Penentuan Sifat Dinamik Tanah

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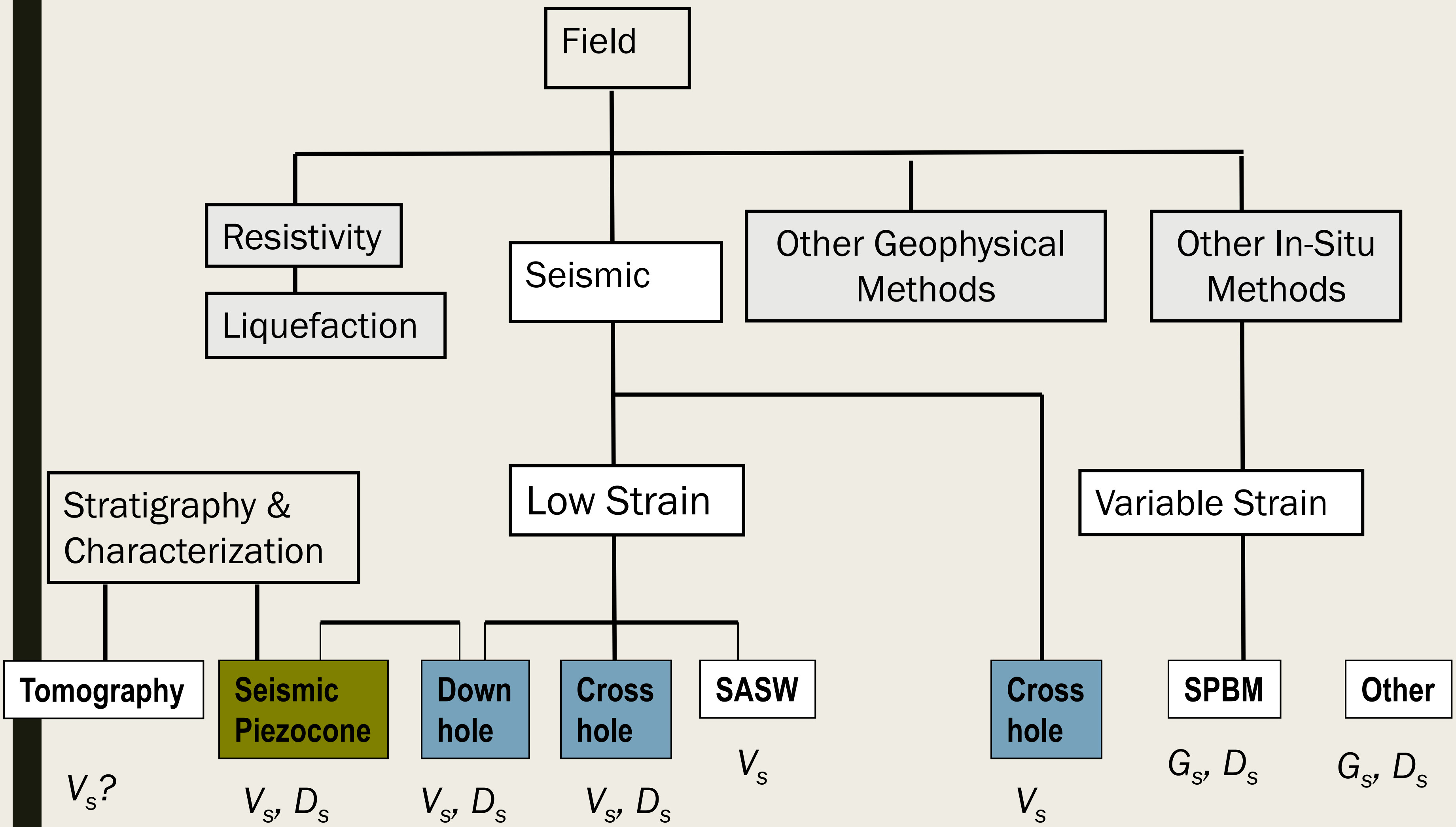
Content

- Parameters for dynamic analysis
  - *Modulus*
  - *Damping*
- Field testing
- Lab Testing
- Correlations

References

- Steven L. Kramer (1995) Geotechnical Earthquake Engineering, Prentice Hall, Chapter 6
- Handout

Pengujian di Lapangan



Pengujian di Lapangan

- Field test allow the dynamic properties of soil be measured in-situ (i.e. in their existing conditions where the complex effects of existing stress and other external conditions affecting the results)
- Field test measure the response of relatively large volume of soil, minimizing the potential of inaccuracy due to size of samples
- Test are aimed for measuring the wave velocity and dynamic properties can be calculated based on this quantity

Metode Geofisik

This method is based on the fact that the velocities of seismic waves traveling through soil & rock material are related to the material's density & elasticity. The denser the material, the greater the velocity

