USERS MANUAL

SCPT SOUNDING

(Seismic Cone Penetration Testing)

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SCPT SOUNDING

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1) THE GEOTECH SCPT EQUIPMENT

1.1 Probes and Equipment available

The Geotech SCPT equipment consists of the following main items:

Rigs or penetrometers: Multipurpose Penetrometer with 10 ton push force, model 210
Multipurpose Penetrometer with 20 ton push force, model 220
Continuous Penetrometer, 20 ton
Multipurpose Site Investigation Rigs with 4 to 7 ton push force, models 504D, 604D, 605D, 705D

CPT(U) Probes:
- 10 sq.cm, with 10, 50 or 100 MPa Point resistance (Qc) range
- 15 sq.cm, with 50 or 100 MPa Point resistance (Qc) range

- Most probes come with three (Qc, fs, u) or four channels (tilt in addition) -

Available channels:
- Point resistance (Qc), 10, 50 or 100 MPa range. Overload capacity: 25%
- Local friction (fs), 1 MPa range. Overload capacity: 50%
- Pore pressure (u), 2.5 MPa range. Overload capacity: 25%
- Tilt
- Temperature

Adapters:
- Electric conductivity (adapter)
- Seismic, uniaxial for shear wave measurements (adapter)

Data Transmission: For seismic CPT, with a shielded cable

Extra features:
- Alarm and emergency stop of push triggered by pre-set maximum point resistance or tilt increment

Data Logging:
- CPT: *CPT-LOG* (Windows) or *CPTE* (DOS) software running on PC notebook (minimum 486 processor)
- SCPT: *SCPT-LOG* (Windows 95) software on PC notebook (minimum Pentium II, 150 MHz)
- Geotech datalogger Geologg-PC

Data Interpretation:
- CPT: *CPT-PRO* by Geosoft, Geotech agent in Poland. Demo version at the Geotech site
- CPT: *CONRAD* by the Swedish Geotechnical Institute
- SCPT: *SCPT-Analysis*

WARNING: The Geotech SCPT Probe Adapter is equipped with a highly sensitive accelerometer. Extreme care should be taken during transportation, storage and handling as not to expose the adapter to

shocks/accelerations over 5,000 ms^{-2} which is the shock limit of the accelerometer.

For CPTU soundings, please refer to the Geotech CPT users manual. The following manual covers only seismic CPT.

1.2 Detailed part list

Seismic CPT Equipment

P.N.	Description
	SCPT Probe Adapter to be mounted on Geotech CPT(U) Probes
	SCPT unit with accelerometer (uniaxial, 0.5 – 10.000 Hz freq. Range) with signal conditioning unit with cable connector, *with calibration sheet*
	Cable transmission of data from probe to surface
	Cable connector on adapter for Seismic and CPTU data communication from probe to surface
	Cable, from probe adapter to PC interface box
	Seismic source generator
	Bottom plate on penetrometer for hammering with trigger sensor
	Sledge hammer
	Triggering cable connected to sledge hammer and crocodile clamp to the bottom plate
	SCPT Data Acquisition and Software
	SCPT signal conditioning unit
	Flat communication cable, SCPT signal conditioning unit – PC card
	Data Acquisition PC card for PC logging
	Seismic CPT software SCPT-LOG (Windows 95, Pentium II, 150 MHz minimum)
	(Notebook not included)

CPTU Equipment

P.N.	Description	P.N.	Description
	I - Cordless CPT System: Minimum Kit Equipment		**III - 10 sq.cm Probe Spares**
		41326	Friction reducer (OD 50 mm)
	CPT Probe and depth synchronisation	41300	Point, hardened steel
41106	Probe 3 channels (qc, fs, u) 10 sq.cm, 50 MPa, temperature compensated	41331	Friction sleeve, hardened steel
		41310	Filter ring brass
41180	Extra channel with tilt sensor	41324	Support ring to X-ring
07279	Depth synchronisation (wire)	07609	Slot filter w/ Support ring for X-ring
41531	Cable depth synchr. To interface box	41380	X-ring
		41391	O-ring, friction sleeve, set of 10
	Acoustic data transmission from probe	41383	O-ring, battery pack
41205	Sound transmitter for 36 mm tapered thread rod, price per probe		
		IV -	**Extra channels, price per probe**
08875	Microphone, top mounted, 20 ton	41180	Tilt sensor
43065	Cable microphone to interface box	08819	Pore pressure sensor (15 sq.cm probe)
		08791	Electric conductivity sensor (4 electrode Wenner array), with
	Data acquisition and software		
08877	CPT interface box for PC logging with		Sound transmitter included, 15 sq.cm
	CPT-LOG software	41132	Temperature sensor

06975 Cable serial interface box to PC
41540 Cable power interface 12V

Acquisition and Display Software for PC (DOS or Windows 3.x)
08871 CPT-LOG (Win 3.1, min 486 required), English version, or

08527 Logging software for PC (CPTE, DOS)
08557 Plotting software (Georit, DOS)
DOS software: (min. req. 286 w harddisk & VGA screen)
Notebook computer

44002 Transportation case for CPT probe

Minimum set of spares
41300 Point, hardened steel
41331 Friction sleeve, hardened steel
41310 Filter ring brass
41380 X-ring
08878 O-ring, friction sleeve, set of 10

