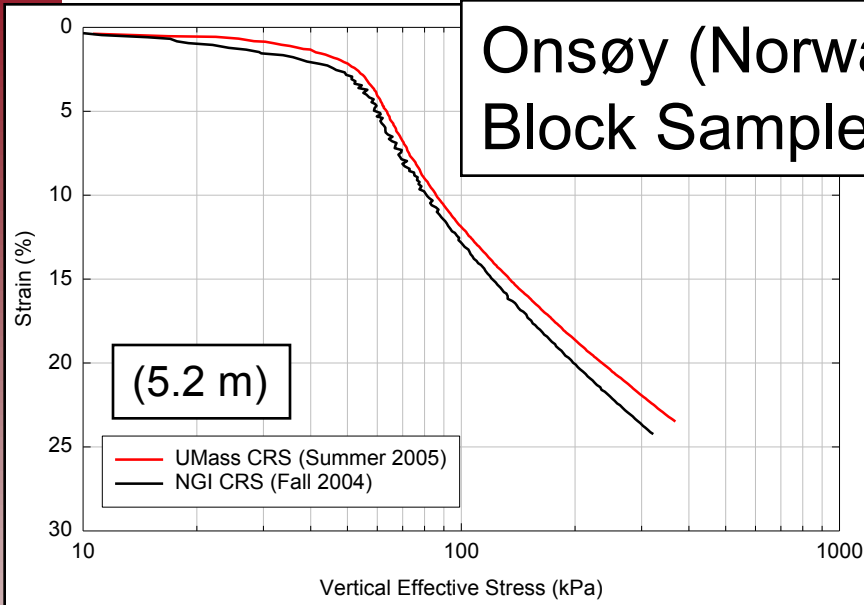
Recommendations:

- Keep soil in tube to reduce shear distortion
- Use transportation boxes with padding and vibration damping
- Store in controlled temperature and humidity room