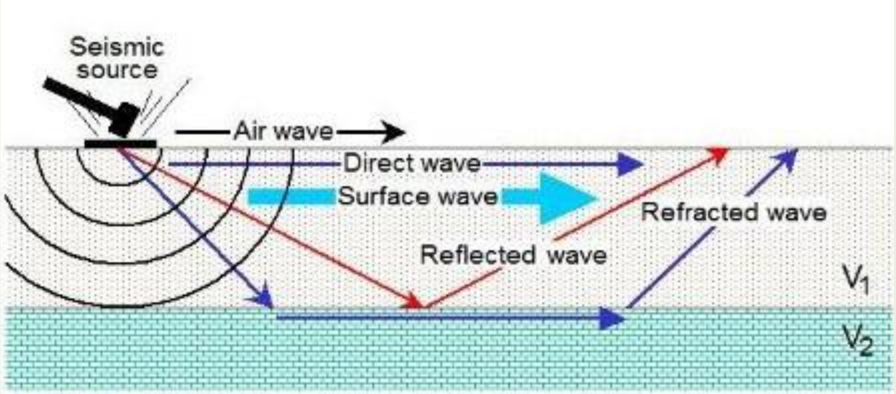
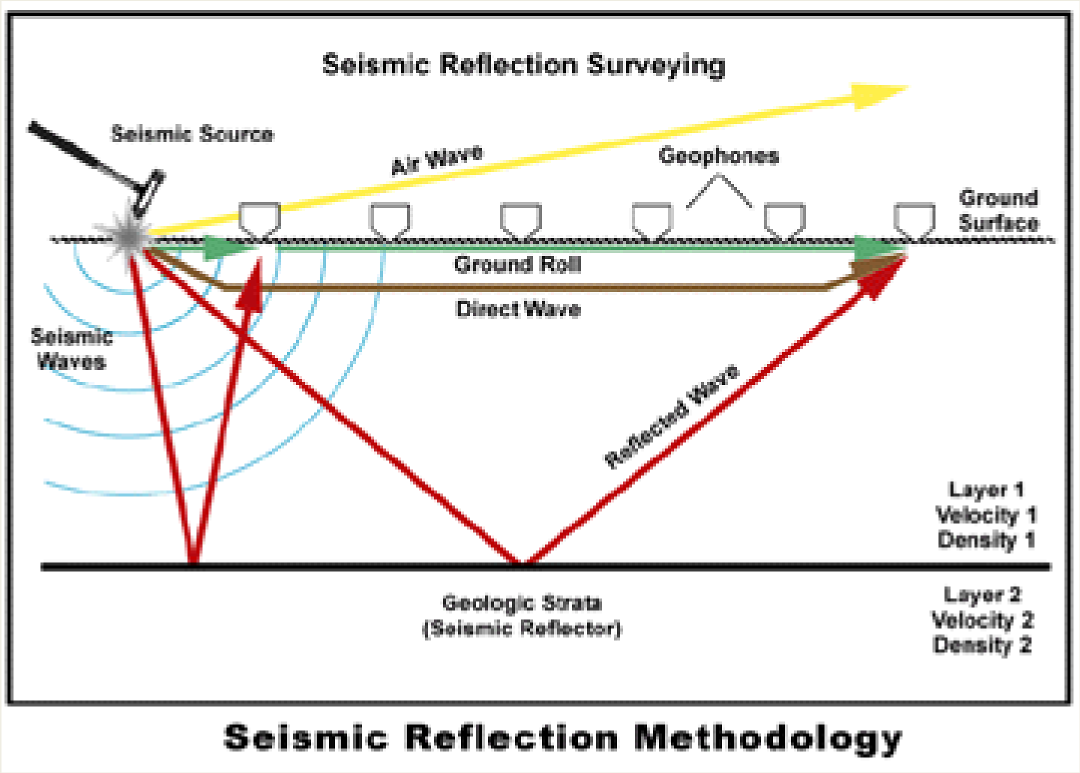


Fig. 2. Major types of seismic waves based on propagation characteristics.

