

UNSATURATED SOIL MECHANICS - INTRODUCTION & APPLICATION

BY

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OUTLINE OF PRESENTATION

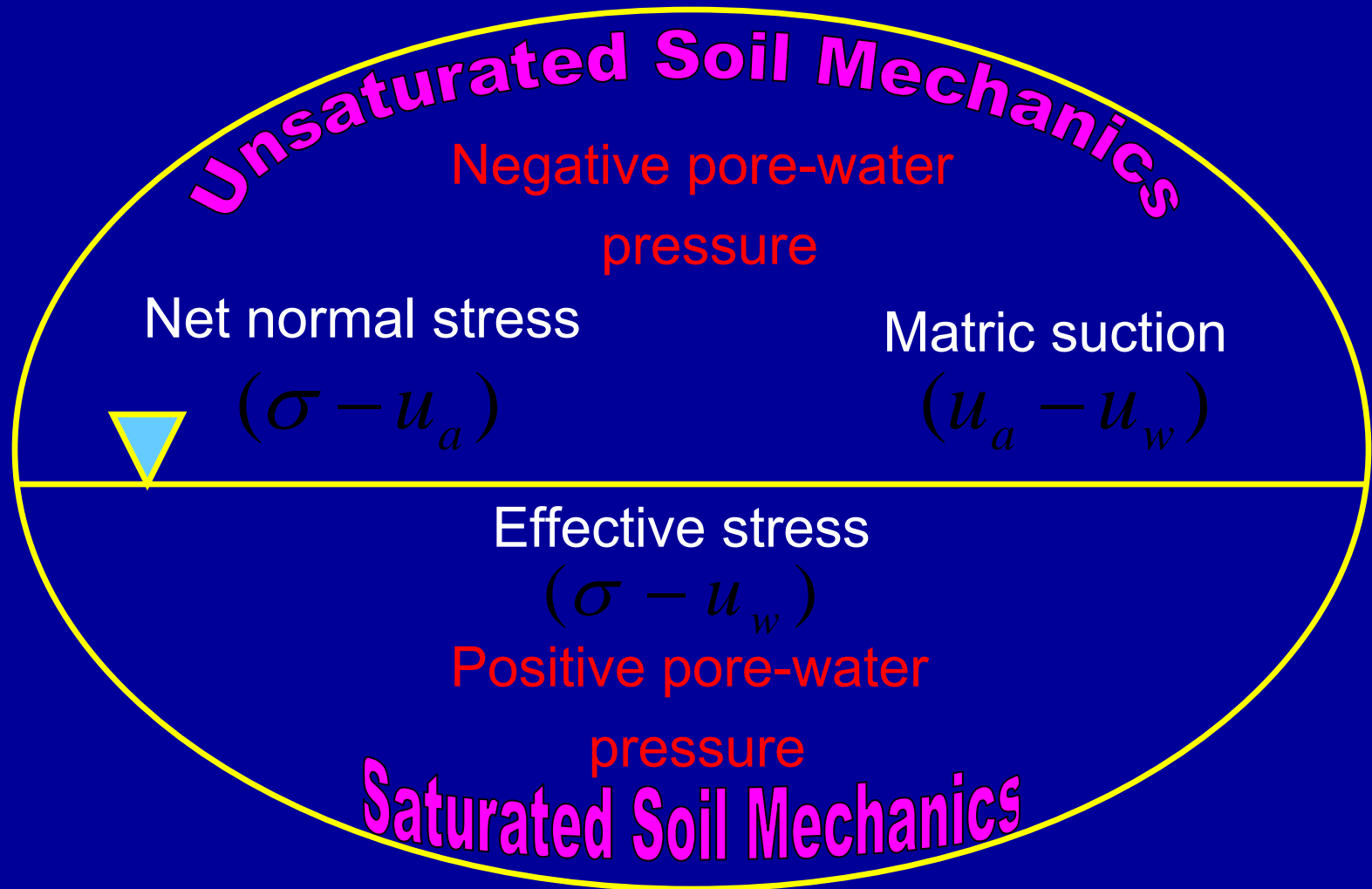
- ❖ Effective Stress Principle
- ❖ Saturated Soils vs. Unsaturated Soils
- ❖ Shear Strength of Unsaturated Soils
- ❖ Unsaturated Soil Testing
- ❖ Application of Unsaturated Soil Mechanics

