

رفتار دینامیکی خاک ها

Hasan Ghasemzadeh

Soil dynamics

□ آزمایشات آزمایشگاهی

□ آزمایشات صحرایی

□ رفتار خاک ها تحت بار سیکلی

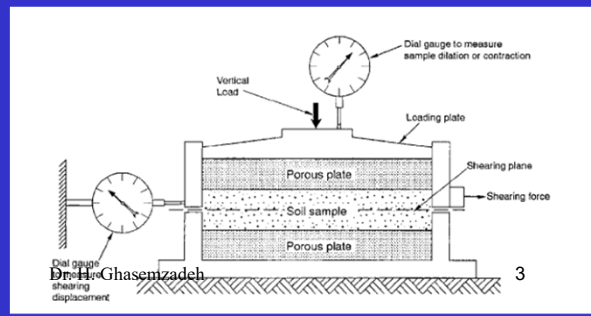
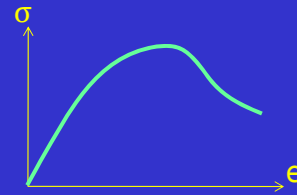
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Direct Shear Test.

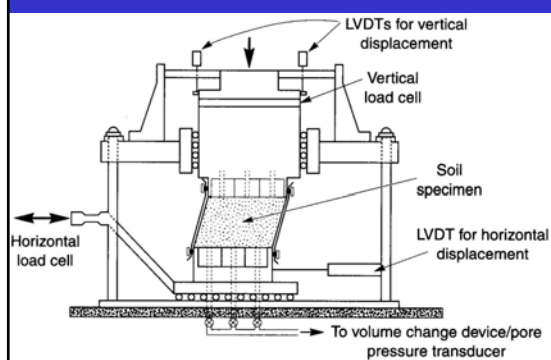


آزمایشات آزمایشگاهی
آزمایش برش مستقیم



Dynamic Simple Shear Apparatus - DSSA

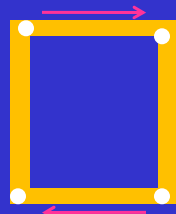
آزمایشات آزمایشگاهی
آزمایش برش مستقیم



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آزمایشات آزمایشگاهی آزمایش برش نوسانی ساده



تعداد نوسانات متناظر با شکست

میرایی - مدول برشی - پتانسیل روانگرایی

تنش قائم ثابت

دوران محورهای تنشهای اصلی

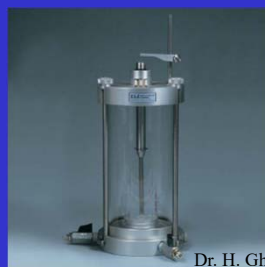
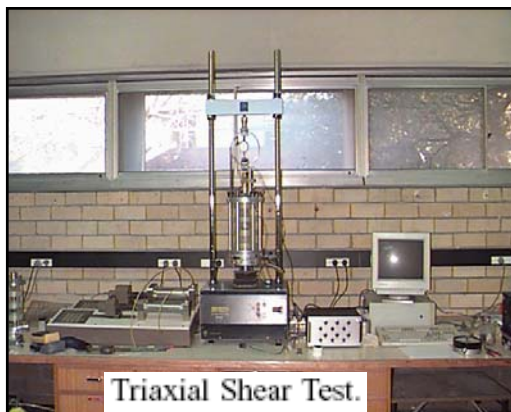
شرایط کرنش مسطح

رسکو و همکاران - کمبریج

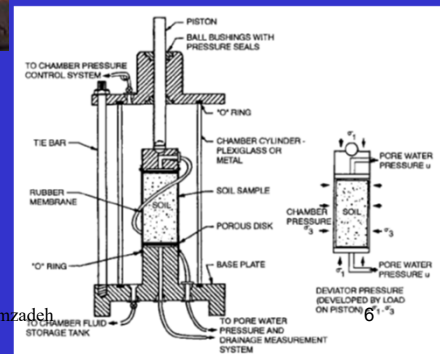
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آزمایشات آزمایشگاهی آزمایش سه محوری



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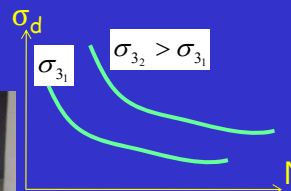


Cyclic Triaxial System



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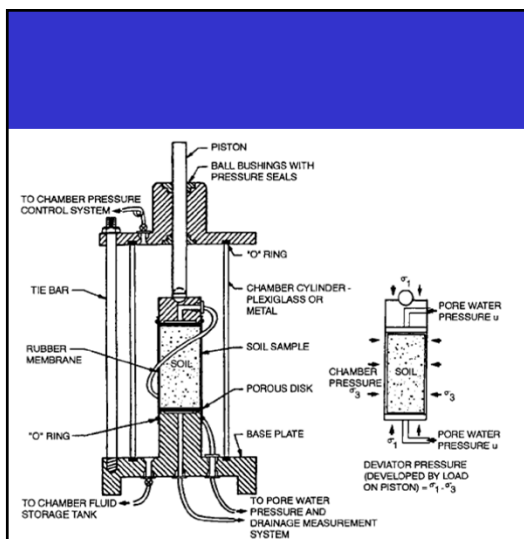
آزمایشات آزمایشگاهی آزمایش سه محوری



تعداد نوسانات متناظر با شکست

$$\sigma_d = \sigma_1 - \sigma_3$$

دوران نود درجه محورهای تنش
های اصلی در هر سیکل



آزمایشات آزمایشگاهی آزمایش سه محوری

آزمایش سه محوری استوانه تو خالی

آزمایش سه محوری واقعی

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آزمایشات آزمایشگاهی

Resonant-Column

آزمایش ستون تشدید

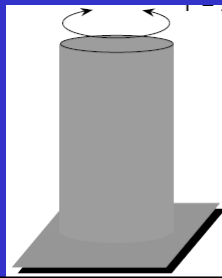
a column of soil is subjected to an oscillating longitudinal or torsional load.
The frequency is varied until resonance occur.

From the frequency and amplitude at resonance the modulus and damping of the soil can be calculated.

A further measure of the damping can be obtained by observing the decay of oscillations when the load is cut off.

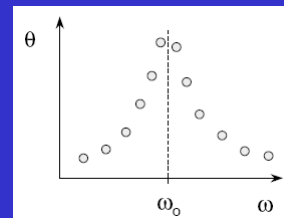
میرایی - مدول برشی

$$T = A \sin \omega t$$



Apply harmonic torque
Measure angular rotation
Sweep across frequencies

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Compute G_{\max} from ω_0

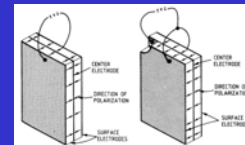
آزمایشات آزمایشگاهی

Bender elements

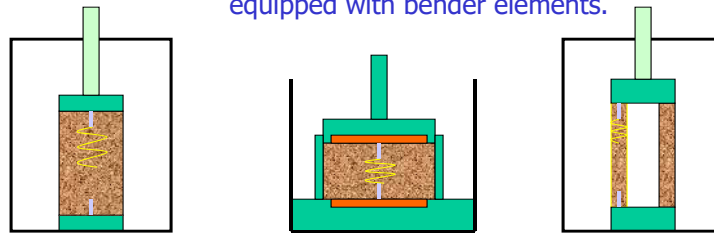
advantages

non-destructive, simple to use, allows for unlimited number of tests during the experiment

سرعت موج برشی
مدول برشی در تغییر مکانهای کم



- Testing apparatus is triaxial, consolidometer, resonant column or etc. equipped with bender elements.



piezoceramics have been combined in different forms to generate and receive shear waves

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In-Situ Tests آزمایشات صحرائی

In-Situ Testing - Objectives

- Select in-situ tests for augmenting, supplementing, and even replacing borings.
- Realize the applicability of various in-situ methods to different soil conditions.
- Recognize the complementary nature of in-situ direct push methods with conventional rotary drilling & sampling methods.
- Recognize values for utilizing these methods and quality implications for their underuse

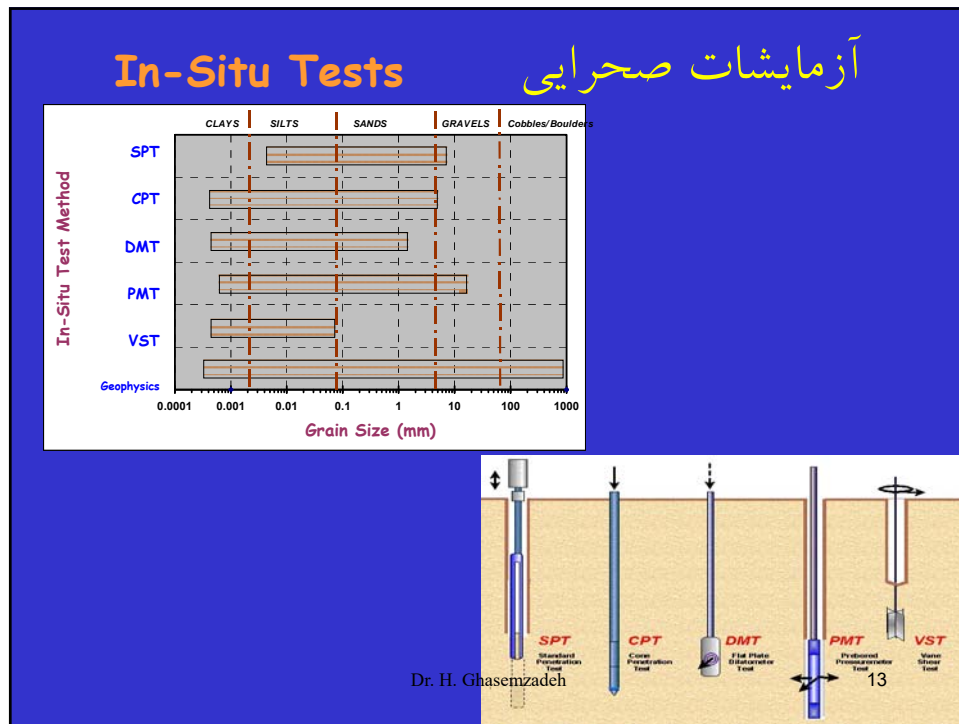
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A.P. Van den Berg Track Truck