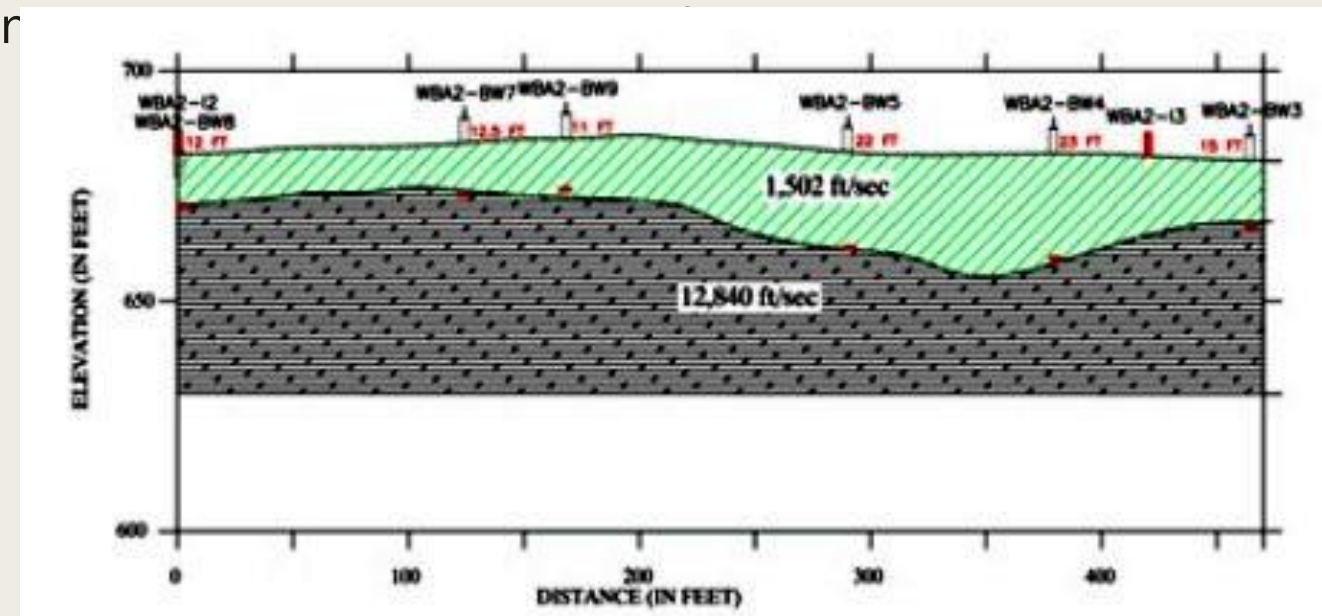
Seismic Reflection test



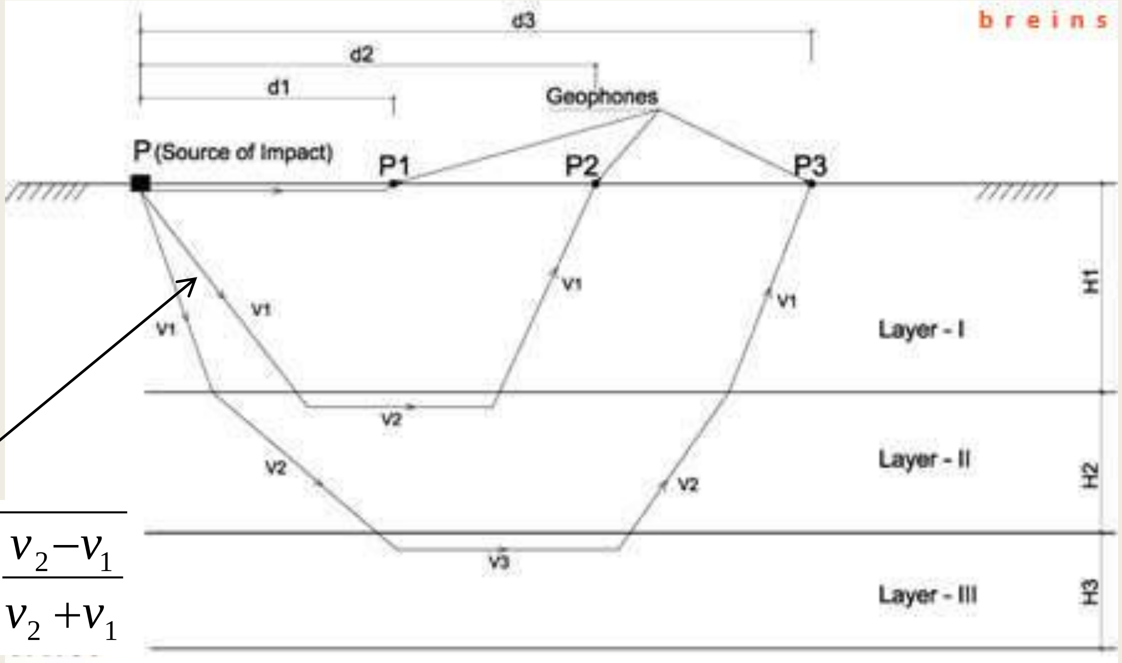
Law of reflection: angle of incidence (α_i) = angle of reflection (α_r)

Seismic Refraction Method

- This method can be used to estimate depths to successively harder strata
- The method can be used to defined the depths of the layers (horizontal, inclined) or even where boundaries are irregular or poorly defined,
- However, it will not detect softer layers below the hard strata
- It car



Seismic Refraction Method



$$H_1 = \frac{L}{2}\sqrt{\frac{v_2 - v_1}{v_2 + v_1}}$$

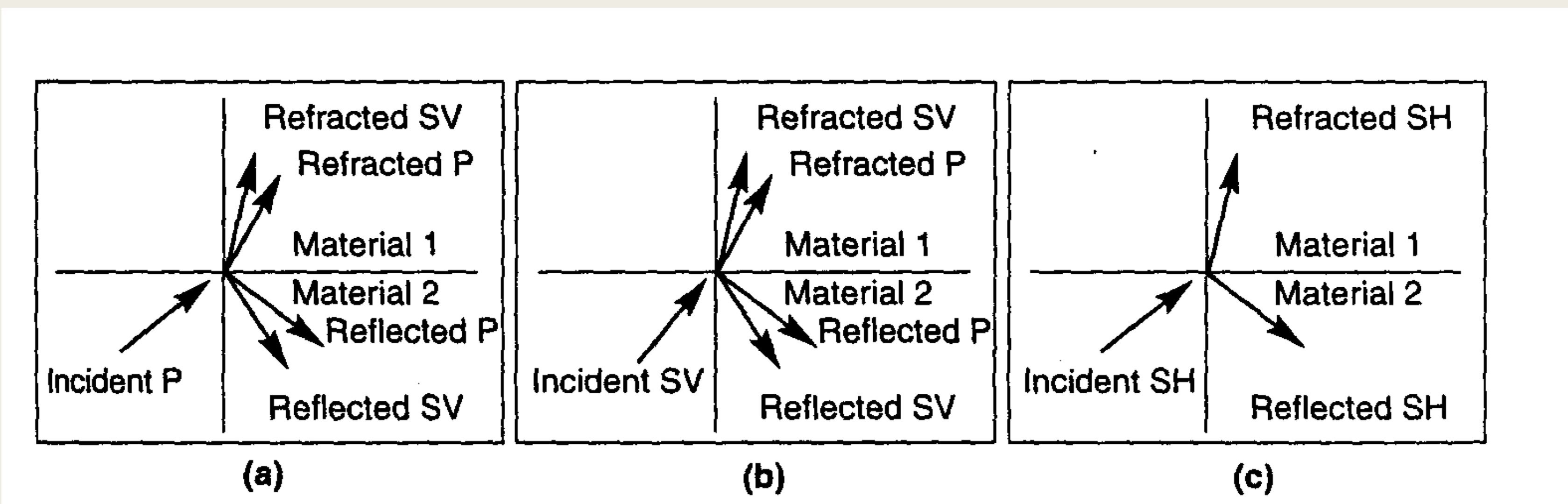
$$H_1 = \frac{t_{i1}}{2}\frac{V_{p1}V_{p2}}{\sqrt{V_{p2}-V_{p1}}}$$

$$H_2 = \frac{1}{2}\left(t_{i2} - \frac{2H_1\sqrt{V_{p3}-V_{p1}}}{V_{p1}V_{p3}}\right)\frac{V_{p2}V_{p3}}{\sqrt{V_{p3}-V_{p2}}}$$

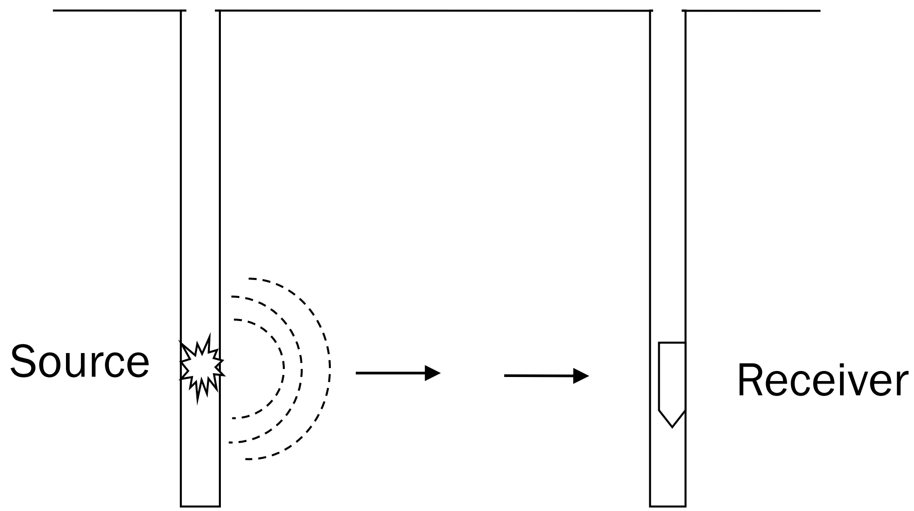
Snell's Law: Law of reflection and refraction