Plastic wrap with 50:50 mix wax & petroleum jelly

Onsøy (Norway) Block Samples

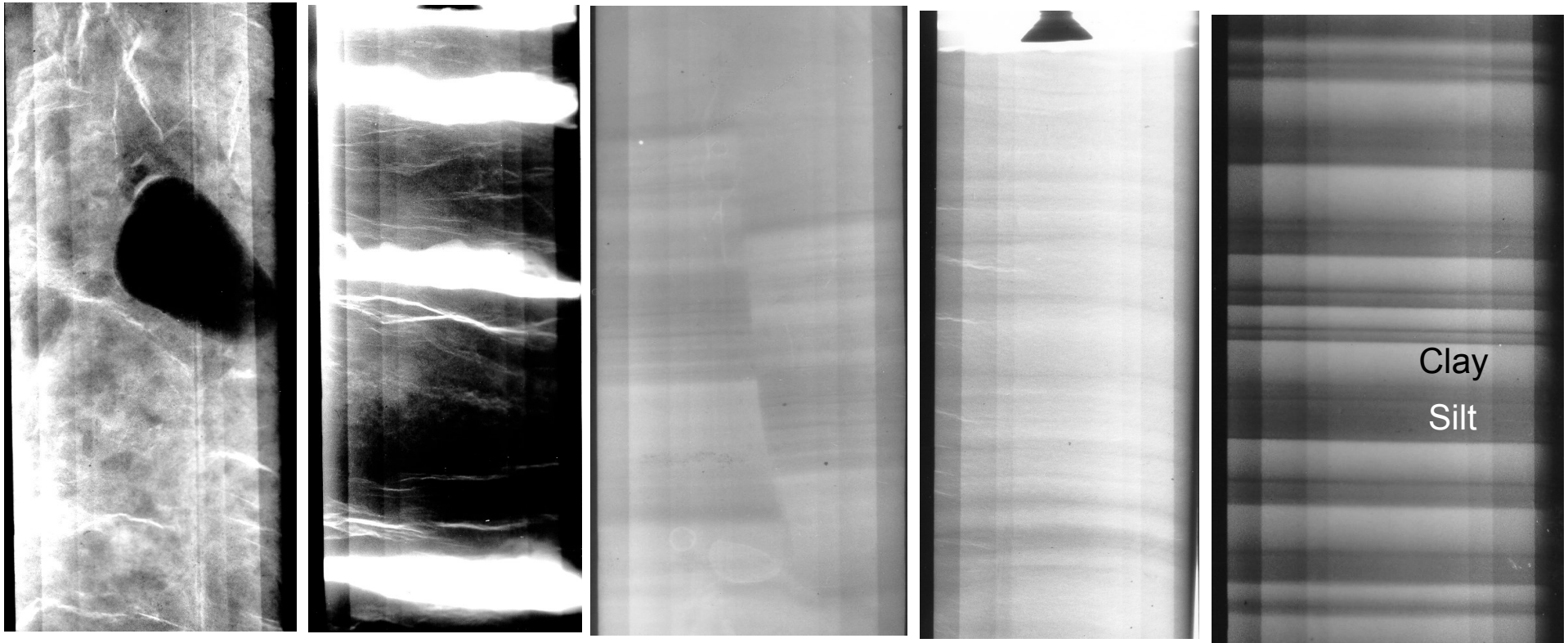


Extrusion of Undisturbed Tube Samples

1. X-Ray tubes if possible: *ASTM 4220 Standard Test Methods for X-Ray Radiography of Soil Samples*
2. Cut tube rather than full length extrusion – especially if stored for long durations
3. Break bond between soil and tube with wire saw

X-rays of Tube Samples

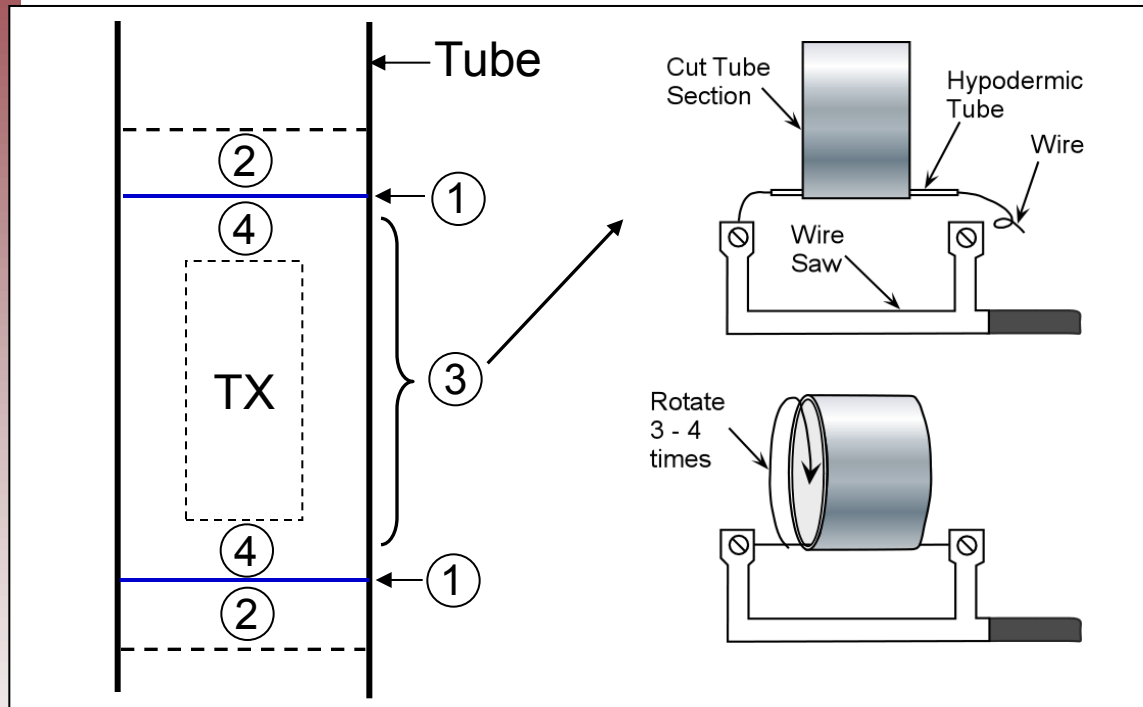
- Soil Macrofabric, Sample disturbance, Intrusions/anomalies