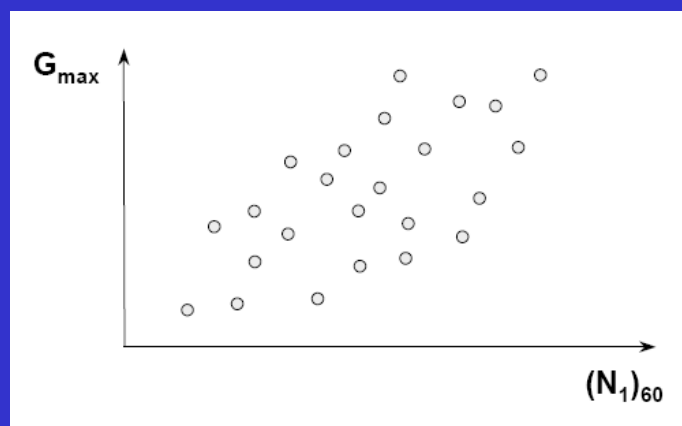
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Shear Modulus Measurement of G_{\max}

Correlation to $(N_1)_{60}$



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بارگذاری صفحه ای

مراحل انجام آزمایش

صفحه ۳۰ در ۳۰ بارگذاری و بار برداری می شود بار و
تغییر مکانها ثبت می گردد

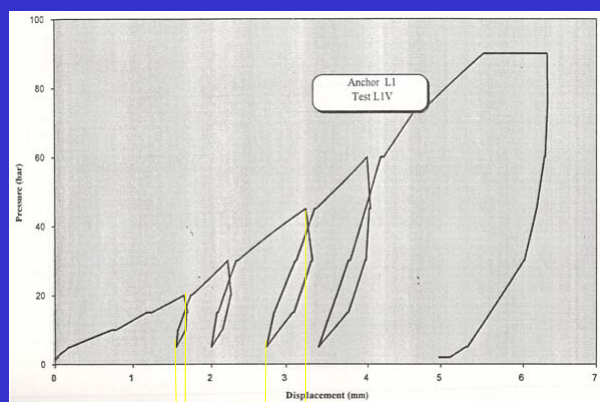
- حفر گالری و آماده سازی
- نصب سیستم آزمایش
- انجام آزمایش
- ارائه نتایج آزمایش



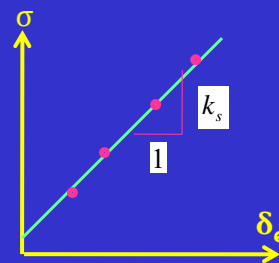
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بارگذاری صفحه ای



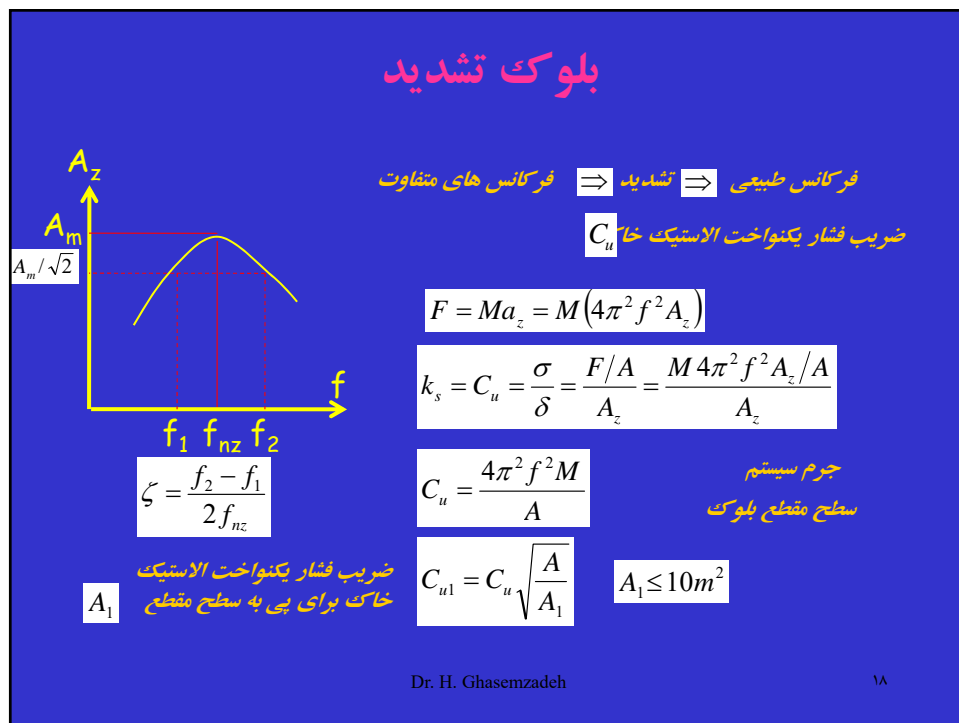
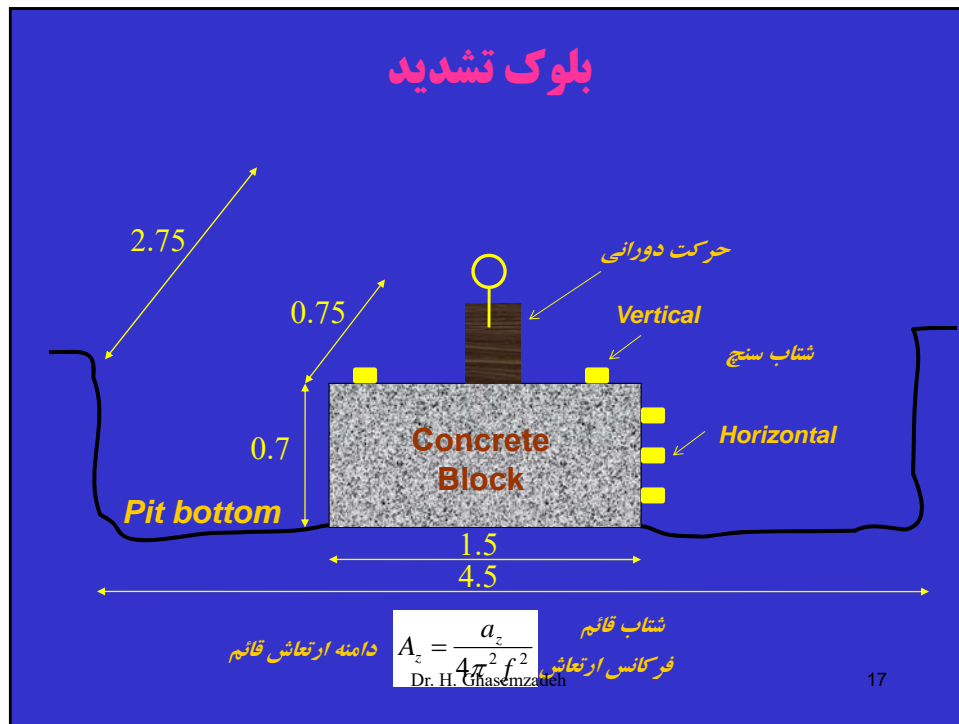
δ_{e1} δ_{e3}



$$k_s = \sigma / \delta$$

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مقادیر تجربی

$$C_u = \frac{E_s}{\beta (1 - \nu^2)}$$

Vesic

روابط تجربی ضریب فشار
یکنواخت الاستیک خاک

$$C_u = \frac{1.13 E_s}{\sqrt{A} (1 - \nu^2)}$$

پراکاش

$$C_\tau = \frac{\text{برشی یکنواخت}}{\text{جابجایی برشی}}$$

ضریب برشی یکنواخت الاستیک خاک C_τ

$$C_\tau = 0.5 C_u$$

Barkan

$$C_\tau = \frac{\sqrt{3}}{3} C_u$$

توصیه مؤسسه استاندارد هندوستان

ارتعاش گهواره ای \Leftarrow تنش غیر یکنواخت

$$C_\phi = 2 C_u$$

Barkan

$$\frac{C_\phi}{C_\psi}$$

ضریب فشار غیر یکنواخت الاستیک خاک

$$C_\psi = \frac{2}{3} C_\tau$$

ضریب برشی غیر یکنواخت الاستیک خاک

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Soil Dynamics Tests (Geophysical Methods)

□ Mechanical Wave Measurements

- Seismic Refraction
- Crosshole Tests (CHT)
- Downhole Tests (DHT)
- Spectral Analysis of Surface Waves (SASW)
- Suspension Logging

□ Electromagnetic Wave Techniques

- Ground Penetrating Radar (GPR)
- Electromagnetic Conductivity (EM)
- Surface Resistivity (SR)
- Magnetometer Surveys (MT)