- Snell considers the change of the direction of ray path at interfaces between materials with different wave velocities. He show that:

$$\frac{\sin i}{V} = \text{constant}$$



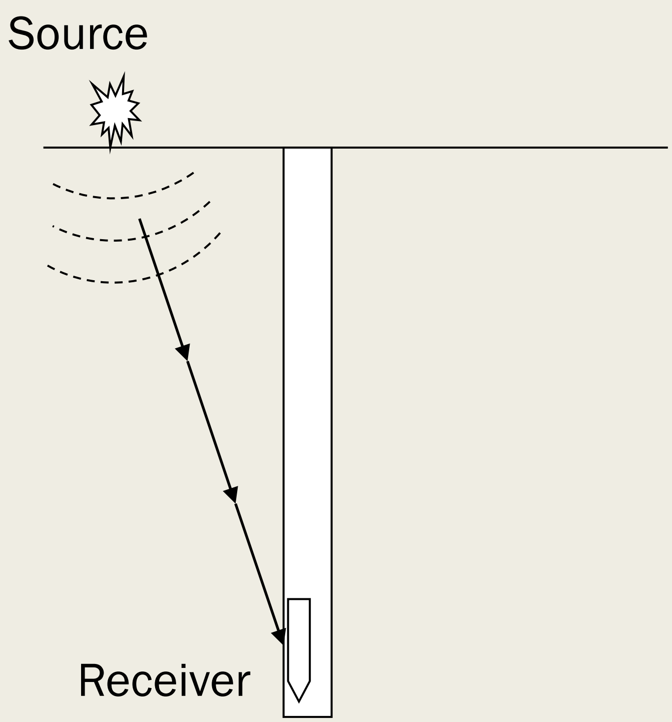
Cross-hole test



Cross-hole test

- Allow determination of shear velocities in individual layer
- Can be used to detect hidden layers missed by refraction surveys
- Reliable data for depth of borehole of 30 – 60 m using mechanical impulse source and up to 150 m for explosive source
- Need to check the velocity obtained (in case of different layers are found)

Down-hole test



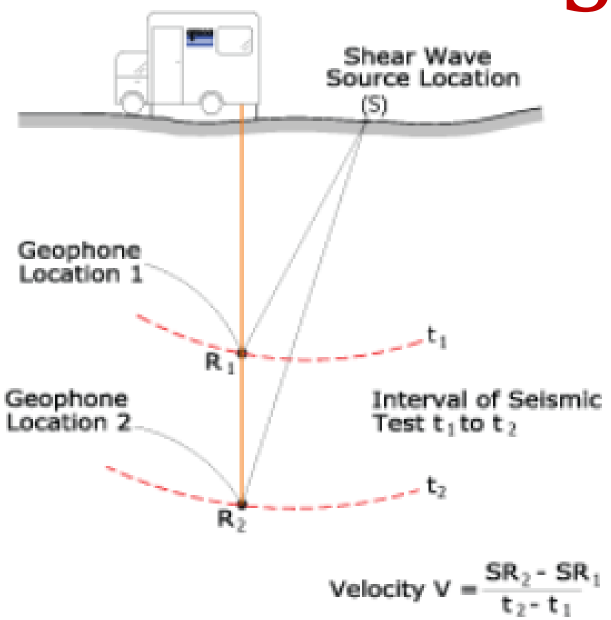
•The objective is to measure travel time of p and s wave from energy source to receiver.
•Plot of distance vs travel time can be generated. slope = velocity
•Can detect hidden layers missed by refraction surveys
•Reliable data for depth of borehole of 30 – 60 m only due to effect of material and radiation damping
•Effort has been mad to measure damping ratio based on this test