Extension rods
07629 Tapered thread rods, 36 x 1.000 mm

09485 Transport case for extension rods (115 x 23 x 17 cm)

II - CPT Probes

41101 Probe 3 channels (qc, fs, u) 10 sq.cm, 10 MPa, temperature compensated
41110 Probe 3 channels (qc, fs, u) 10 sq.cm, 100 MPa, temperature compensated
08480 Probe 2 channels (qc, fs), 15 sq.cm 50 MPa, temp. Compensated Sound transmitter included
08879 Probe 2 channels (qc, fs), 15 sq.cm 100 MPa, temperature compensated Sound transmitter included

V – Sound transmission

41205 Sound transmitter for 36 mm tapered Thread rod, price per probe
00000 Mud adapter for microphone

VI - Equipment for running CPT in cable mode

(P.N. 41205, 41508 & 43065 not required)

08546 Signal conditioning box for cable mode Transmission
08861 Connector CPT probe to cable, for cable Mode transmission (10 & 15 sq.cm probes)
08870 Cable, price per m

VII – Equipment for probe calibration

08543 Sound transmitter replacement for probe Testing in laboratory
08546 Interface box for cable mode transmission
08880 Pressure chamber
41520 Qc, fs and u adapters for calibration

VIII - Data Acquisition and Software

08100 Geologg/PC- Datalogger & Processor
41450 Overload control (max. point resistance or max tilt angle), to be mounted in Interface box or Geologg

Software
08871 CPT-LOG (Win 3.1, min 486 required), English version
08872 Same, French version
08876 Same, German version
08873 Interpretation program Conrad by the Swedish Geotechnical Institute

Interpretation program CPT-PRO by Geosoft
08882 Standard version: CPT SOIL, interpretation
08882 Pro. version CPT-SOIL + CPT-SECTION Professional version + Profile editor

All items are described in the Geotech catalogue or on the Geotech web site http://www.geotech.se. The main brochures and data sheets are included at the back of the present manual

1.3 The Geotech Seismic CPT(U) System

Due to the required density of data transmission, the traditional Geotech cordless data communication cannot be used. The signals from the CPTU probe and from the seismic adapter are sent with a shielded cable to the data acquisition at the surface.

The sound transmitter (P.N. 41205) and microphone (P.N. 08875) are therefore not used in this application.

1.4 Technical data

SCPT Probe Adapter

L= , Ø36 mm
Accelerometer:
Freq. Range: 0.5 – 10.000 Hz
Resonant freq.: 35 kHz

Shock limit: 5.000 g
Op. temp. range: -50 +121°C
Spectral noise: Noise: <10µV/vHz

CPTU Probe

See CPT Manual

Signal conditioning unit composed from:

1. Differential pre-amplifier stage
2. Programmable gain amplifier
3. Programmable low pass filter
4. Trigger unit with programmable gain

General specifications of the signal conditioning unit:

1. Power supply requirements: 12 V DC 400 mA
2. Size: 160 x 100 x 80 mm
3. Weight: 1.0 kg

Differential pre-amplifier specifications:

1. Gain: 3.5 dB
2. Common mode suppression: > 90 dB

System gain specifications (full scale signal ±10 V):

1. Gains: 9 dB – 95 dB adjustable in 6dB increments (15 positions)

Programmable filter

1. 2nd order low pass filter
2. Cut-off frequencies adjustable in 5 increments:
   1kHz, 1.78 kHz, 3.16 kHz, 5.62 kHz, 10 kHz

Trigger:

1. Programmable Gain in four instal-ments: 0dB, 20 dB, 40 dB, 60 dB
2. Full wave rectifier on output

Other signal condidtioning features:

1. Independent 2 mA/12V current sources for excitation of sensors available via jumper selections for both Trigger and Linear Amplifier
2. Programmable settings via software based selections

Software requirement

SCPT-LOG (Win 95^{TM}): IBM PC© or compatibles, Pentium II processor, 150 MHz
Three function mouse to run the data analysis modules

2) EQUIPMENT NEEDED

2.1 Checklist

A. One notebook is used for logging both CPTU and SCPT data. The minimum requirements are: PC Notebook, IBM or IBM compatible, Pentium II, 150 MHz processor.

The notebook has to be equipped with one COM ports and one PCMCIA card slot. The card slot is connected to the SCPT signal-conditioning unit. The COM port is connected to the CPT Interface box (P.N. 41410).

B. Geotech SCPT Interface box with signal conditioning unit
Triggering cable
Flat cable SCPT interface box to PC card
PC card in Pentium II notebook

C. Sledge hammer
Bottom plate with triggering sensor
Triggering cable, connected to hammer, bottom plate (crocodile clamps) and SCPT signal conditioning unit

D. Geotech CPT Interface box for PC logging (P.N. 41410).
Cable power interface 12 Vdc (P.N. 41540).
Cable serial CPT interface box to PC (P.N. 06975).
Cable CPT interface box to SCPT interface box

C. Depth synchronisation unit (also called Depth encoder) (P.N. 07279).
Cable depth synchronisation to interface box (P.N. 41531).

D. Cable SCPT adapter to PC Interface box (P.N. 43065).

E. CPT(U) Probe (10 sq.cm: P.N. 41106, 41101, 41110 or 15 sq.cm 08480)
SCPT Adapter with cable adapter and cable mounted. Never disconnect the cable.

