1.11 Resonant Column Test

1. PURPOSE

- Determining the dynamic deformation properties (shear modulus and damping ratio) of soils.

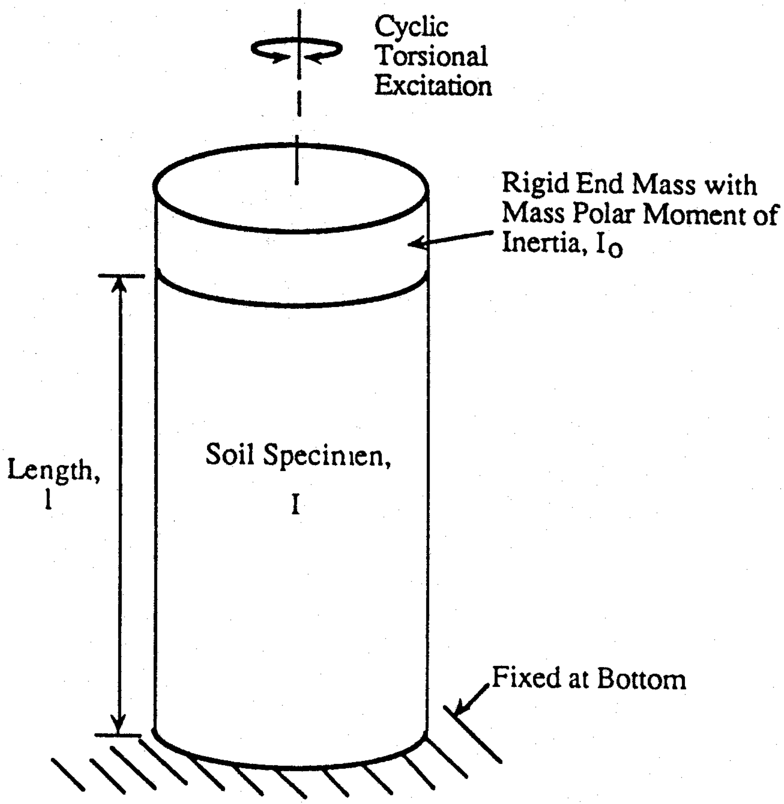


Fig. 5 Idealized fixed-free RCTS Equipment

2. PROCEDURE

2.1 Preparation and Set-up of Specimen

Method	Sample
Trimming	Block-like or Frozen
Suction	Non-block

2.2 Back Pressure Saturation (if necessary)

- Check the degree of saturation by measuring B-value

2.3 Torsional Excitation Process

i) Apply confining pressure and measure volume change or vertical displacement.
ii) Apply harmonic torsional excitation to the specimen with varying frequency.
iii) Obtain the response of the acceleration amplitude with varying frequency and find the first-mode resonance where output voltage of accelerometer is maximized.
iv) Record the resonant frequency and the amplitude of vibration.
v) Obtain the free-vibration decay curve (using an oscilloscope) by shutting off the driving force while the specimen is vibrating at the resonant frequency. (or find the frequencies where the amplitude of vibration is 0.707 times of first-mode resonance.)

vi) Repeat the process described ii) ~ v) with increasing the amplitude of torsional excitation. (in general, γ can reaches about 10^{-1}%.)

vii) Increase the confining stress and repeat ii) ~ vi).

