

# Liquefaction Susceptibility by Laboratory Tests

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# LIQUEFACTION

*“Liquefaction of soil”* is a state of particle suspension resulting from release of contacts between particles.



When liquefaction occurs, the strength of the soil decreases and, the ability of a soil deposit to support foundations for buildings and bridges is reduced.



Niigata 1964





## KOBE 1995





# 1967 ADAPAZARI EARTHQUAKE – HOTEL SAPANCA

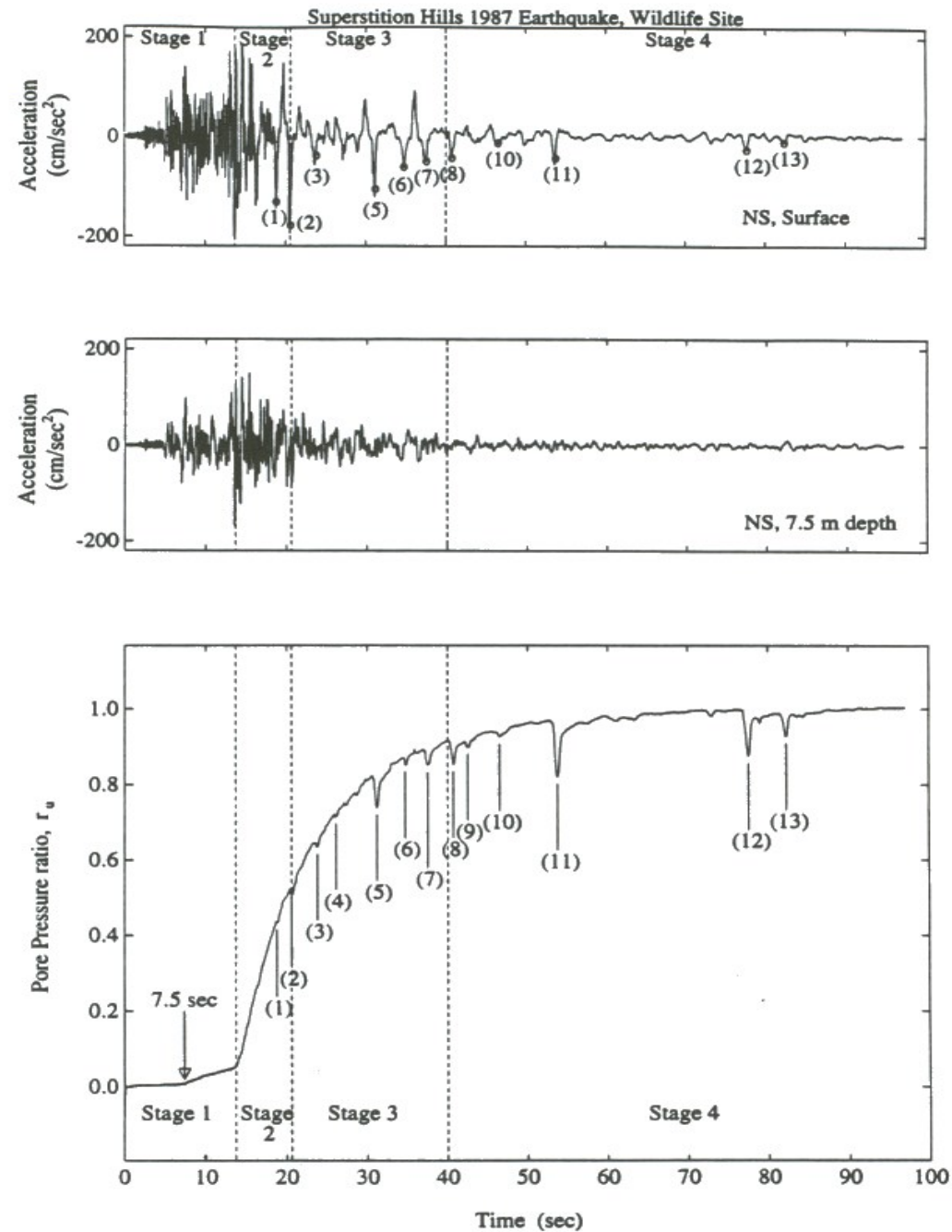






**7.1M Darfield Earthquake of Sept. 3, 2010 (New Zealand)**

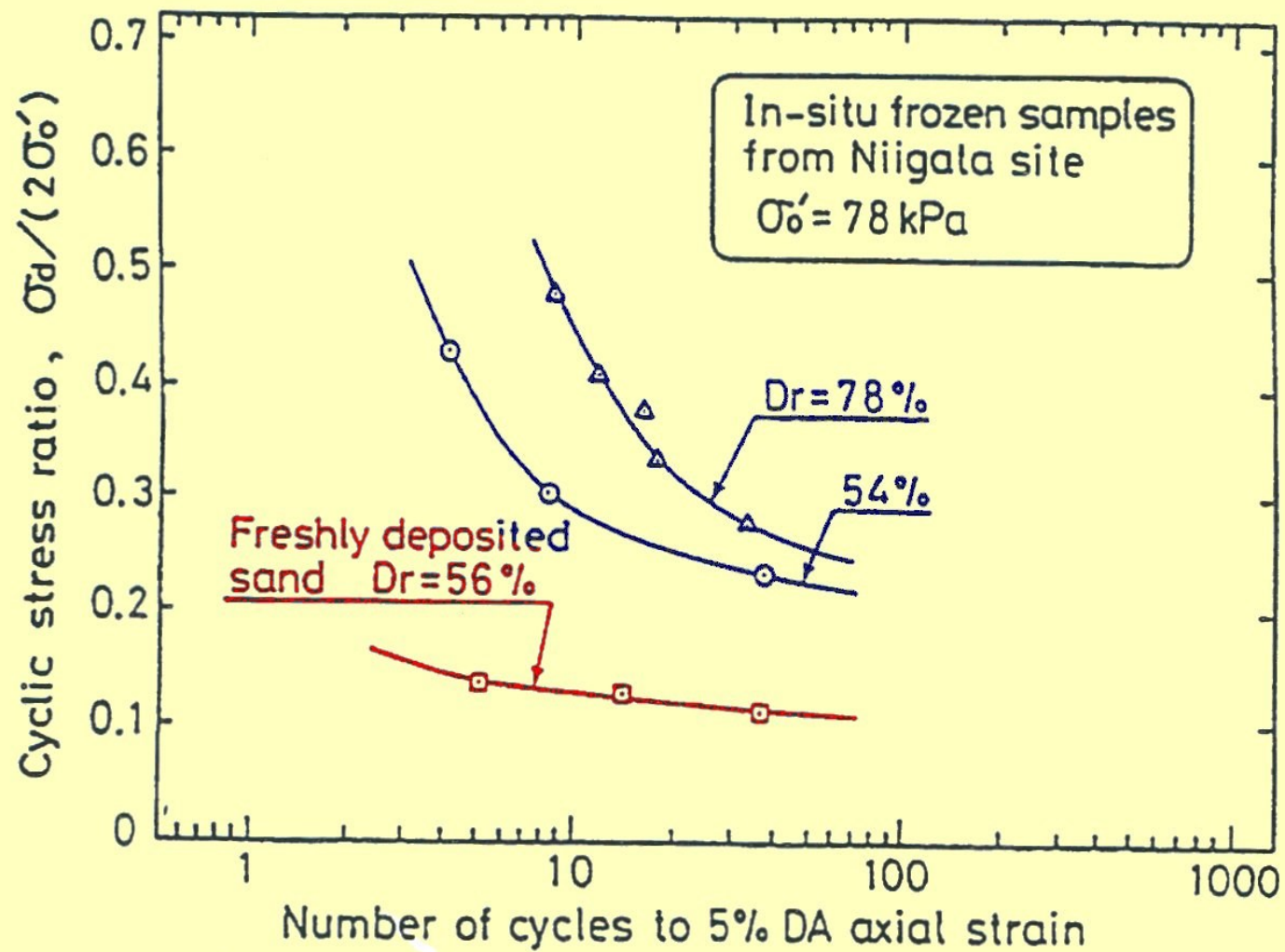
## Wildlife site record



# FACTORS AFFECTING LIQUEFACTION

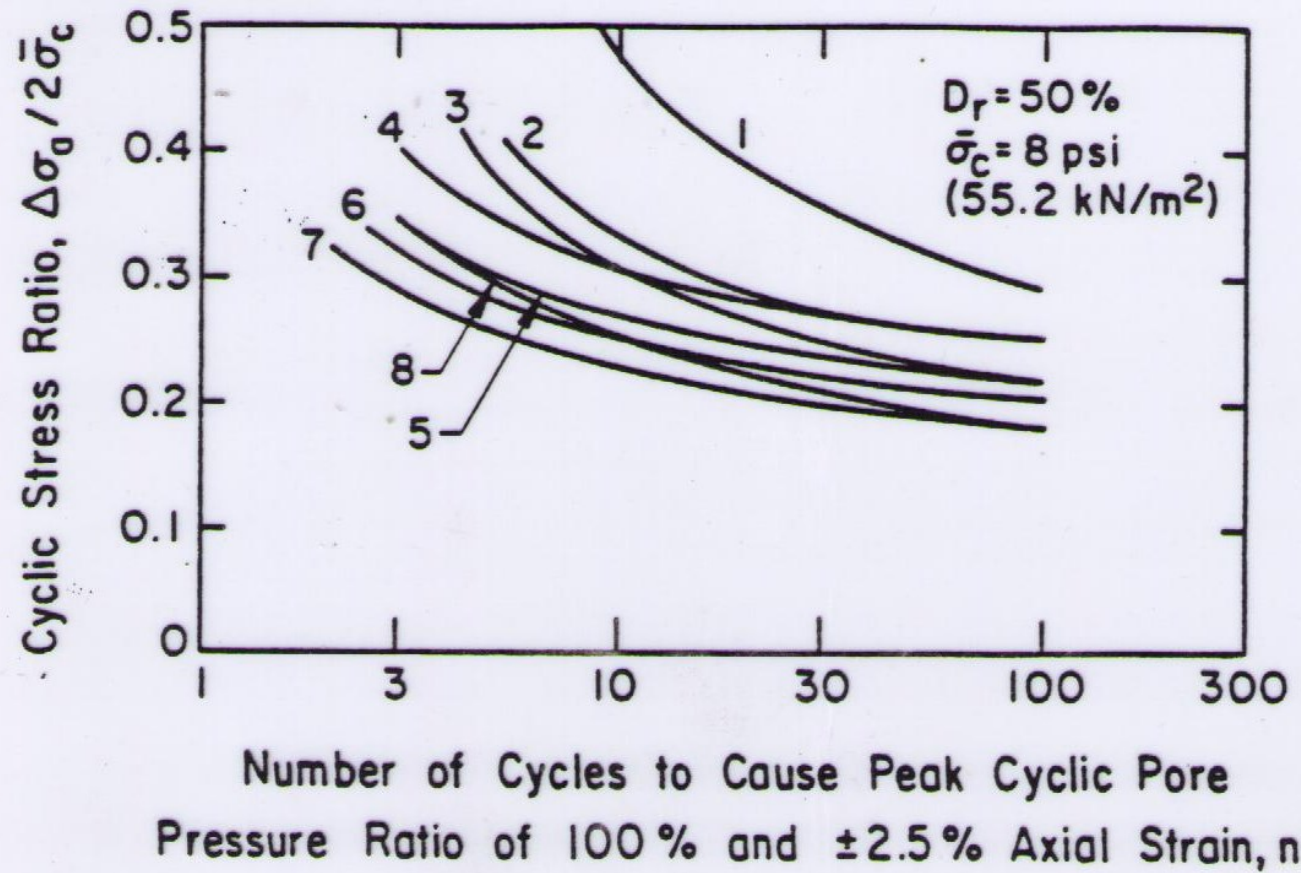
- Relative Density
- Overconsolidation Ratio
- Time after deposition
- Grain Size, shape, and distribution
- Fines Content and Plasticity
- Saturation, depth of ground water table
- Seismic history





Effect of remolded versus undisturbed samples

# Sample preparation



<u>Curve No.</u>	<u>Method of Compaction</u>
1	High frequency vibrations on moist samples
2	Moist tamping
3	Moist rodding
4	Low frequency vibrations on dry samples
5	High frequency vibrations on dry samples
6	Pluviated-water
7	Pluviated-air
8	Dry rodding