G. Calibration certificate for the CPTU probe and user manual.

H. Can with deaired points (10 sq.cm probes: P.N. 41300) and deaired filter rings (10 sq.cm probes: P.N. 41310). Bring at least as many filter rings as the planned number of sounding during the day.

I. Container and funnel with glycerine. If a funnel with a 10 sq.cm bottom opening is not available, cut bottom and top (at approx. 10 sq.cm or 36 mm diameter) of a large soft drink plastic bottle

J. Drill rods, generally Ø36 x 1000 mm, tapered thread (P.N. 07629).

K. Pushing unit: penetrometer or geotechnical site investigation rig.

L. If required anchoring equipment.

M. CPTU Logging software CPT-LOG or CPTGL.
SCPT logging and analysis software SCPT-Log and SCPT-Analysis

3) MODIFICATION OF PC INTERFACE BOX (P.N. 4140) FOR SCPT USE

The Signal Conditioning Box for SCPT and cable CPT data has to be powered from the PC Interface box (P.N. 41410). The older models have to be slightly modified as far as the power connection of the microphone socket.

An extra 2-pole contact is therefore provided with the SCPT equipment and is installed as follows:

1. Open the PC Interface box and lift the rack of electronic cards
2. Identify the power card with three sockets at its short end: one 2-pole and one 4-pole
3. Disconnect the red lead (+) the A-pin on the 6-pole microphone socket and isolate it or disconnect its other end on the pin of the depth encoder socket
4. Connect it to the red lead of the new 2-pole contact
5. Insert the new 2-pole contact in the socket on the power board that is not previously occupied on the power board

Alternatively, if a new 2-pole contact is missing, follow 1 through 3, then connect the A-pin of the 6-pole microphone socket to the E-pin of the 6-pole power socket.

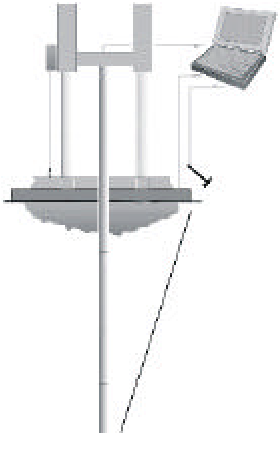
The PC Interface box is ready to connected as described in the SCPT manual

4) PREPARATION FOR SCPT SOUNDINGS

4.1 Setup of Seismic Source for SCPT Data Acquisition

The seismic source can either be:
- Airgun dug into a pit into the ground;
- “Buffalo” type gun or dynamite in a pit in the ground
- Sledge hammer or piston blows on steel plates stuck on the ground, underneath vehicles

The first two sources provide S and P waves, while the third essentially only S or P waves for each blow. The setup of this third source is for the shear waves as on the figure, right.



Seen from above, the setup is as on the figure underneath. The following items are important to follow in order to optimise the quality of the recorded traces:

Shear waves:

- Isolate the rod string from the rig underneath which, the sledge hammer blows are applied. On a CPT truck or cabin crawler with a guide tube between the foot of the penetrometer and the ground, it may be necessary to apply the blows underneath other vehicles; or only do SCPT tests when pulling up the rod string, with no bushing and guide casing
- Not to apply the hammer blows too close to the rod string (minimum 1 to 3 m)
- The "L" shaped bottom plates should be equipped with transversal teeth to improve the contact with the ground
- The bottom plates have to be parallel with the orientation of one of the S-Wave accelerometers in the SCPT cone adapter, i.e. the two bottom plates and the hole, through which the rod string is fed, have to be aligned
- In order to provide a repeatable source for seismic attenuation analysis, use a hydraulic or pneumatic piston, or a sledge hammer swinging around a fixed point.