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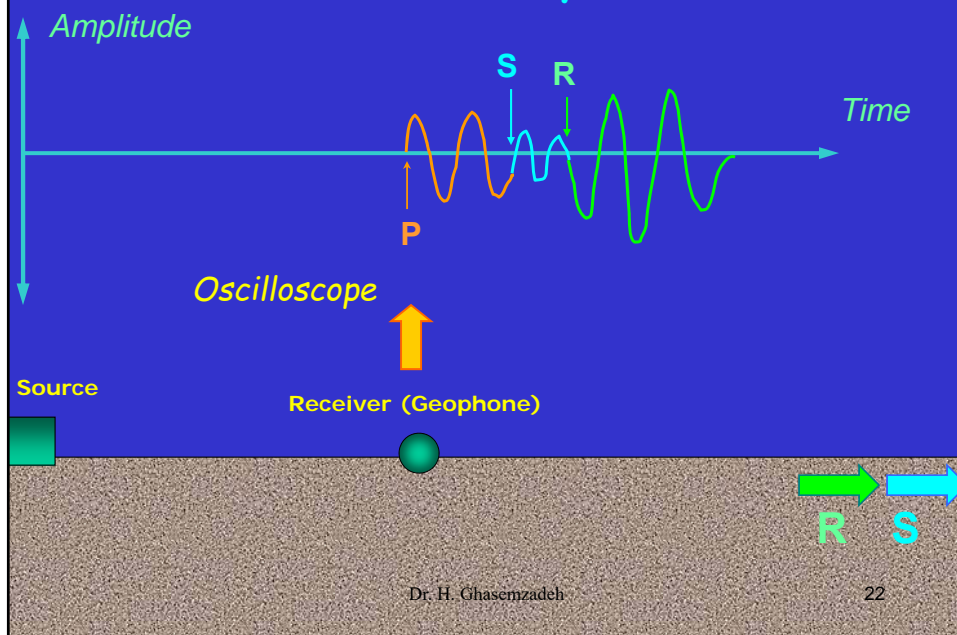
Mechanical Wave

- **Nondestructive measurements** ($\gamma_s < 10^{-4}\%$)
- **Both borehole geophysics and non-invasive types** (conducted across surface).
- **Measurements of wave dispersion:** velocity, frequency, amplitude, attenuation.
- **Determine layering, elastic properties, stiffness, damping, and inclusions**
- **Four basic wave types: Compression (P), Shear (S), Rayleigh (R), and Love (L).**

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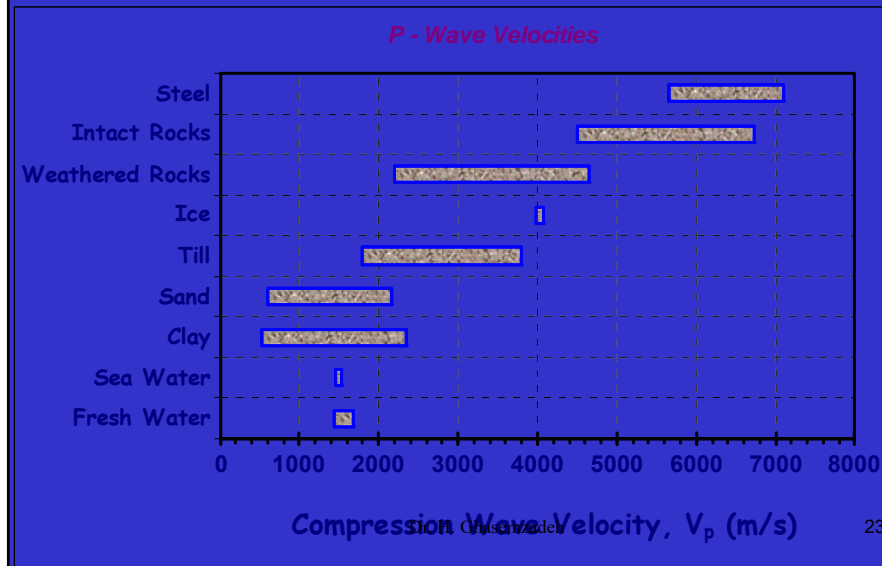
Mechanical Body Waves



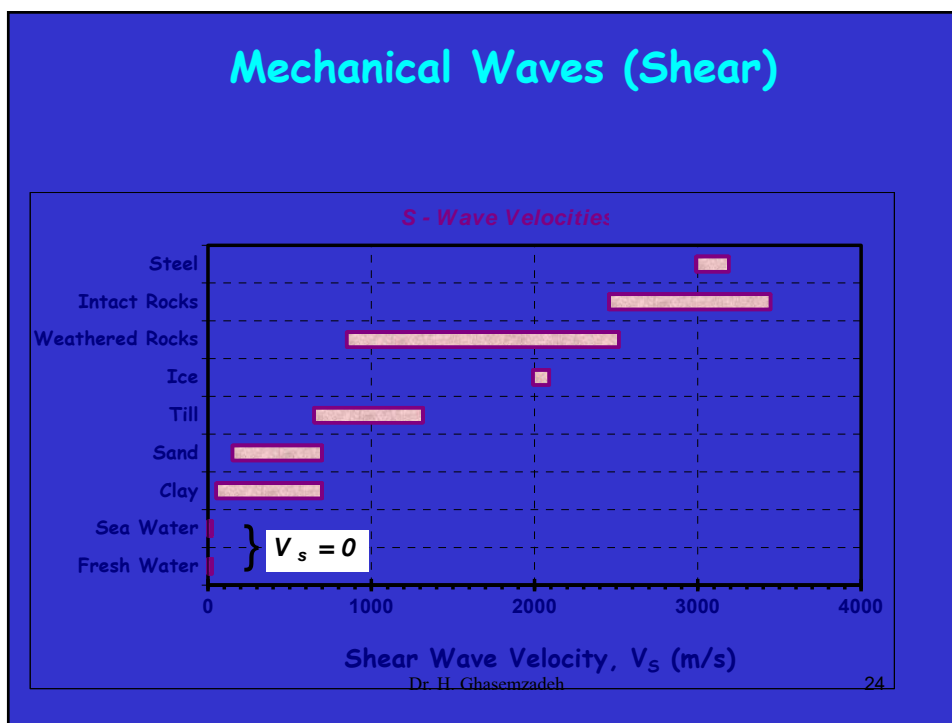
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Mechanical Waves (Compression)



Mechanical Waves (Shear)



Geophysical Equipment



Seismograph



Spectrum Analyzer



Portable Analyzer



Velocity Recorder

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Seismic Refraction

ASTM D 5777

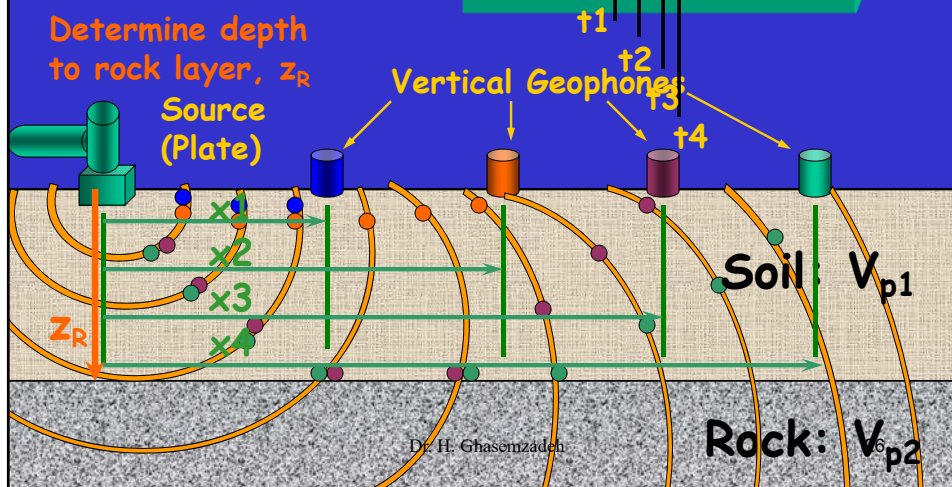
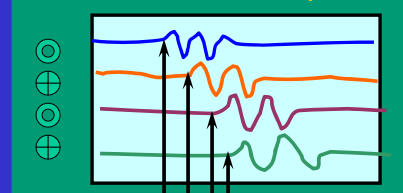
Note: $V_{p1} < V_{p2}$

Determine depth
to rock layer, z_R

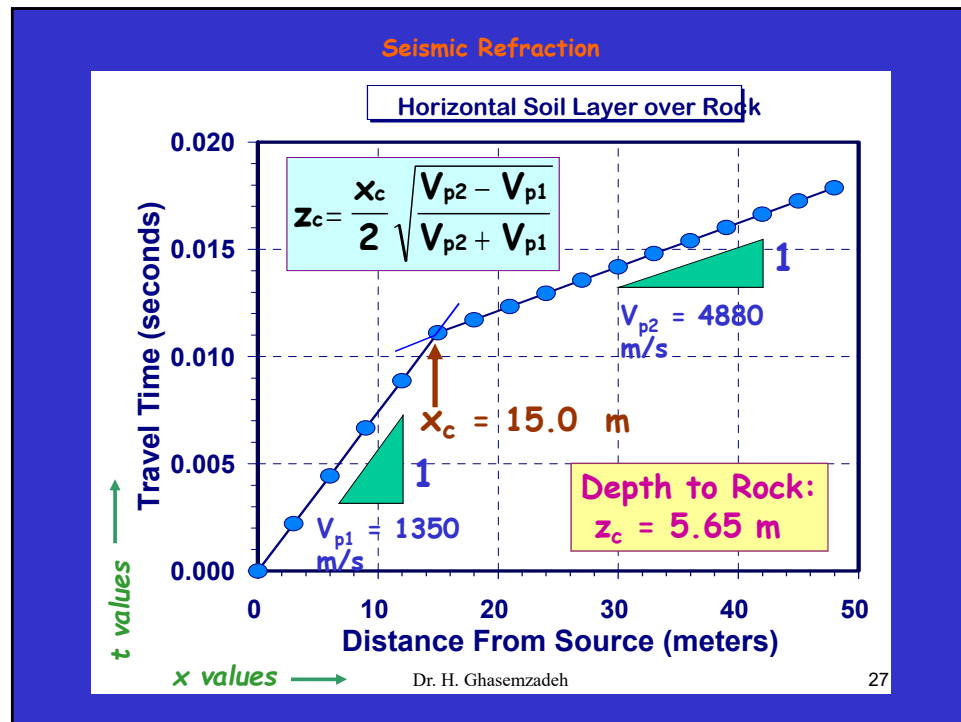
Source
(Plate)

