N93-26412

cSc

Lunar Regolith and Structure Mechanics

Stein Sture

Third Annual Symposium
November 21 & 22, 1991

LUNAR REGOLITH AND STRUCTURE MECHANICS

Frank Barnes
Hon-Yim Ko
Stein Sture

Tyrone R. Carter
Kraig A. Evenson
Mark P. Nathan
Steve W. Perkins

- MODELING OF REGOLITH-STRUCTURE INTERACTION IN EXTRATERRESTRIAL CONSTRUCTED FACILITIES
- DENSIFICATION OF LUNAR SOIL SIMULANT
- VIBRATION-ASSISTED PENETRATION OF LUNAR SOIL SIMULANT

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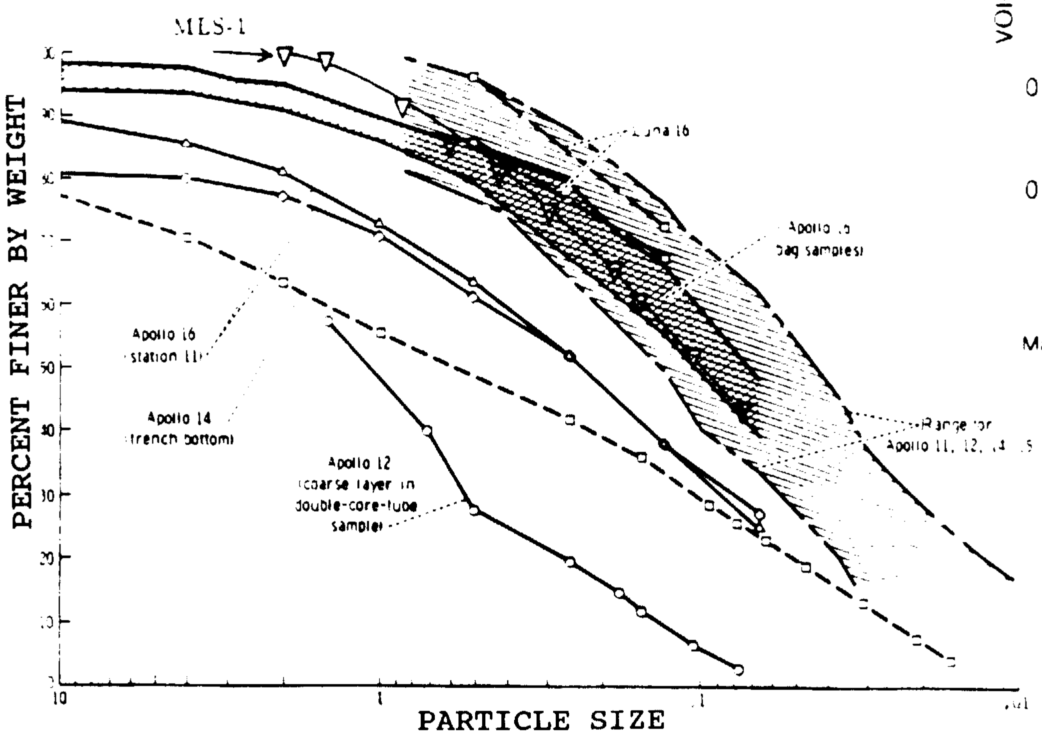
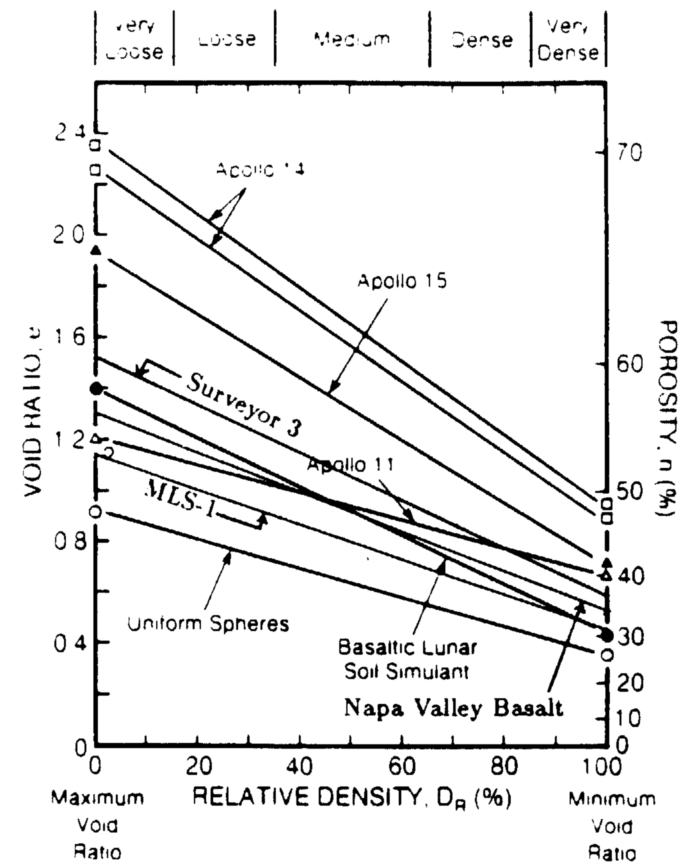
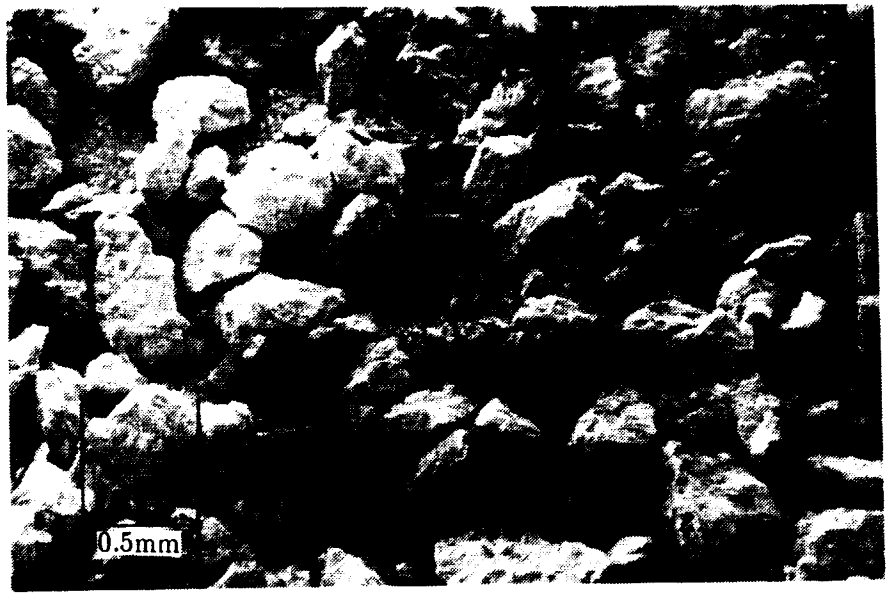
MINERALOGY AND PHYSICAL PROPERTIES OF LUNAR REGOLITH AND MLS ARE VERY CLOSE



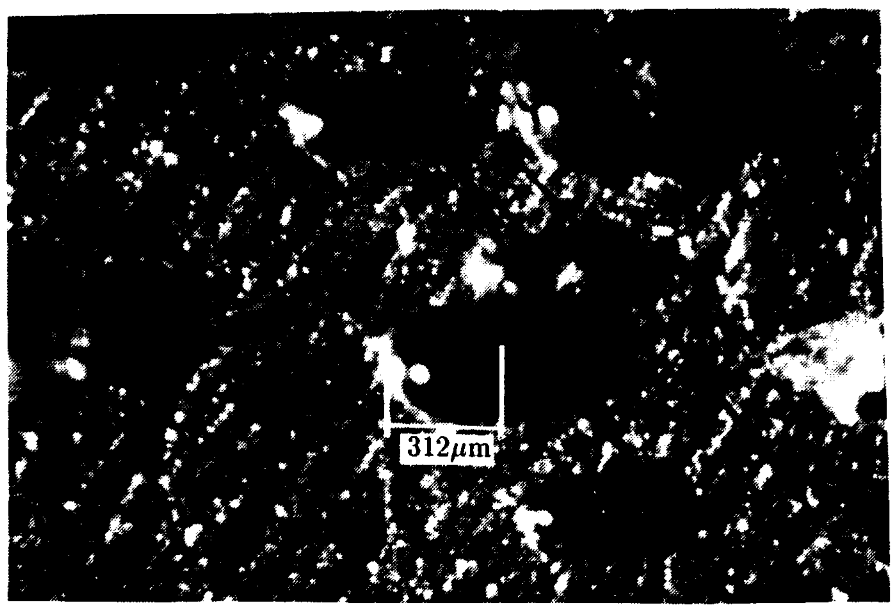
Grain Size Distribution Curves for Apollo Samples and Recombined MLS-1



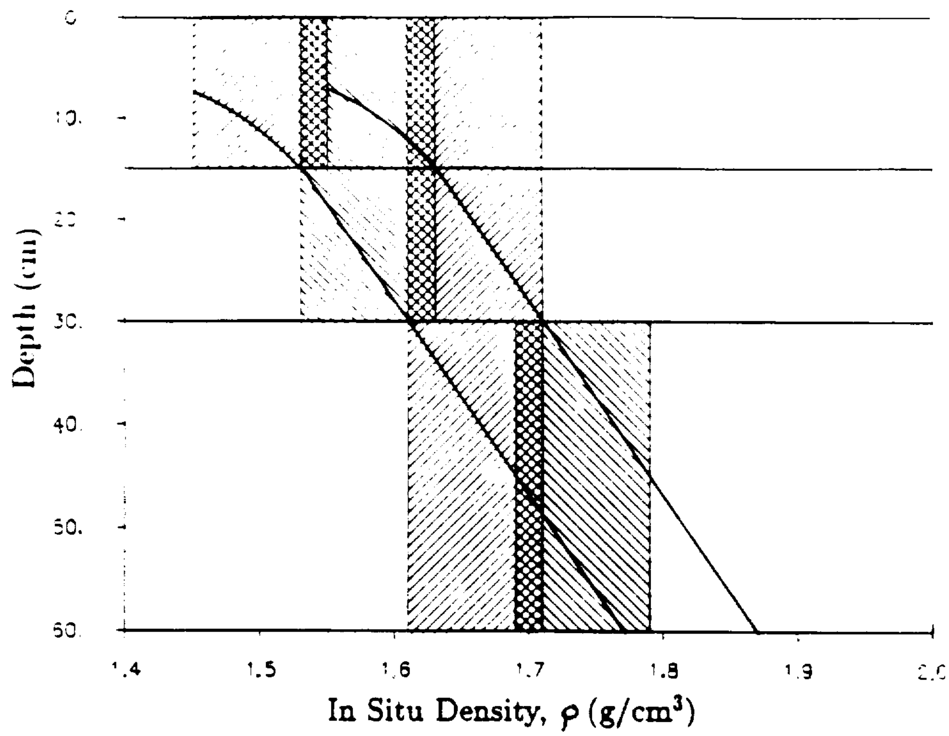
Maximum and Minimum Void Ratio for Lunar Soil and Simulants