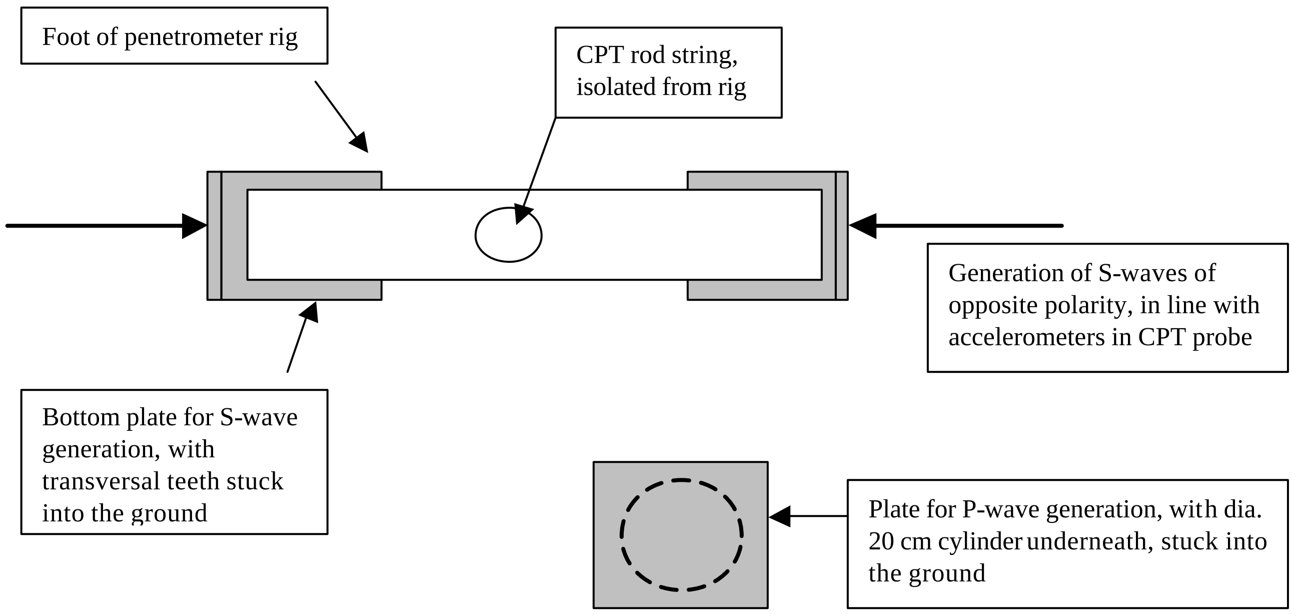


Figure 1: SCPT Acquisition Setup

P-waves:

- Place a square plate, minimum 1 to 3 m from the rod string. The plate shouldhave a dia. 20 cm, 20 cm long cylinder welded underneath, minimum one meter from the rod string, with no contact with the rig
- Apply vertical sledge hammer blows on the plate
- For a repeatable source of energy, use a fall weight, similar to SPT tests.

4.2 Step by step

1. Disconnect the shielded cable from the SCPT signal conditioning unit or the probe and cover the contact.

2. Thread the cable through all the required extension rods.

3. Connect the SCPT cable to the SCPT signal conditioning unit.

4. Introduce the SCPT probe, *orienting the probe so that one S-wave accelerometer is parallel with the S-wave bottom plates!!* This is to endure the best signal to noise ratio.

One or two bottom plates can be provided. Sledge hammer blows parallel with the ground surface will give polarised shear waves. In case the recording of oppositely polarised traces is requested, the sledge hammer blows have to be directed from two points opposite points, at the same distance from the extension rods. The offset perpendicular to the accelerometer axis should be as small as possible. Typically, it would be from both sides of the drill mast. The delivered software does not require however polarised traces in the data analysis.

Connect the triggering cable to the SCPT signal conditioning box and the free lead to a bottom plate with the crocodile clamp.

5. Mount the SCPT adapter on the CPTU probe and, when needed, prepare the probe for pore pressure measurements as described in the Geotech CPT manual

6. Prepare the depth encoder as described in the Geotech CPT manual

7. Instead of pushing the extension rods with the usual Geotech microphone use cable CPT drillhead adapter

5) SCPT SOUNDING

Start the SCPT-LOG software at the beginning of the sounding and preset the acquisition parameters as described in the SCPT-LOG manual.

After having read the zeroes of the CPTU channels, start the CPT sounding bearing in mind to orientate the probe so that the accelerometer is parallel with the sledge hammer blows. This is not important when using a shot gun.

SCPT tests are noise sensitive. It is therefore important that the engine of the penetrometer or drill rig is turned off when doing a SCPT test. In addition, make certain that the extension rod string is isolated from the drill rig or penetrometer.

Stop the penetration and if desired do a dissipation test. Thereafter:

1. Go into PAUSE (see CPT-LOG manual),
2. The case may be, *turn off the switch on the PC Interface box* to reduce electrical noise
3. Start the SCPT-Log software and set the depth, gain and distance to the source. The sensitivity of the sensors are set to 100 m/s^2. Never change the sampling rate during a test. *Analysis of traces with different sampling rate is not possible!!*

4. Hit the bottom plates with the sledge hammer, from one or the other side, or on the P-plate and inspect the recorded traces.
5. Turn the switch on the PC Interface box
6. Go back to the CPT-LOG software and press Start (F2)
7. Resume the CPT(U) sounding.

The next SCPT test is done in the same way as above. The interval shear velocity can be easily calculated in the field, for quality assessment, by running the seismic analysis software SCPT-Analysis.

At the end of the sounding, go into PAUSE with CPT-LOG, pull back the rods and read the zeroes of the channels of the CPTU probe.

6) AFTER THE SCPT SOUNDING

Check for wear and tear

After sounding, it is very important to check that the SCPT adapter is clean and that no water has infiltrated into the end contact (towards the CPT probe). If so change the O-rings before the connectors get oxidated.

The CPTU probe has to be cleaned as described in the Geotech CPT manual.

7) OBJECTIVES FOR SEISMIC CPT TESTS

Seismic CPT tests are carried out in soils to evaluate:

1. Liquefaction risk
2. Dynamic moduli
3. Attenuation

The following is a summary of in particular:

- National Institute of Standards and Technology (NISTIR) 6277: Draft Guidelines for Evaluating Liquefaction Resistance Using Shear Wave Velocity Measurements and Simplified Procedures, 121 pp. 1999
- Prevost, J. H. and Popescu, R.: Constitutive Relations for Soil Materials: http://www.ceor.princeton.edu/~radu/papers/const/const.html

7.1 Liquefaction Risk Analysis

Shear wave analysis (SCPT and SASW - Spectral Analysis of Surface Waves) have become a commonly used method for predicting the risk of liquefaction due to earthquake loading.

Advantages compared with SPT blow counts and CPT are:

- Measurements are possible in soils difficult to sample and where penetration tests may be unreliable
- Where possible, direct comparisons can be made between laboratory and field behaviour

Layers with a potential risk of being liquefied in an earthquake are non plastic, below the ground water table and where the interval shear wave velocity V_{SI} and penetration resistance are generally low.