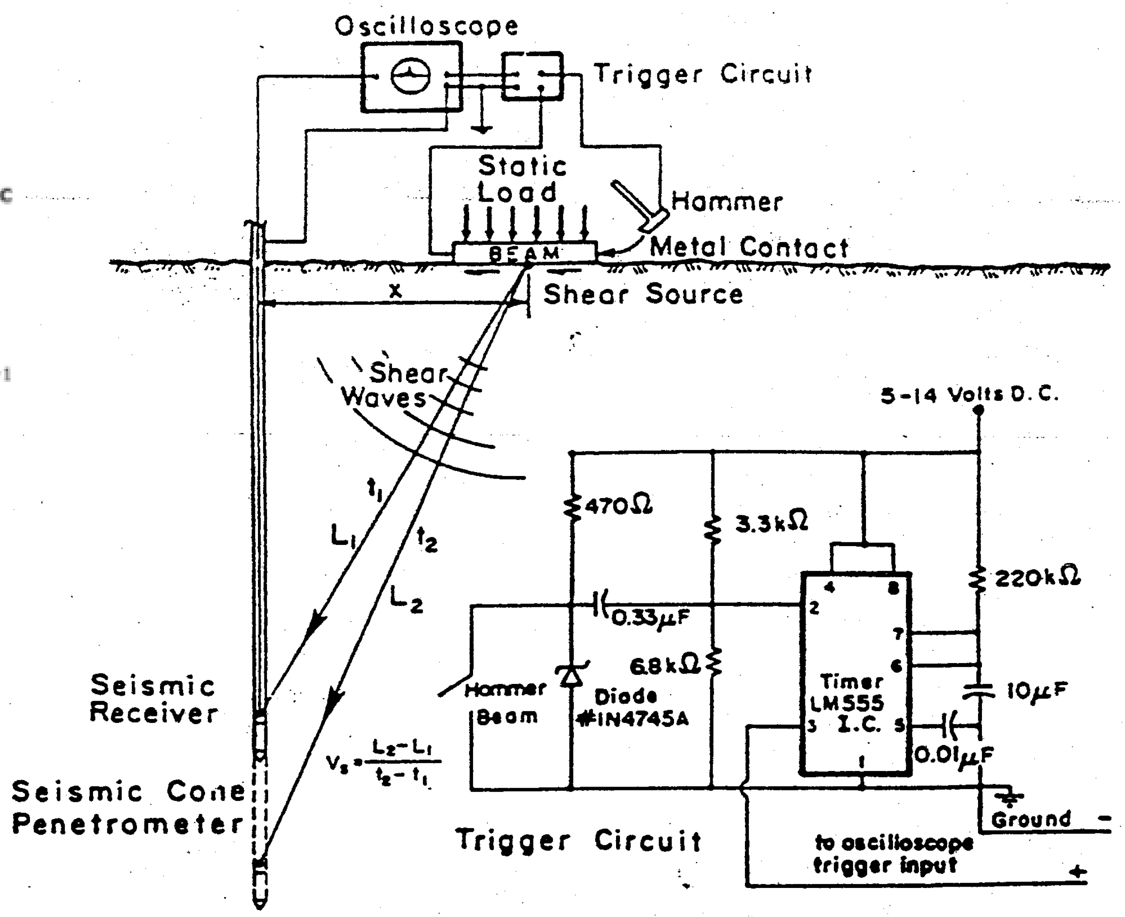
SCPTU test

Seismic Cone Penetration Test with pore water pressure measurement is currently the most ideal overall methods for determining the dynamic properties of soil in-situ is the SCPTU (developed since 1980), because

- ✓ It provides continuous stratigraphic logging
- ✓ Able to assess continuous density/state conditions
- ✓ GWT conditions and parameters
- ✓ Direct determination of small strain modulus and damping
- ✓ Ability to correlate well with SPT databases
- ✓ Undrained strength of cohesionless soil
- ✓ Limited depth (up to 50 m only)

SCPTU Test





ig. 1. A Typical Arrangement for Conducting SCPTU (after Stewart and Campanella, 1993)

Other tests

- Seismic logging
- Steady state vibration (Rayleigh wave) test
- Spectral Analysis of Surface Waves (SASW)
- Seismic cone test
- SPT test
- CPT test
- Dilatometer
- Pressuremeter (SPBM, SBTS)

Refer to chapter 6 Kramer book

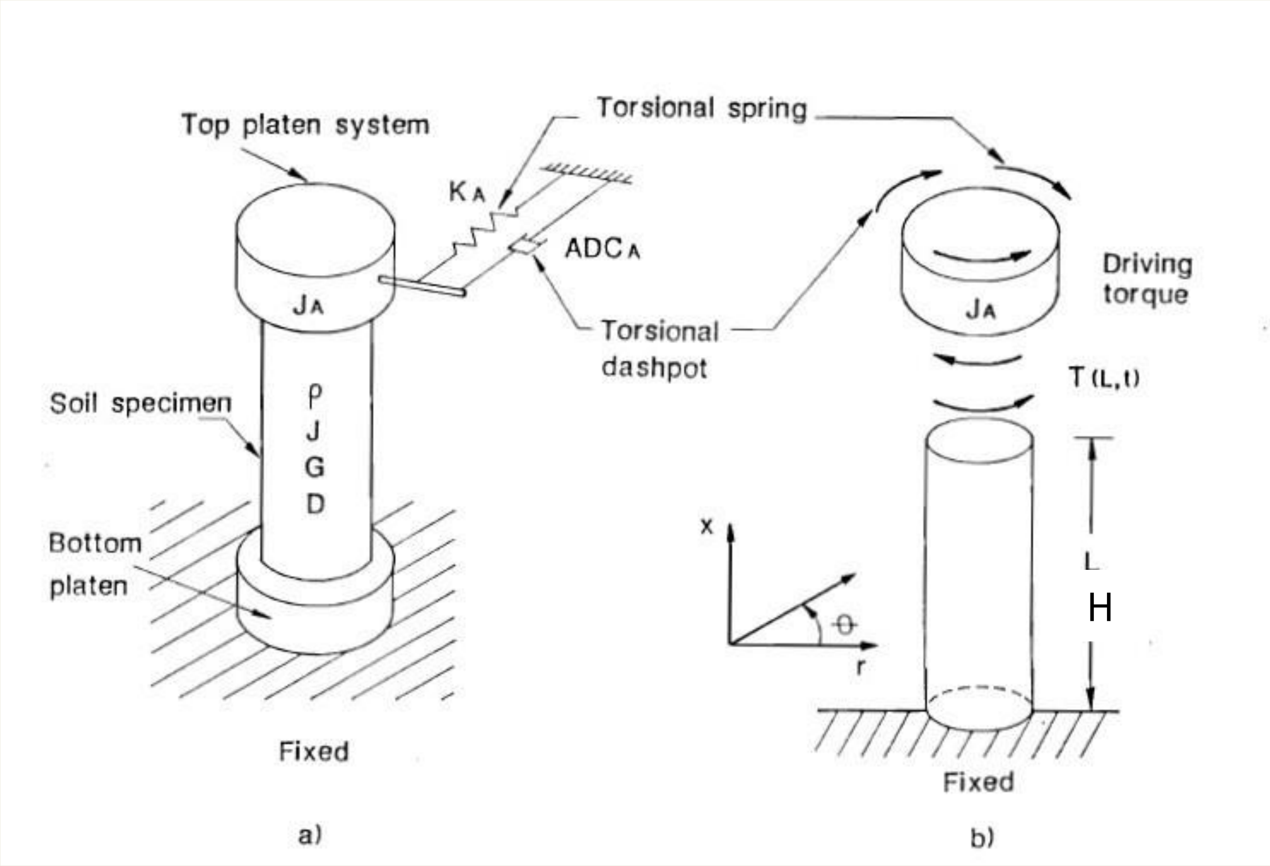
Laboratory Tests

- Usually performed on small specimen – subjected to uniform initial stresses and uniform changes in stress and strain conditions

- No lab test can represent all possible stress and strain paths with general rotation of principal axes; consequently, different tests will be most suitable for different problems

- Different seismic soil test for different strain level:
  - *Low strain level,* 10^{-6} - 10^{-4} *- Resonant Column (solid samples)*
  - *Bender element*
  - *High strain level: cyclic triaxial, cyclic simple shear, cyclic torsional shear, shaking table, etc*

Resonant Column Test



φ_1 = constant as a function of rotational moment of inertia J to the moment of inertia of mass above soil sample J_o. For resonant column test with fixed-free configuration, J/J_o approach infinity, hence $\varphi_1 = \pi/2$

Other tests

- Ultrasonic Pulse test
  - *Can measure wave propagation velocities*
  - *Useful for very soft materials like seafloor sediments as test can be carried out while soil is still in sampling tubes*