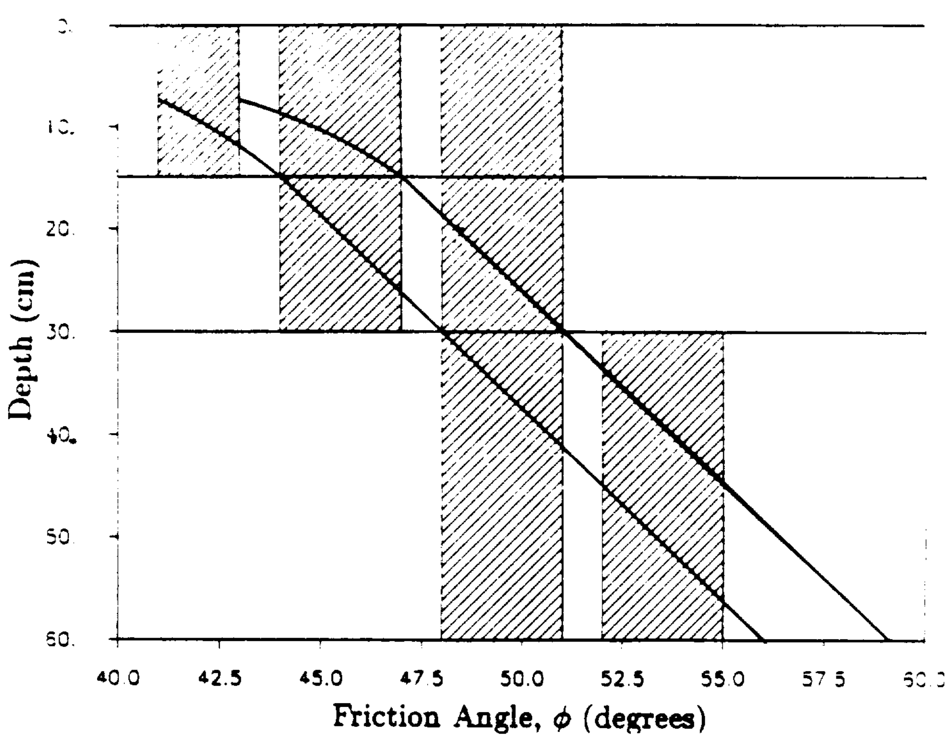
REGOLITH



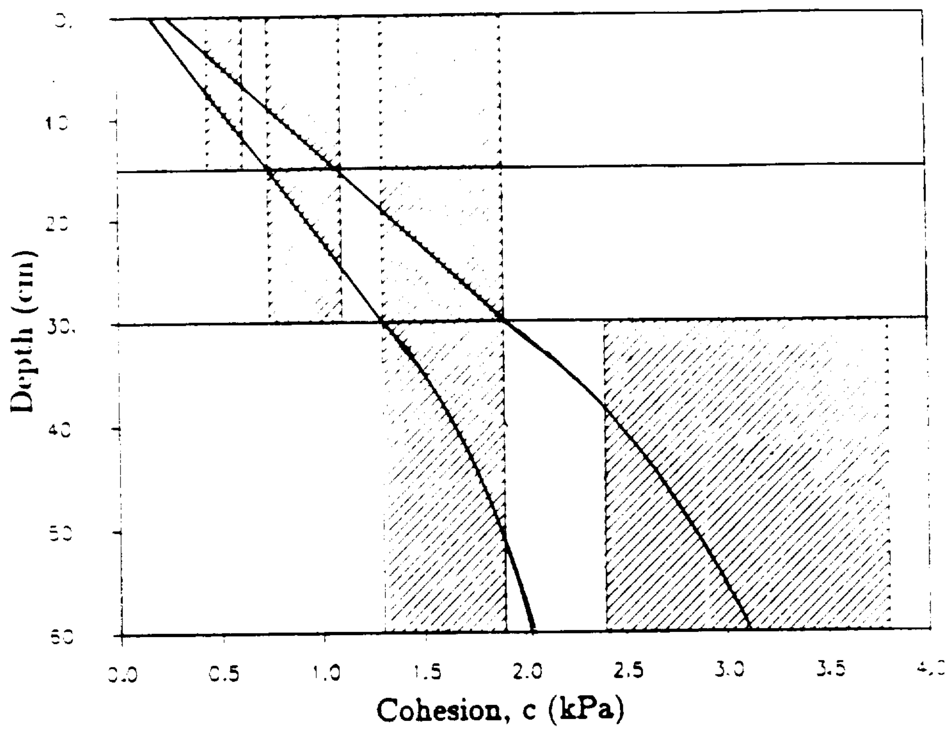
SPHERULES



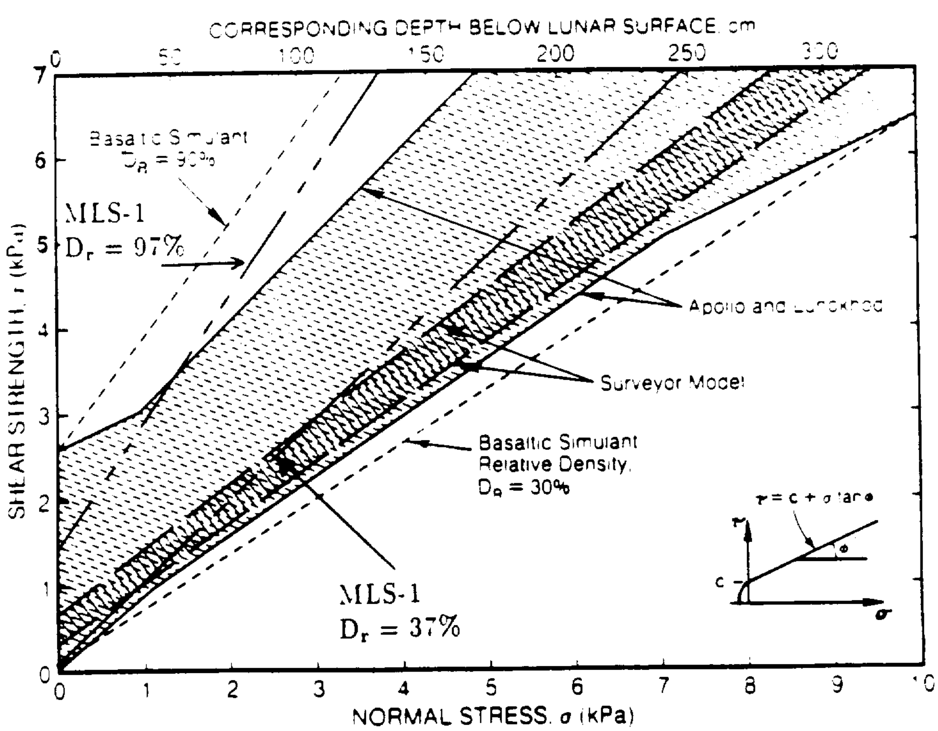
Best Estimates of Lunar Soil In Situ Density Versus Depth (data after Carrier, 1990)



Best Estimates of Lunar Soil Friction Angle Versus Depth (data after Carrier, 1990)



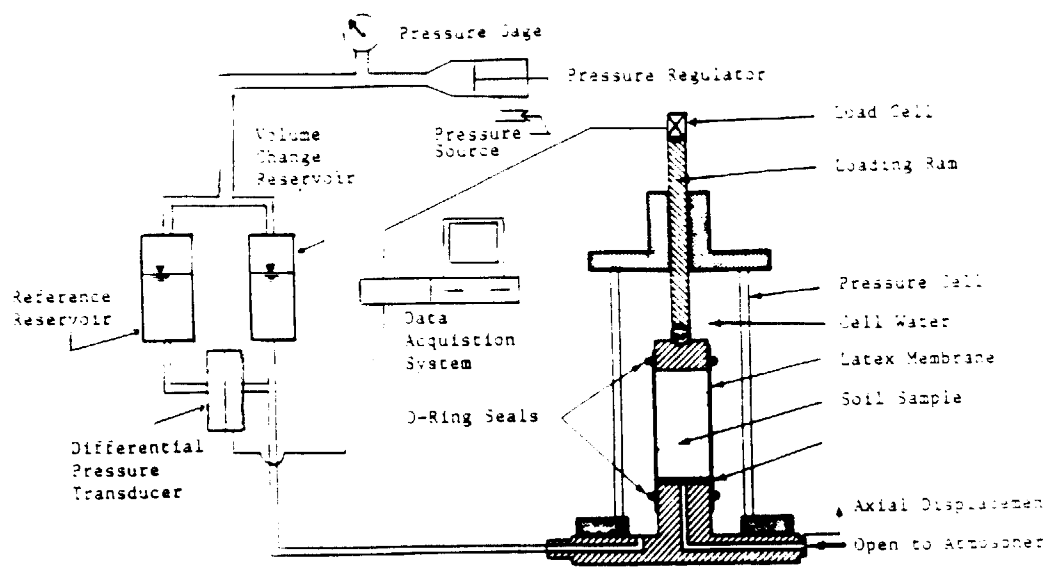
Best Estimates of Lunar Soil Cohesion Versus Depth (data after Carrier. 1990)



Mohr-Coulomb Peak Strength Envelopes for Lunar Regolith and MLS-1 (after Carrier et al., 1991)

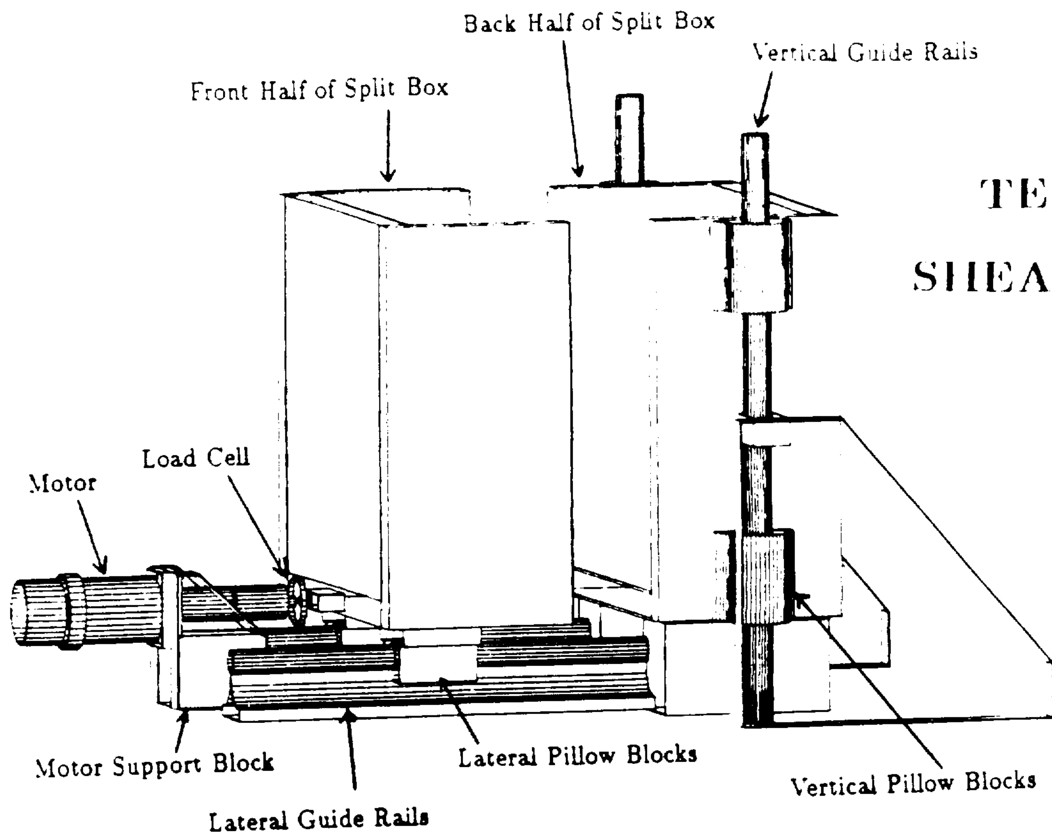
MECHANICAL PROPERTIES OF A SIMULATED LUNAR SOIL

TRIAXIAL COMPRESSION EXPERIMENTS (MLS)