[75 mm tube samples]

NGI now doing CAT scans of tube samples

Sample Extraction – Thin walled tubes

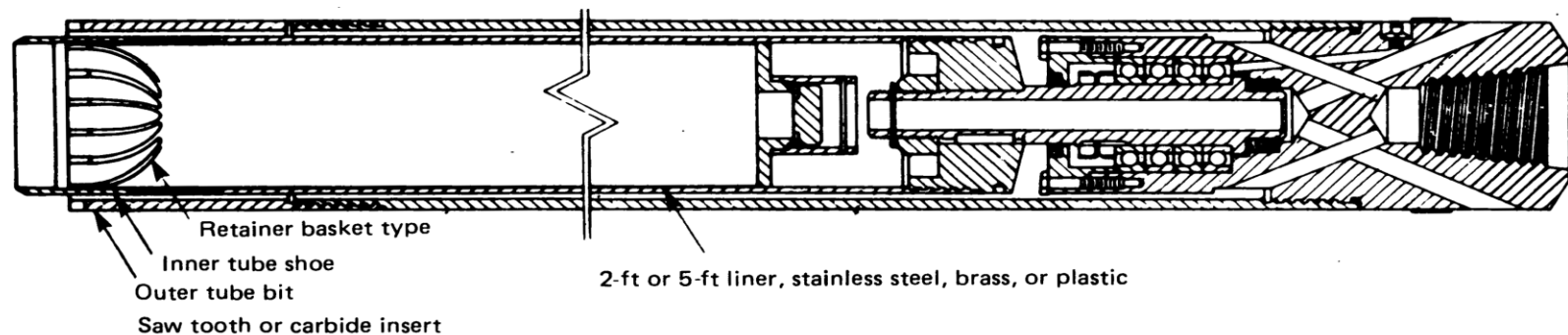


- ① Cut tube and soil
- ② Water content and/or strength index tests
- ③ Debond and extrude
- ④ Trim specimen