- Piezoelectric Bender Element Test (Dyvik&Madshus, 1985) – allow measurement of shear wave velocity on specimens
  - *Constructed by bonding 2 piezoelectric materials together in such a way that a voltage causes 1 to expand while the other contracts, causing element to bend.*
  - *Time different between 2 voltage pulses, divided with distance between tips of bender element gives s-wave velocity of specimen*

High-Strain Element Tests

Cyclic Triaxial Test

- *Most commonly used test for measurement of dynamic soil properties at high strain level*
- *Cylindrical specimen is placed between top and bottom loading platens and surrounded by a thin rubber membrane (see Figure 7).*
- *Specimen subjected to radial stress, usually applied pneumatically and axial stress – principal stress always vertical and horizontal*
- *Difference between axial and radial stress is deviator stress – in cyclic test, deviator stress is applied cyclically, either stress-controlled or strain-controlled*
- *Most common to perform with radial stress held constant and axial stress cycled at about 1 Hz frequencyDuring test, cyclic axial load, specimen axial deformation and pore water pressure in soil specimen are recorded*
- *Test can be performed on isotropically and anisotropically consolidated conditions, thereby producing stress paths*

Cyclic Triaxial Test

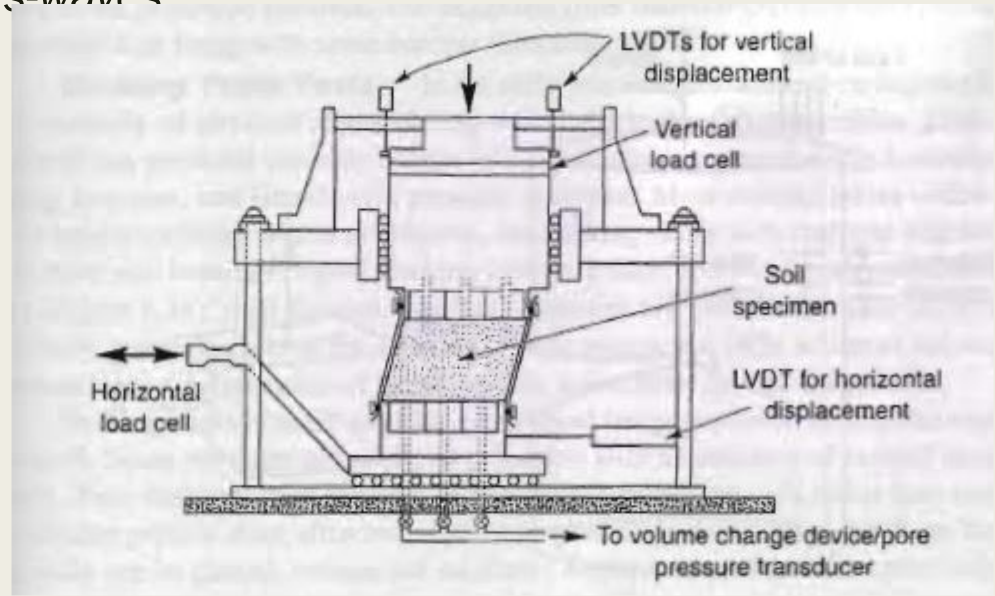
Stresses and strains measured can be used to compute shear modulus and damping ratio

$$G = \frac{E}{2(1+\nu)}$$

$$D = \frac{A_{loop}}{4\pi\, A_{traingle}}$$

Cyclic Direct Simple Shear Test

- *Test capable of reproducing earthquake stress conditions much more accurately than cyclic triaxial test*
- *Most commonly used for liquefaction studies*
- *In this test, a short, cylindrical specimen is restrained against lateral expansion by rigid boundary series of stacked rings.*
- *By applying cyclic hor. shear stresses to top or bottom of specimen, test specimen is deformed in a same way as element of soil subjected to vertically propagating s-waves*



Cyclic Torsional Shear Test

- *Use hollow cylinder apparatus*
- *This test allows isotropic or anisotropic initial stress conditions and can impose cyclic shear stresses on horizontal planes with continuous rotation of principal stress axes*
- *Most commonly used to measure stiffness and damping characteristics over a wide range of strain levels*
- *Test on solid specimens produces shear strain, range from zero along axis of specimen to a maximum value at the outer edge*
- *Hollow cylinder tests offer the best uniformity and control over stresses and drainage – specimen preparation can be difficult and equipment not widely available*