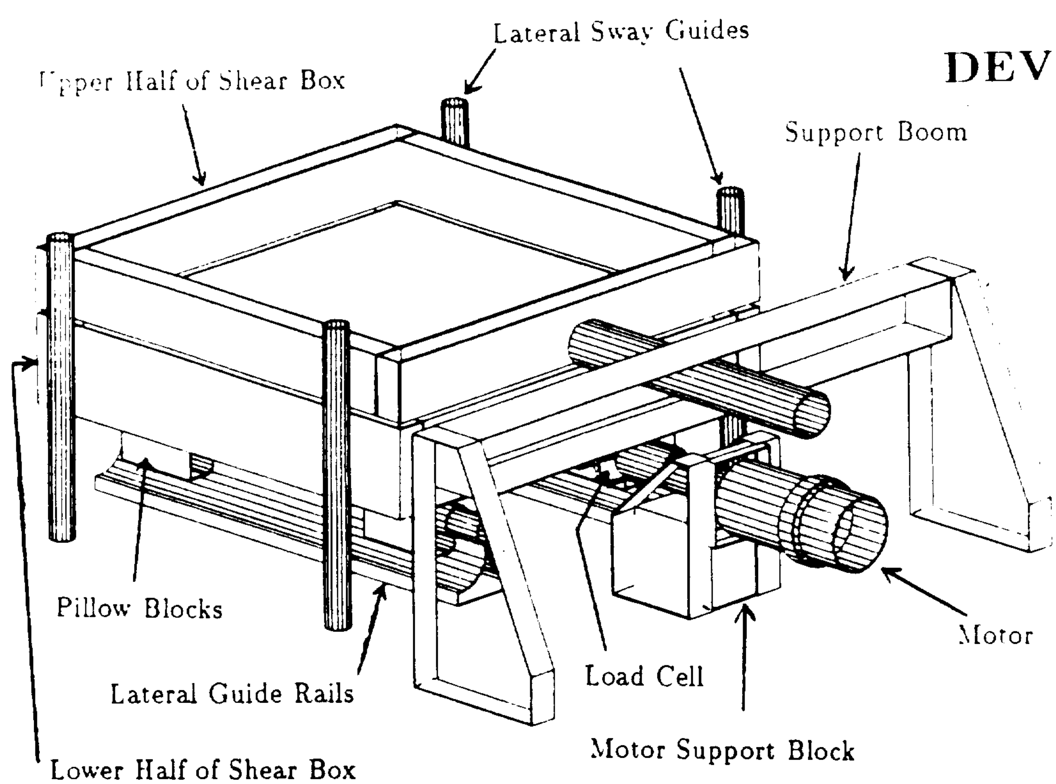


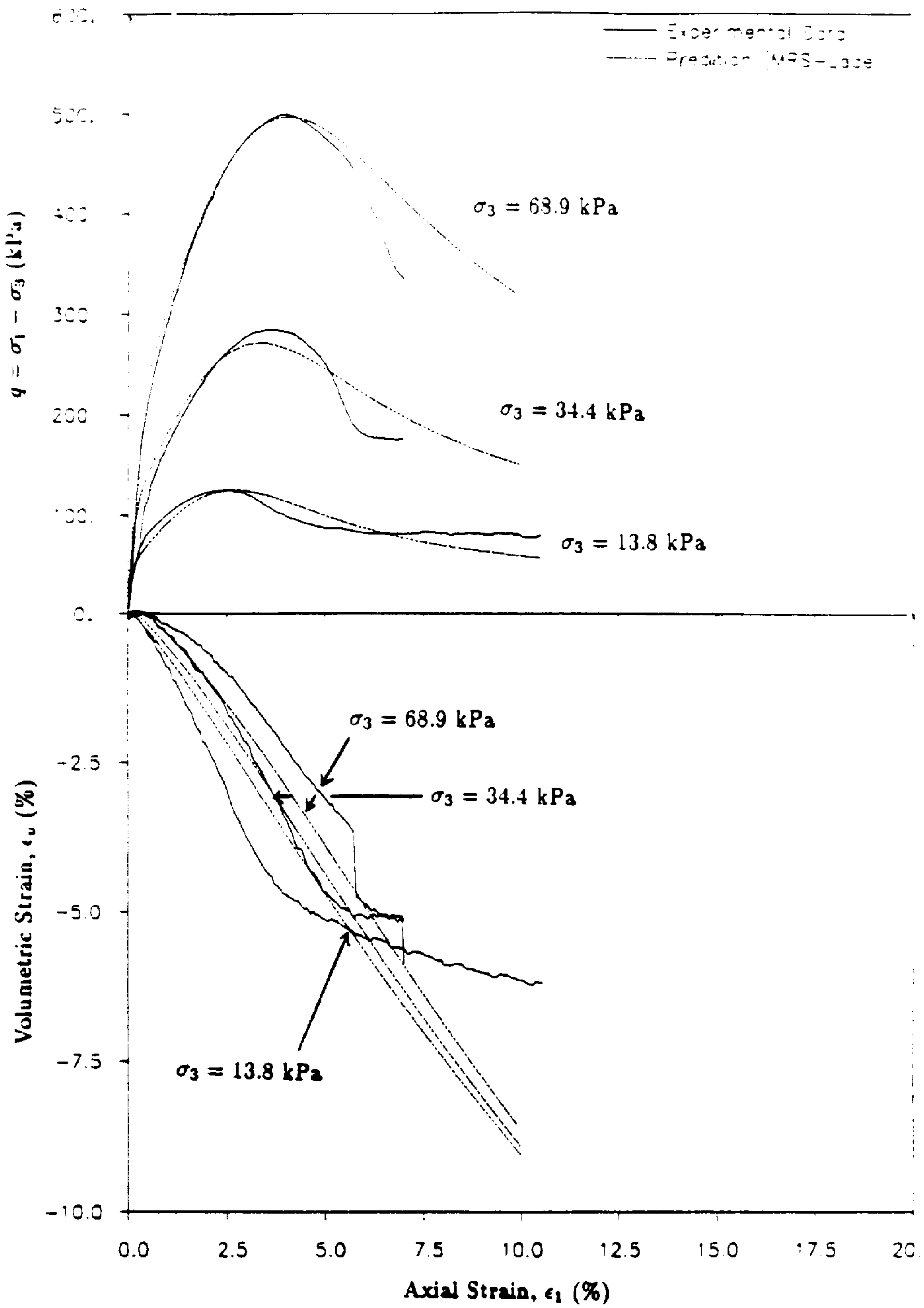
Schematic Diagram of the Triaxial Testing System

TENSION-SHEAR DEVICE

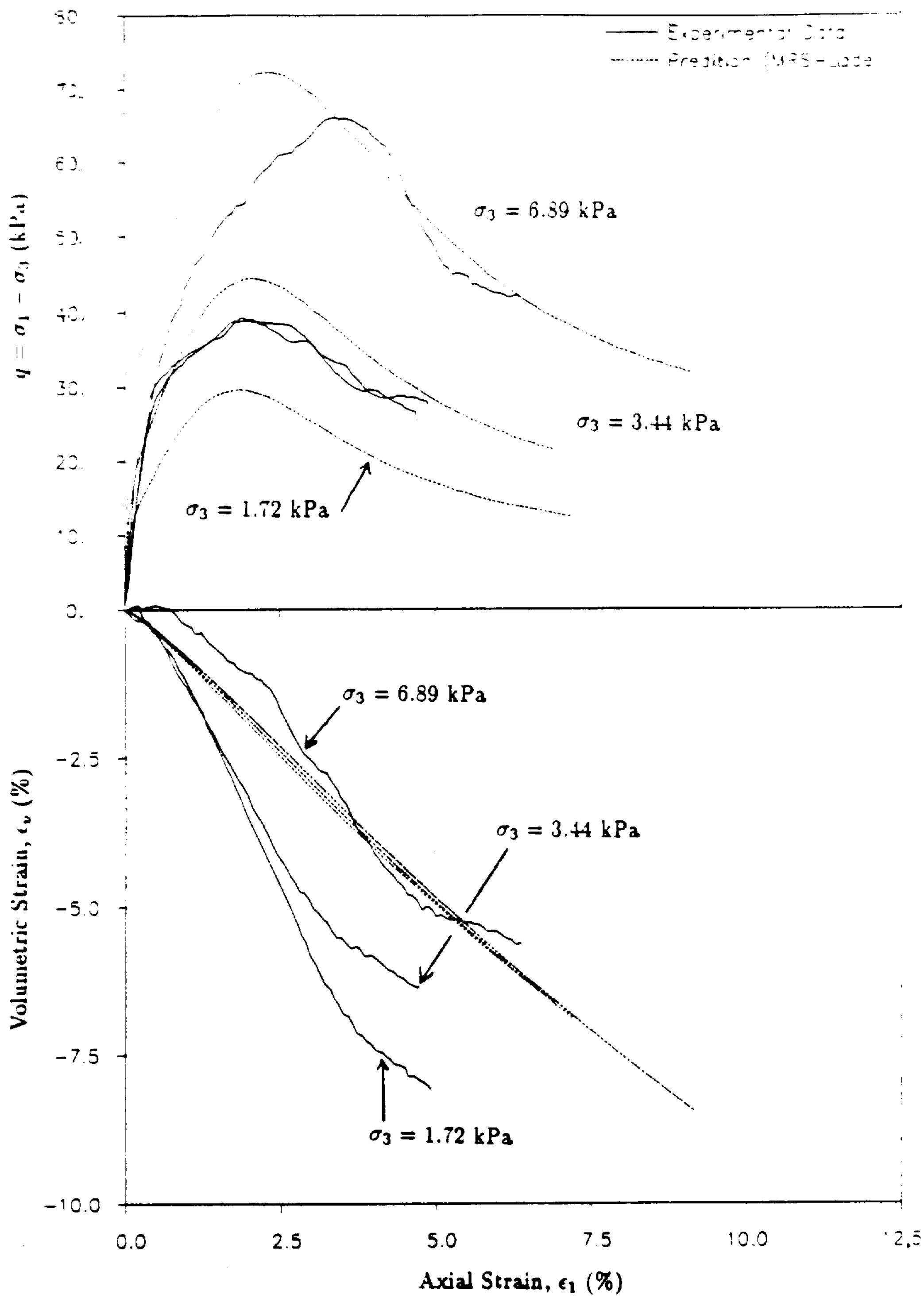


DIRECT SHEAR DEVICE

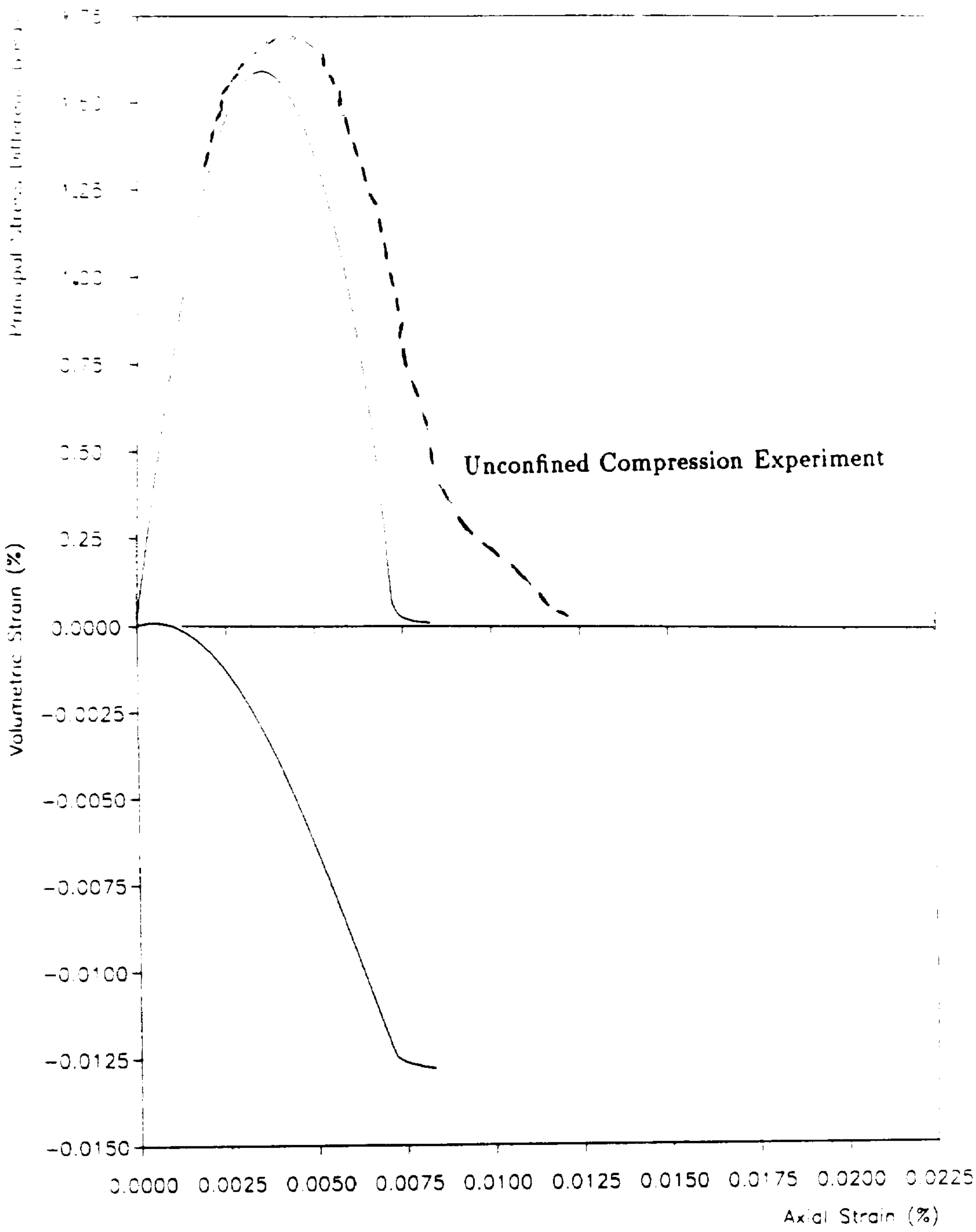




CTC Experimental Results and Predictions For "High" Confining Stress Levels (Dense)