TERZAGHI'S EFFECTIVE STRESS PRINCIPLE

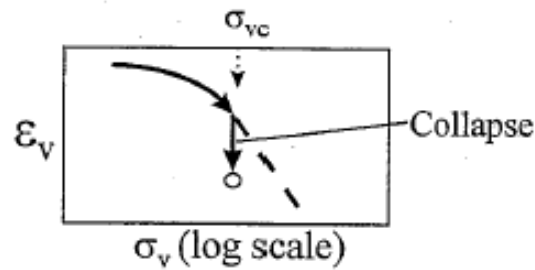
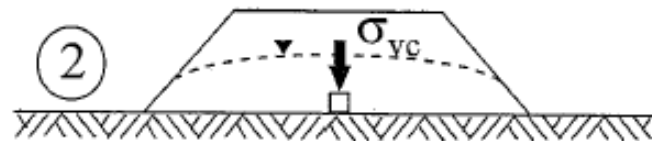
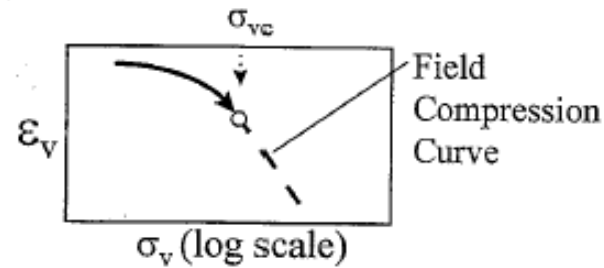
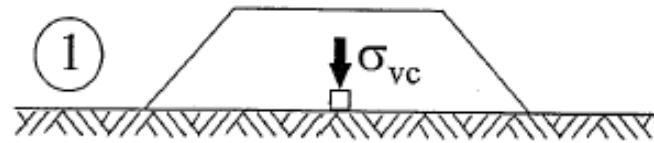
- Changes in volume and shearing strength of a soil are due to changes in effective stress.
- The effective stress is defined as the excess of the total applied stress over the pore pressure

$$(\sigma - u_w).$$

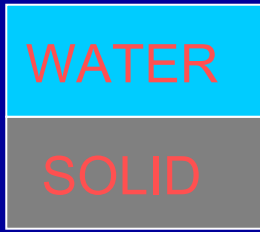
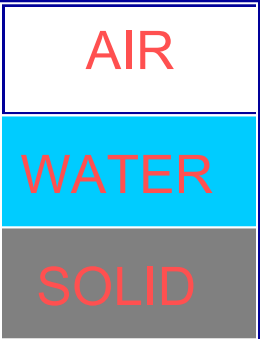
GENERALIZED WORLD OF SOIL MECHANICS