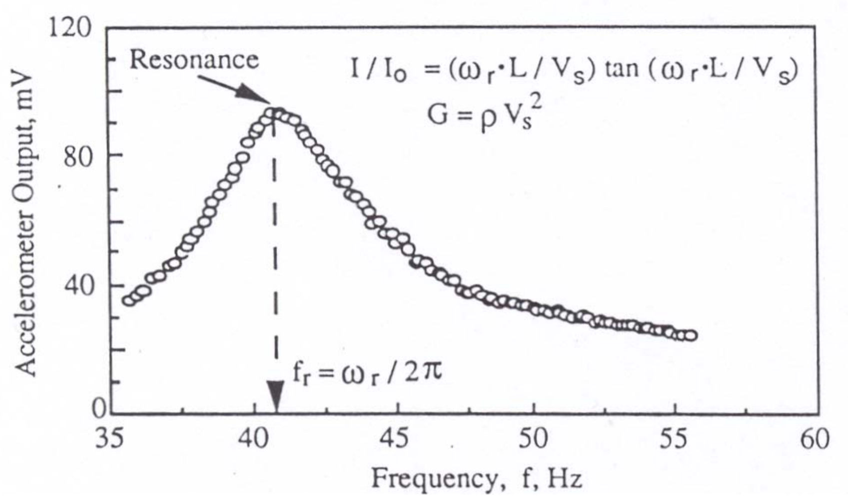


Fig. 6 Typical frequency response curve

3. CALCULATION OF TEST RESULTS

3.1 Shear Modulus

- Calculate the shear wave velocity of soil sample, V_s, as follows:

$$\frac{\sum I}{I_0} = \frac{\omega_n \cdot l}{V_s} \tan\left(\frac{\omega_n \cdot l}{V_s}\right)$$

where

$\sum I$	:	sum of I_s and I_m,
I_s	:	mass moment of inertia of soil,
I_m	:	mass moment of inertia of membrane,
I_0	:	mass moment of inertia of rigid end mass at the top of sample,
l	:	length of the specimen,
ω_n	:	undamped natural circular frequency of the system

- Calculate the shear modulus using shear wave velocity

$$G = \rho \cdot V_s^2$$

where

ρ	:	total mass density of the soil

3.2 Shear Strain

- Calculate the shearing strain

$$\gamma = r_{eq} \frac{A_c \cdot T_r^2}{4\pi^2 \cdot CF} \cdot \frac{1}{D_{ac}} \cdot \frac{1}{l}$$

where

r_{eq}	:	equivalent radius(0.707r or 0.67r),
A_c	:	output voltage of accelerometer,
T_r	:	resonant period,
CF	:	accelerometer calibration factor,
D_{ac}	:	distance between the location of accelerometer and the axis of the specimen, and
l	:	length of specimen

3.3 Damping Ratio

- Calculate the damping ratio using free-vibration decay method or half-power bandwidth method

- Calculate the damping ratio using free-vibration decay method

$$D = \sqrt{\frac{\delta^2}{4\pi^2 + \delta^2}}$$

where

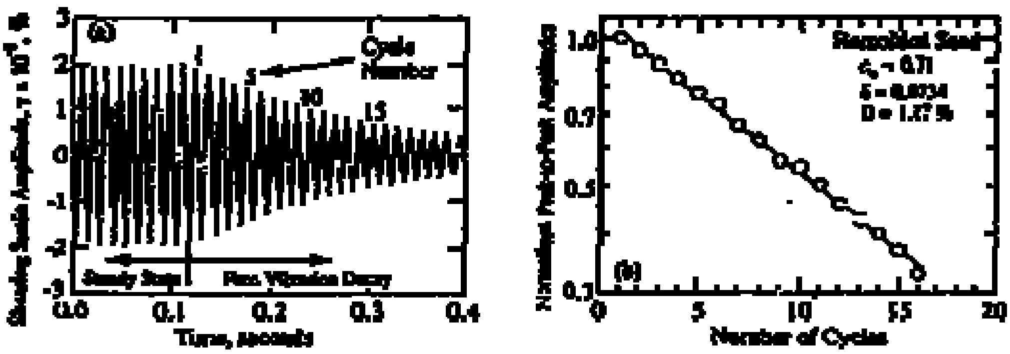
δ : logarithmic decrement of strain amplitudes, which is defined as:

$$\delta = \ln\left(\frac{Z_1}{Z_2}\right) = \frac{2\pi D}{\sqrt{1 - D^2}}$$

where

Z_1, Z_2 : two successive strain amplitudes of motion, and

D : material damping ratio



(a) Free-vibration decay curve (b) Analysis of free-vibration decay curve

Fig. 7 Determination of material damping ratio from the free-vibration decay curve