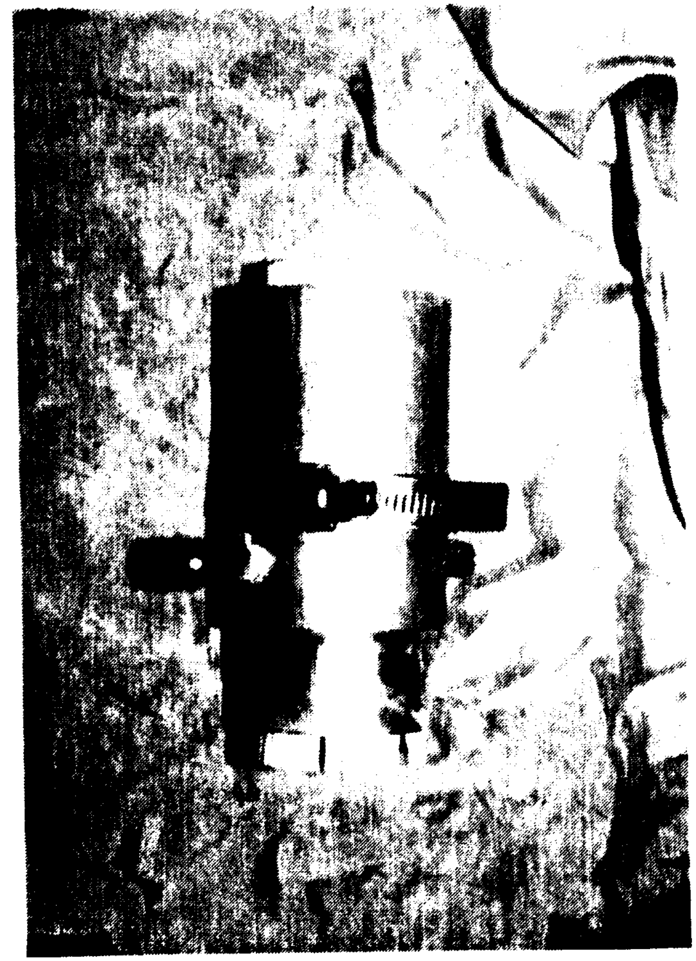


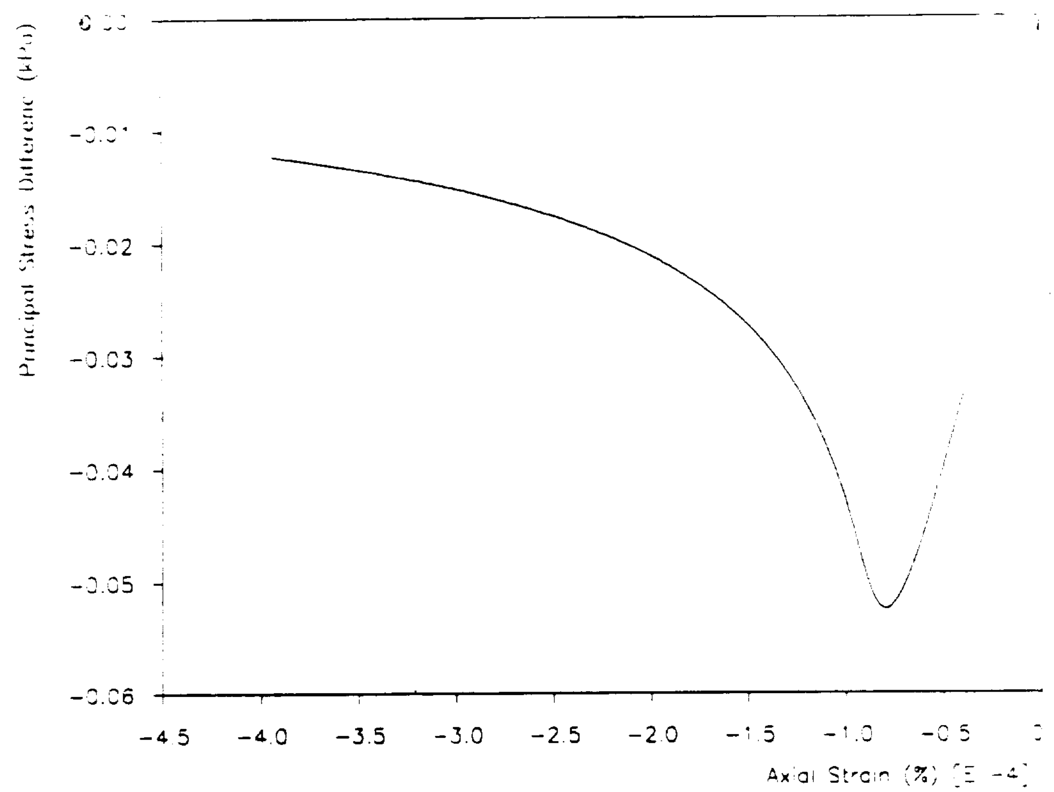
CTC Experimental Results and Predictions For "low" Confining Stress Levels (Dense)



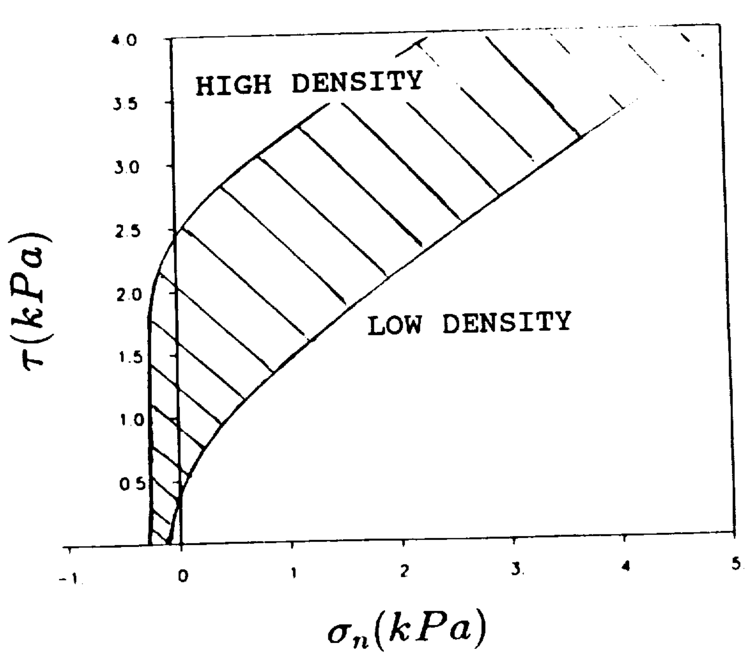
MRS-Lade Prediction for Unconfined Compression Test From Calibration at Ultra-Low Stress Levels

TENSILE STRENGTH EXPERIMENT





MRS-Lade Prediction for Unconfined Tension From Calibration at Ultra-Low Stress Levels



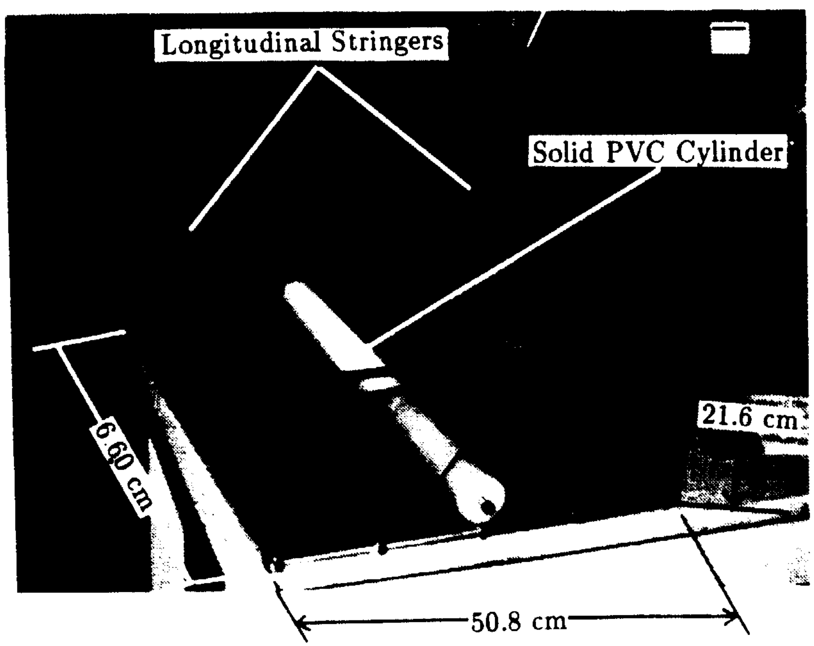
ULTIMATE STRENGTH ENVELOPE FOR MLS-1

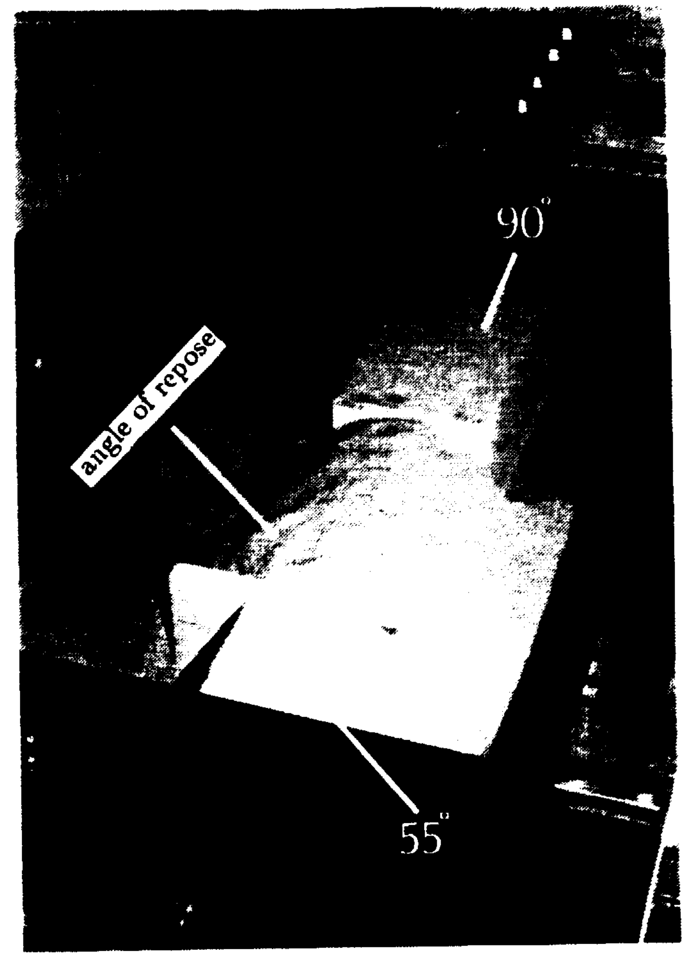
TYPICAL RANGES OF ENGINEERING PROPERTIES FOR DRY TERRESTRIAL COHESIONLESS SOILS AND LUNAR REGOLITH (REAL AND SIMULATED)

- ADVANTAGES
  - Increased Strength
  - Increased Stiffness
  - Subsurface Homogeneity
- DISADVANTAGES
  - Electrostatic Attraction To All Non-Geologic Matter
  - Difficult To Excavate

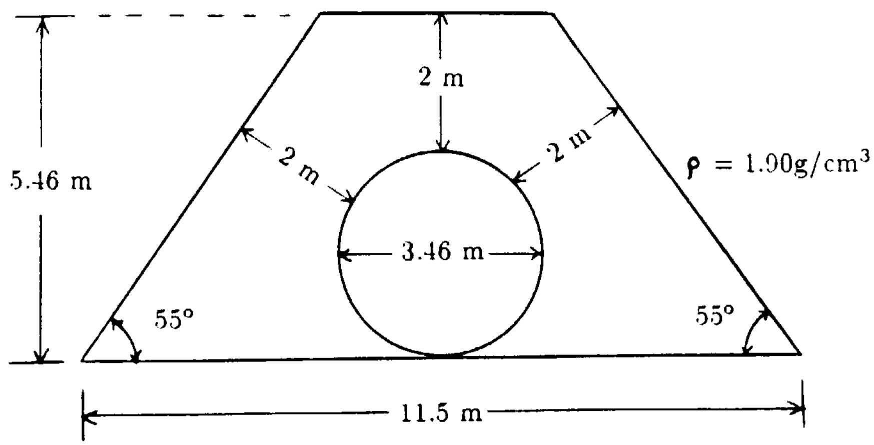
	Terrestrial Soils	Lunar Regolith and MLS
Friction Angle (ϕ,°)	30-38	44-66
Cohesion/Adhesion (c, $\frac{kN}{m^2}$)	0	0.05-4.50
Specific Mass of Solids (ρ_s, $\frac{g}{cm^3}$)	2.7	3.1
Mass Density of Particulate Void-Solids Composite (ρ, $\frac{g}{cm^3}$)	1.4-1.9	1.8-2.2
Unit Weight (γ, $\frac{kN}{m^3}$)	14-19	2.9-3.6
Bearing Capacity of a 0.10 m by 0.10 m Footing on Level Ground (q_f, $\frac{kN}{m^2}$)	8-45	27-1840
Modulus of Subgrade Reaction (est.) (k_s, $\frac{MN}{m^3}$)	0.5-15	$1\text{-}10^4$