Denison Core Barrel

1. For stiff, hard fine grained soils and soft rocks
2. Rotating outer barrel with fixed inner barrel and liner

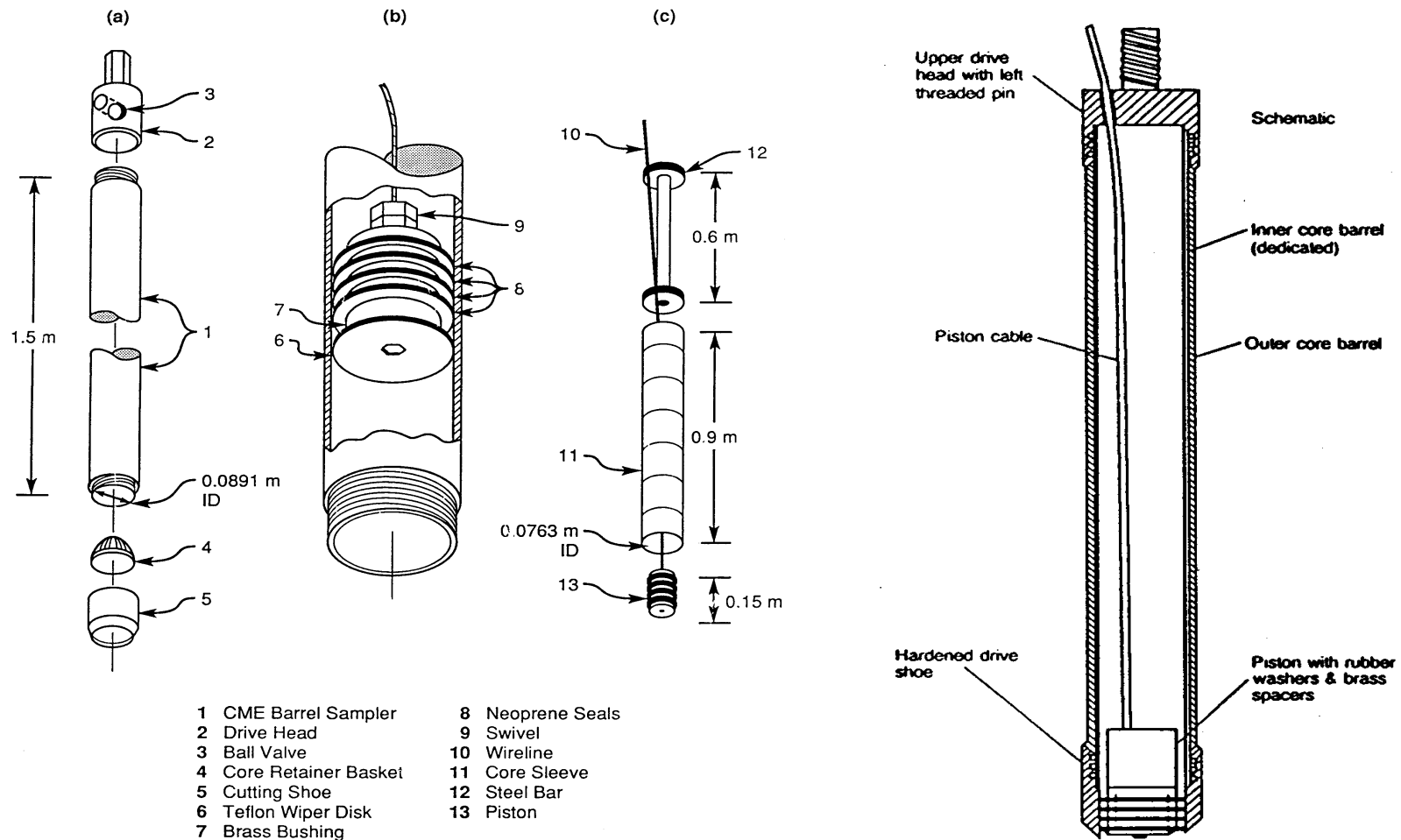


Pitcher Tube Sampler

1. For stiff, hard fine grained soils and soft rocks
2. Similar to Dennison sampler – outer rotating core barrel with bit and an inner stationary thin wall sampling tube
3. Inner tube is spring loaded such that it either leads or trails the outer barrel depending on soil stiffness