# Testing technique

Turkey, Yugoslavia, Romania

Wet tamping  $D_r = 60\%$

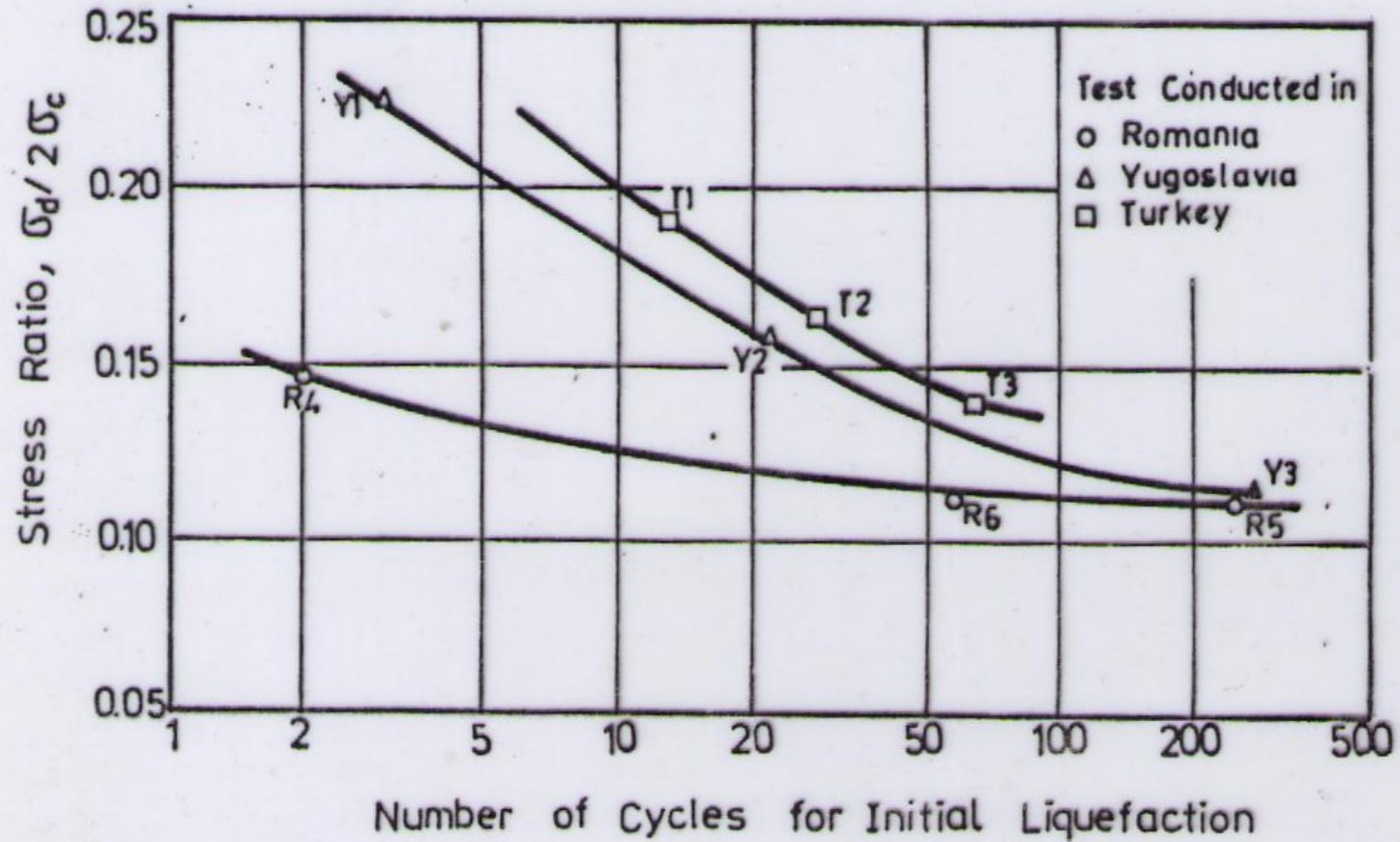


Figure 3. Liquefaction Test Results on Podima Sand

# Grain characteristics

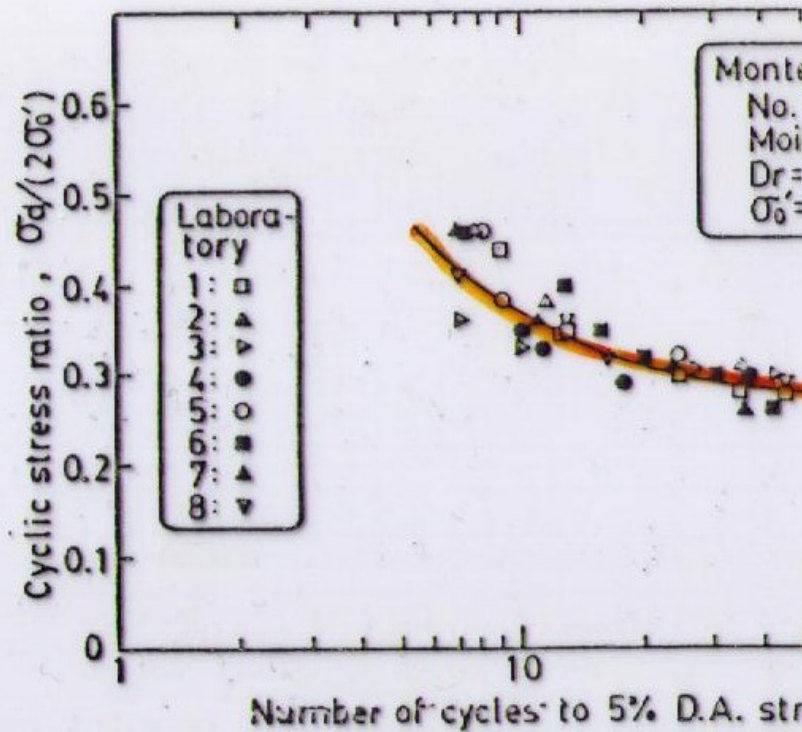


Fig. 3. Results of the co-operative tests on cyclic strength of sand (Silver *et al.*, 1976)

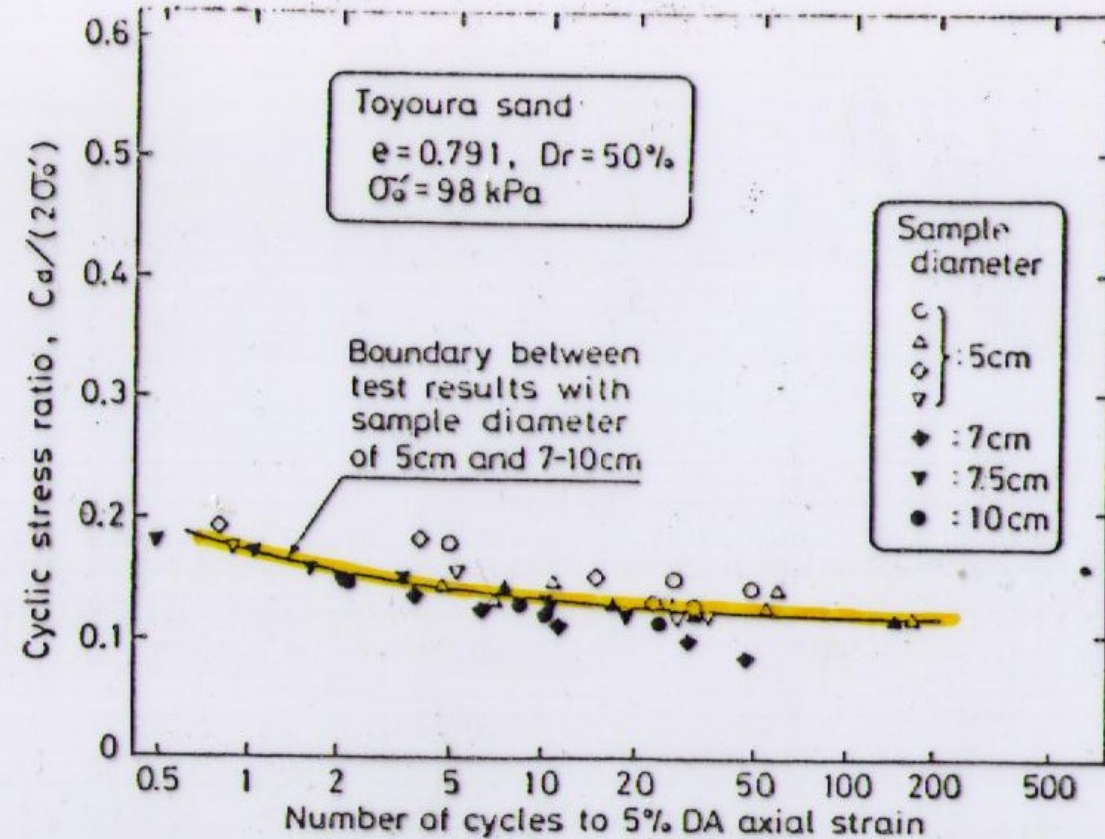
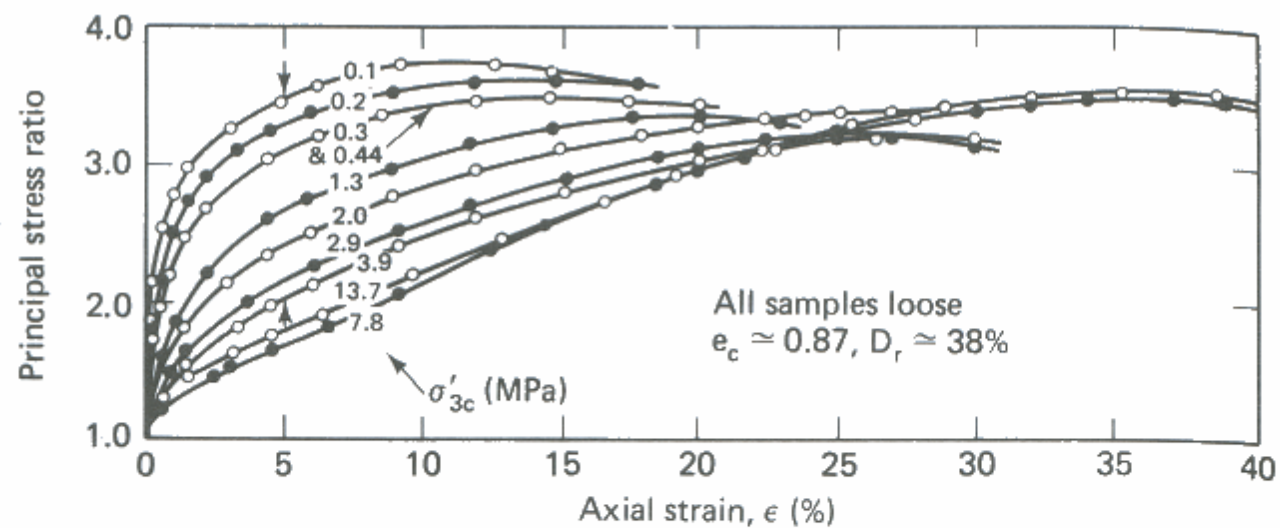


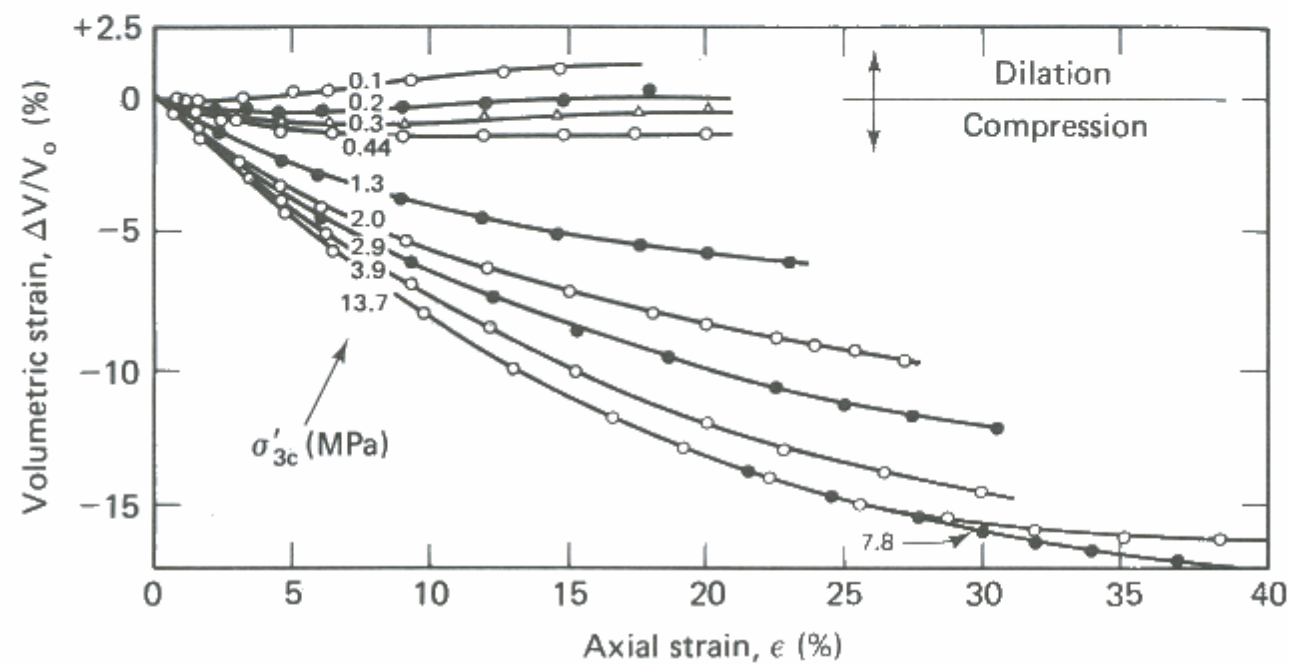
Fig. 4. Results of the co-operative tests in Japan on cyclic strength of sand (Toki *et al.*, 1986)