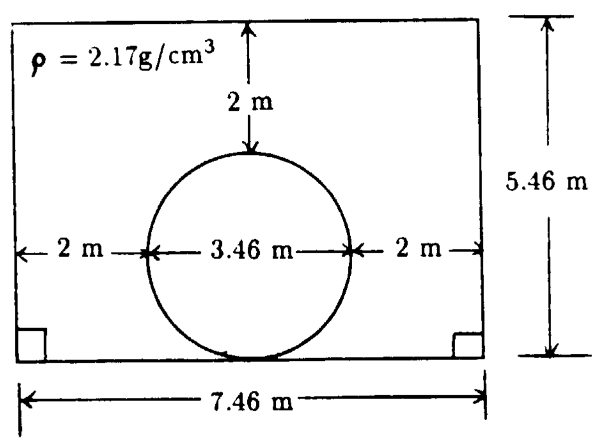
CENTRIFUGE MODELING OF REGOLITH-STRUCTURE INTERACTION





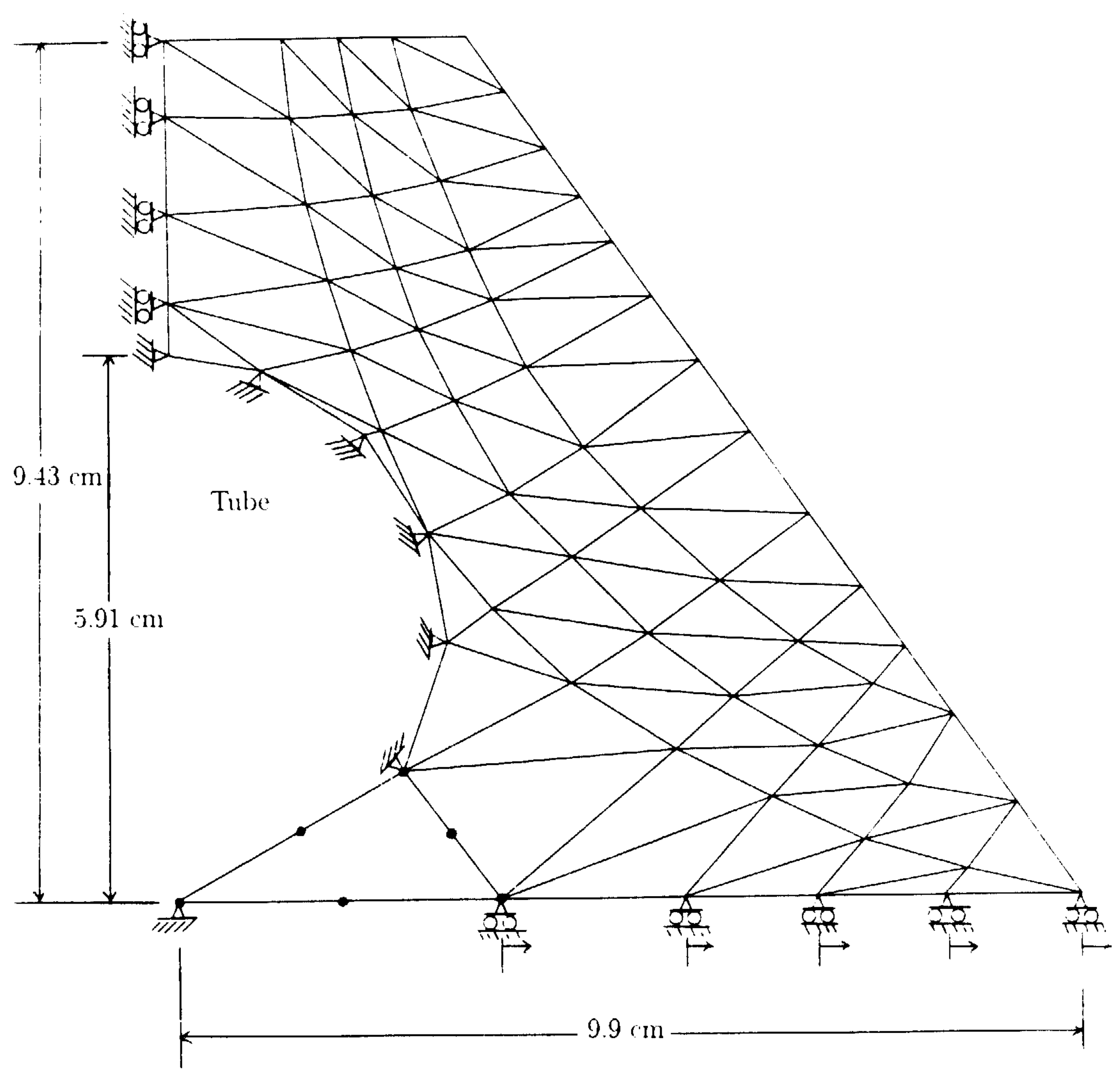
MODEL





Lunar Prototype II.II.M. Dimensions

SLOPE ANGLE	VOLUME [m^3]
30°	1,245
55°	705
90°	690


9.43 cm
5.91 cm
Tube
9.9 cm

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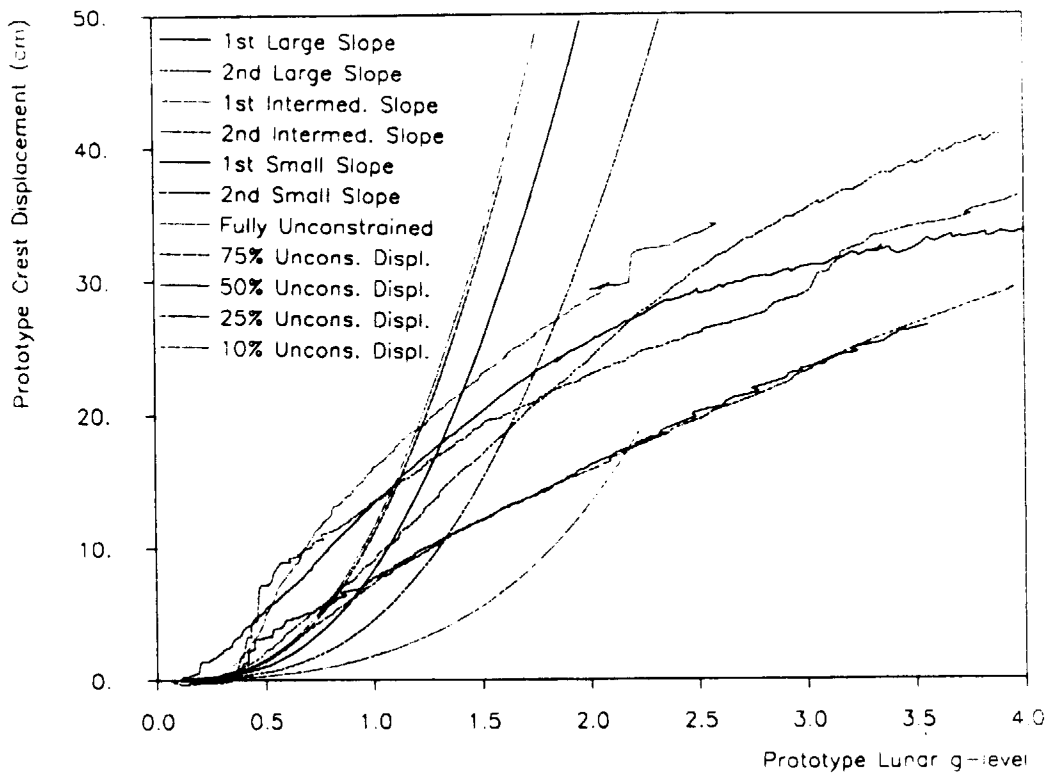
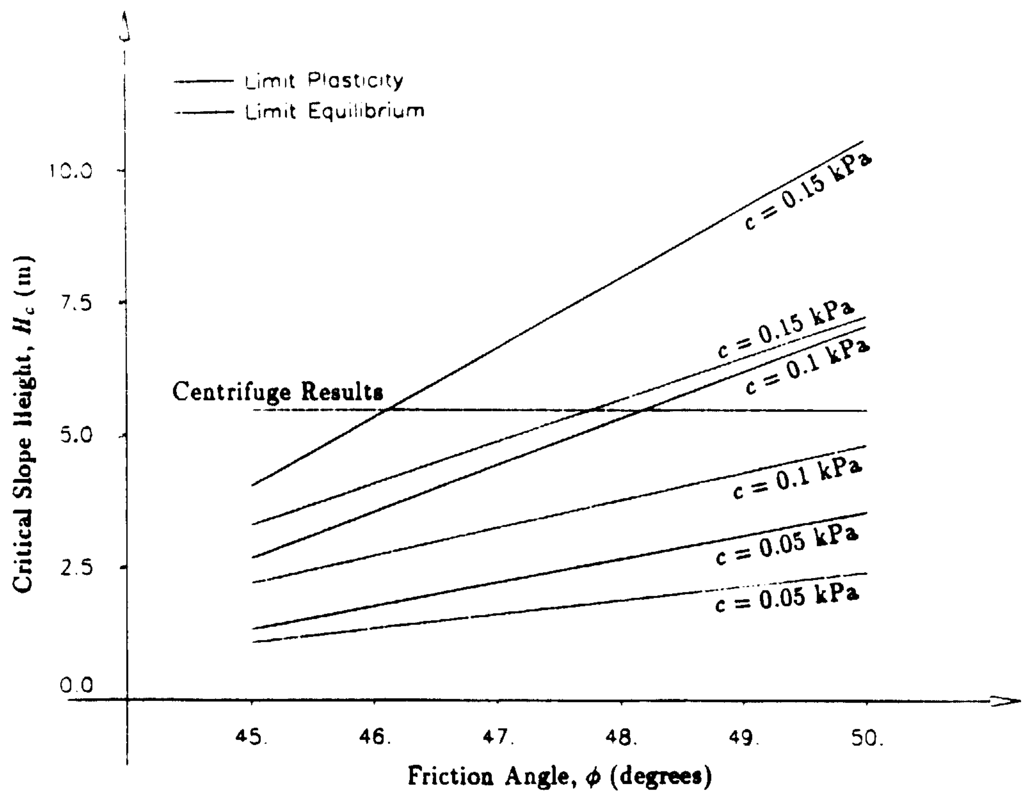


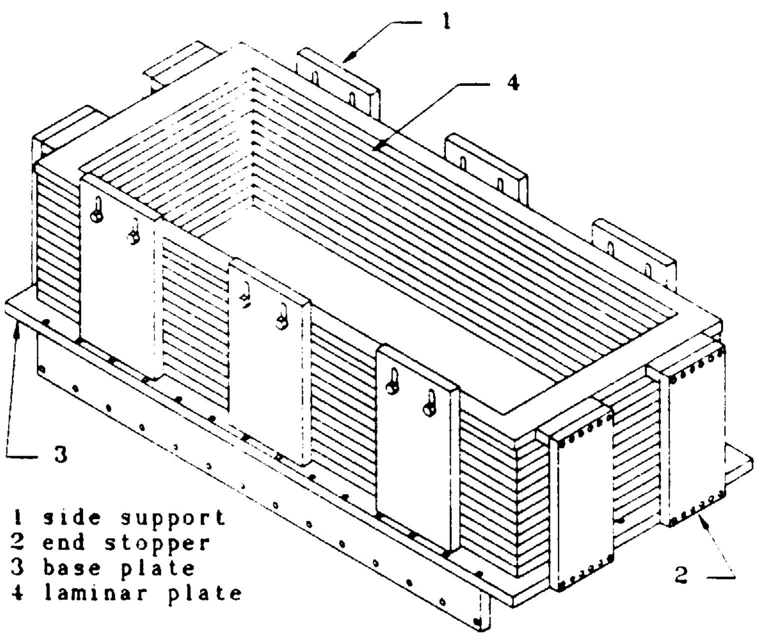
Prototype Crest Displacement (cm)
50.
40.
30.
20.
10.
0.
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Prototype Lunar g-level
1st Large Slope
2nd Large Slope
1st Intermed. Slope
2nd Intermed. Slope
1st Small Slope
2nd Small Slope
Fully Unconstrained
75% Uncons. Displ.
50% Uncons. Displ.
25% Uncons. Displ.
10% Uncons. Displ.



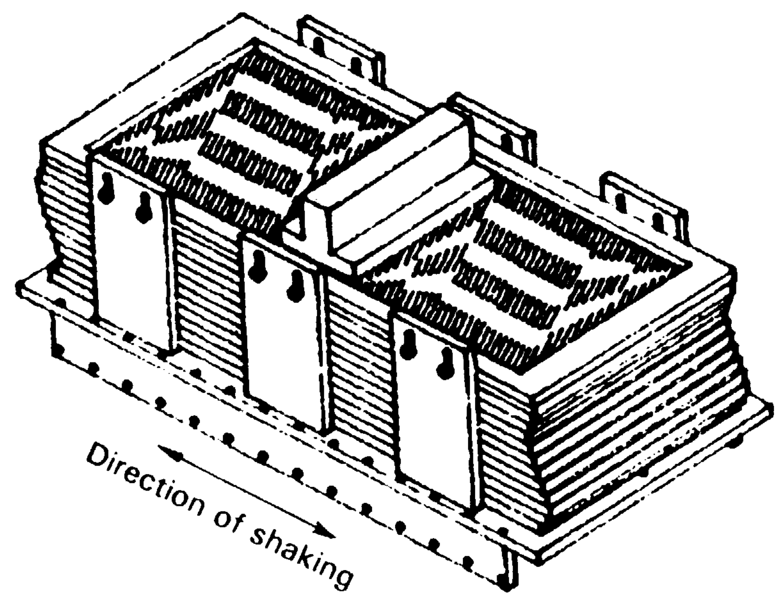
Comparison of Conventional Slope Stability Solutions To Centrifuge model