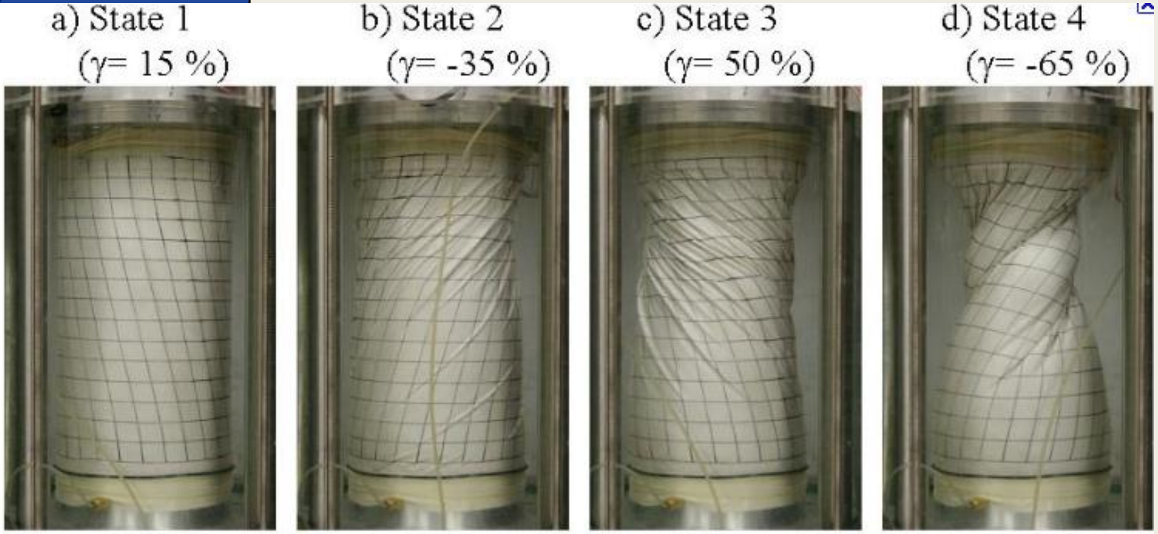


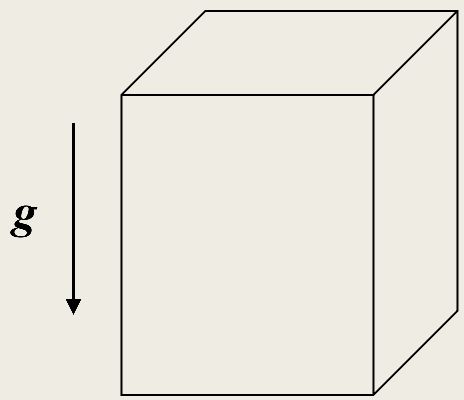
Photo 5. Deformation of specimen during undrained cyclic torsional shear test up to extremely large strain

Shaking Table Test

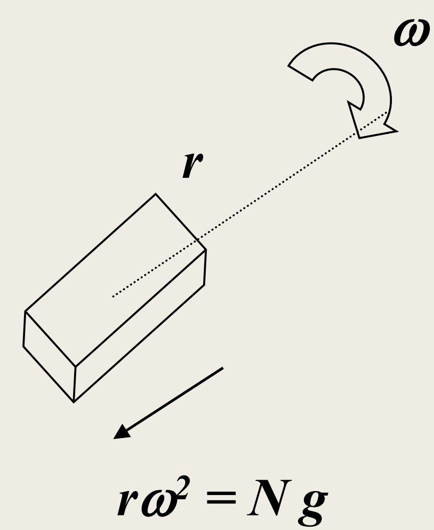
- *Can give insight into liquefaction, post-earthquake settlement, foundation response & lateral earth problems*
- *Utilise single horizontal translation degree of freedom – usually driven by servo-hydraulic actuators*

Centrifuge Tests

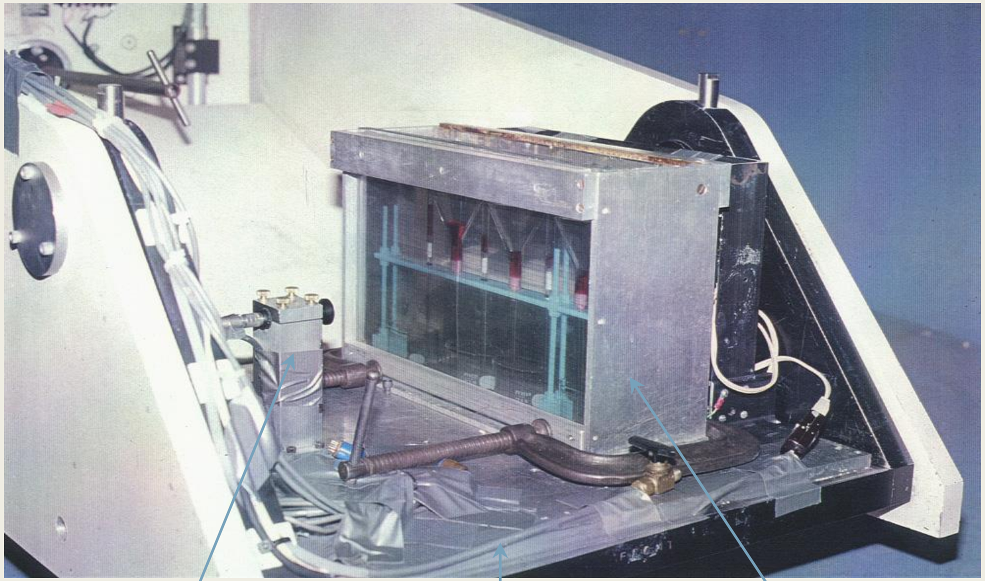
- *The test uses centrifugal acceleration to simulate gravitational acceleration*
- *In this test, a 1/N-scale model located at a distance, r from the axis of centrifuge is rotated at a rotational speed, $\Omega = \sqrt{N/r}$, which is sufficient to raise the acceleration field at the location of the model to N times the acceleration of gravity.*



Prototype - full-scale



Model - scale1/*N*



Miniature camera

1.0 m radius balanced arm centrifuge with swinging platform

Glass-fronted box filled with water

Empirical Correlations

Empirical Correlation for shear modulus

- Hardin & Black (1968)
- $$G_{\max} = \frac{6900\,(2.17-e)^2}{1+e}\left(\sigma_o'\right)^{0.5}$$ for granular soil with e>0.80
- $$G_{\max} = \frac{3230\,(2.97-e)^2}{1+e}\left(\sigma_o'\right)^{0.5}$$ for granular soil with e <0.60 or clay
- Hardin & Drnevich (1972)

$$Gs' = \frac{3230\,(2.97-e)^2}{1+e}(OCR)^k\left(\sigma_o'\right)^{0.5}$$

PI	**0**	**20**	**40**	**60**	**80**	**100**
k	0	.18	.30	.41	.48	.50

- Dobry (1988) $Gs' = 1000\,Kii\,\sqrt{(\sigma_o')}$

Soil type	***Kii***
Loose sand	8
Medium sand	12
Dense sand	16
Sand&Gravel	30-40

Empirical Correlations for shear modulus

Seed & Idriss (1970)		G_{max} = 1000-3000 S_u
Hara et al (1974)	TXUU	$G_{max} = 5.16\ S_u^{\ 1.012}$
Arango et al (1978)	UCT	G_{max} = 1790 S_u
	TXUU	G_{max} = 1163 S_u
	TXCU	G_{max} = 813 S_u
Anderson et al(1978)		G_{max} = 1200-1800 S_u
Paoliani et al (1989)	TXUU &VST	G_{max} = 500-600 S_u
Bucklovalas et al (1989)	VST	G_{max} = 800 S_u
	TXUU	G_{max} = 1800 S_u
Barros (1994)		$G_{max}/S_u = f$ (PI and OCR)