Vertical Geophones:

oscilloscope



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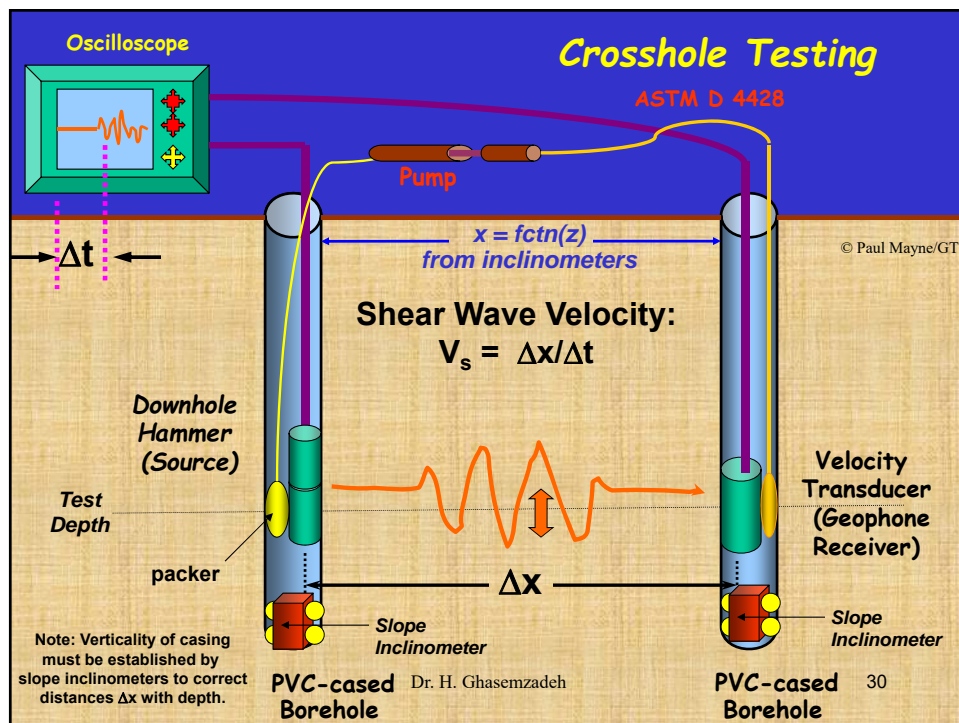
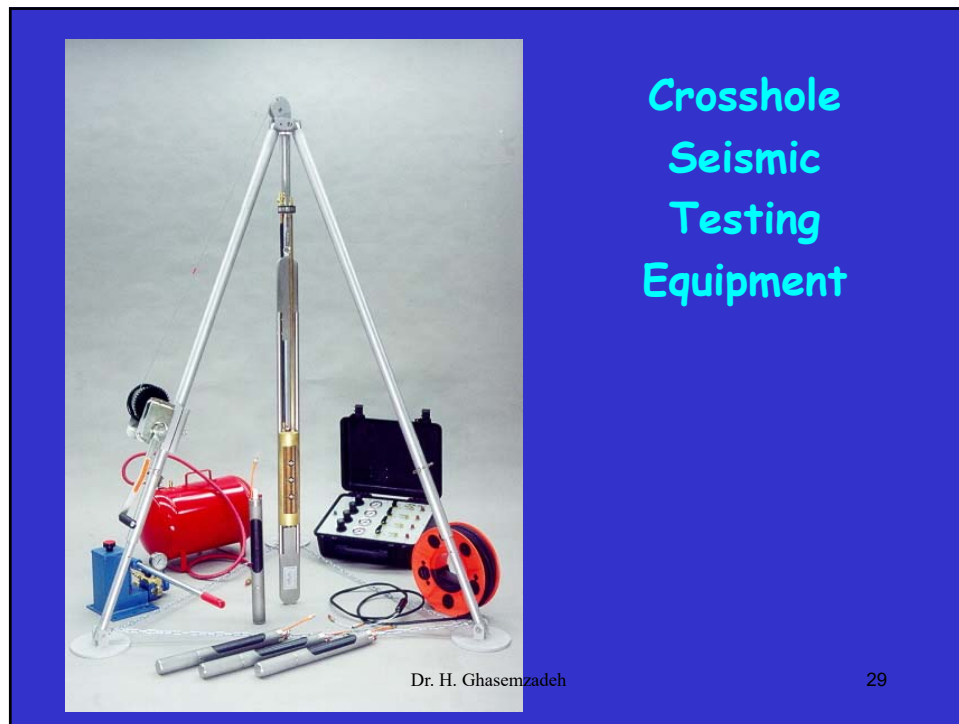


Shear Wave Velocity, V_s

- Fundamental measurement in all solids (steel, concrete, wood, soils, rocks)
- Initial small-strain stiffness represented by shear modulus: $G_0 = \rho_T V_s^2$ (alias $G_{dyn} = G_{max} = G_0$)
- Applies to all static & dynamic problems at small strains ($\gamma_s < 10^{-6}$)
- Applicable to both undrained & drained loading cases in geotechnical engineering.

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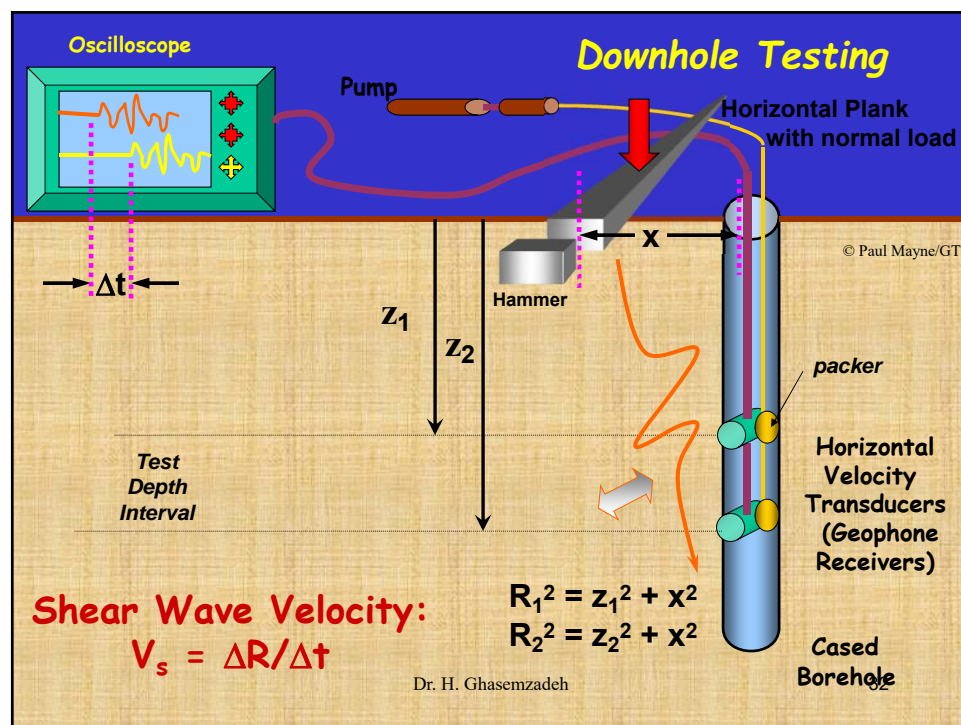


Downhole Seismic Testing Equipment



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Automated Seismic Source

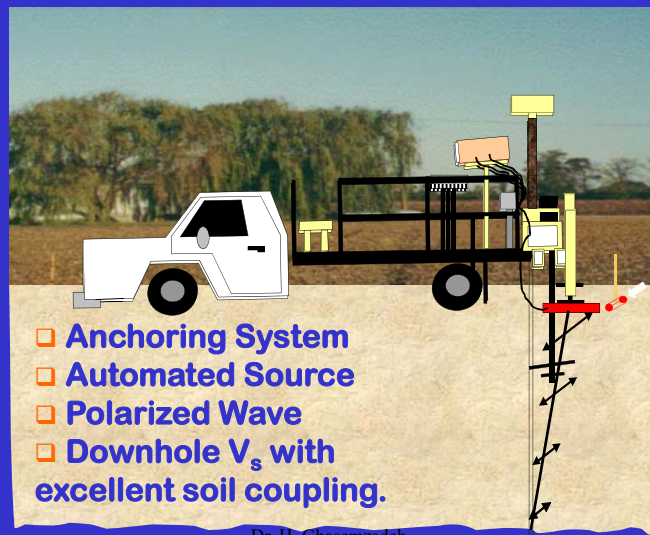


- Electronically-actuated
- Self-contained
- Left and right polarization
- Modified beam uses fin to enhance shear wave generation
- Successfully tested to depths of 20m
- Capable of being used with traditional impulse hammer