I. Basic concepts

Critical layers are also identified as those where the cyclic stress ratio, CSR, relative to the overburden stress-corrected shear wave velocity, V_{S1} is the greatest, meaning:

1. Cyclic stress ratio, CSR, represents the seismic loading on the earth, *Eq. 1*
2. Overburden stress-corrected shear wave velocity, V_{S1}: Shear wave velocity, V_S , measurement corrected to a reference vertical (or overburden) stress of 100 kPa. *Eq. 2*

1. The cyclic stress ratio, CSR, at a given depth in a level soil deposit:

$$CSR = t_{av}/s'_v = 0.65\,(a_{max}/g)(s_v/s'_v)r_d$$ *(Seed and Idriss, 1971)* Eq. 1

Where:

t_{av}	=	The average equivalent uniform shear stress generated by the earthquake assumed to be 0.65 of the maximum induced stress,
a_{max}	=	The peak horizontal ground surface acceleration, estimated using empirical attenuation information
s'_v	=	The initial effective vertical (overburden) stress at the depth in question,
s_v	=	The total overburden stress at the same depth,
g	=	The acceleration of gravity, and
r_d	=	A shear stress reduction coefficient to adjust for flexibility of the soil profile

(I.e. the formula is based on Newton's second law, with the third part of the equation = ratio between two accelerations x mass)

2. The overburden stress-corrected shear wave velocity:

Interval velocity within the critical layer are first calculated then corrected for the overburden stress using the following formula:

$$V_{S1} = V_S(P_a/s'_v)^{0.25} = V_S(100/s'_v)^{0.25}$$ *(Sykora, 1987, Robertson et al., 1992)* Eq. 2

Where: P_a = A reference stress, 100 kPa or approximately atmospheric pressure, and

s'_v = The initial effective vertical (overburden) stress at the depth in question,

3. The peak horizontal ground surface acceleration, a_{max}, is a characteristic of the ground shaking intensity and is defined as the peak value in a horizontal ground acceleration record that would occur at the site without the influence of excess pore-water pressures or liquefaction that might develop (Youd et al., 1997). The regional value is generally provided by the national authorities

4. The shear stress reduction coefficient r_d to adjust for flexibility of the soil profile is defined as follows:

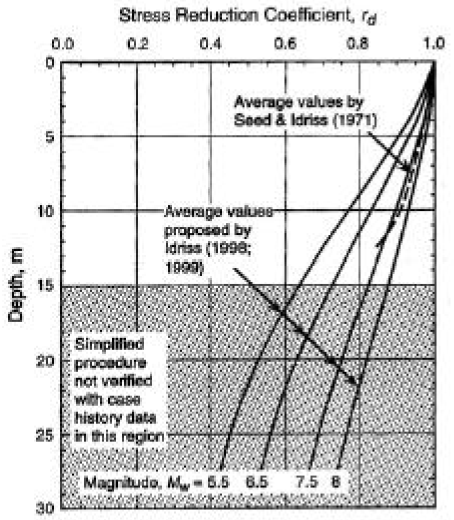


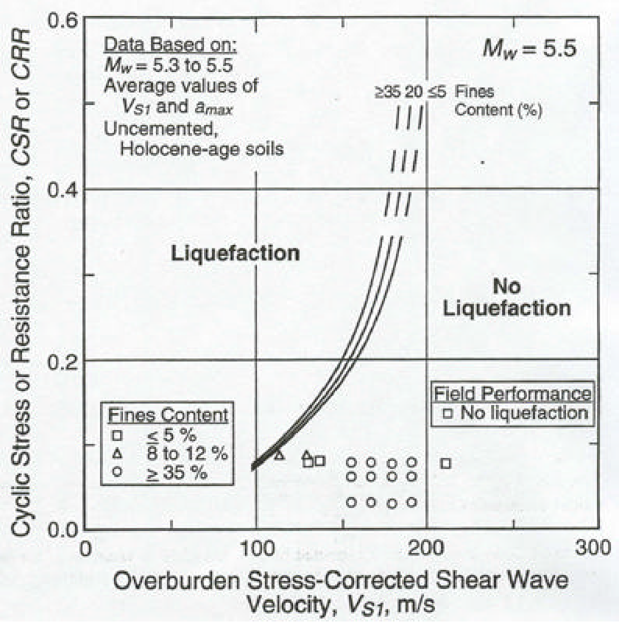
Figure 2: Variation of the average stress reduction coefficient, r_d, with detph (Seed & Idriss, 1998, 1999) with average of range determined by Seed & Idriss (1971)

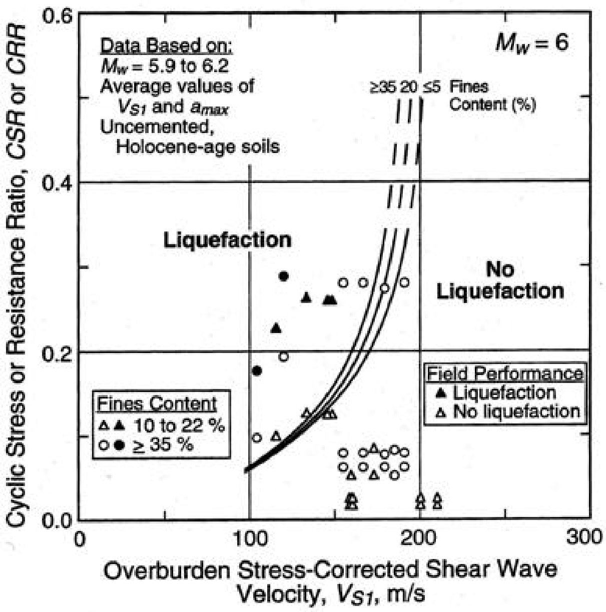
5. The earthquake magnitude scaling factor MSF and moment magnitude M_w
These relate as follows:

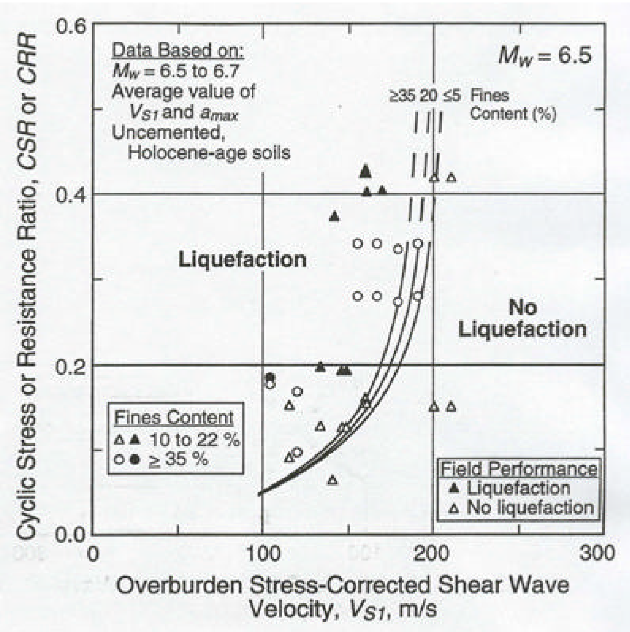
$MSF = (M_w/7.5)^n$ Eq. 3

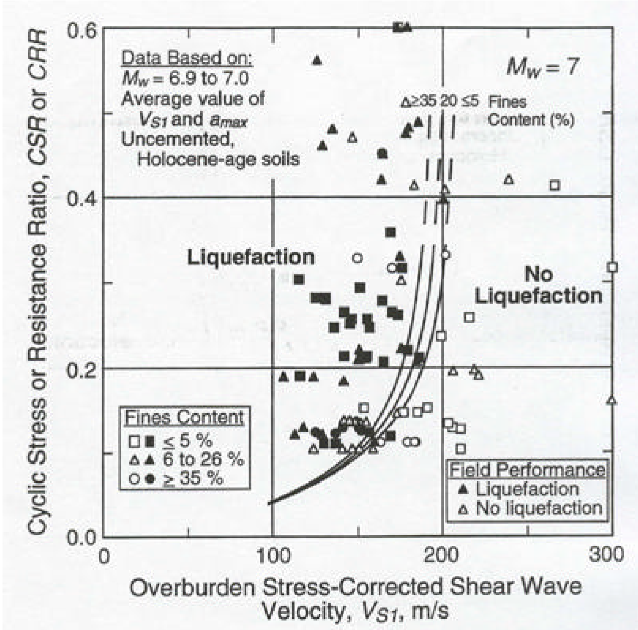
Where: *MSF* = Magnitude scaling factor
M_w Earthquake moment magnitude
n An exponent. For earthquakes with magnitude = 7.5, n = -2.56 – -3.3, For earthquakes > 7.5, n = -2.56

The two parameters relate to each other as on the figures 2 to 6 below, showing the NISTIR 6277 recommended liquefaction resistance curves based on overburden stress-corrected shear wave velocities for earthquake with magnitudes near 5.5, 6, 6.5 7, 7.5 and 8.