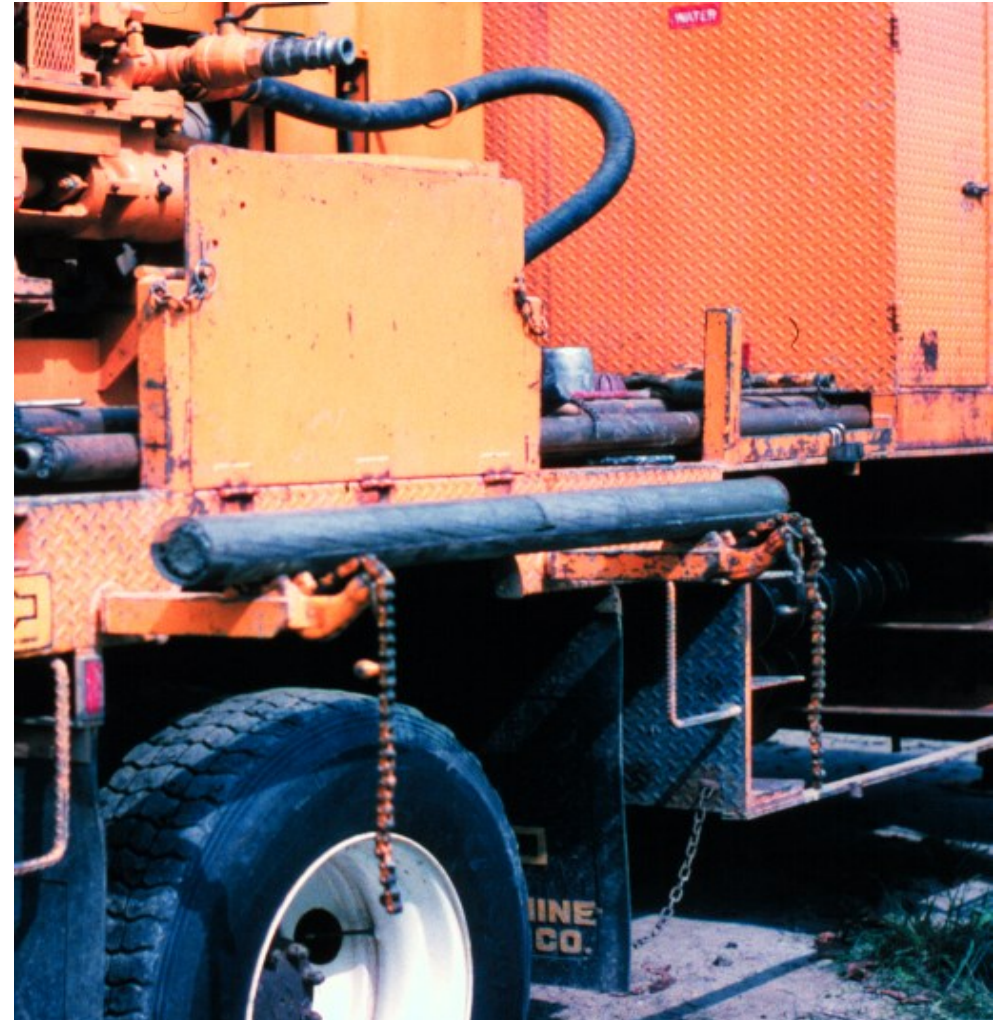
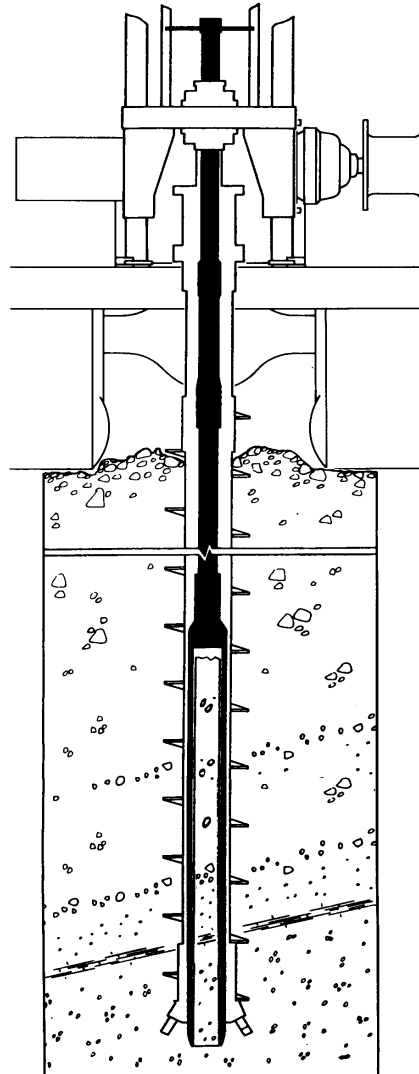
Core Barrel Sleeve Sampler

Wireline - Cohesionless sands and gravels



CME Semi-continuous sampler

Uses 5 to 10 ft liners in sample barrel which is inside hollow stem auger



Boat Longyear Sonic Drill Rig

Uses 10 ft barrel sections to collect "undisturbed" samples



SOA Solution to tube sampling: Block Sampling → best quality



Sherbrooke Block Sampler

- successfully used on several commercial projects
(e.g., NGI, Boston Central Artery)

Block sampling – sensitive Leda Gloucester Clay (Ottawa, Canada)



Louisiana – Atchafalaya River



... wood!