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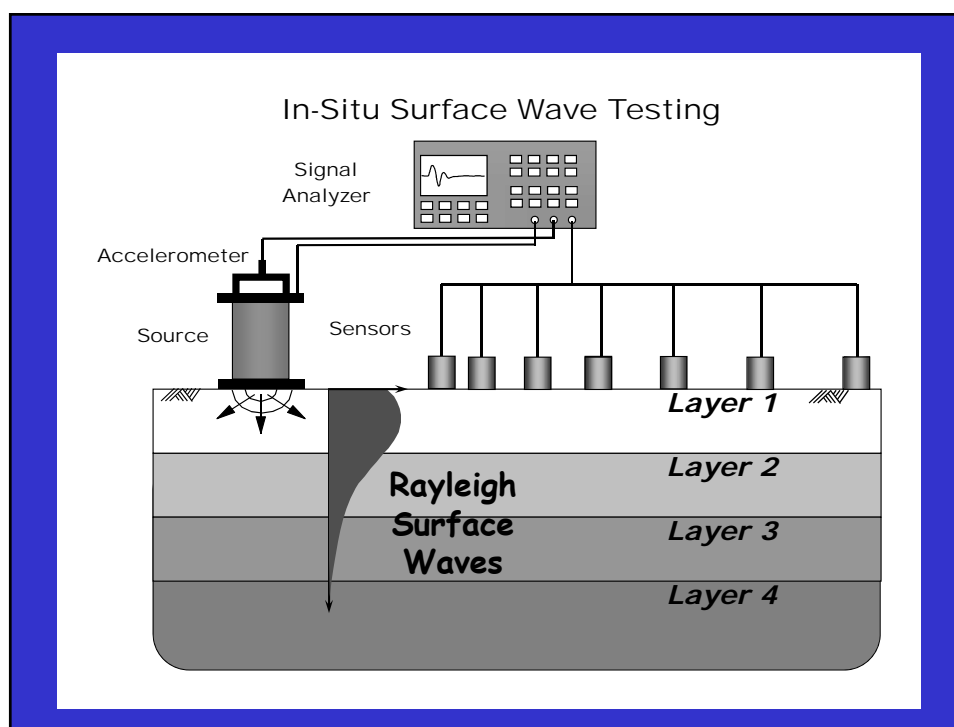
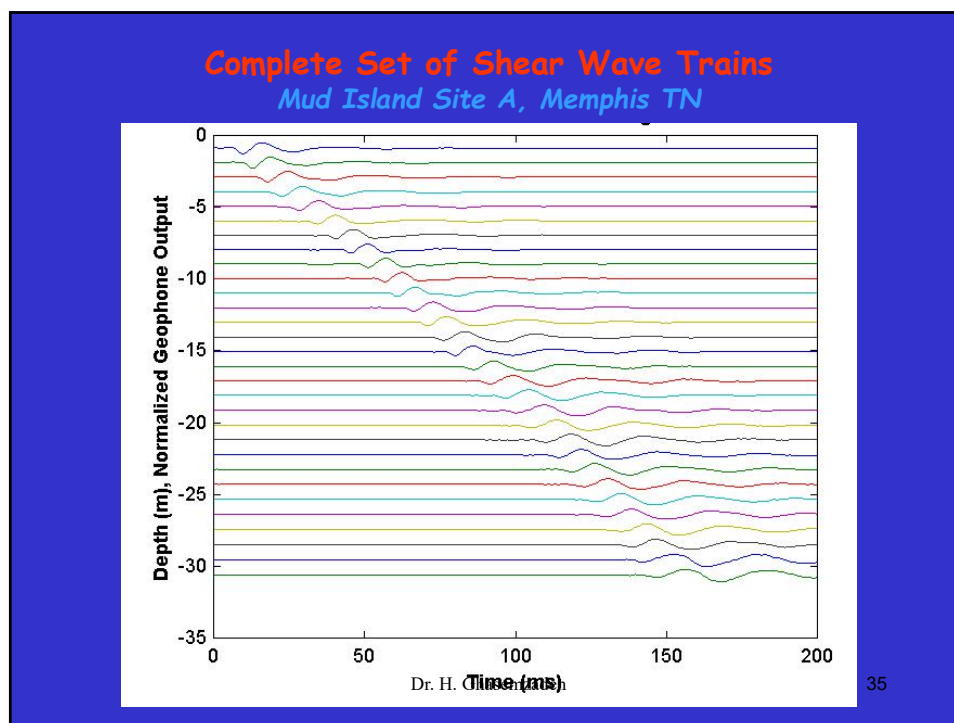
Downhole Shear Wave Velocity

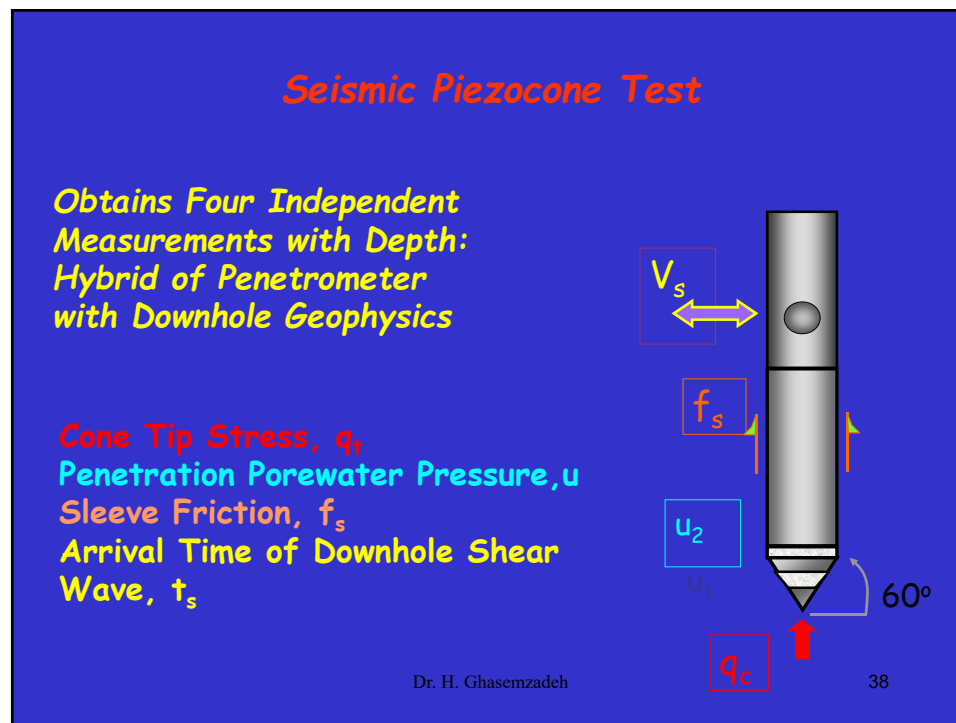
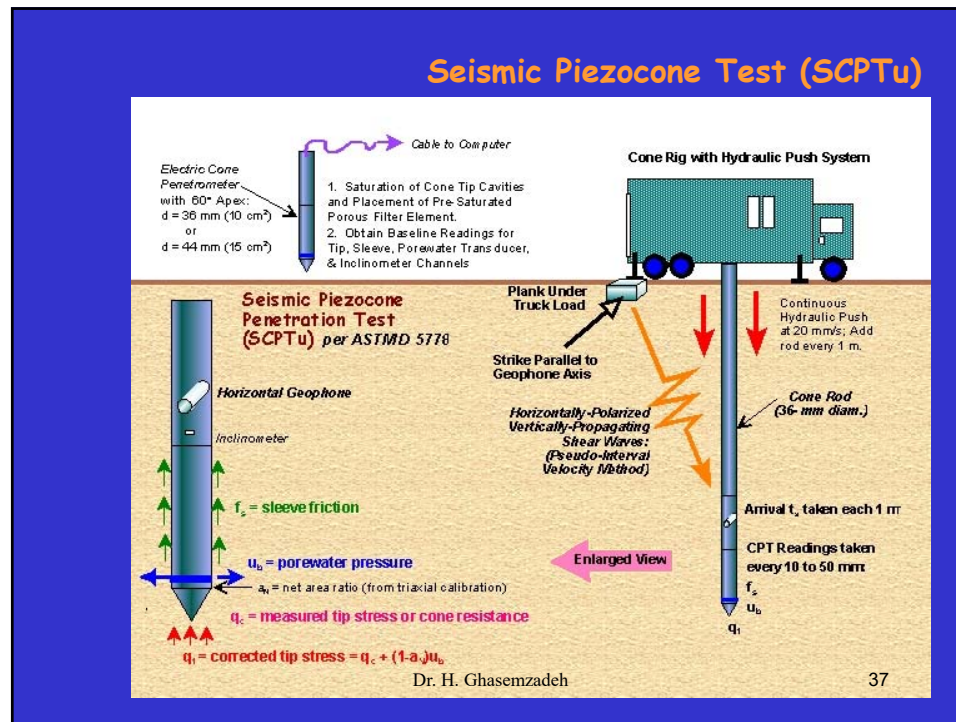


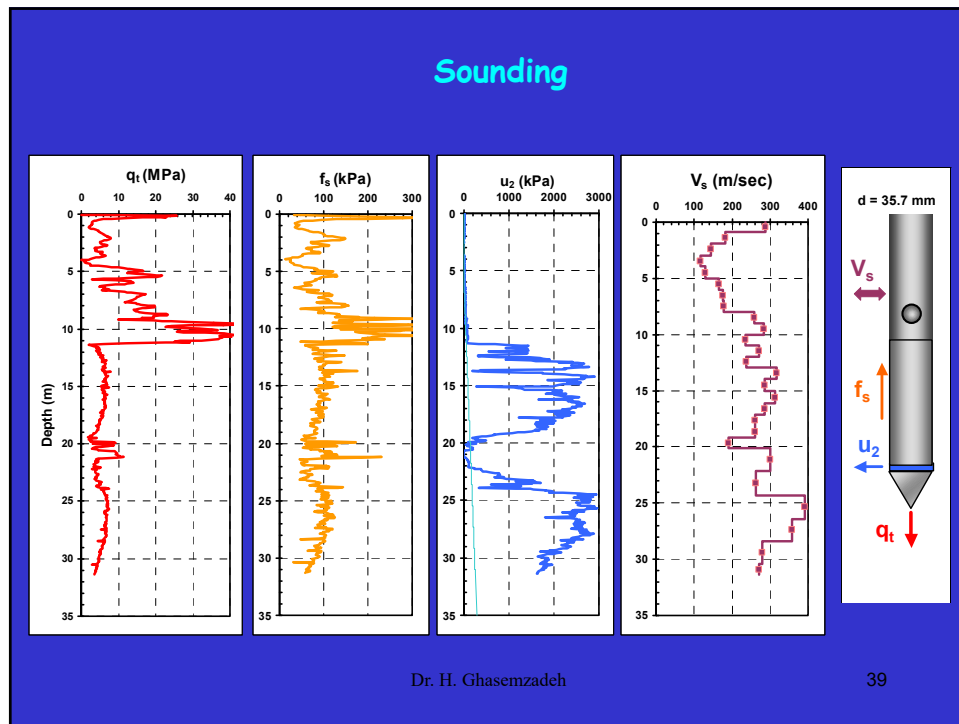
- Anchoring System
- Automated Source
- Polarized Wave
- Downhole V_s with excellent soil coupling.