DENSITY OF LUNAR REGOLITH

LAMINAR CONTAINER TO SIMULATE FREE FIELD MOTION

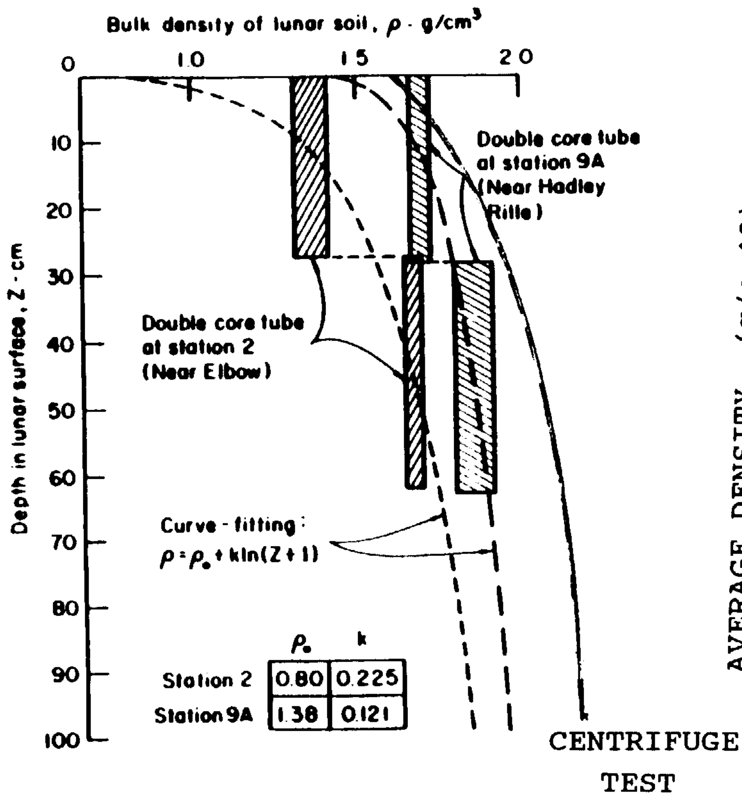


BEFORE SHAKING



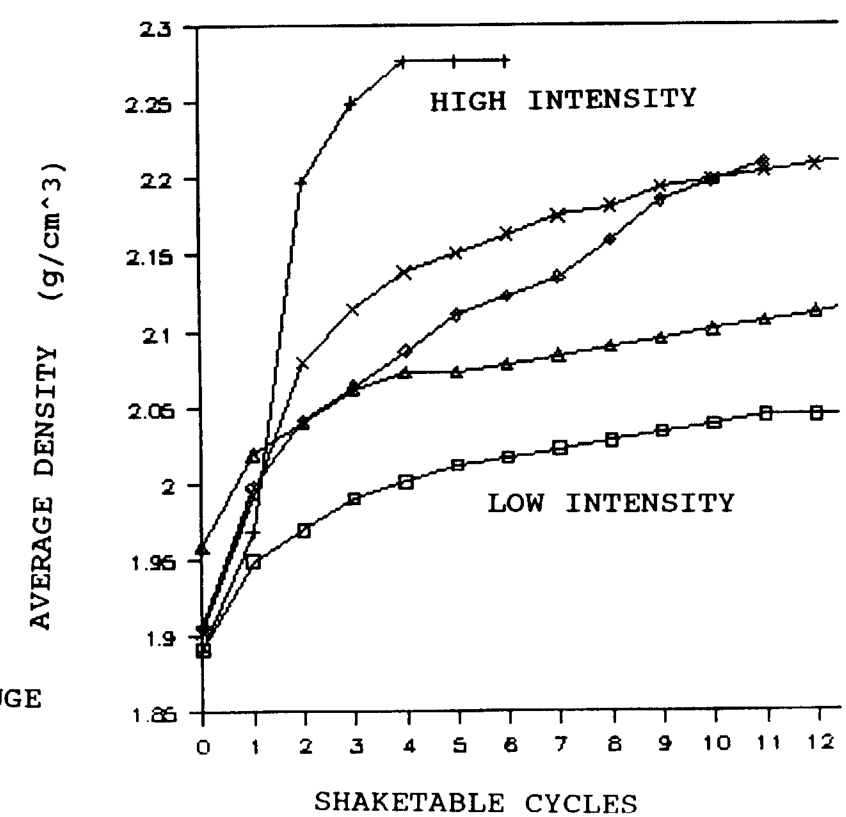
DURING SHAKING

PHYSICAL PROPERTIES OF LUNAR REGOLITH



APOLLO 15 CORE TUBE SITES

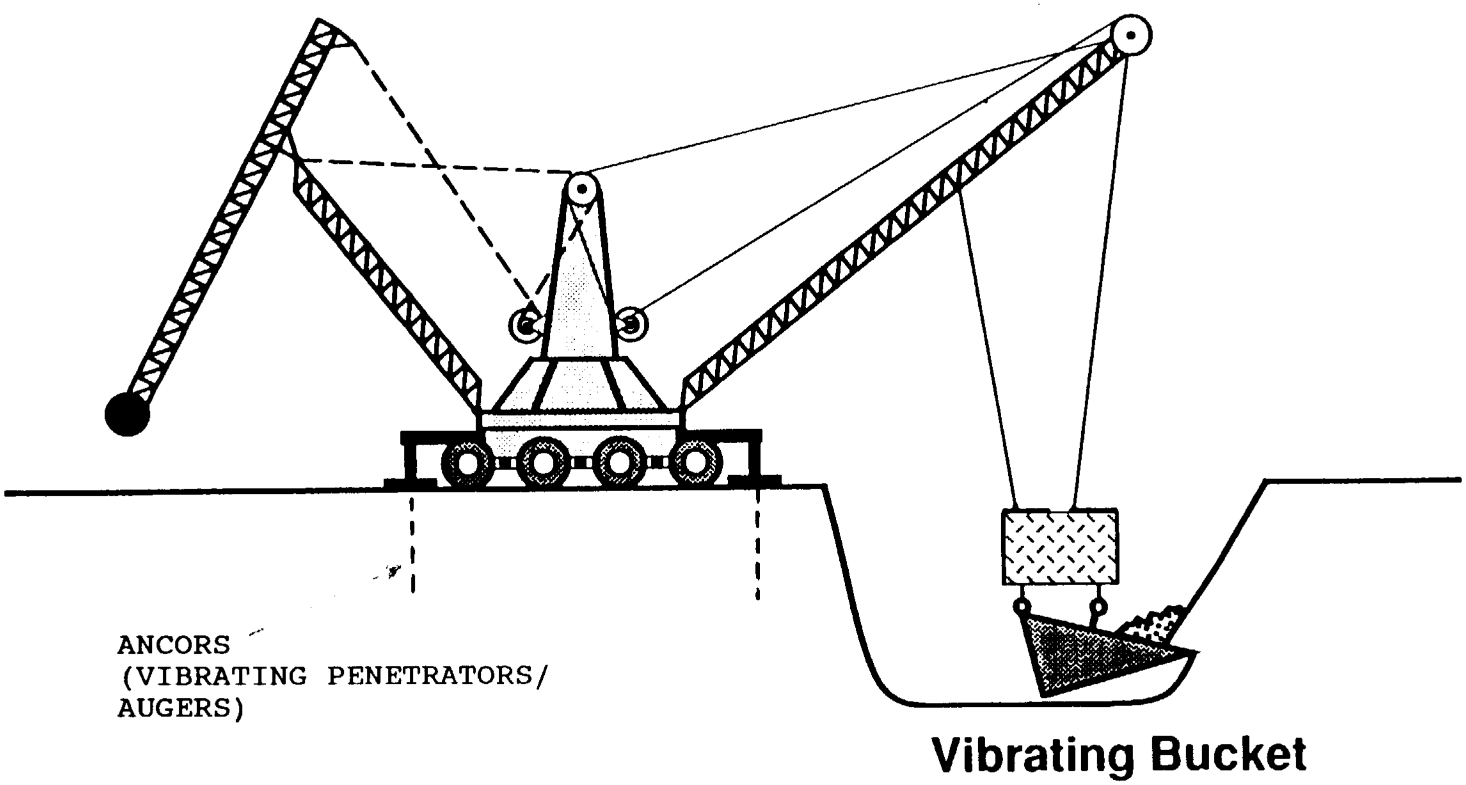
(Mitchell et al., Proc. 3rd Lunar Sci. Conf., 1972)



(5 TESTS AT DIFFERENT INTENSITIES)

LUNAR CRANE CAN PROVIDE EXCAVATING CAPABILITY USING A VIBRATING EXCAVATOR

(After Martin Mikulas)



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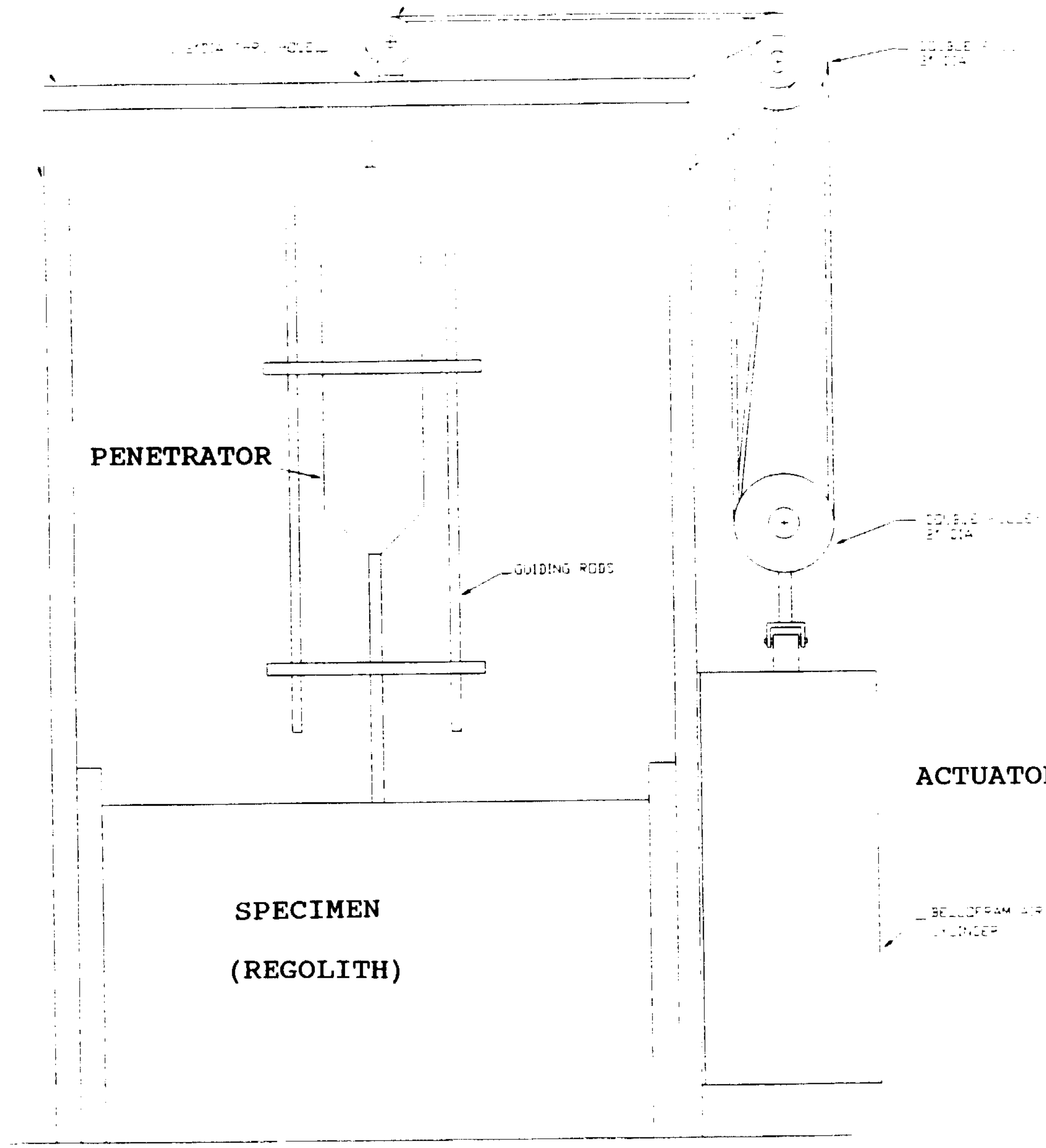
CENTRIFUGE MODELING OF PENETRATOR PERFORMANCE