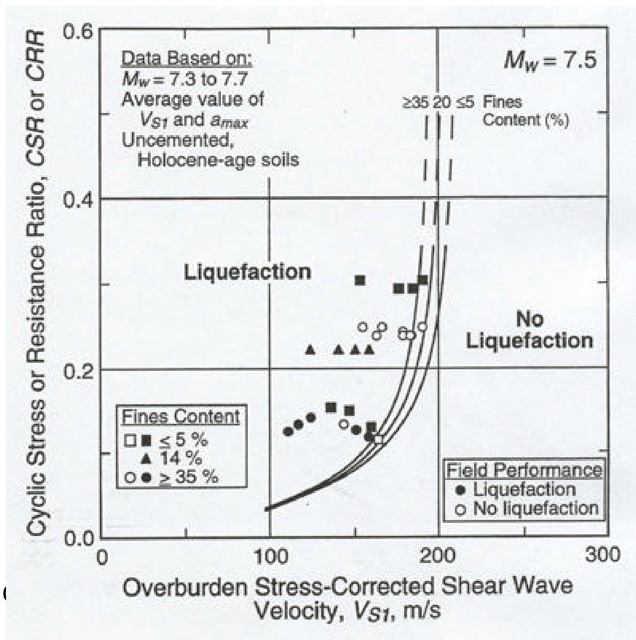


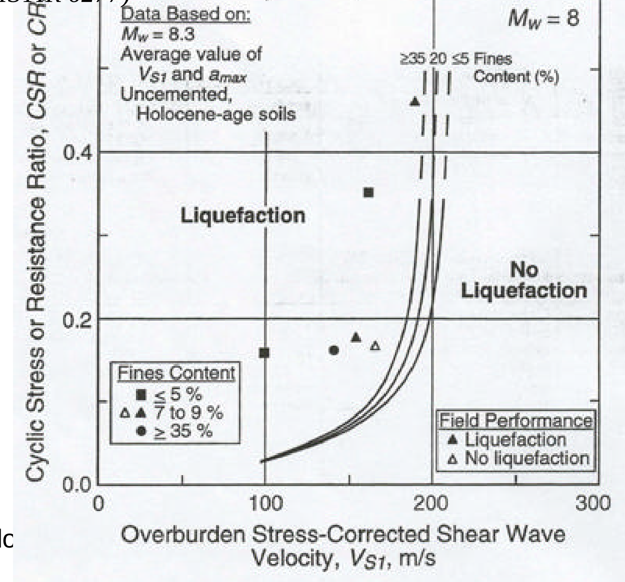






ves, Cyclic Stress or Resistance ratio, CSR and
ISTIR 6277)





II. Procedure for evaluating the liquefaction risk is (NISTIR 6277):

1. Evaluation of the Cyclic Stress Ratio (CSR) and the Overburden Stress-Corrected Interval Shear Wave Velocity (V_{S1})

1.1. Analyze SCPT (or SASW) data and construct interval shear wave velocity profiles, combined with information on soil type, fines content, soil density and penetration resistance
1.2. Identify the ground water table depth and seasonal variations
1.3. Calculate the total and effective overburden stress for each SCPT measurement depth
1.4. Correct the interval shear wave velocity, V_S , to the reference overburden stress of 100 kPa: V_{S1}, as in Eq. 2
1.5. Determine the design earthquake moment magnitude, M_w, and the expected peak horizontal ground surface acceleration, a_{max}.
1.6. For each measurement depth below the water table, calculate the cyclic stress ratio, as in Eq. 1. The stress reduction coefficient is estimated using Fig. 1
1.7. Check the risk of liquefaction on the CSR/ V_{S1} graph with the expected earthquake moment magnitude

2. Determination of the Cyclic Resistance Ratio (CRR) curve on the CSR/ V_{S1} graphs:

CRR is related to V_{S1} as follows

$$CRR = a[(CV_{S1}/100)^2 + b(1/(V^*_{S1} - CV_{S1}) - 1/V^*_{S1})] \text{ MSF} \qquad \text{Eq. 4}$$

Where: C = A factor to corret for high values of VS1 caused by cementation, aging, and negative pore-water pressures

1.8. As the CRR curves in Fig. 2-6 are limited to a CSR of 0.35, they are extrapolated with a limiting upper value of the overburden stress-corrected shear wave velocity V_{S1}. This upper value for liquefaction occurrence, V^*_{S1}, is calculated for each measurement depth using the relations below:

V^*_{S1} = 215 m/s for sands and gravels with FC = 5%
V^*_{S1} = 215 – 0.5(FC-5) m/s for sands and gravels with 5% < FC < 35%
V^*_{S1} = 200 m/s for sands and silts with FC = 35%

FC = Average fines content in percent by mass>

If the fines content is unknown, assume 215 m/s for V^*_S

1.9. Determine the value of the correction factor C. This value can be assumed equal to 1, if the soil to be evaluated is uncemented, less than 10 000 years old, and lies below the ground water table when the seismic tests were conducted. If the soil is cemented, more than 10 000 years, or lies above the ground water table, the value of C may be estimated to 0.6 to 0.8 based on the interpretation according to Rollins et al. (1998a) and Ohta and Goto (1978). If the soil conditions are unknown and penetration data are not available,a ssume 0.6 for C.

1.10. For each measurement depth below the water table, calculate the cyclic stress ratio (*CRR*), as shown in Eq. 4. The stress reduction coefficient r_d is estimated using Fig. 1.

1.11. Plot values of V_{S1} and *CSR*, and the appropriate liquefaction resistance curves using Eq. 2 and Eq. 3 with:

a = 0.022,
b = 2.8, and
n = -2.56.

Liquefaction is predicted at the site if the data points plot to te left of the CRR curve.

III. References:

National Institute of Standards and Technology (NISTIR) 6277 (1999): Draft Guidelines for Evaluating Liquefaction Resistance Using Shear Wave Velocity Measurements and Simplified Procedures, 121 pp.

Rollins, K.M., Evans, M.D., Diehl, N.B. and Daily, W.D. III (1998): Shear modulus and damping relationships for gravels. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 124, No. 5. p. 396-405

Ohta, Y. and Goto, N. (1978): Physical background of the statistically obtained S-wave velocity equation in terms of soil indexes. Butsuri-Tanko (Geophysical Exploration), vol. 31, No. 1, p. 8-17 (in Japanese translation by Y. Yamamoto)

Seed, H.B. and Idriss, I.M. (1971): Simplified Procedure for Evaluating Soil Liquefaction Potential. Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 97, SM), pp. 1249-1273

7.2 Soil Elastic Constants

The elastic constants can be evaluated in the field. With shear waves alone, only the Shear modulus at small strain (G_0), with compression and shear waves, the Elastic (E) and Bulk (B) moduli, the Poisson ratio (?) and the Lamé constant (?):

Shear modulus at small strain G_0 or G_{max} = $?V_{Si}{}^2$

Compression modulus M_0 = $?V_{Pi}{}^2$

The elastic constants expressed as a function of the shear modulus the Poisson ratio:

Elastic modulus E = $2G_0(1+?)$

Bulk modulus B = $2G_0(1+?)/3(1-2?)$

Poisson ration ? = $(1-2(V_{Si} / V_{Pi})^2)/(2-2(V_{Si} / V_{Pi})^2)$

Where: ? is the mass density of the soil
V_{Si} is the interval shear wave velocity
V_{Pi} is the interval compression wave velocity

7.3 Attenuation

The energy dissipation of a wavelet (in the form of heat) as it travels through a medium is referred to as its attenuation or absorption by the medium. In general terms, the in-situ stratiraphy acts as both a low pass filter and an attenuator as a seismic wavelet travels through it. The decrease in amplitude of the wavelet due to absorption is exponential and can be defined in both the distance and time domains.