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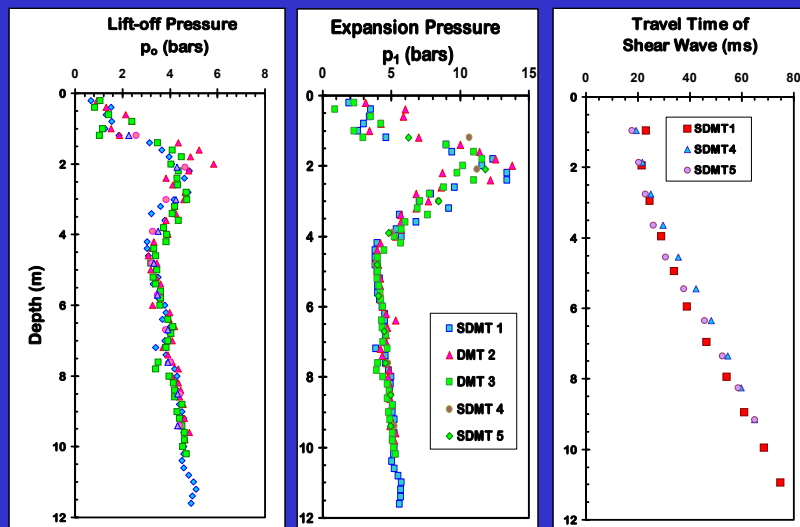
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Seismic DMTs at UMASS, Amherst



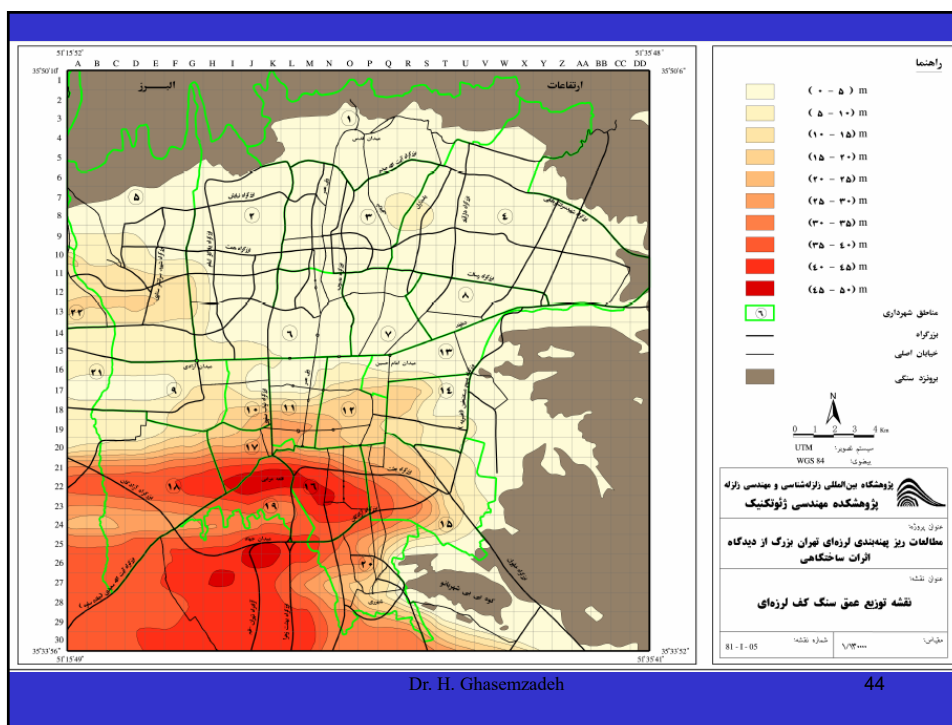
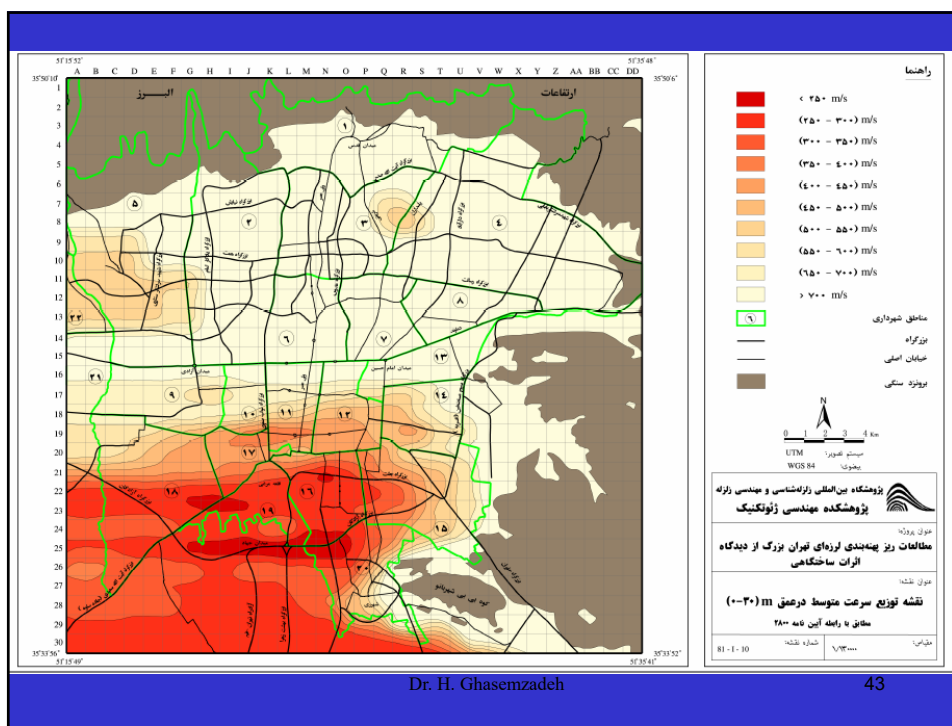
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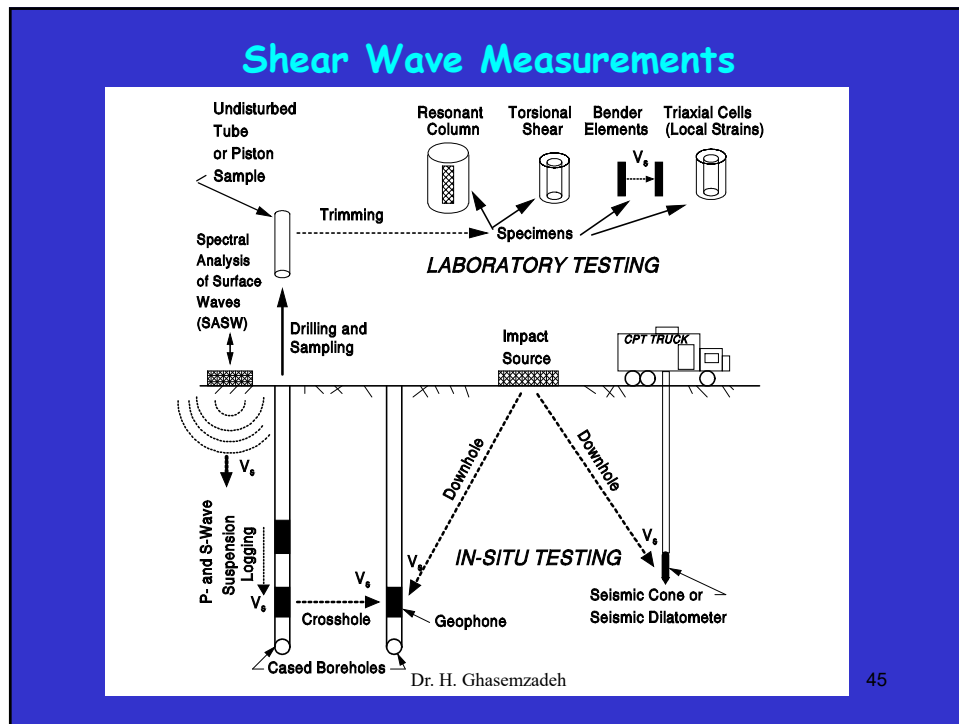
Boreholes Data Collection

Property	Method
Shear (s) and compression (p) wave velocity	<input type="checkbox"/> Suspension (p-s) logging <input type="checkbox"/> Downhole logging (impulsive and vibratory sources)
Density	<input type="checkbox"/> Gravity-density logging <input type="checkbox"/> Compensated density ($\gamma\text{-}\gamma$ logging)
Geometry of contact (depths/thicknesses)	<input type="checkbox"/> Geologic logs (examination of core/cuttings) <input type="checkbox"/> Geophysical logging suite Compensated density ($\gamma\text{-}\gamma$) Neutron porosity Dual induction resistivity Full waveform sonic
Modulus reduction and damping	<input type="checkbox"/> Resonant column and torsional shear tests
Sediment particle size	<input type="checkbox"/> Gradation testing
Borehole condition	<input type="checkbox"/> Acoustic televiewer <input type="checkbox"/> Caliper logging <input type="checkbox"/> Gyroscope surveys

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More Measurements is

More Better

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Soil Dynamics Tests (Geophysical Methods)

Electromagnetic Wave Techniques

Electromagnetic Wave

- Nondestructive methods
- Non-invasive; conducted across surface.
- Measurements of electrical & magnetic properties of the ground: resistivity (conductivity), permittivity, dielectric, and magnetic fields.
- Cover wide spectrum in frequencies ($10 \text{ Hz} < f < 10^{22} \text{ Hz}$).