CSR = 0.14  
5% DA  
N = 20

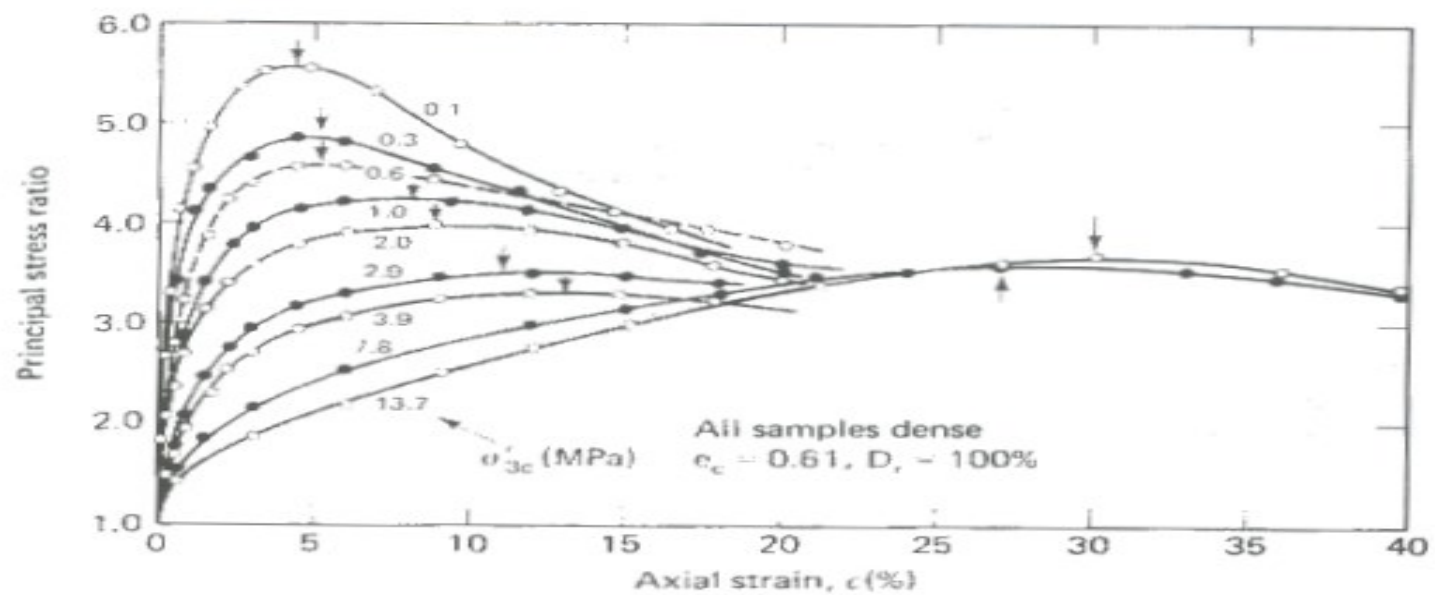




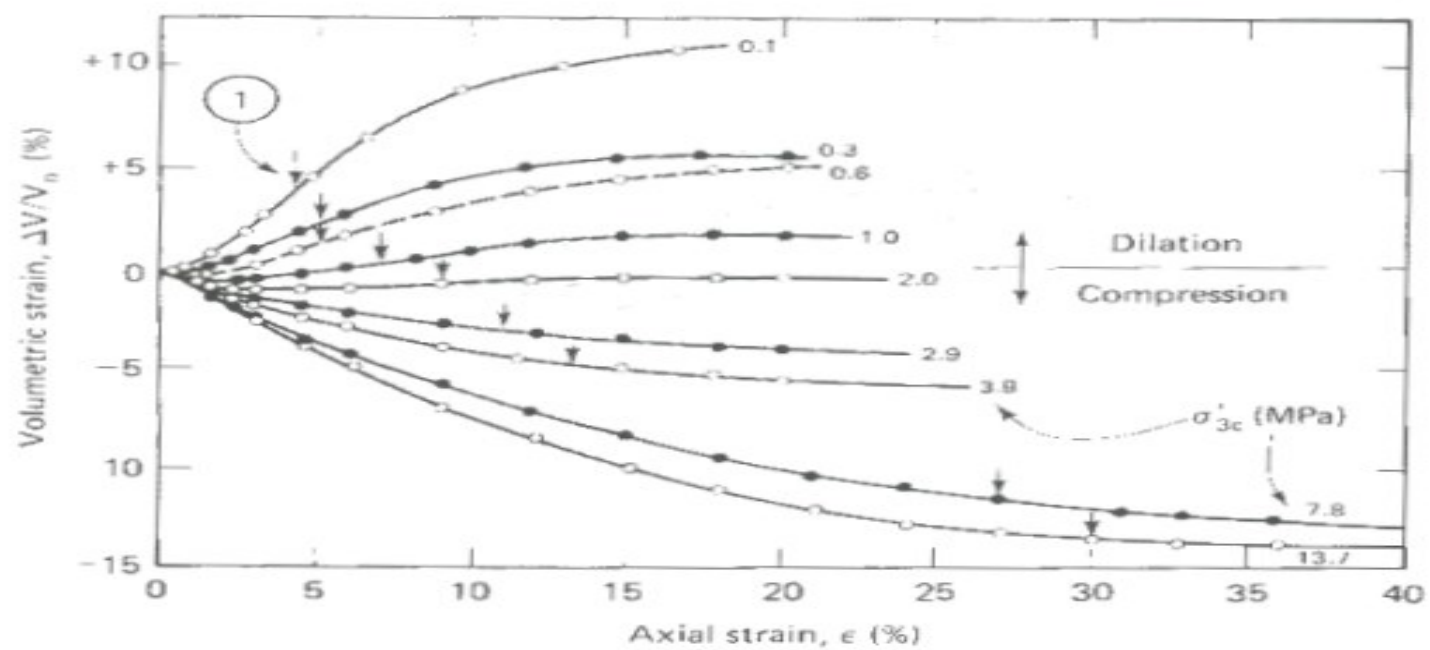
(a)



(b)



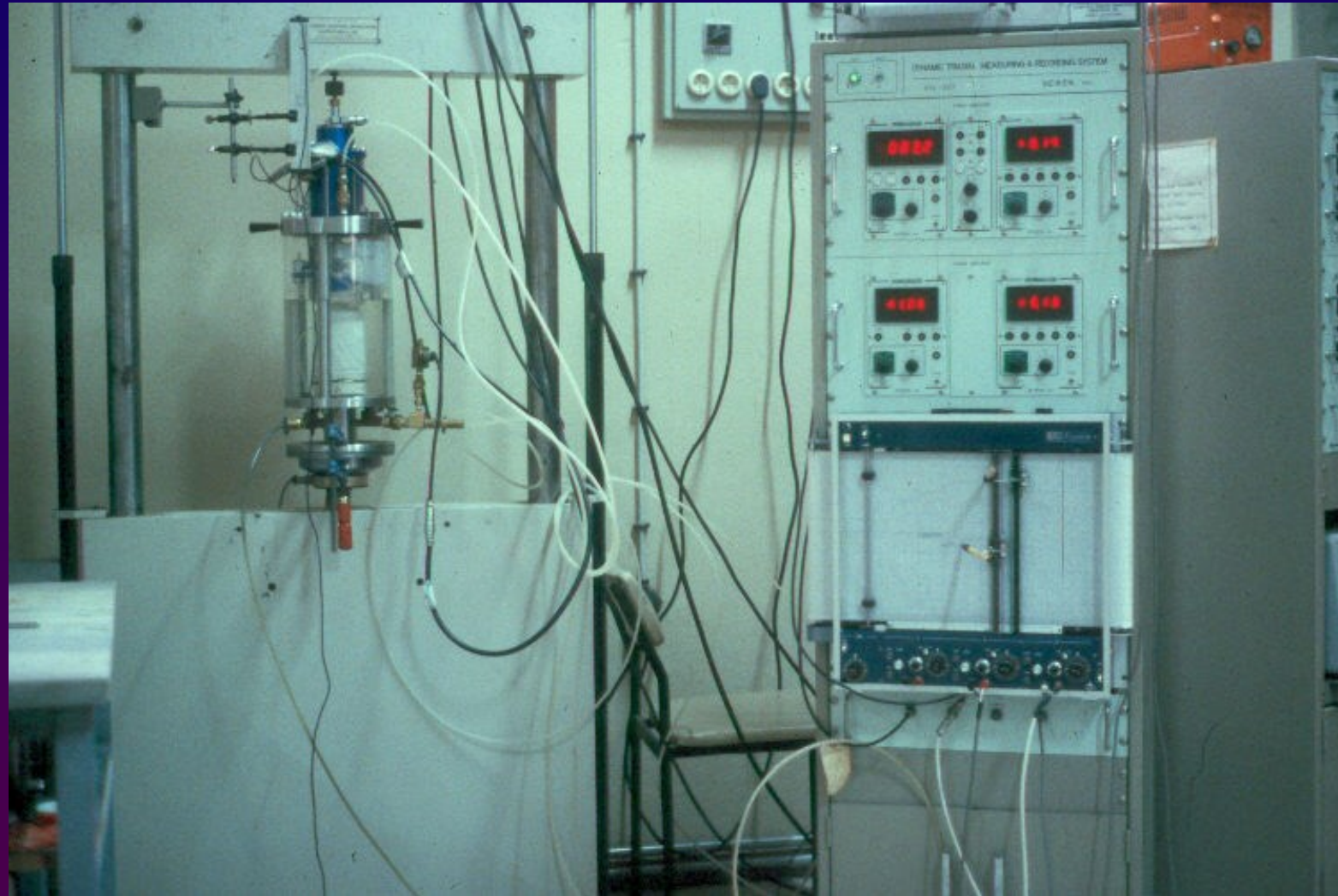
(a)

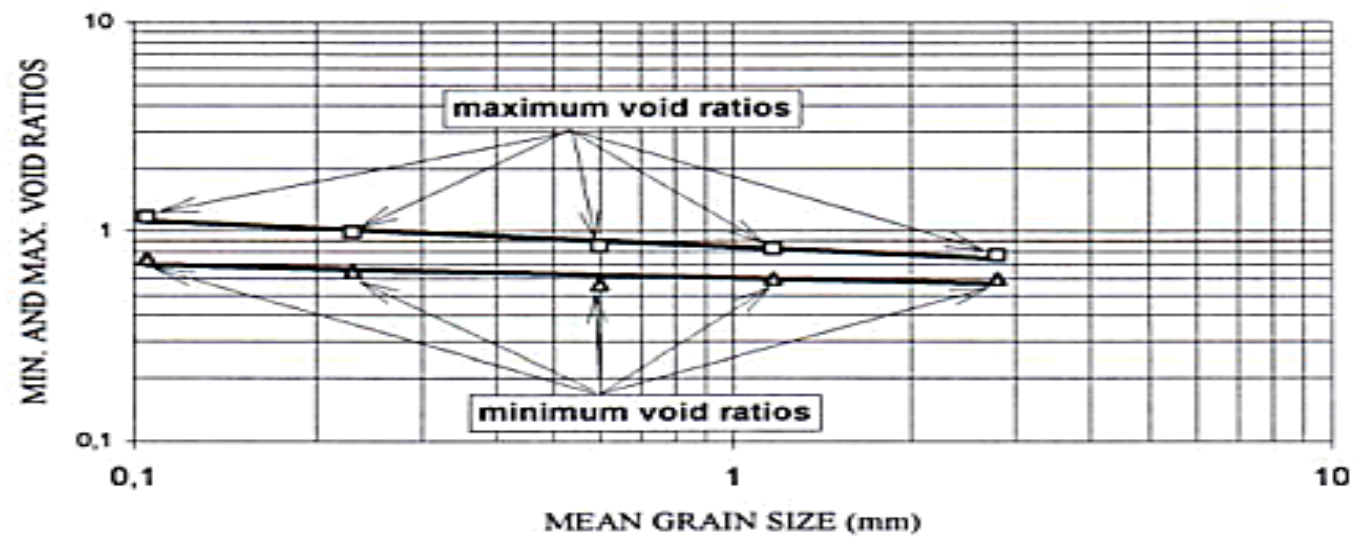
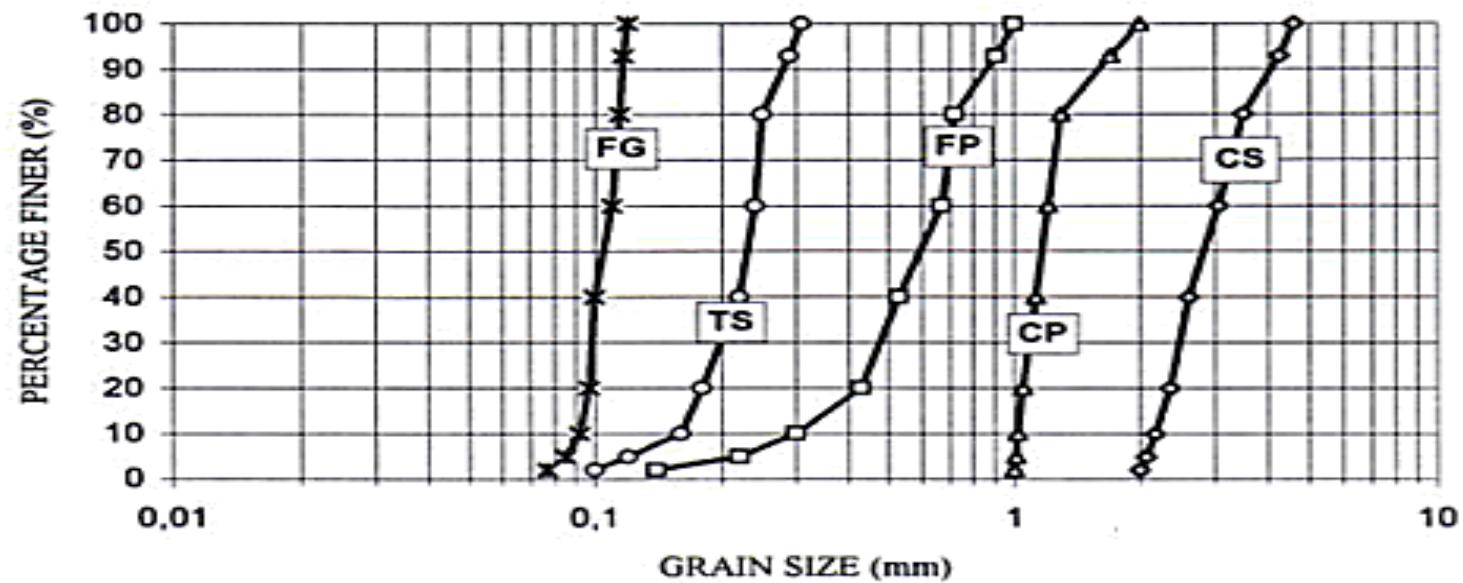


(b)

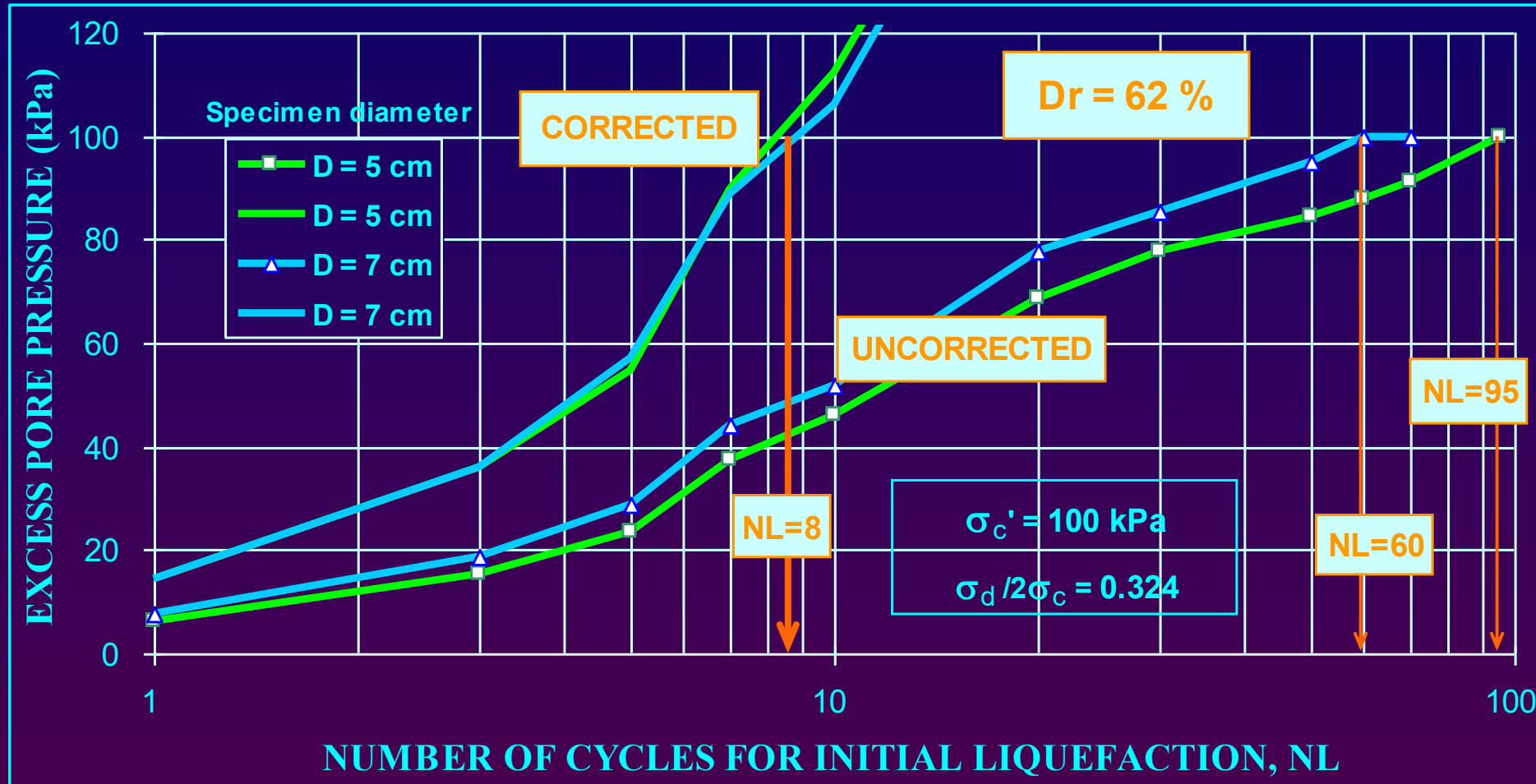


1978-1982  
ITU  
MAÇKA









**Effect of membrane penetration**

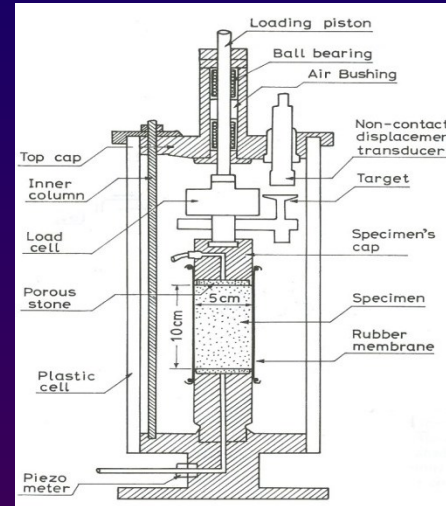
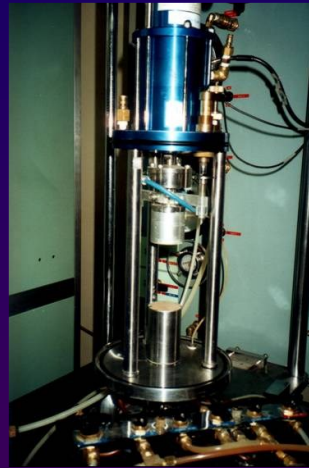
# ITU CIVIL ENGINEERING FACULTY CYCLIC TRIAXIAL TESTING SYSTEM