In the distance domain, the expression of an elastic wavelet as it travel through distance is

$$A(x) = A_0 e^{-ax}$$

In the time domain it is: $A(t) = A_0 e^{-ht} \cos ?t$

Where:

Where:	x	=	Travelling distance
	a	=	Absorption coefficient (Distance domain)
	h	=	Absorption coefficient (Time domain), h = a?/T
	T	=	Wavelet period
	$?$	=	Wavelet wavelength (i.e. V = ?/T)
	Q	=	p/a? is the quality factor

Attenuation is typically defined for S and P waves as $D_S = 1/(2Q_S)$ and $D_P = 1/(2Q_P)$ respectively.

The most common type of analysis is by spectral ratio.

Model Number 352C65 | GEOTECH **SHEAR ACCELEROMETER** | Revision: B, ECN #: 9075

DYNAMIC PERFORMANCE			
Voltage Sensitivity	mV/g [mV/(ms⁻²)]	100 [10,2]	(±10%)
Measurement Range (for ±5V output)	±g pk [±ms⁻² pk]	50 [491]	
Frequency Range: (±5%)	Hz	0.5 to 10,000	
(±10%)	Hz	0.3 to 12,000	
(±3 dB)	Hz	0.2 to 20,000	
Mounted Resonant Frequency	kHz	≥35	
Phase Response: ±5° (at 70°F [21°C])	Hz	2 to 15,000	
Broadband Resolution (1 Hz to 10 kHz)	g rms [ms⁻² rms]	0.00016 [0,0015]	[2]
Amplitude Linearity	%	±1	[1]
Transverse Sensitivity	%	≤5	
ENVIRONMENTAL			
Shock Limit - All Axes (maximum)	±g pk [±ms⁻² pk]	5,000 [49 050]	
Operating Temperature Range	°F [°C]	-65 to +250 [-53 to +121]	
Temperature Response	%/°F [%/°C]	See Graph	[2]
Strain Sensitivity	g/µε [(ms⁻²)/µε]	≤0.005 [≤0,05]	
ELECTRICAL			
Excitation Voltage/Constant Current	VDC/mA	18-30/2-20	
Output Impedance	ohms	<100	
Output Bias	VDC	8-12	
Discharge Time Constant	sec	0.8-2.4	
Warm Up Time (within 10% of output bias)	sec	<10	
Spectral Noise: (1 Hz)	µg/√Hz [(µms⁻²)/√Hz]	60 [588]	[2]
(10 Hz)	µg/√Hz [(µms⁻²)/√Hz]	16 [157]	
(100 Hz)	µg/√Hz [(µms⁻²)/√Hz]	5 [49]	
(1 kHz)	µg/√Hz [(µms⁻²)/√Hz]	1.5 [14,7]	
Ground Isolation	ohms	Optional	
MECHANICAL			
Sensing Element	material/geometry	Ceramic/Shear	
Housing	material/sealing	Titanium/Welded Hermetic	
Size (hex x height)	in [mm]	0.28 x 0.32 [7,1 x 8,1]	
Weight	oz [gm]	0.070 [2,0]	
Electrical Connector	type/location	5-44 Coaxial/Side	
Mounting Thread	size	5-40 Male	
Mounting Torque	in-lb [N-cm]	8-12 [90-135]	

All specifications are at room temperature unless otherwise specified.

OPTIONAL VERSIONS

Optional versions have identical specifications and accessories as listed for the standard model except where noted by the letter prefixes below. More than one option may be used.

☐ A - Adhesive Mount
Add Accessories: (1) Model 080A90 Quick Bonder
Note: Mounting Stud Removed – Adhesive Mounting Base *Not* Required

☐ J - Ground Isolated

High Frequency Range: +5%/+10%/+3dB	kHz	8/10/16
Mounted Resonant Frequency	kHz	≥30
Electrical Base Isolation	ohms	$>10^8$
Size (hex x height)	in [mm]	0.37 x 0.45 [9,5 x 11,4]
Weight	oz [gm]	0.1 [2,8]

☐ M - Metric Mount
Modify Accessories: (1) Model M080A15 Base replaces (1) Model 080A15

☐ W - Water Resistant Cable
Electrical Connector — type/location — Sealed Cable/Side

NOTES:
[1] Zero based best straight line method.
[2] Typical.

SUPPLIED ACCESSORIES:
080A109 Petro Wax Sample (1)
080A15 Adhesive Mounting Base (1) *
NIST Traceable Calibration Certificate

* Except A Option

Drawn:	Engineer: DS	Sales: SL	Approved:	Spec Number
Date:	Date: 5/7/98	Date: 5/5/98	Date: 5/6/98	8339