- Calculate the material damping ratio using half-power bandwidth method

$$D \cong \frac{f_2 - f_1}{2 f_r}$$

where

f_1 : frequency below the resonance where the strain amplitude is A $(= 0.707 A_{max})$

f_2 : frequency above the resonance where the strain amplitude is A $(= 0.707 A_{max})$

f_r : resonant frequency where the strain amplitude is A_{max}

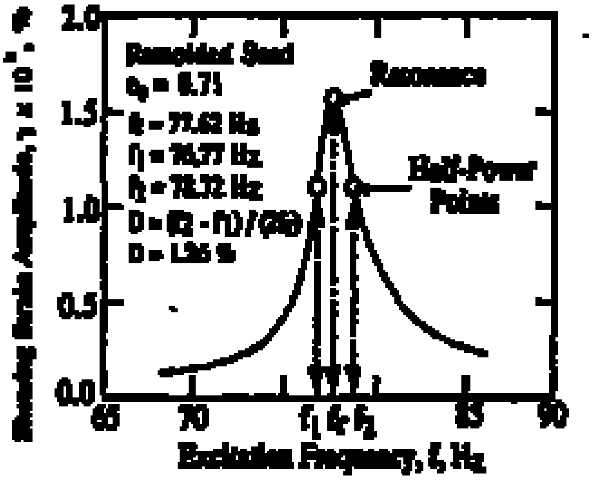
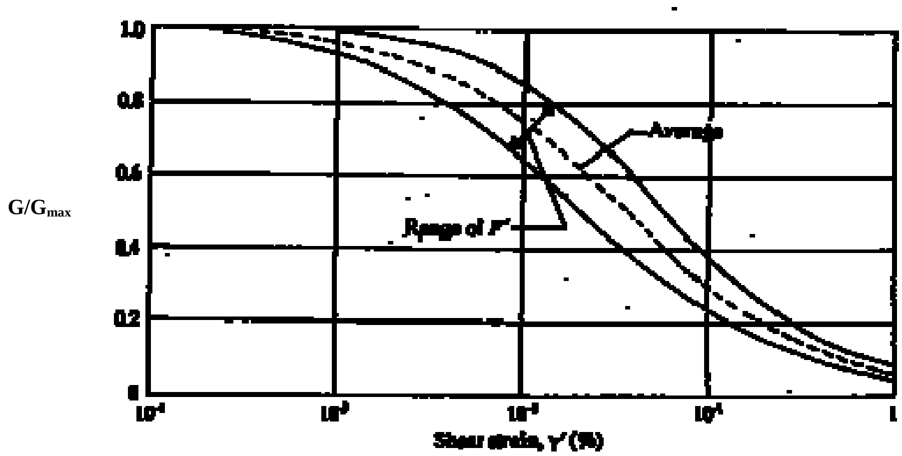
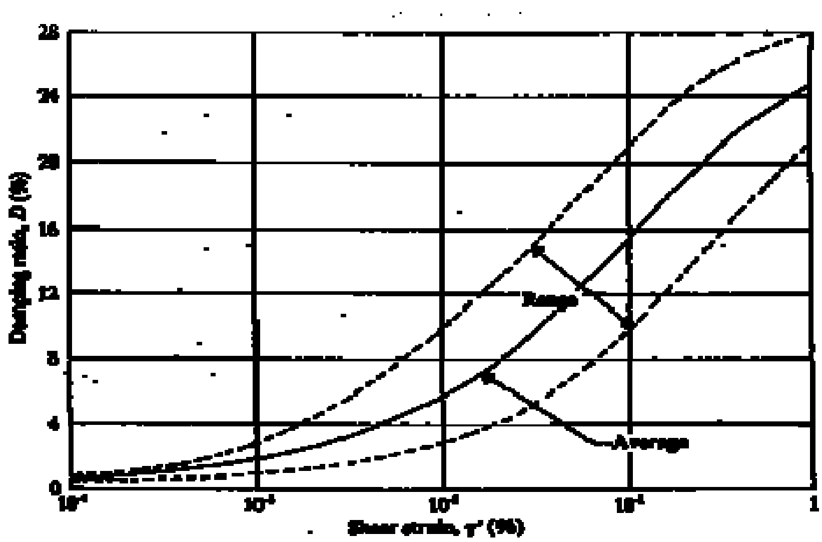


Fig. 8 Determination of material damping from the half-power bandwidth method



(a) Shear modulus



(b) Damping ratio

Fig. 9 Typical results of deformation properties from resonant column test