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Electromagnetic Wave

□ Surface Mapping Techniques:

- Ground Penetrating Radar (GPR)
- Electrical Resistivity (ER) Surveys
- Electromagnetic Conductivity (EM)
- Magnetometer Surveys (MS)

□ Downhole Techniques

- Resistivity probes, MIPs, RCPTu
- 2-d and 3-d Tomography

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Ground Penetrating Radar (GPR)

- GPR surveys conducted on gridded areas
- Pair of transmitting and receiver antennae
- Short impulses of high-freq EM wave
- Relative changes in dielectric properties reflect differences in subsurface.
- Depth of exploration is soil dependent (up to 30 m in dry sands; only 3 m in wet saturated clay)

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Ground Penetrating Radar (GPR)



Xadar



Sensors & Software



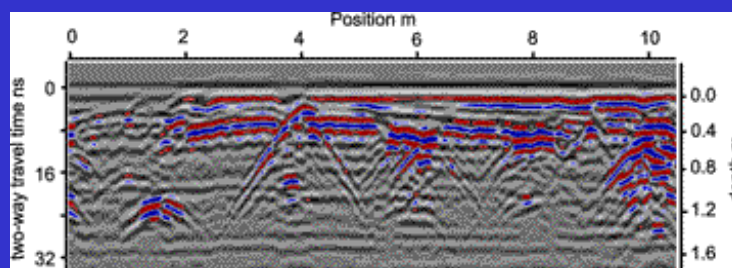
GeoRadar

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Illustrative Results from Ground Penetrating Radar (GPR)

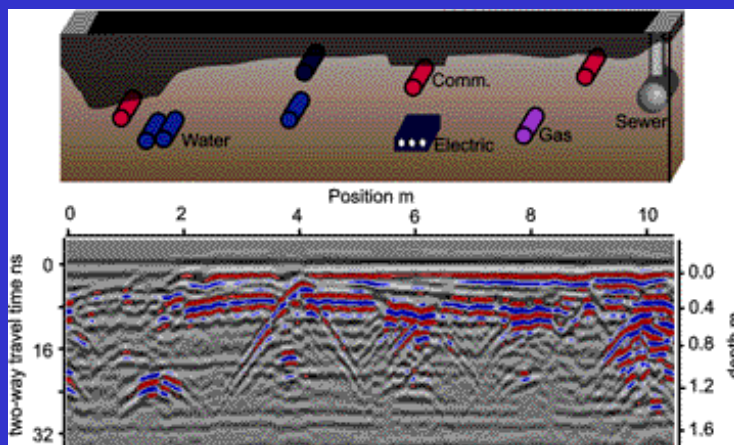
Crossing an underground utility corridor



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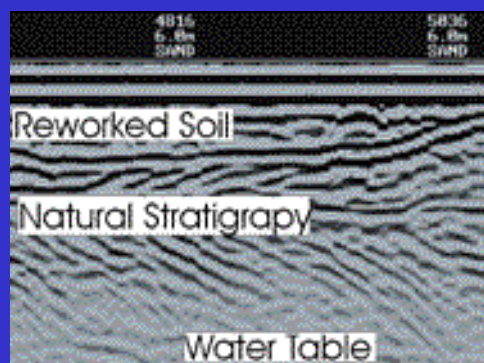
Illustrative Results from Ground Penetrating Radar (GPR)



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Illustrative Results of Ground Penetrating Radar (GPR)



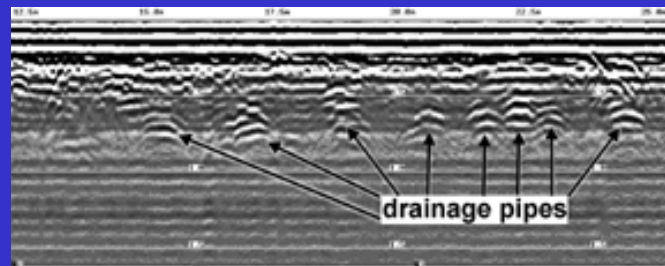
Geostratigraphy

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Examples of Ground Penetrating Radar (GPR)

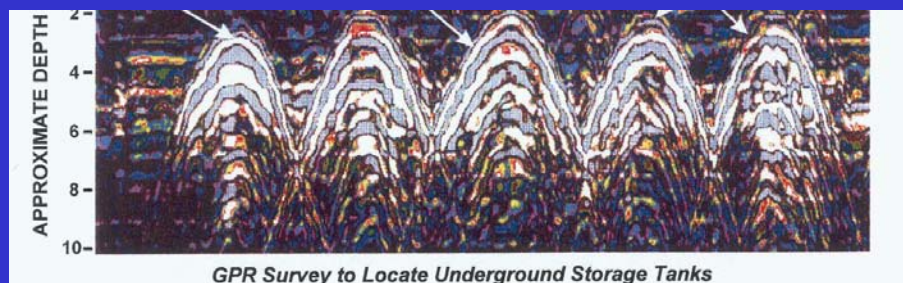
Useful in Locating Underground Utilities



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Results from Ground Penetrating Radar (GPR)

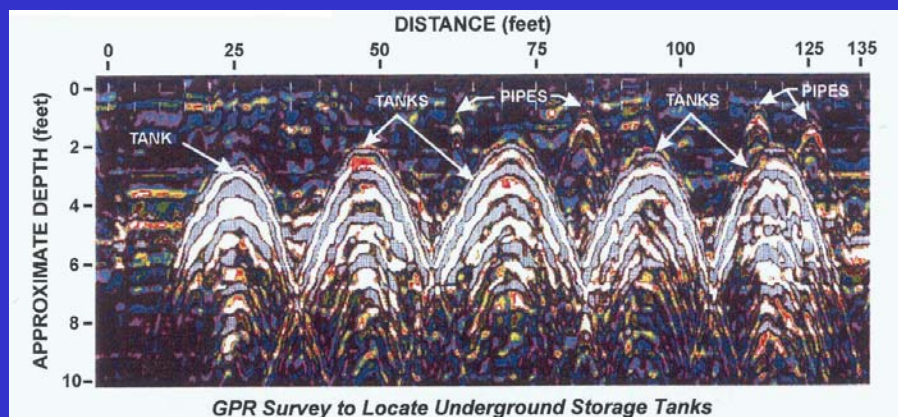


GPR Survey to Locate Underground Storage Tanks

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Results from Ground Penetrating Radar (GPR)



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Electrical Resistivity Measurements



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Electrical Resistivity (ER) Surveys

- Resistivity ρ_R (ohm-m) is an electrical property. It is the reciprocal of conductivity
- Arrays of electrodes used to measure changes in potential.
- Evaluate changes in soil types and variations in pore fluids
- Used to map faults, karst features (caves, sinkholes), stratigraphy, contaminant plumes.

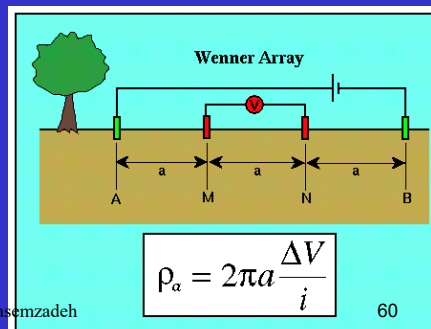
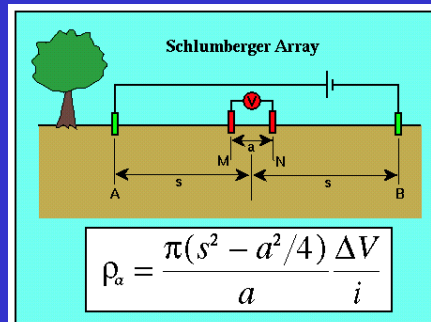
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Electrical Resistivity Measurements

What will be gained by changing electrode spacing?