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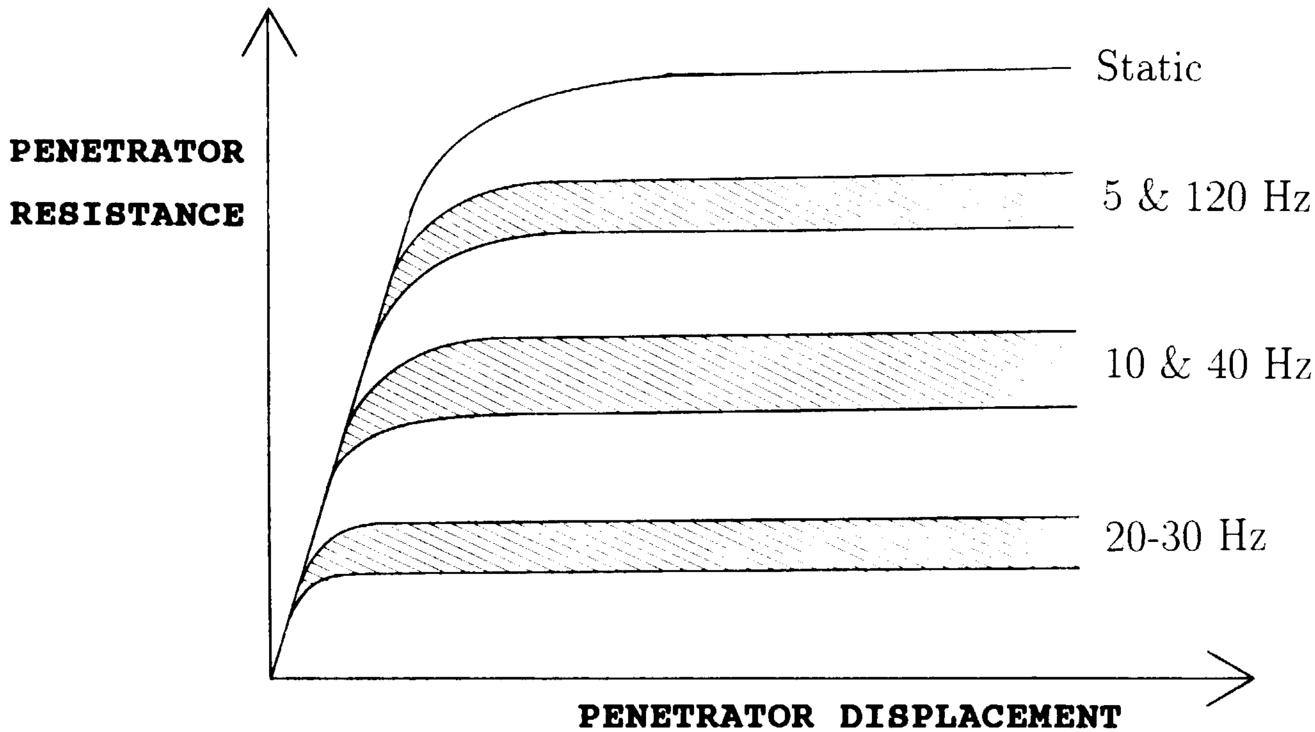
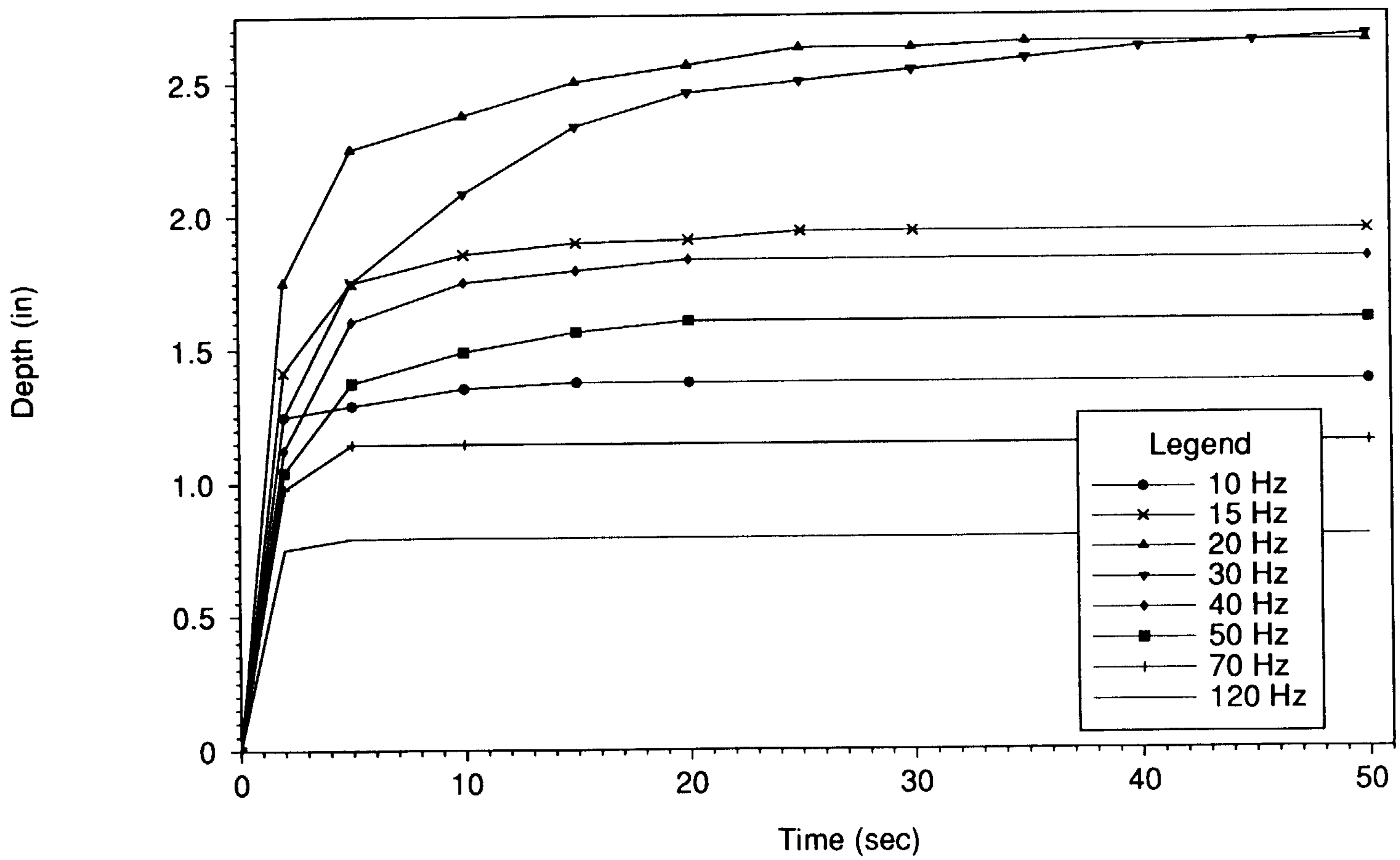
Static Vs. Vibration Assisted Penetration



Average Depth - 6" Steel Tip Rod



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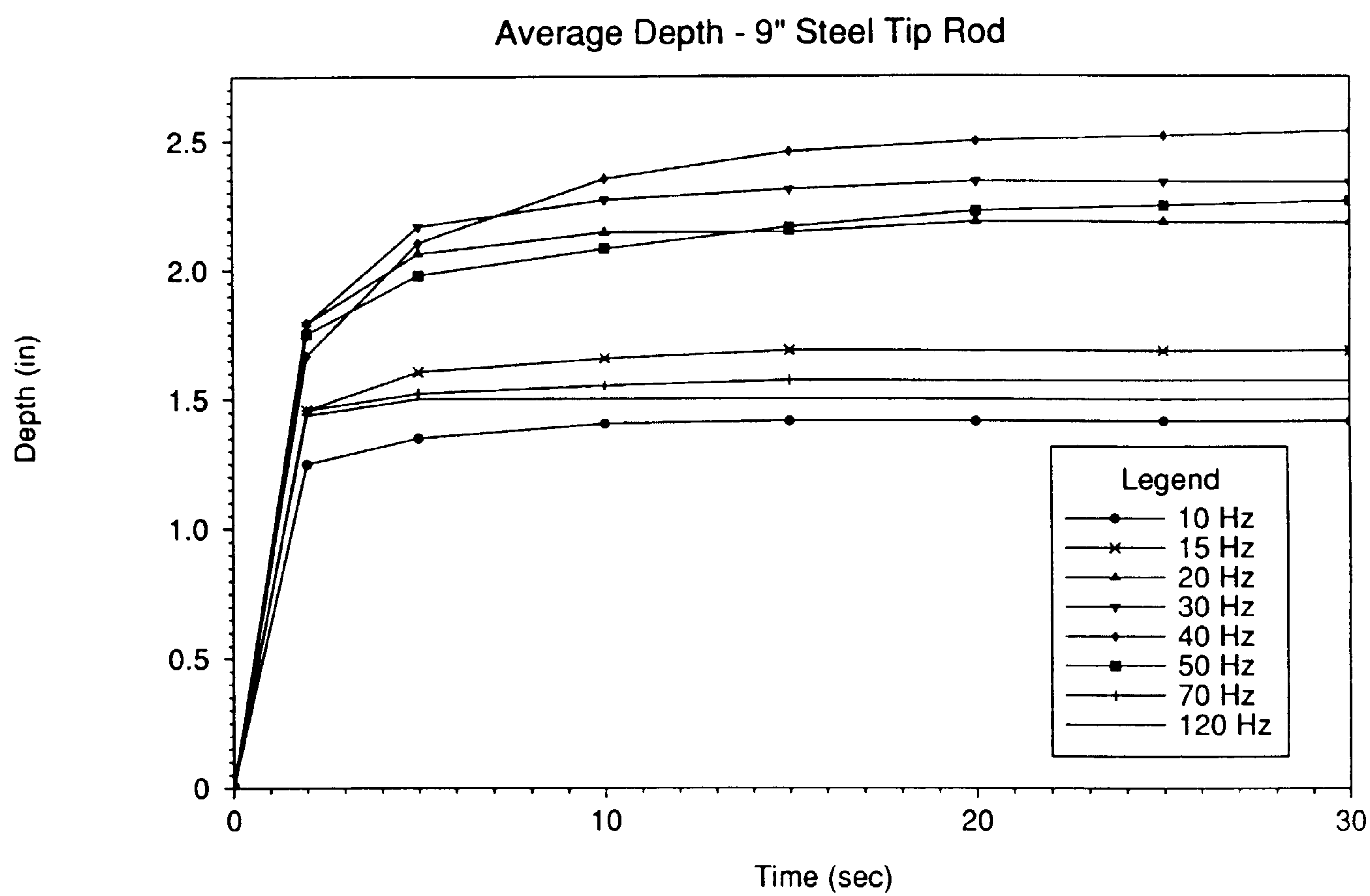
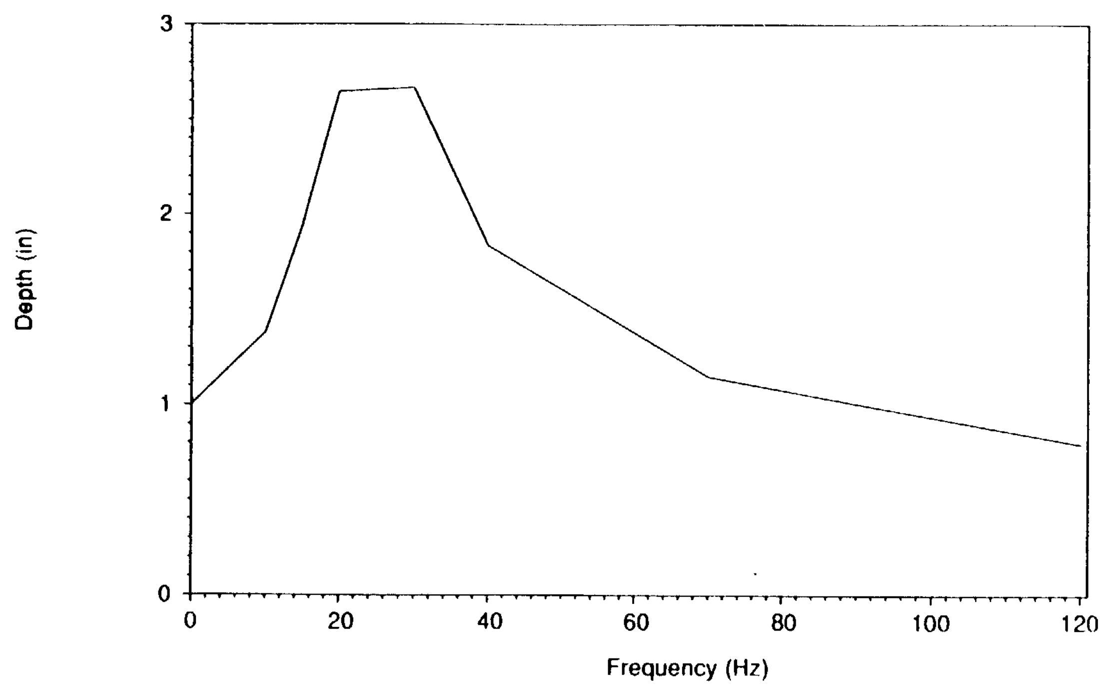


Average Depth - 9" Steel Tip Rod
Depth (in)
2.5
2.0
1.5
1.0
0.5
0
0
10
20
30
Time (sec)
Legend
10 Hz
15 Hz
20 Hz
30 Hz
40 Hz
50 Hz
70 Hz
120 Hz