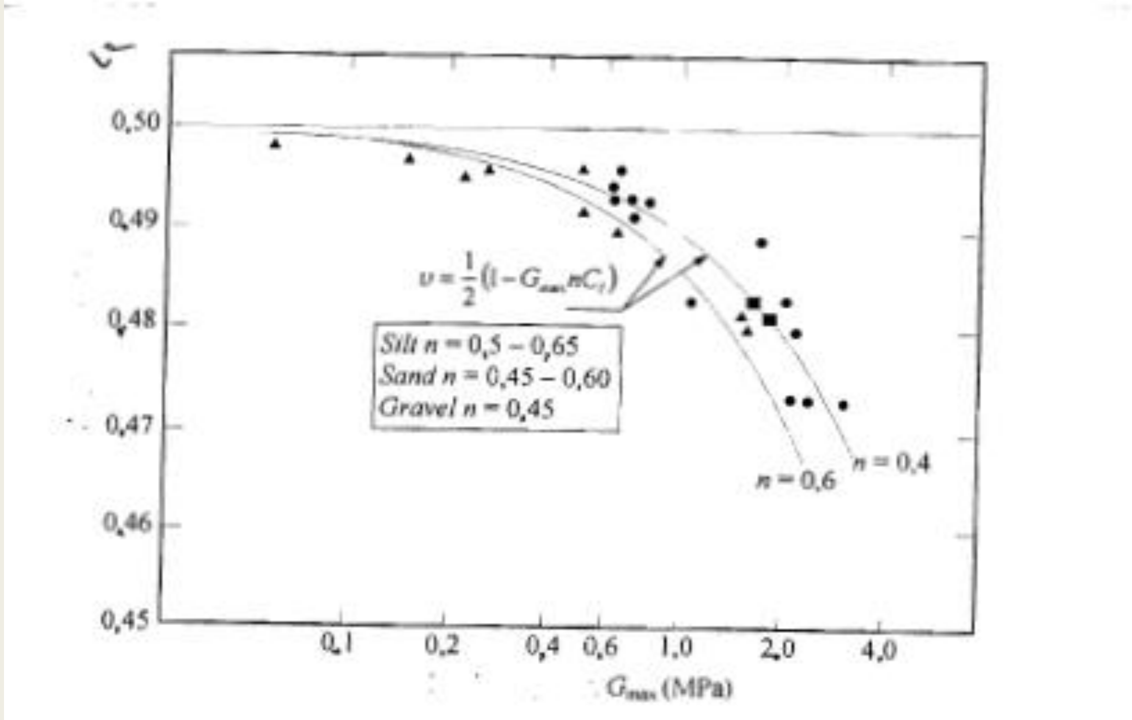
PI	OCR=1	OCR=2	OCR=3
15-20	1500	1250	1000
20-25	1100	950	800
35-45	600	520	450

Dynamic Poisson's Ratio

$$\nu = \frac{1 - \left(\dfrac{V_p^2}{2V_s^2} \right)}{1 - \left(\dfrac{V_p^2}{V_s^2} \right)}$$

Soil type	Poisson's ratio
Nearly dry sand, stiff clay, rocks	0.25
Wet silty sand (S=50-90%)	0.35
Nearly saturated clay (above gwt)	0.40
Saturated clay (below gwt)	0.50

Poisson's ratio vs shear modulus



Empirical correlation G_{max} with SPT data

G_{max} (kPa)	Reference	Soil type
$G_{max} = 11500\ N^{\ 0.8}$	Ohsaki&Iwasaki (1973)	Clay & sand
$G_{max} = 14070\ N^{\ 0.68}$	Imai & Tonouchi (1982)	Clay & sand
$G_{max} = 6220\ N$	Seed et al (1983)	Sand

Empirical correlation G_{max} with CPT data

G_{max} (Mpa)	Reference	Soil type
$G_{max} = 28\ q_c^{\ 1.40}$	Bouckolavas (1989)	Clay

Empirical correlation V_s with SPT data

V_s (m/sec)	Reference	Soil type
$V_s = 9.1\ N^{0.337}$	Imai (1970)	Clay & sand
$V_s = 85.3\ N^{0.341}$	Ohta & Goyo (1978)	Clay & sand
$V_s = 96.6\ N^{0.314}$	Imai & Tonouchi (1982)	Clay & sand
$V_s = 101\ N^{0.29}$	Sykora & Stokoe (1983)	Sand
$V_s = 69\ N^{0.17} D^{0.2} F_1 F_2$ D = depth (m)	Ohta & Goto (1978)	All types

Soil Type	F_1
Alluvial	1.0
dilluvial	1.3

Soil type	F_2
Clay	1
Fine sand	1.09
Medium sand	1.07
Coarse sand	1.14
Sandy gravel	1.15
gravel	1.45

Shear wave velocity in different soil medium

Material	V_s **(m/sec)**
Loose sand/soft clay	< 150
Slightly stiff clay	250
Stiff clay/ dense sand	350
Hard clay / very dense sand	450
Clayey shale / soft rock	600
Highly fractured rock	1000
Rock	1500

Shear wave velocity in different medium

TABLE 3–5
Representative Velocity Values[1–2]

Unconsolidated materials	ft/s	m/s
Most unconsolidated materials	Below 3000	Below 914
Soil		
Normal	800–1500	244–457
Hard packed	1500–2000	457–610
Water	5000	1524
Loose sand		
Above water table	800–2000	244–610
Below water table	1500–4000	457–1219
Loose mixed sand and gravel, wet	1500–3500	457–1067
Loose gravel, wet	1500–3000	457–914
Consolidated materials		
Most hard rocks	Above 8000	Above 2438
Coal	3000–5000	914–1524
Clay	3000–6000	914–1829
Shale		
Soft	4000–7000	1219–2134
Hard	6000–10,000	1829–3048
Sandstone		
Soft	5000–7000	1524–2134
Hard	6000–10,000	1829–3048
Limestone		
Weathered	As low as 4000	As low as 1219
Hard	8000–18,000	2438–5486
Basalt	8000–13,000	2438–3962
Granite and unweathered gneiss	10,000–20,000	3048–6096
Compacted glacial tills, hardpan, cemented gravels	4000–7000	1219–2134
Frozen soil	4000–7000	1219–2134
Pure ice	10,000–12,000	3048–3658

[1] Courtesy of Soiltest, Inc.
[2] Occasional formations may yield velocities that lie outside these ranges

THANK YOU