Depth of ER survey: i.e., greater spacing influences deeper



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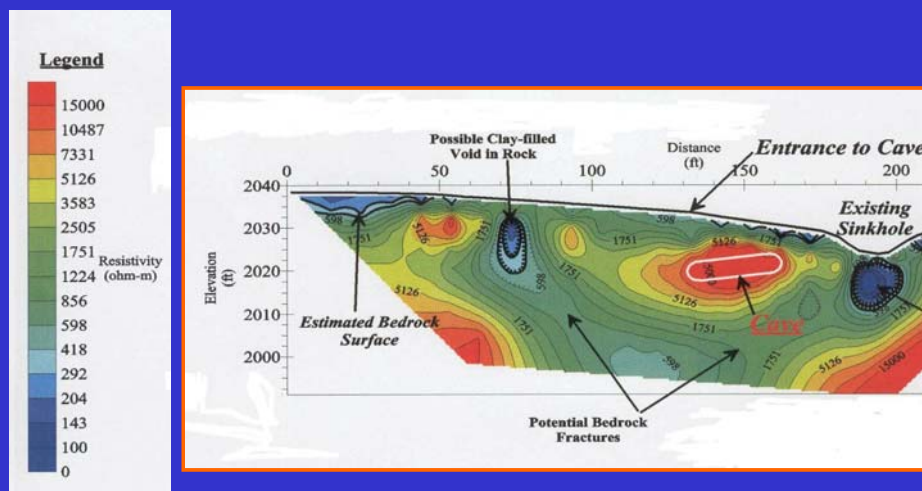
Electrical Resistivity Measurements

جنس خاک	مقاومت ویژه ($\Omega.m$)
زمین گلی	20-100
خاک گیاهدار	10-150
ذغال سنگ مرطوب	5-100
خاک رس نرم	50
خاک آهک دار و خاک رس فشرده	100-200
ماسه رس دار	50-500
خاک دارای قطعات سنگ	1500-3000
سنگ آهک نرم	100-300
سنگ آهک فشرده	1000-5000
شیست	50-300
گرانیت و ماسه سنگ	1500-10000

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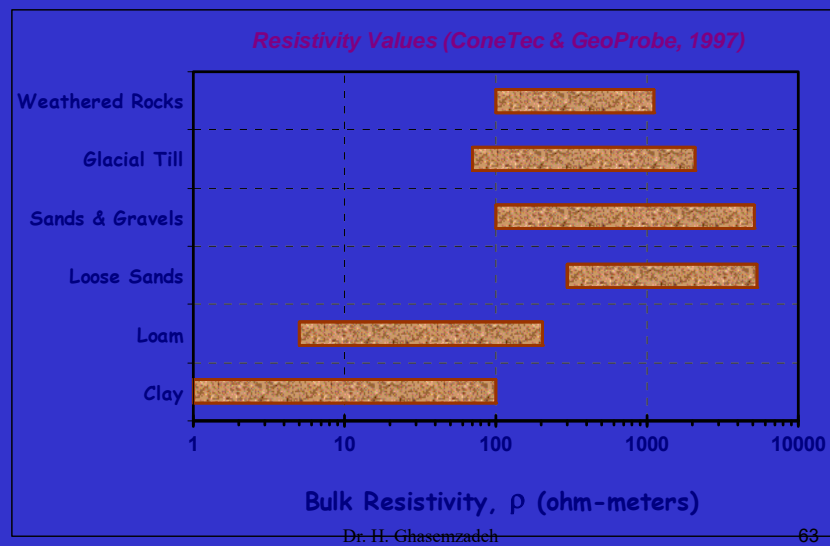
Electrical Resistivity Measurements



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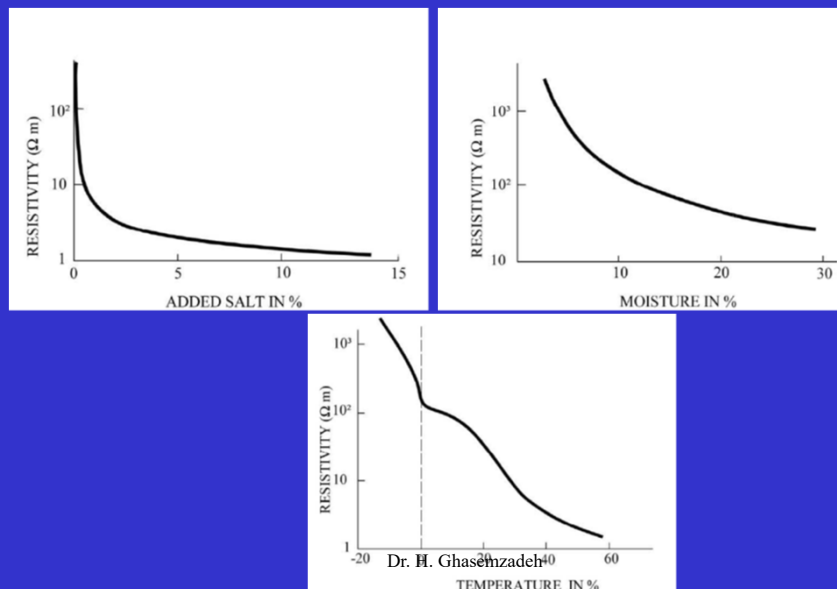
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Electrical Resistivity Measurements

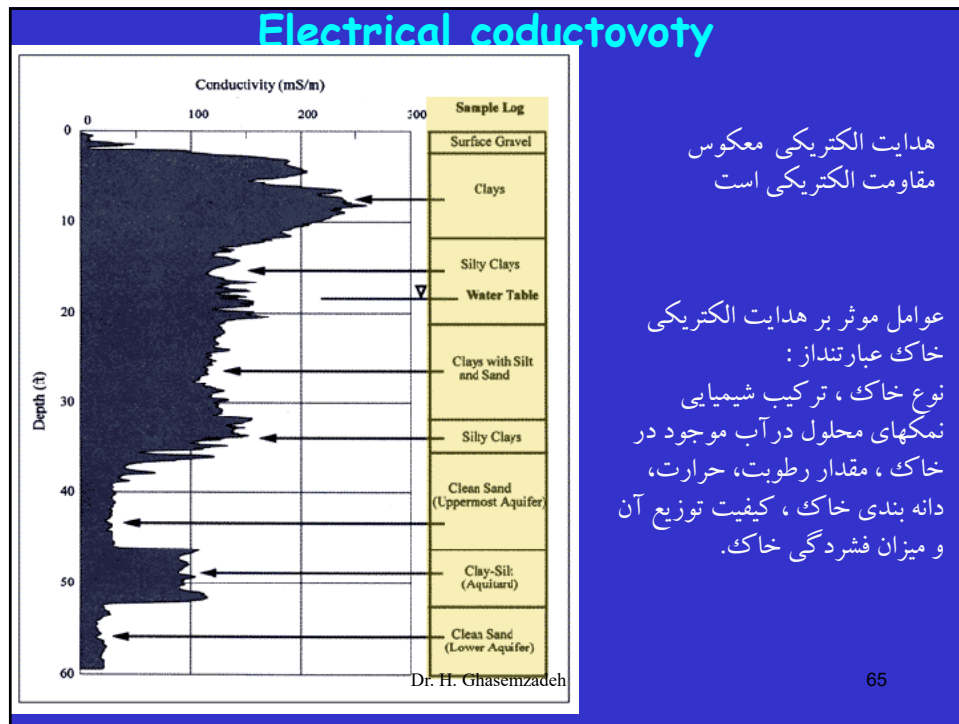


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Electrical Resistivity Measurements

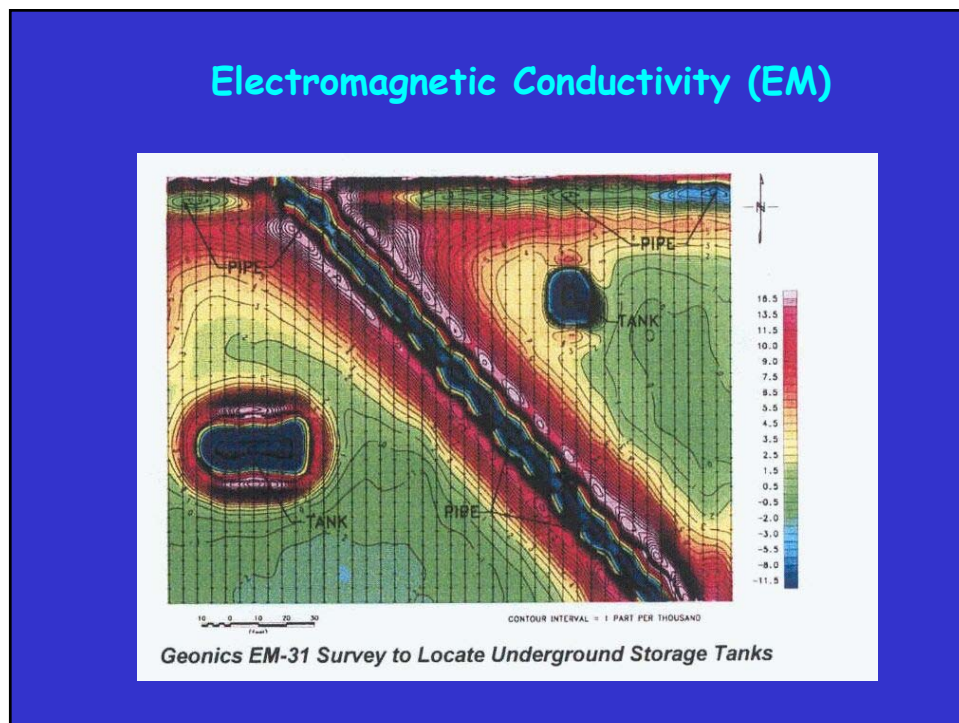


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هدایت الکتریکی معکوس
مقاومت الکتریکی است

عوامل موثر بر هدایت الکتریکی
خاک عبارتند از:
نوع خاک، ترکیب شیمیایی
نمکهای محلول در آب موجود در
خاک، مقدار رطوبت، حرارت،
دانه بندی خاک، کیفیت توزیع آن
و میزان فشردگی خاک.

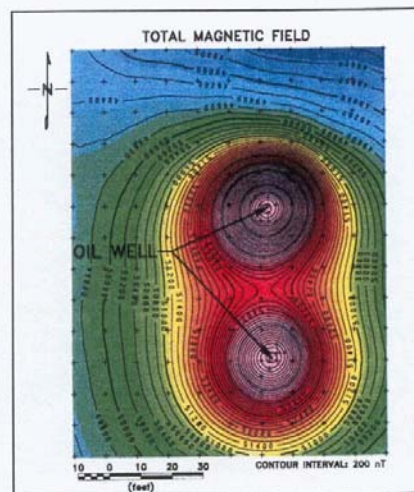


Magnetometer Surveys (MS)

Measure relative changes in the earth's magnetic field across a site.



Geometrics G-858 Magnetometer



Magnetic Survey to Locate
Abandoned Oil Wells