# Laboratory Measurement of Dynamic Soil Properties

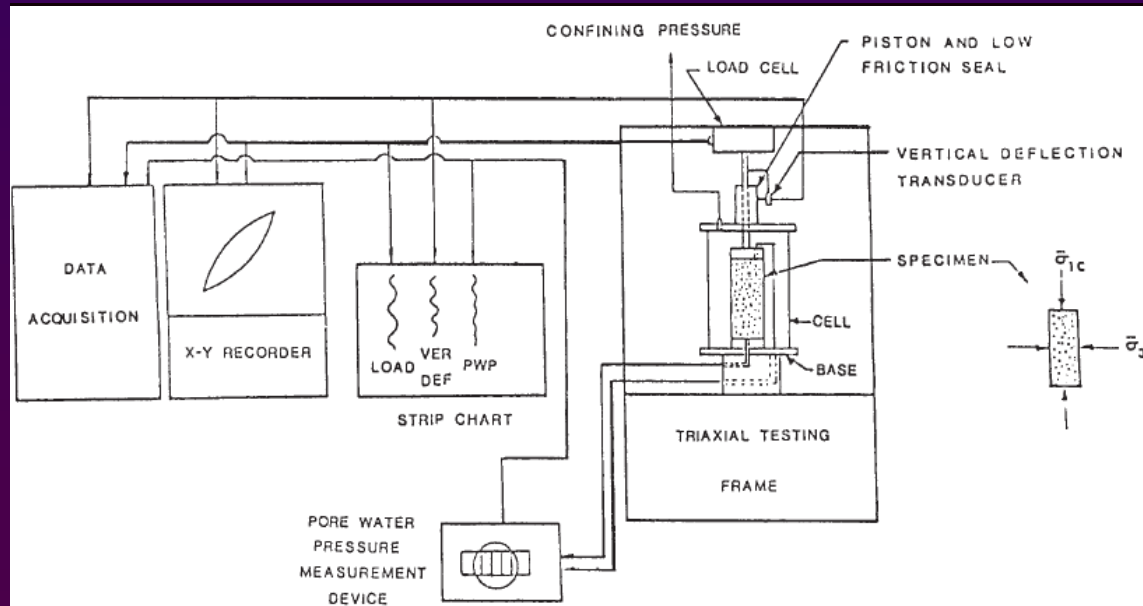
## Cyclic Triaxial Test (CTT)

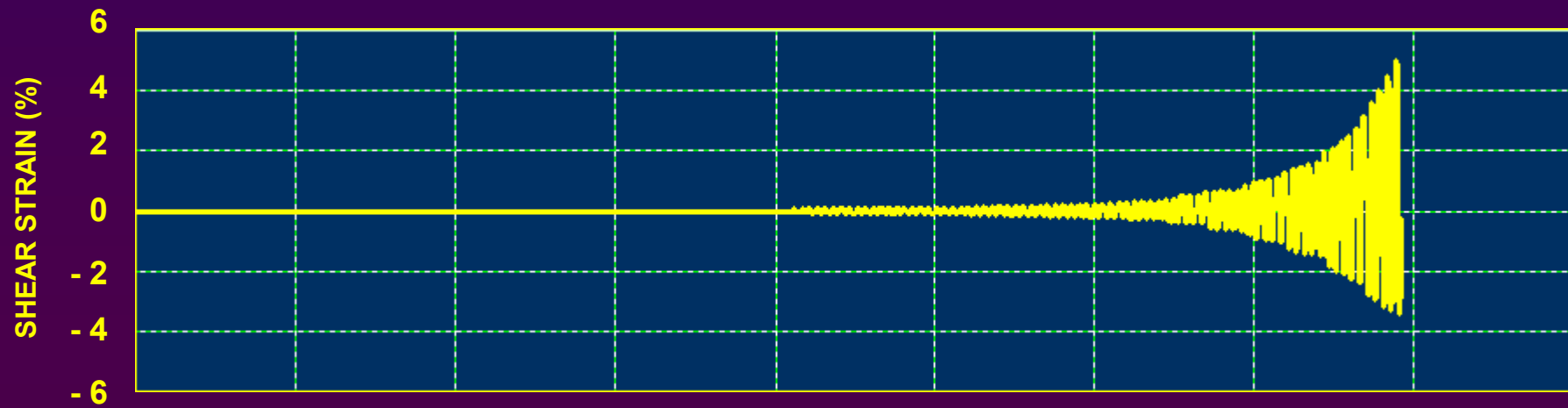
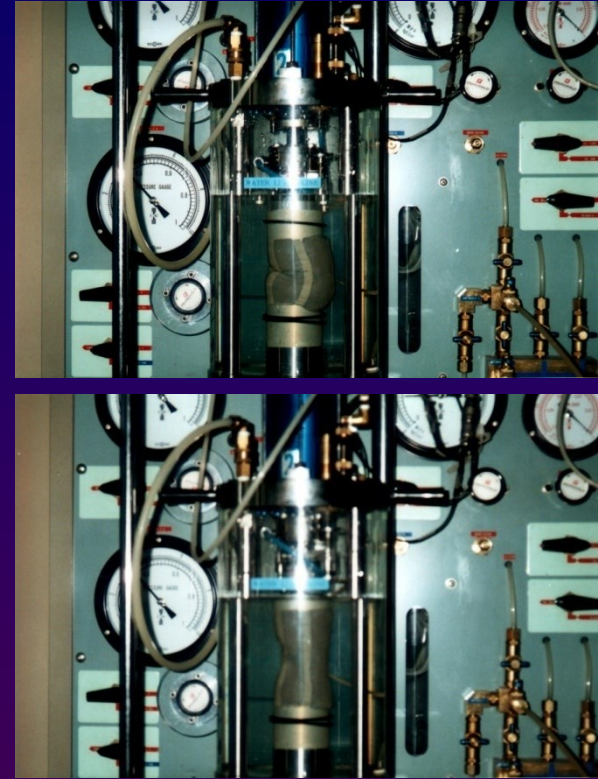
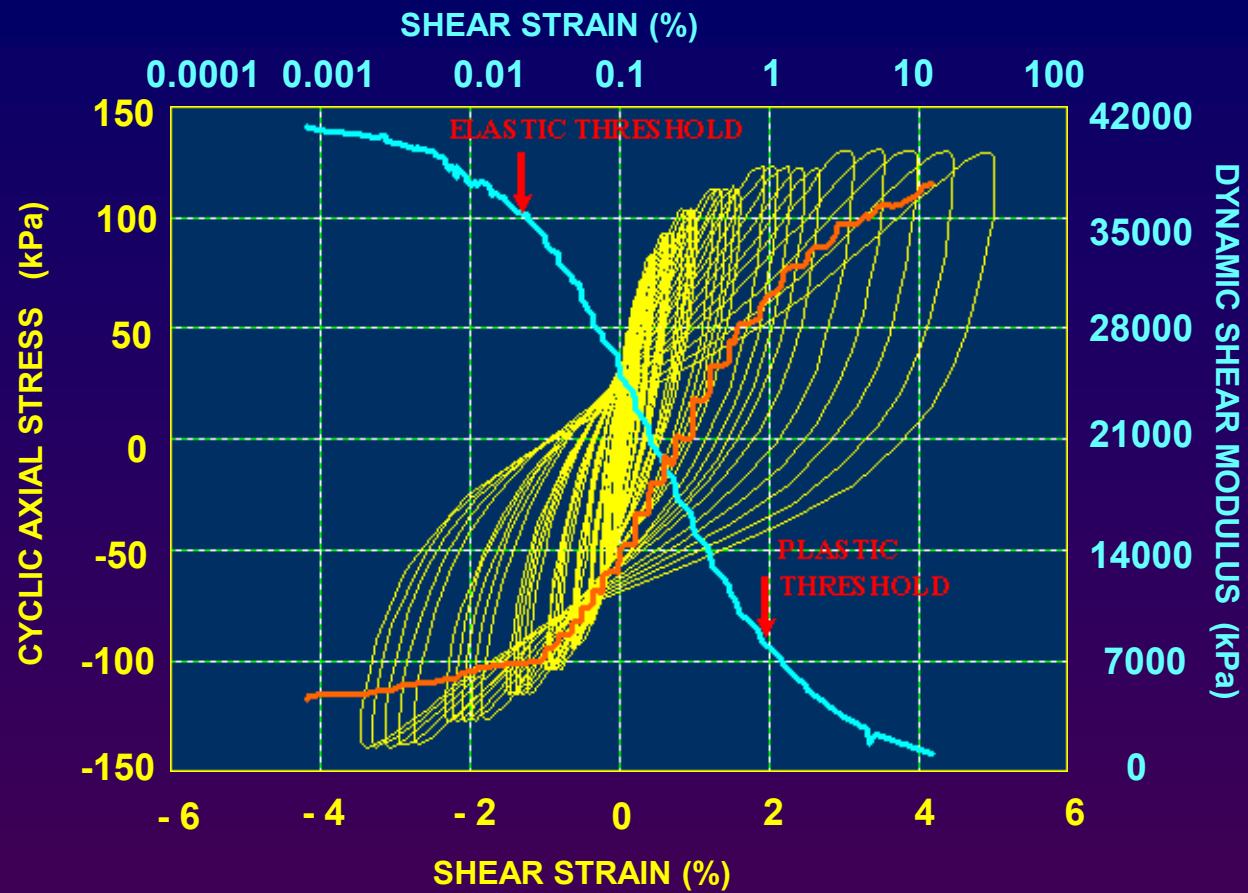


- cylindrical specimen placed between top and bottom loading plates sealed by a rubber membrane
- confined in a triaxial chamber subjected to radial stress through pressurized cell fluid
- axial stress applied on top through loading rod

Testing procedure:

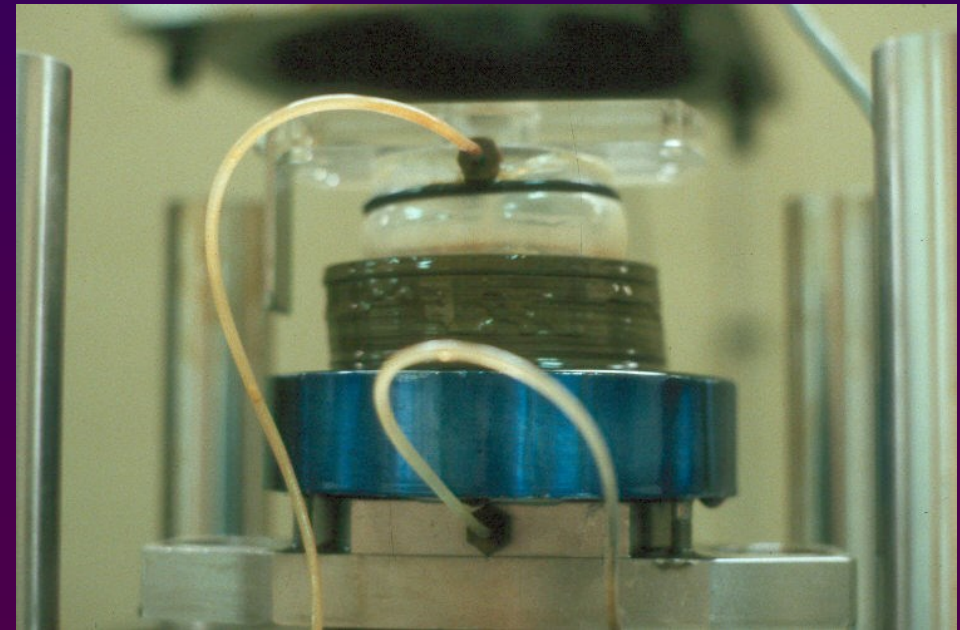
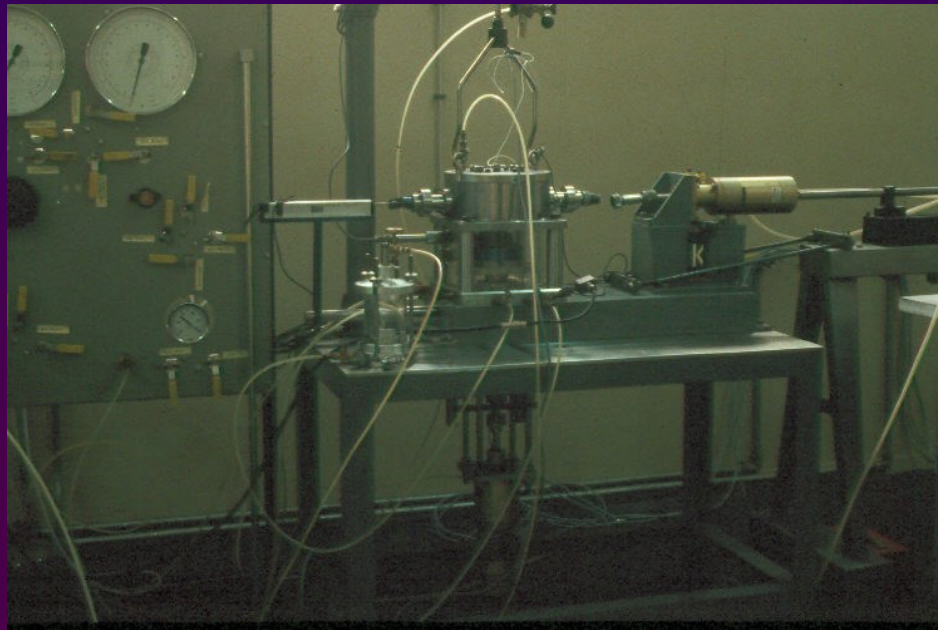
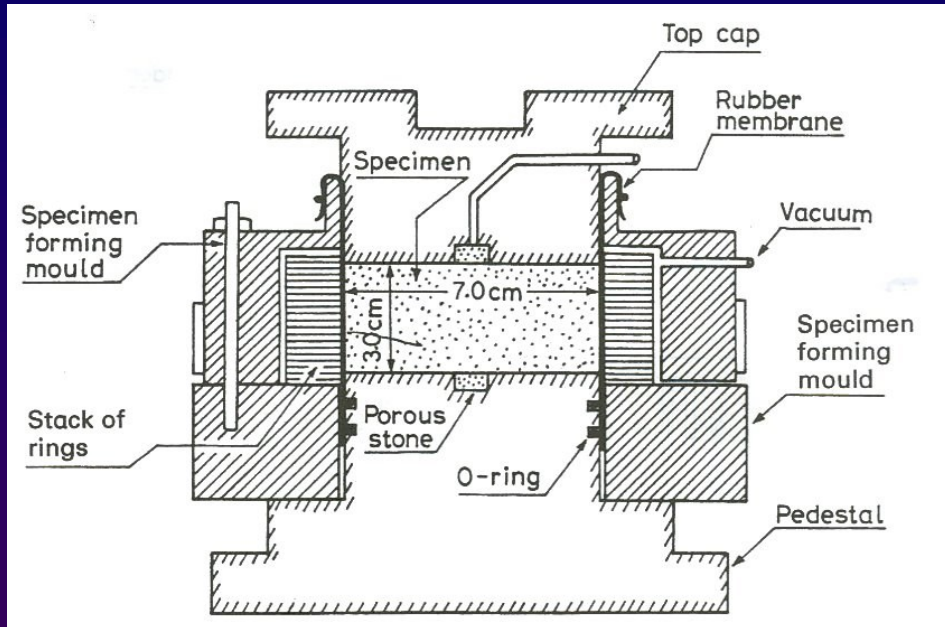
1. saturation and consolidation to reproduce initial in situ conditions
2. cyclic loading under undrained conditions by applying sinusoidally varying axial load
3. axial load, axial deformation, and porewater pressure development with time are monitored.





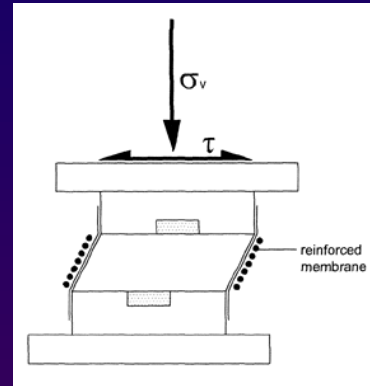
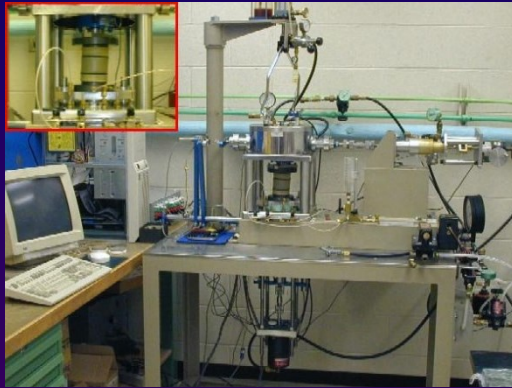


# Cyclic simple shear



# Laboratory Measurement of Dynamic Soil Properties

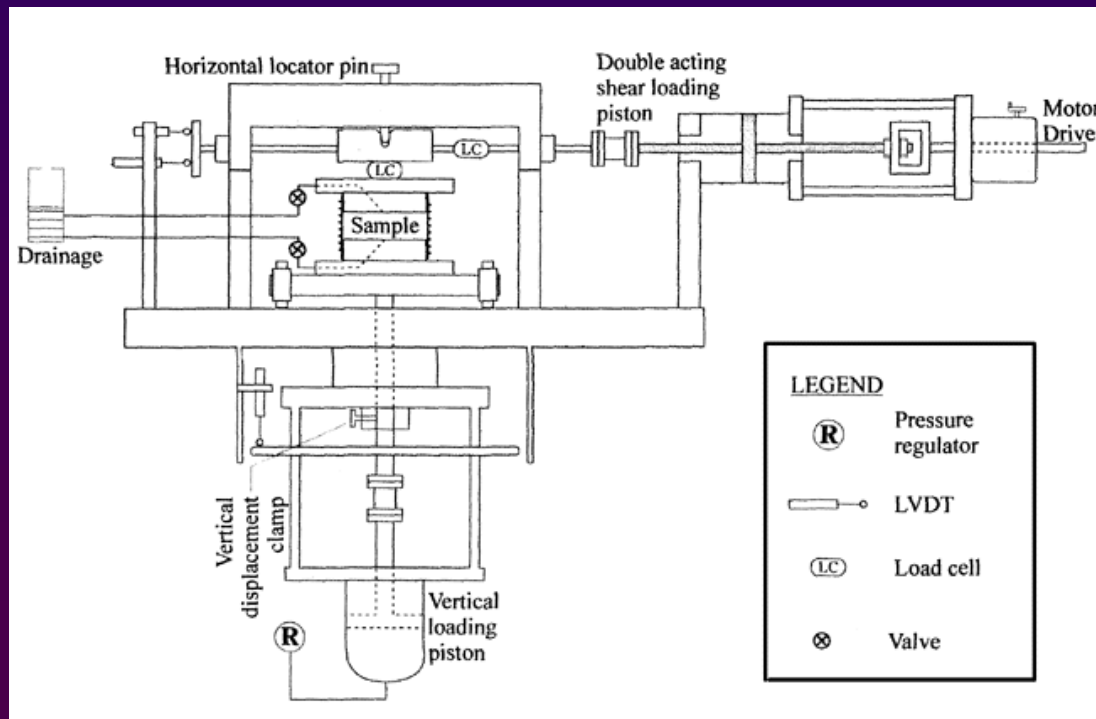
## Cyclic Simple Shear Test (CSST)



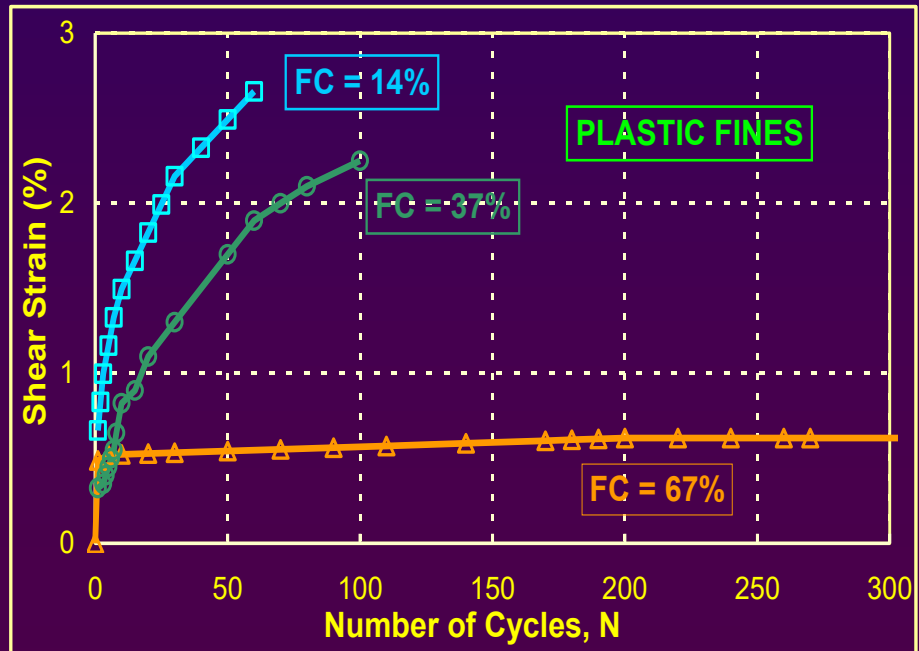
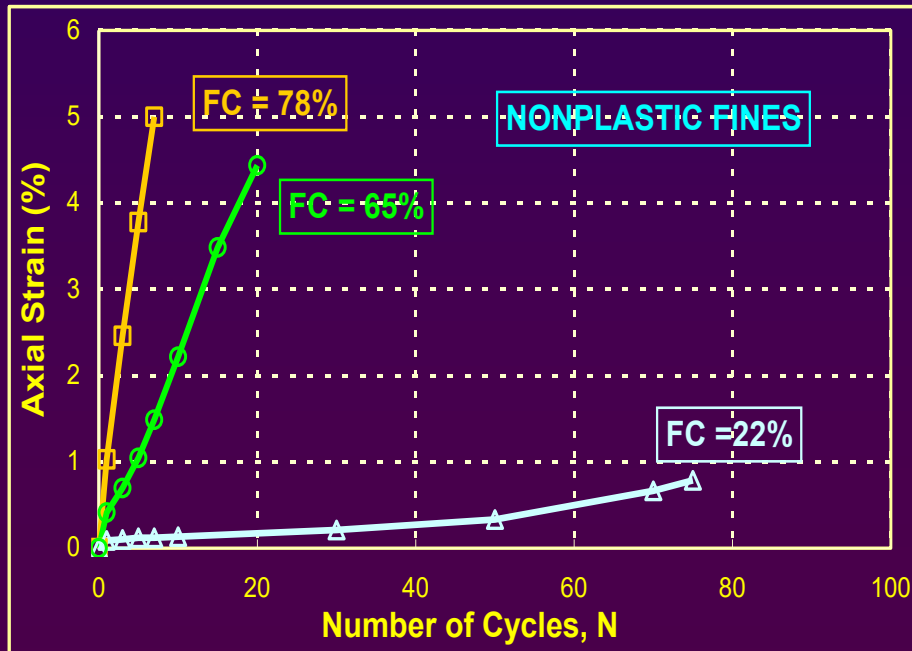
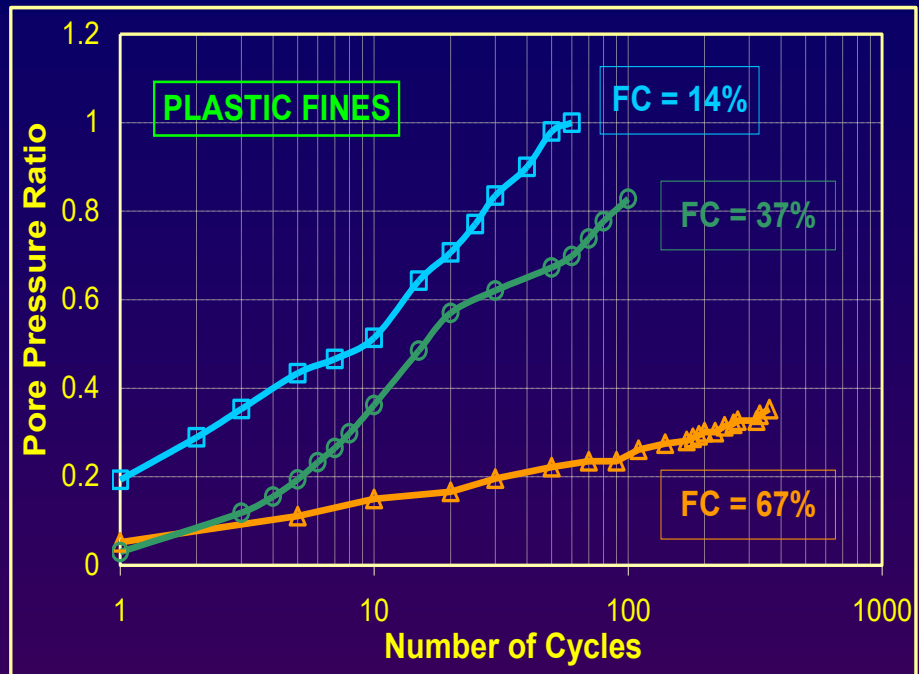
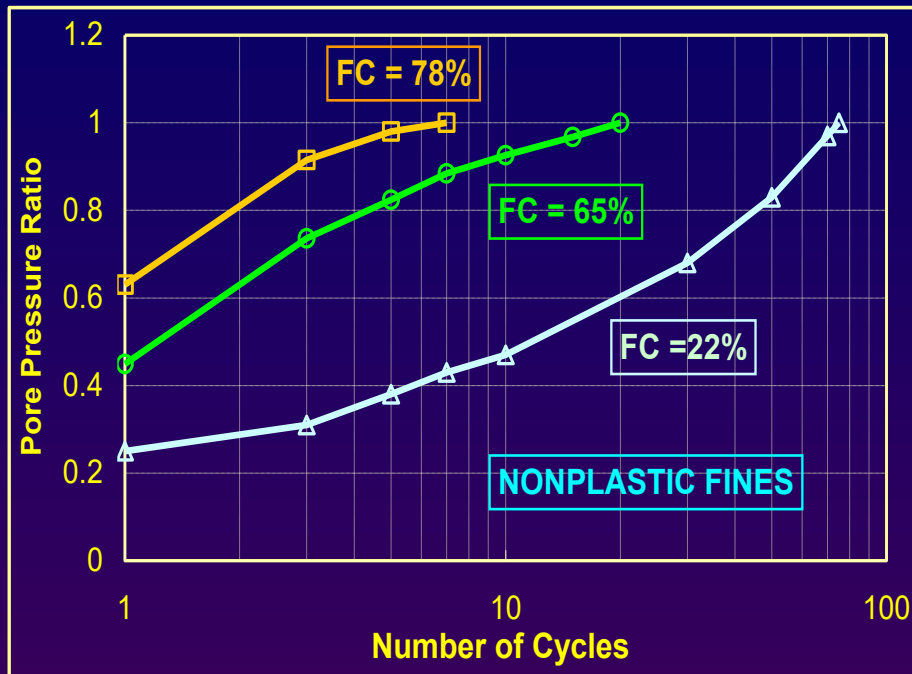
- short cylindrical soil specimen is constrained axially between two parallel, rigid platens and laterally by a steel reinforced rubber membrane, such that constant cross sectional area is ensured.
- axial stress applied from top
- shear stress applied through horizontal loading