RESPONSE OF 6 IN. STEEL PENETRATOR



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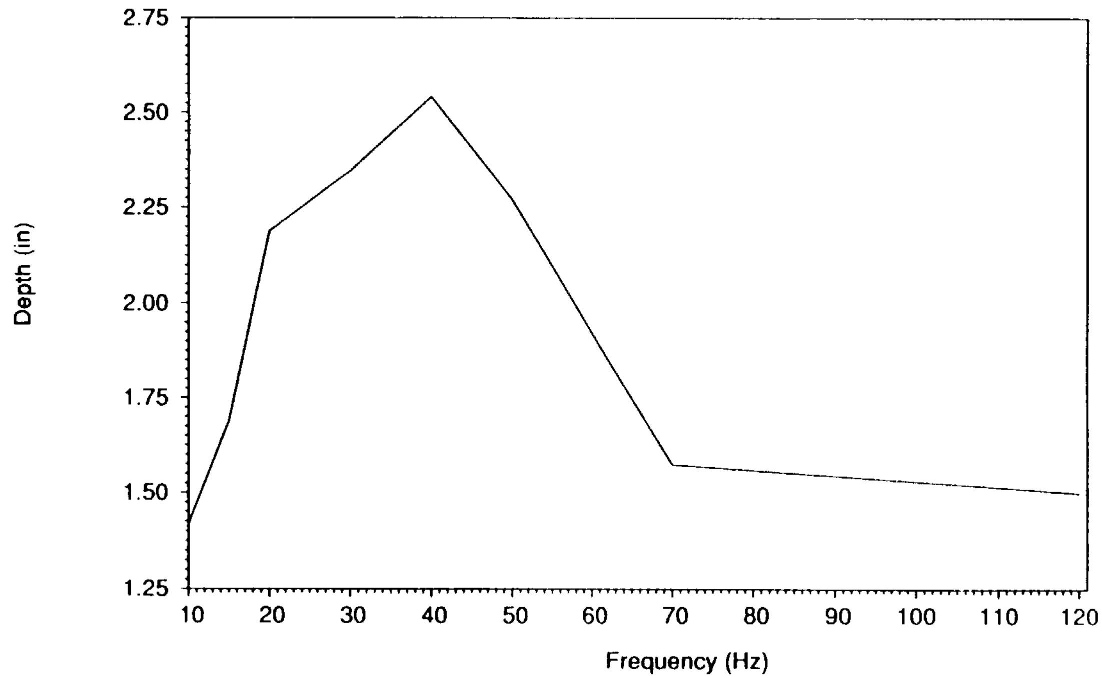
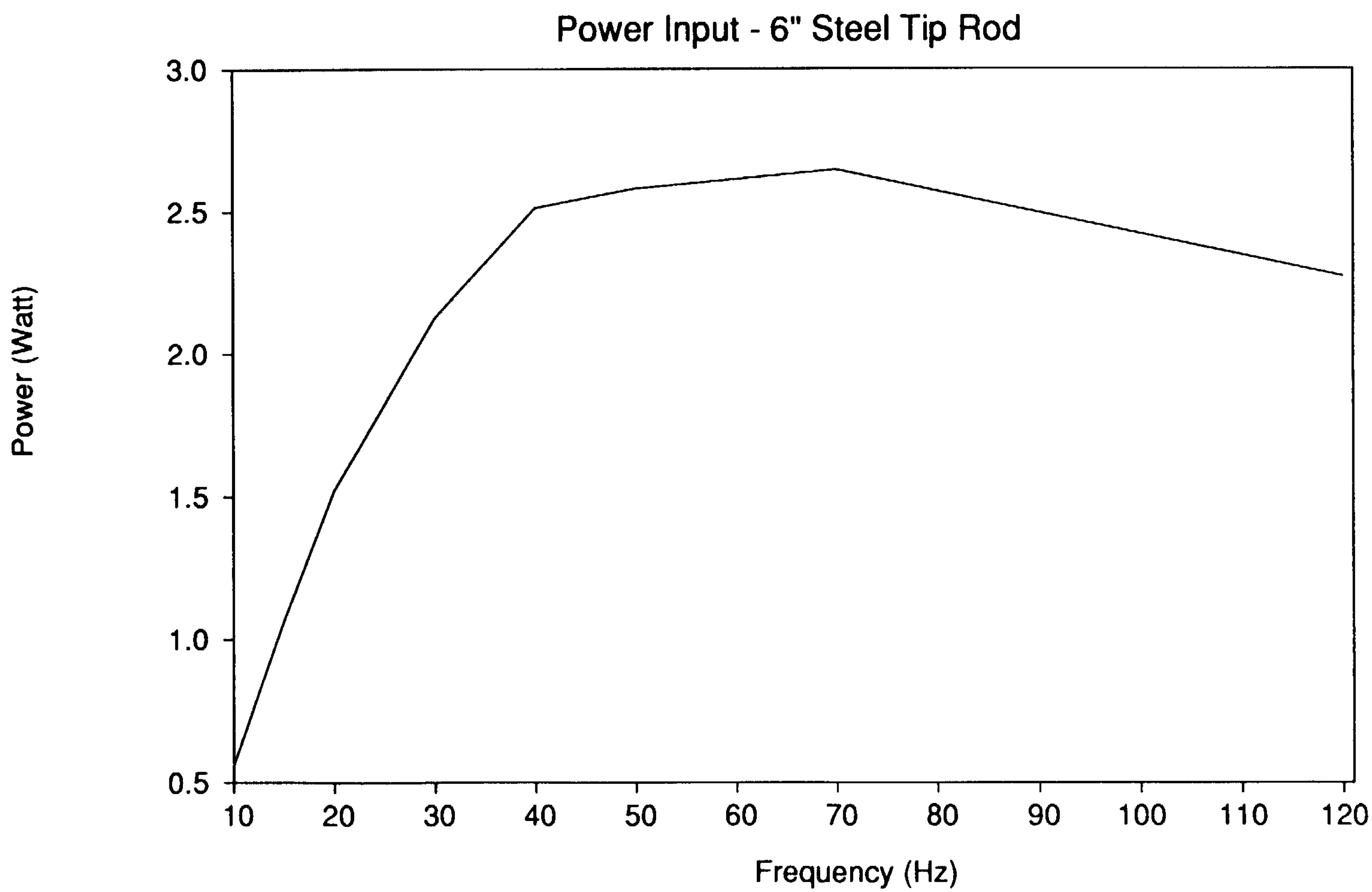
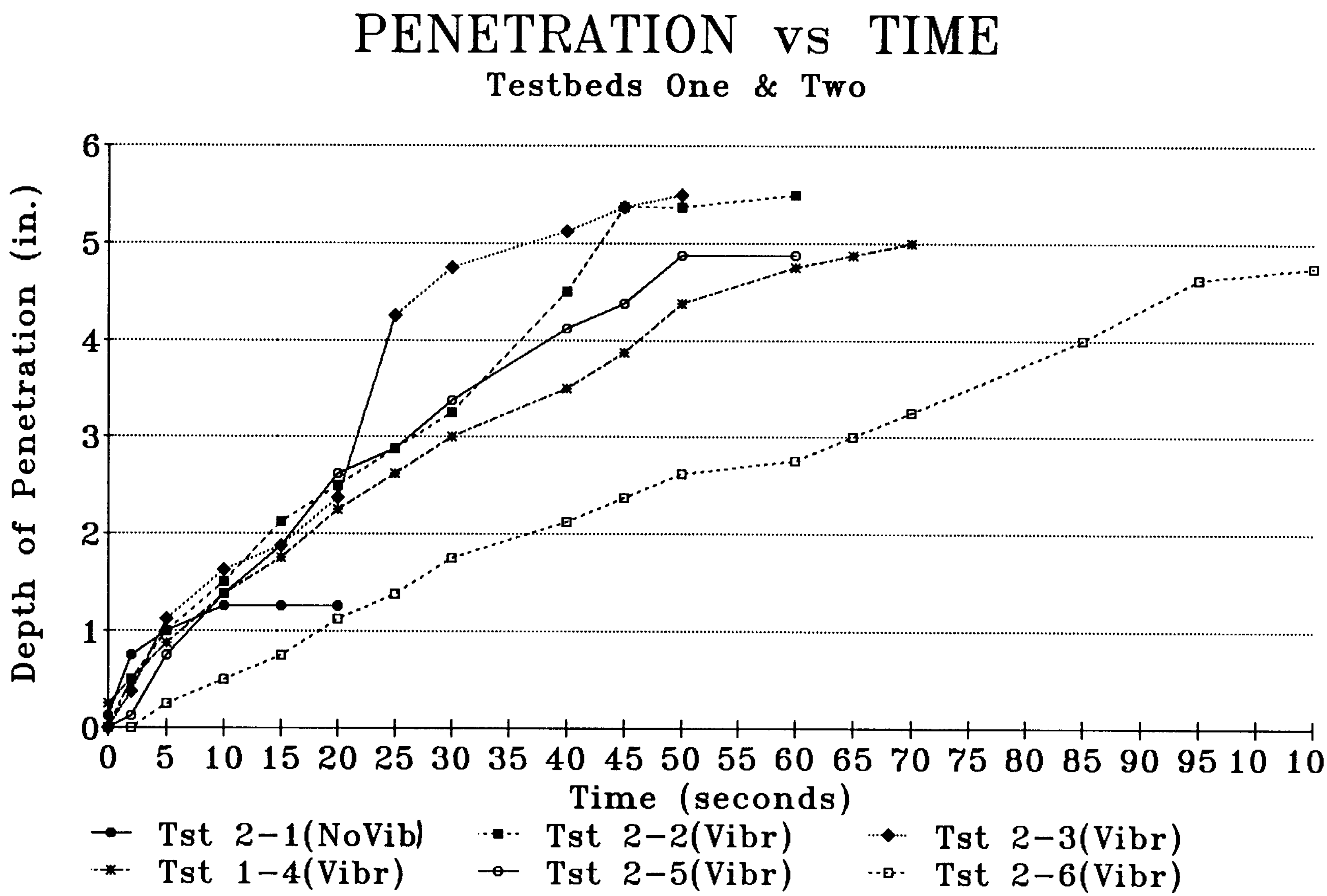
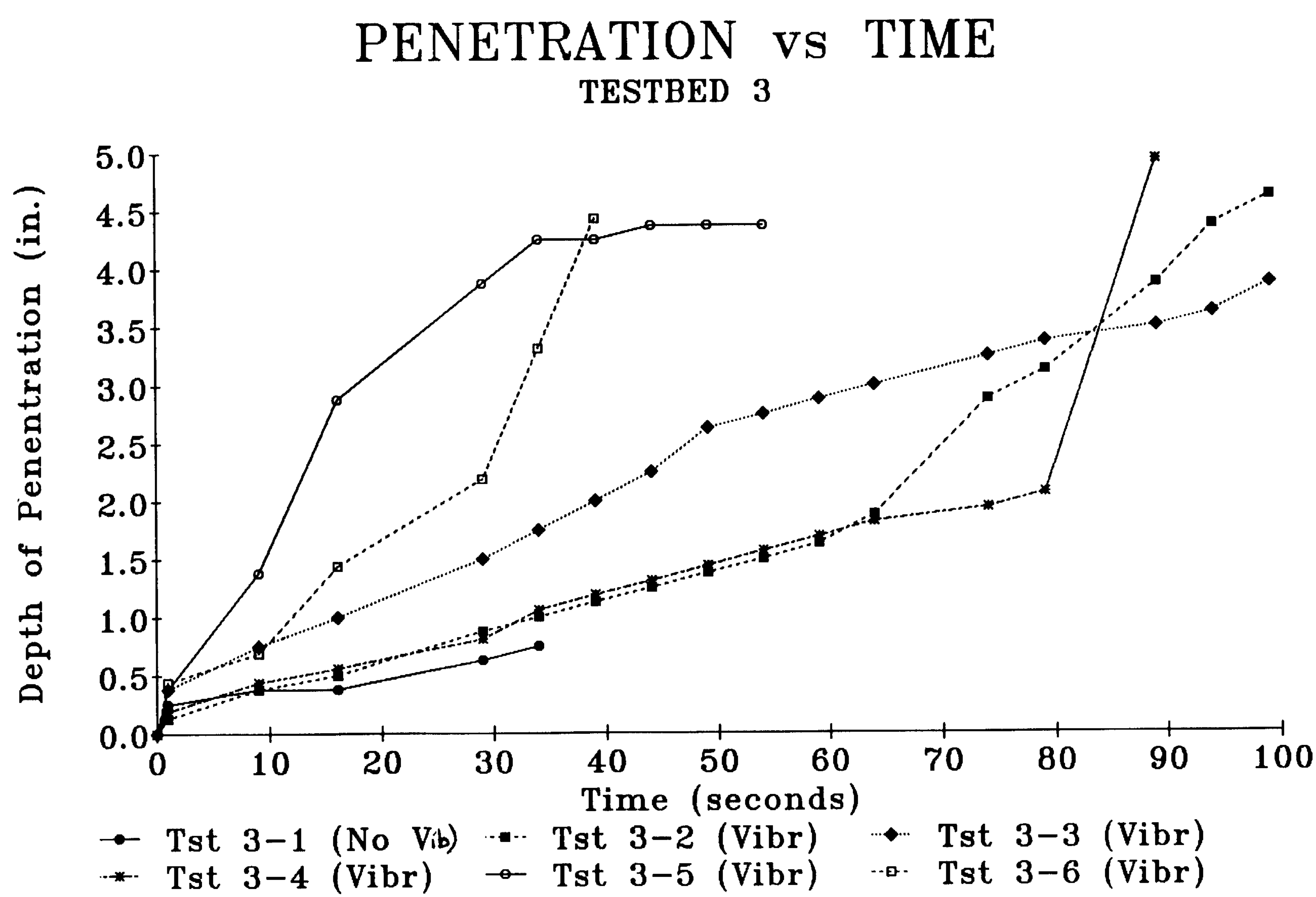
RESPONSE OF 9 IN. STEEL PENETRATOR




Power Input - 6" Steel Tip Rod
Power (Watt)
3.0
2.5
2.0
1.5
1.0
0.5
10
20
30
40
50
60
70
80
90
100
110
120
Frequency (Hz)



PENETRATION vs TIME
Testbeds One & Two
Depth of Penetration (in.)
0
1
2
3
4
5
6
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 10 10
Time (seconds)
Tst 2-1(NoVib)
Tst 2-2(Vibr)
Tst 2-3(Vibr)
Tst 1-4(Vibr)
Tst 2-5(Vibr)
Tst 2-6(Vibr)


PENETRATION vs TIME
TESTBED 3
Depth of Penentration (in.)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
Time (seconds)
Tst 3-1 (No Vib)
Tst 3-2 (Vibr)
Tst 3-3 (Vibr)
Tst 3-4 (Vibr)
Tst 3-5 (Vibr)
Tst 3-6 (Vibr)