Soil Samples for Chemical Analysis

- Example for Hydrocarbons

1. Use steam cleaned core barrel sampler
2. Insert into nitrogen filled glovebox
3. Extrude into aseptic sampling environment
4. All containers and instruments autoclaved prior to sampling

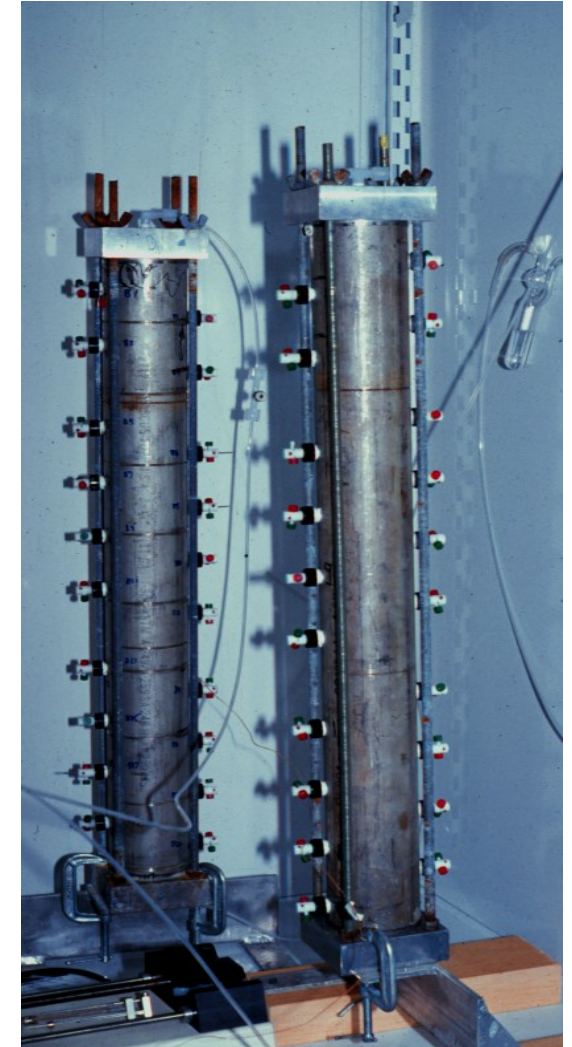
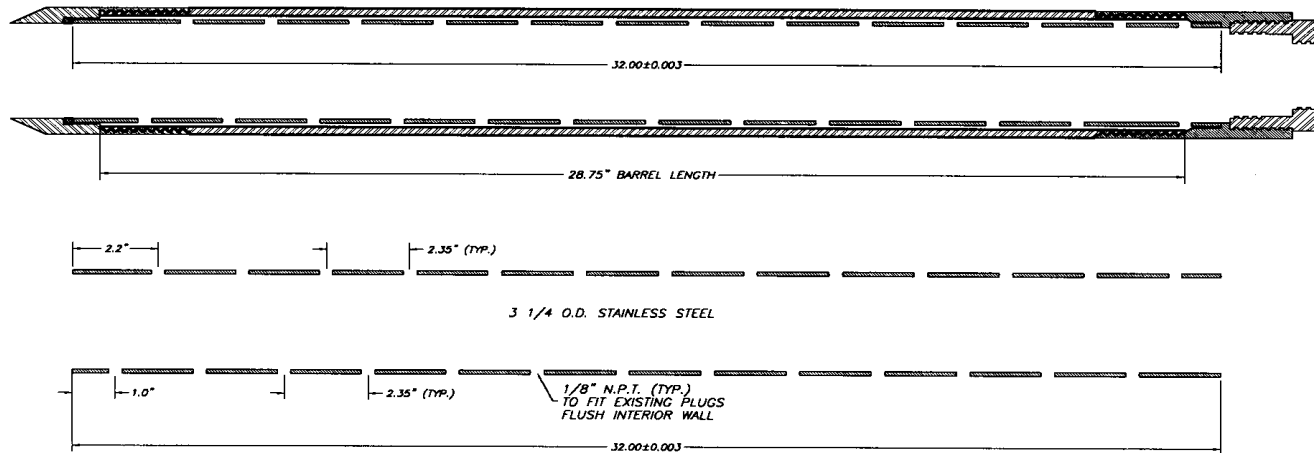
Steam cleaning hollow stem augers



Syringe barrel collection of samples for environmental analysis



Core Barrel Sleeve Sampler



Summary

1. Many options for soil sampling, although often there are regional practices
2. Sample disturbance is a critical issue
3. Disturbed samples are suitable for soil identification and basic classification tests
4. Undisturbed samples are essential for accurate measurement of engineering properties