### Testing procedure:

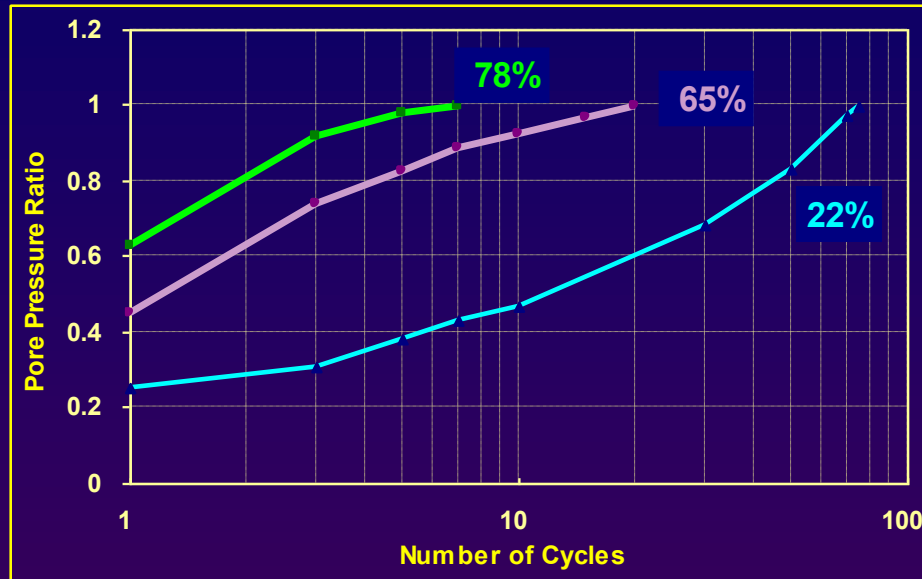
- saturation and consolidation to reproduce initial in situ conditions (loaded axially to consolidate one-dimensionally)
- shear loading under undrained conditions by applying cyclic horizontal shear stresses to the top or bottom of the specimen.
- cyclic load, shear displacement, and porewater pressure development with time are monitored.



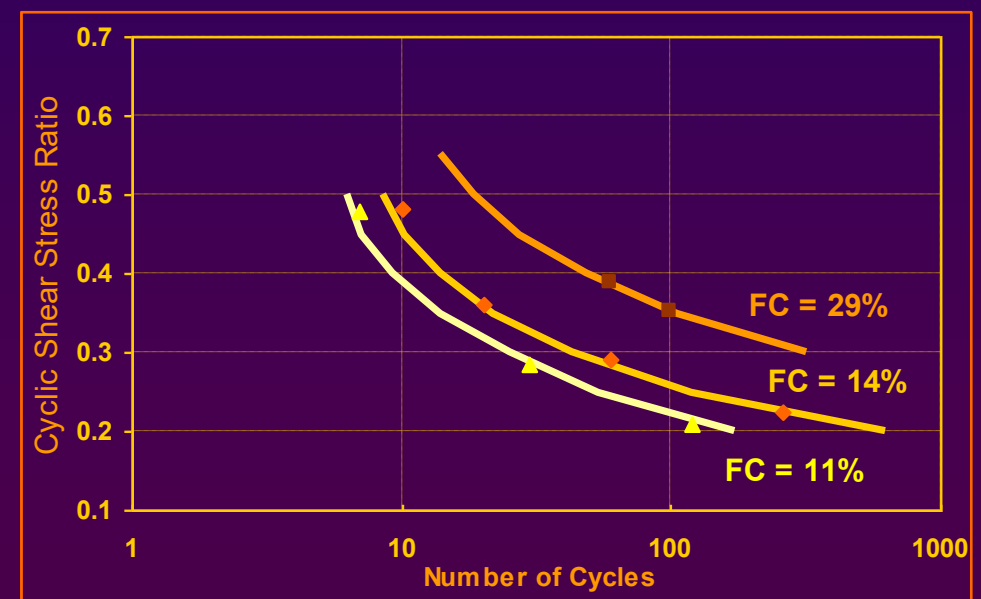
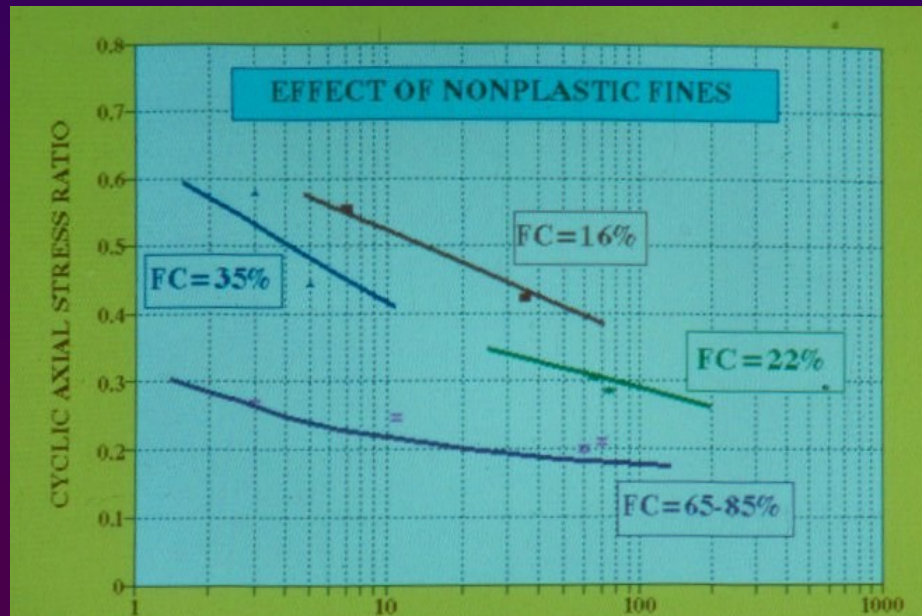
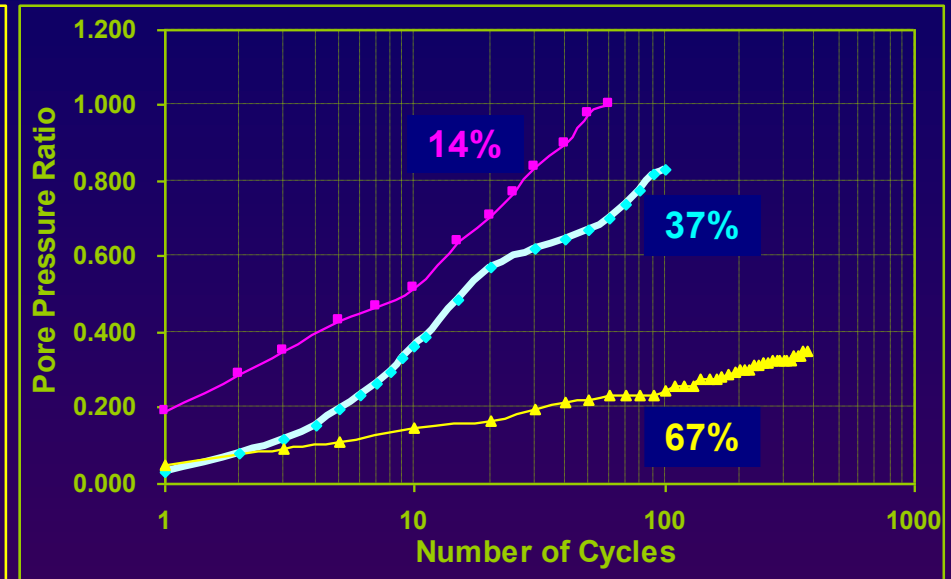




## THE EFFECT OF NON PLASTIC FINES

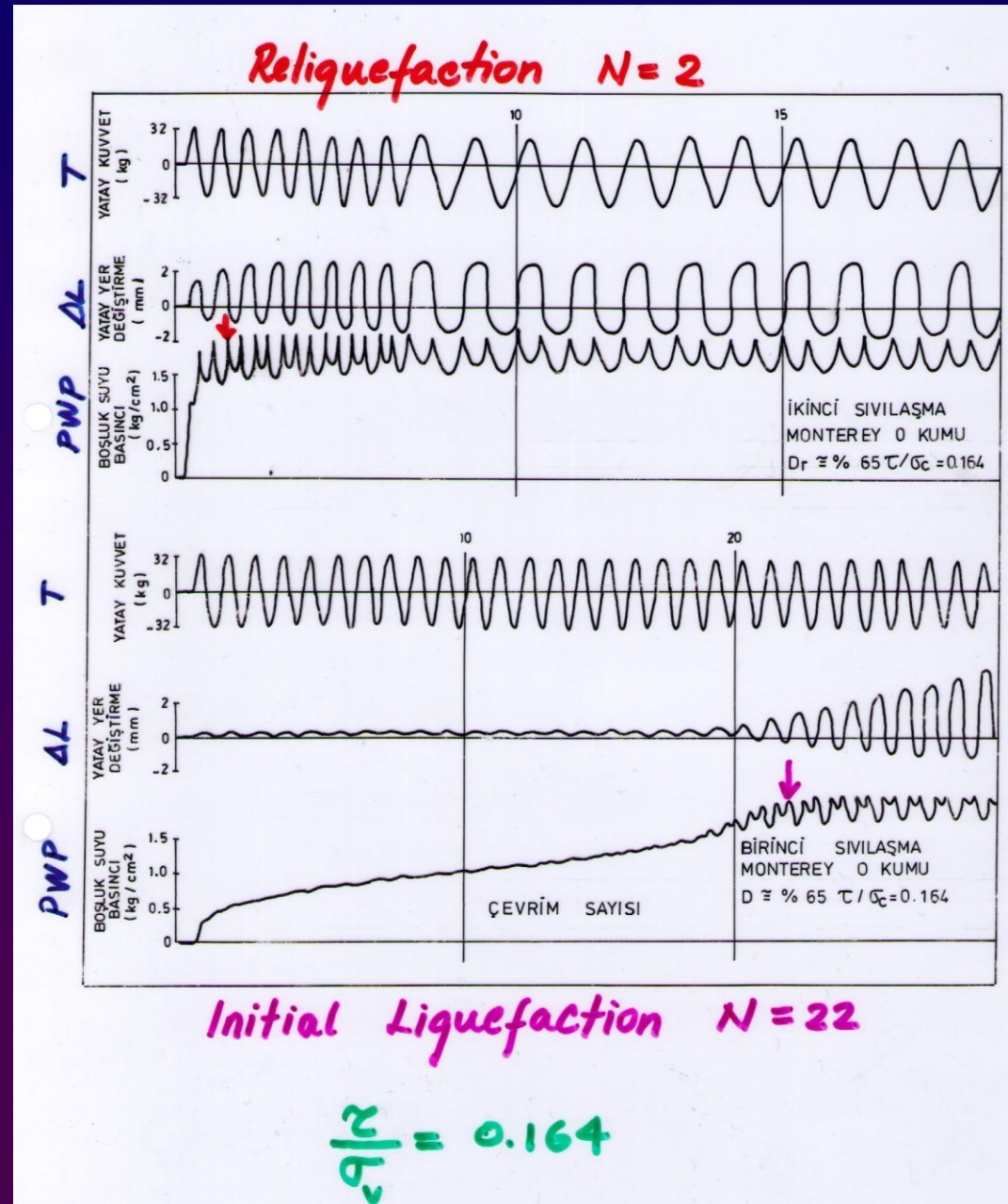


## THE EFFECT OF PLASTIC FINES



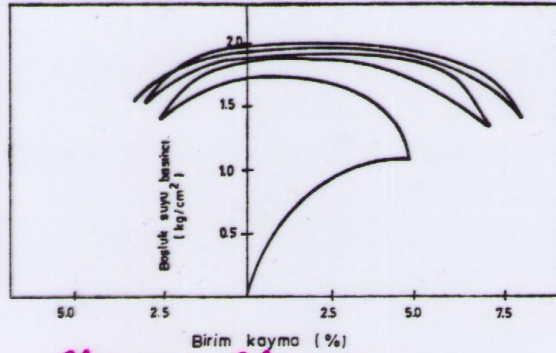


# Reliquefaction



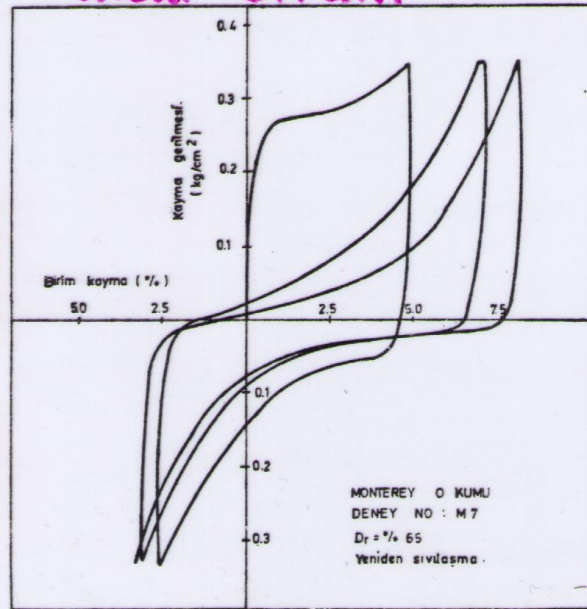
# Reliquefaction

Pore Pressure



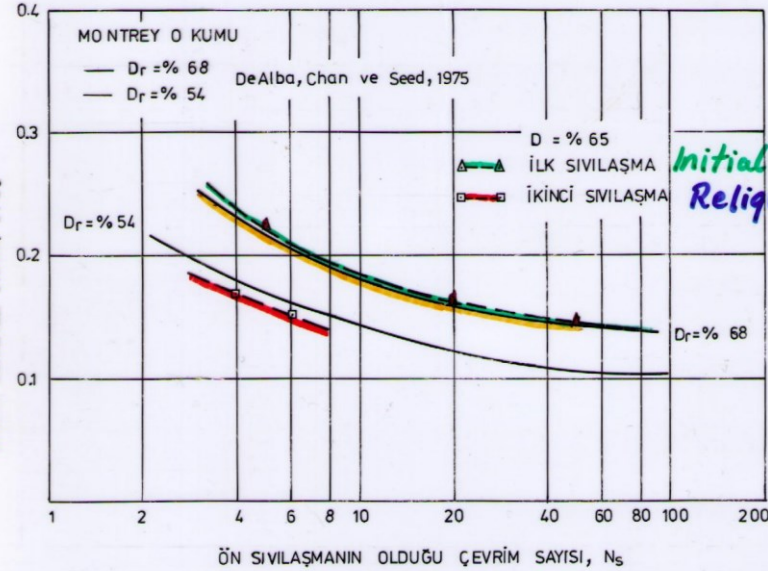
Shear Strain

Shear Stress



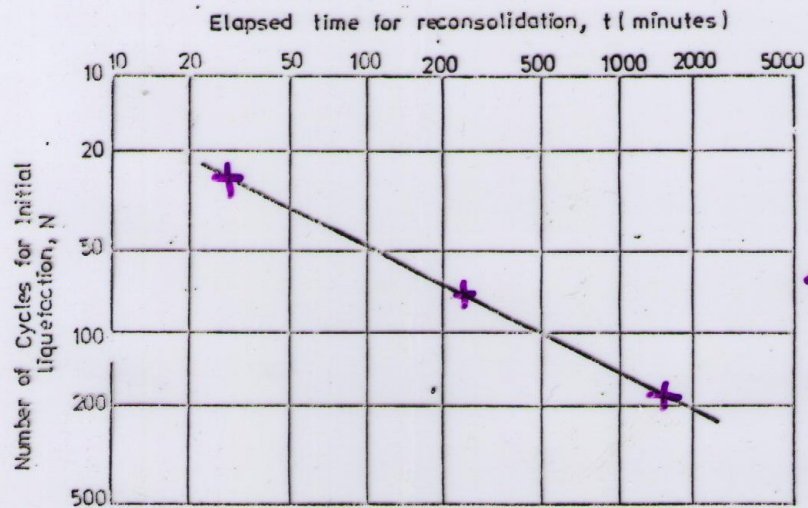
Reliquefaction

Stress Ratio



Number of Cycles for Initial Liquefaction

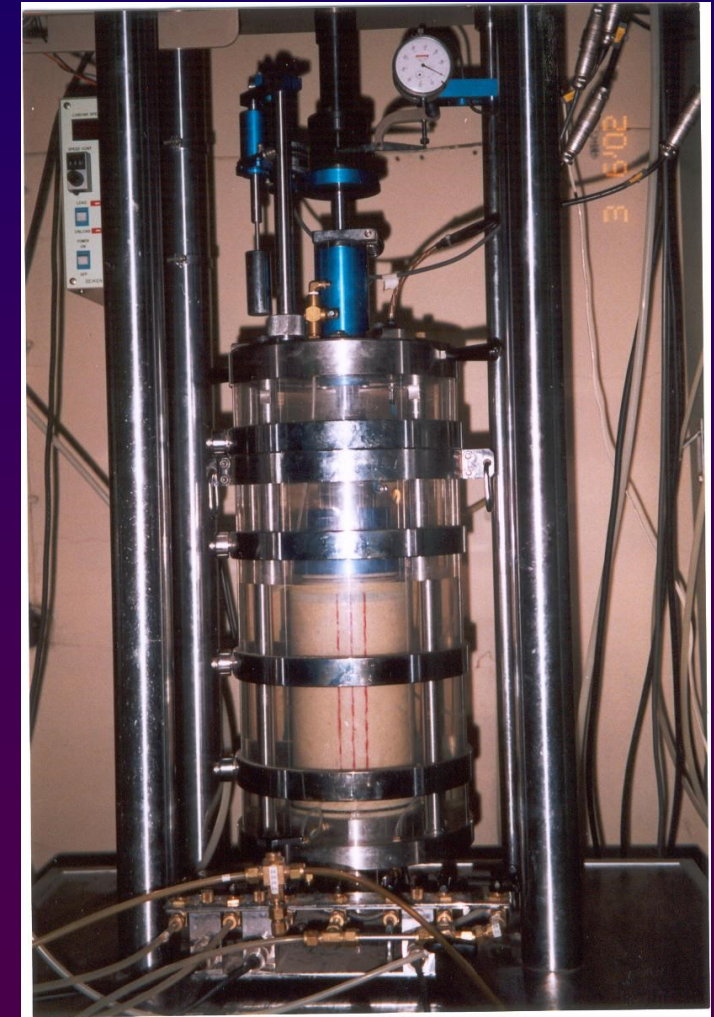
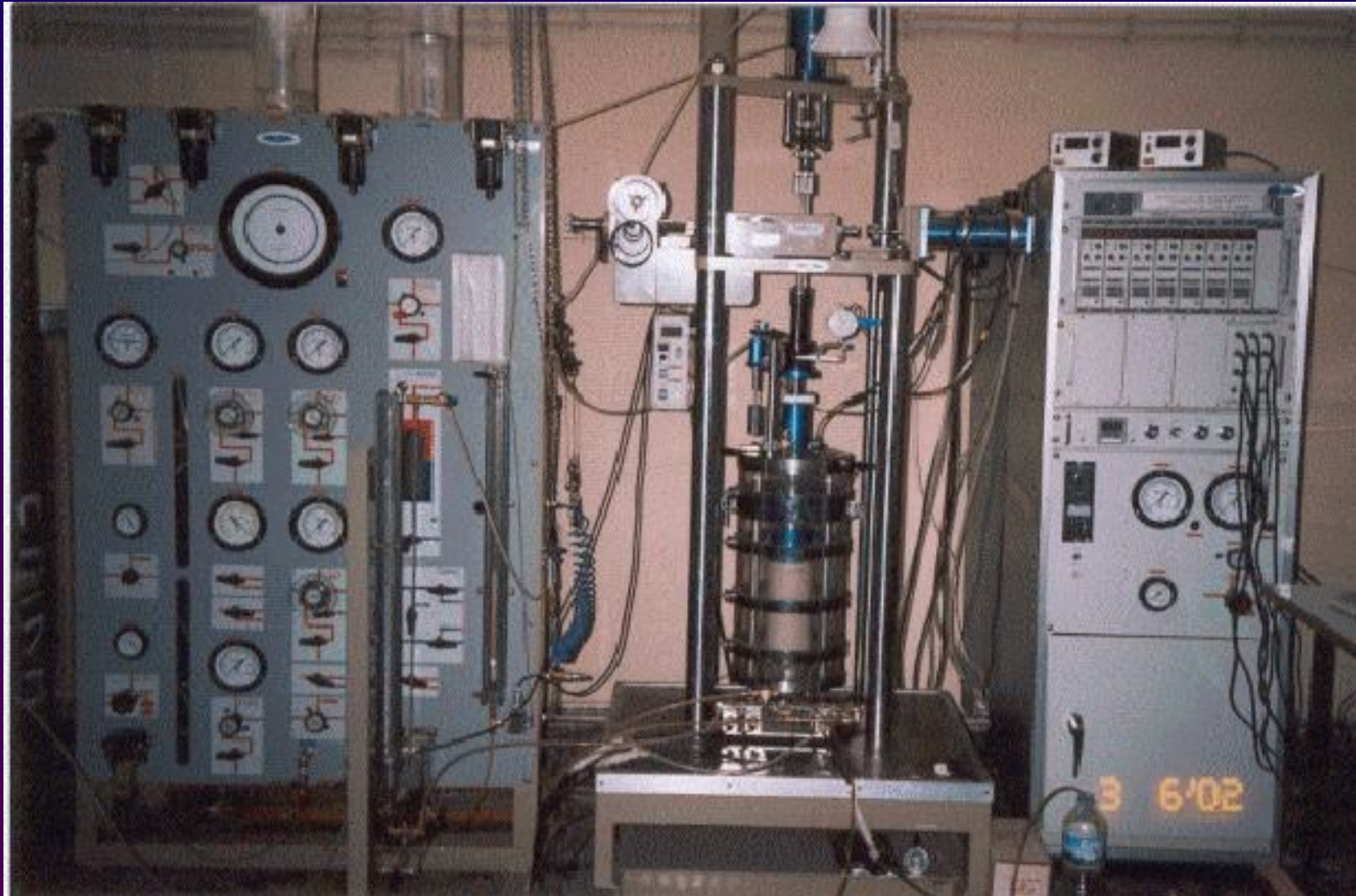
Initial Lig. Rliquefaction



15"  
4 saat  
1 gün

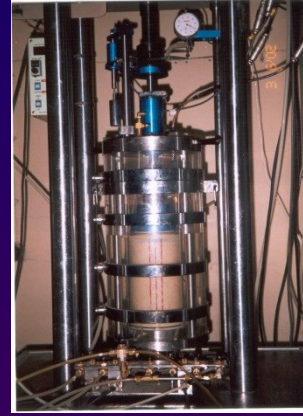


# ITU CIVIL ENGINEERING FACULTY CYCLIC TORSIONAL HOLLOW CYLINDER TESTING SYSTEM

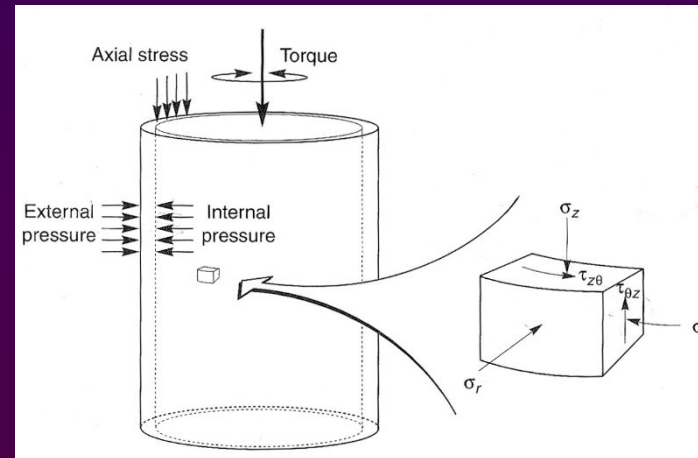
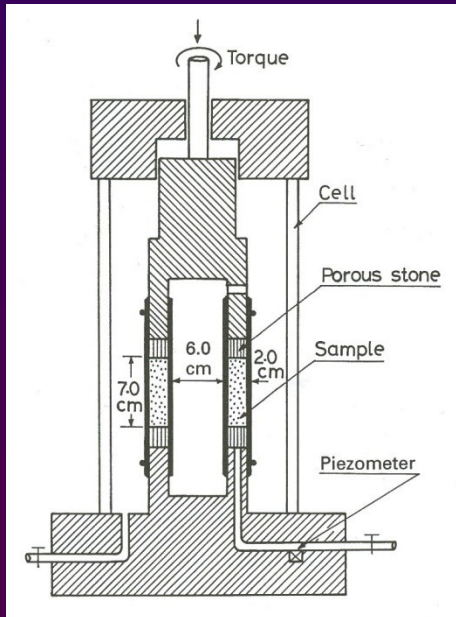


# Laboratory Measurement of Dynamic Soil Properties

## Cyclic Torsional Shear Test (CTST)

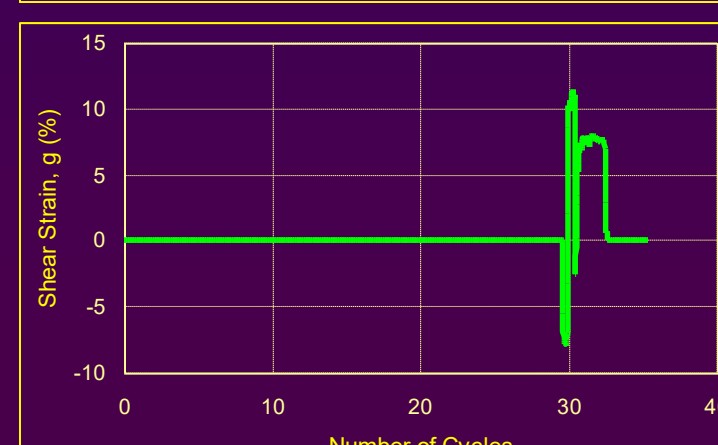
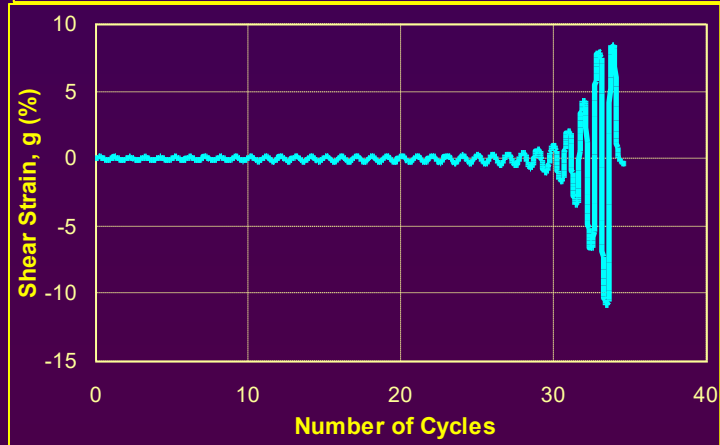
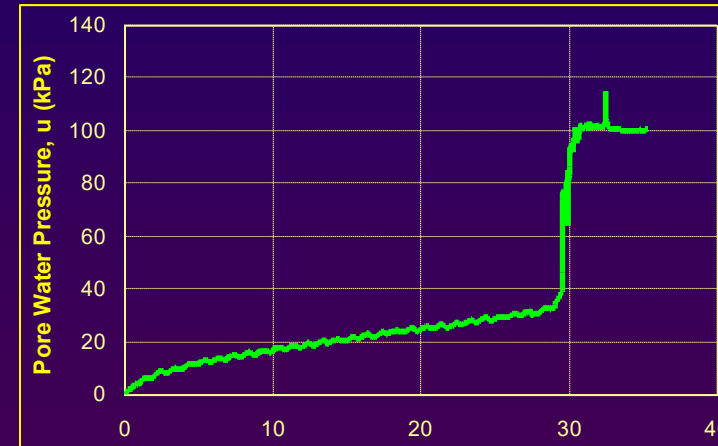
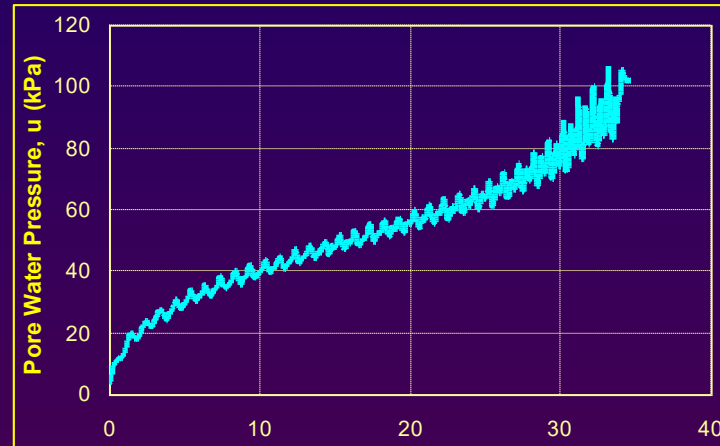
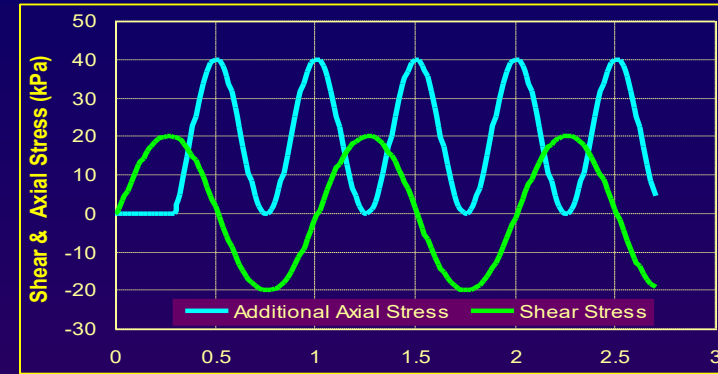
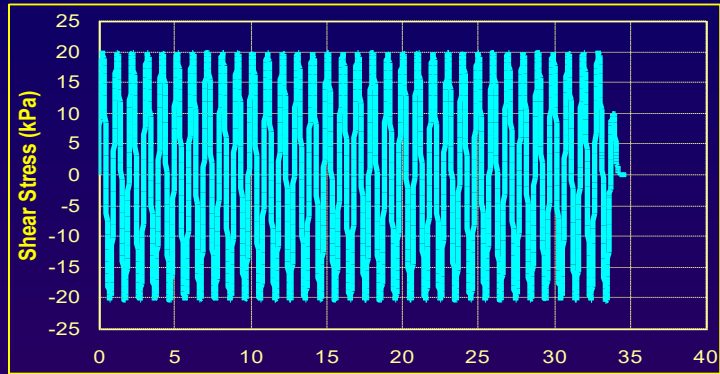


- A cylindrical or hollow cylindrical soil specimen is enclosed in rubber membrane and confined in a triaxial chamber where it is subjected to in situ confining pressure.
- Axial load and torque is applied to the top of the specimen.
- Axial load, torque, axial deformation, angular rotation and porewater pressure development with time are monitored.

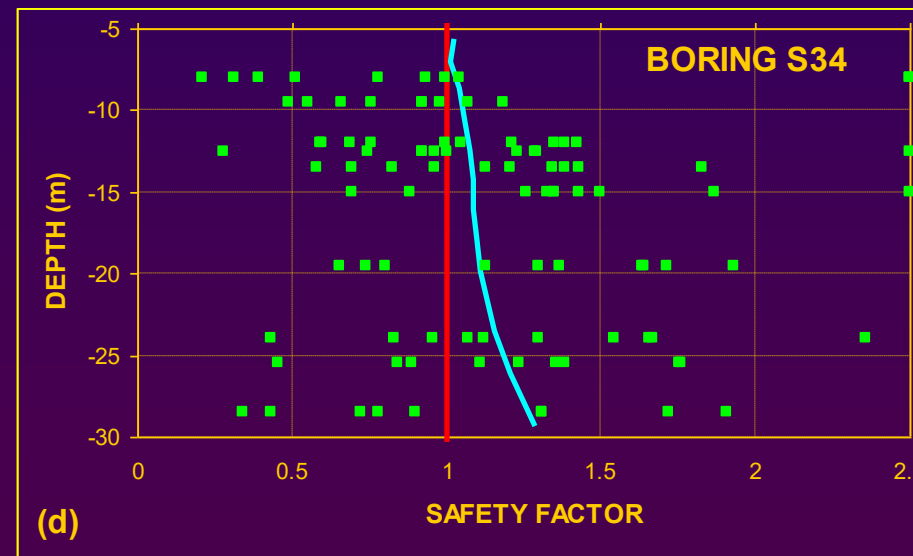
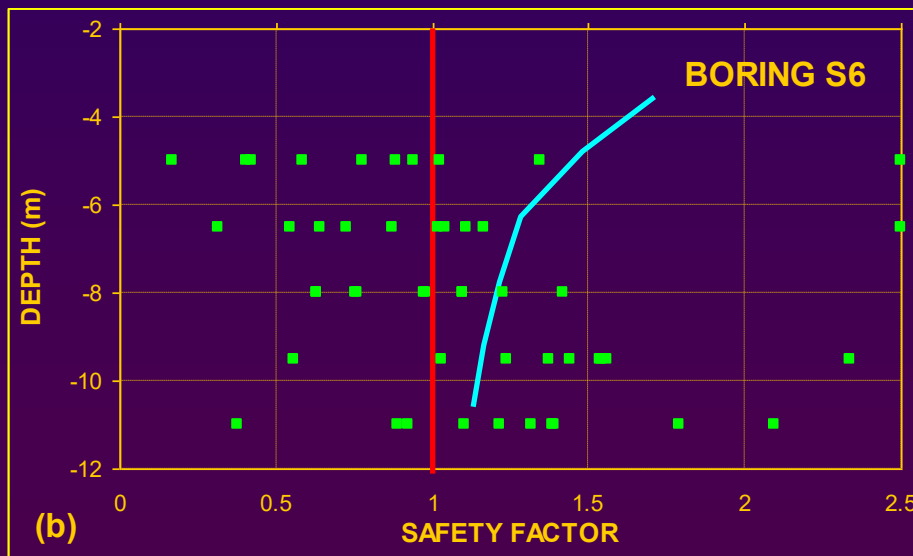
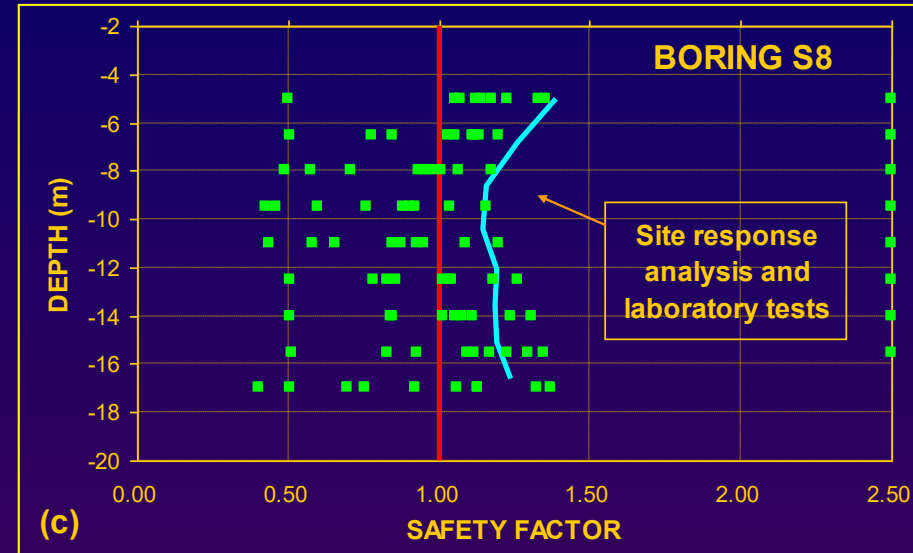
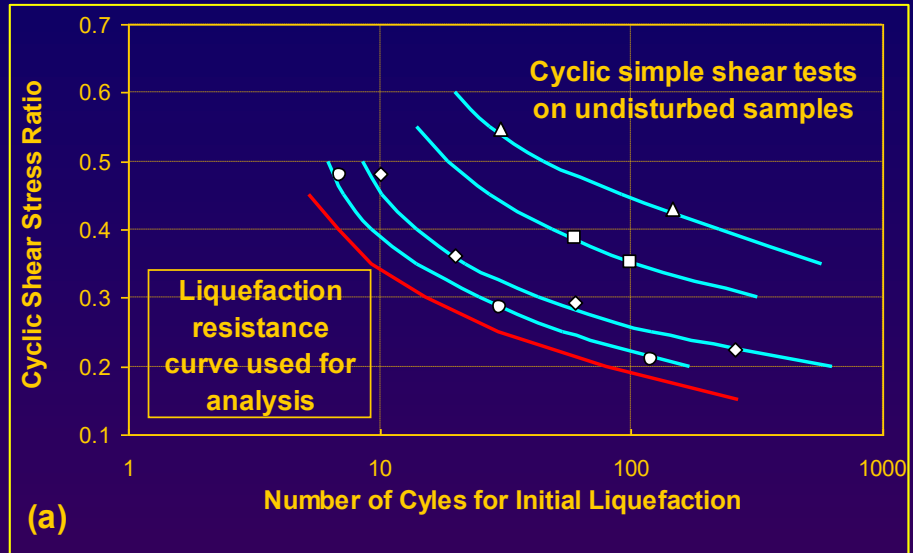




# Toyoura Sand, Isotropic Consolidation, $D_r=50\%$ , $\sigma_o=98$ kPa, $F_r=0.1$ Hz

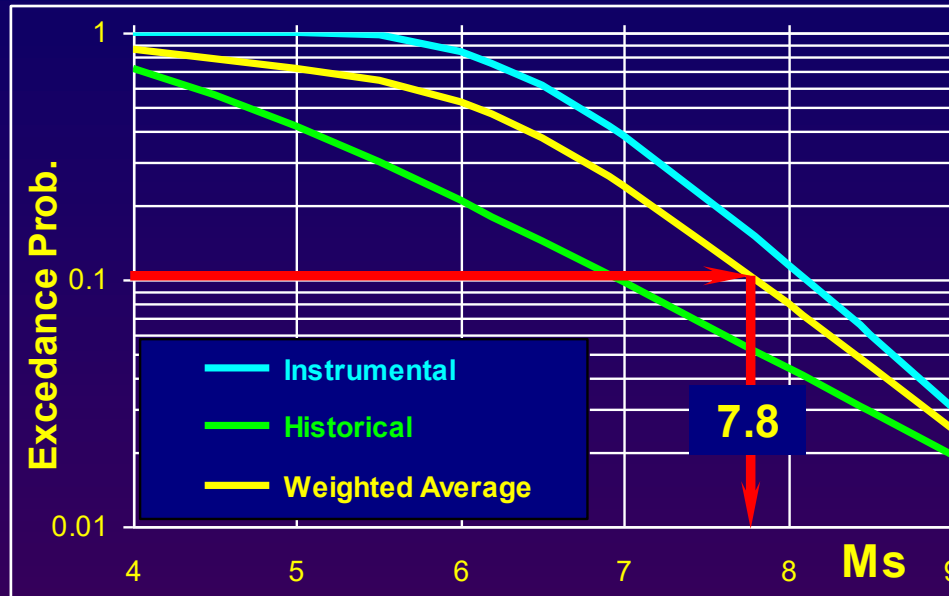




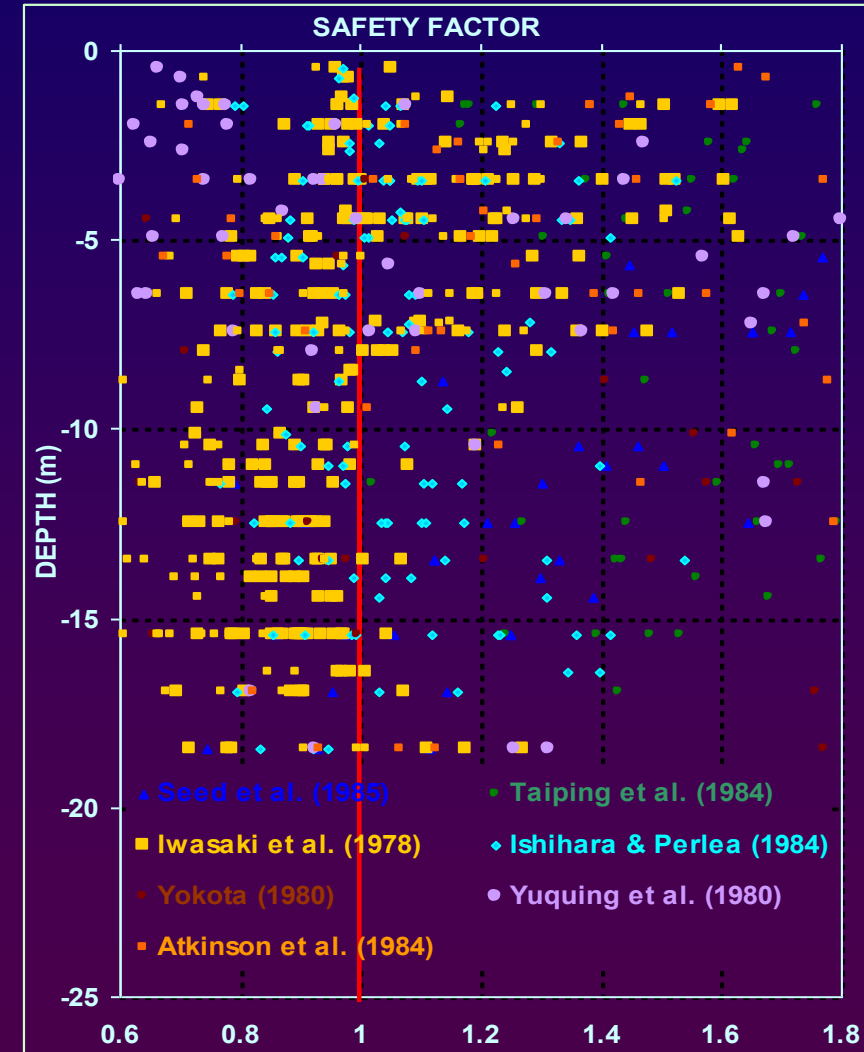


## GEMLIK BORUSAN FACTORY - 1990

# TOYOTOSA FACTORY - 1992



Return Period (years)	100	200	500	1000
Magnitude (Ms)	6.2	6.9	7.8	8.4
Peak Horz. Acc.(g)	0.11	0.17	0.29	0.41



21 Boring 114 SPT SAMPLES

# ACKNOWLEDGEMENTS

1. G.Öğünç, Dynamic Triaxial Liquefaction Experiments and Re-Liquefaction, MS Thesis, July 1981
2. C. Ertuğrul, Liquefaction Evaluation by Dynamic Simple Shear Experiments, MS Thesis, February 1981
3. A. Erken, The Effect of Membrane Penetration in Triaxial Compression Tests of Sands, Ph.D. Thesis, 1987
4. E.Alhas, Liquefaction of Silty and Clayey Sands, MS Thesis, July 1994
5. Y.Kozacıoğlu, Determination of Shear Strength of Sands Using Direct Shear Box and Torsional Ring Shear, MS Thesis, July 1988
6. V. Okur, Stress Strain and Strength Behaviour of Fined Grained Soils under Different Dynamic Stress Amplitudes, Ph.D. Thesis, February 2002
7. S. Altun, Evaluation of cyclic behavior of soil with torsional shear test, Ph.D. Thesis, February 2003



*THE END*