SOIL COLLAPSE

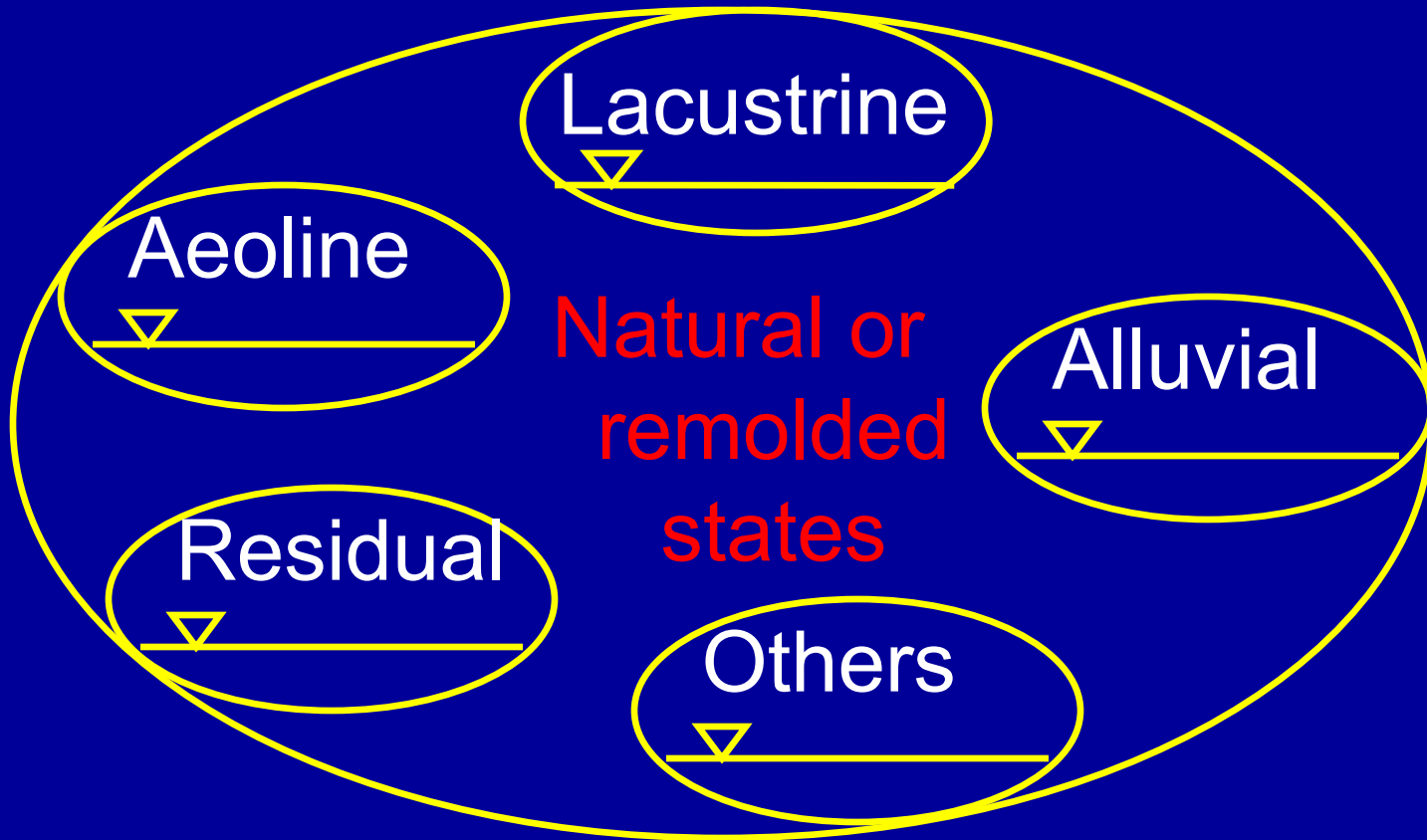


SATURATED VS. UNSATURATED SOIL

SOIL CONDITION	PORE MEDIUM	u_w	STRESS VARIABLES
SATURATED 	WATER	≥ 0	$(\sigma - u_w)$
UNSATURATED 	AIR & WATER	< 0	$(\sigma - u_a)$ $(u_a - u_w)$

CHATEGORIZATION BASED ON GEOLOGIC ORIGINS

Each soil type can be unsaturated in its natural or its compacted condition.



Unsaturated soil behavior does not favor a particular geologic genesis.

NEED FOR UNSATURATED SOIL MECHANICS

In the USA alone “Each year, shrinking and swelling soils inflict at least \$2.3 billion in damages to houses , buildings, roads, and pipelines-more than twice the damage from floods, hurricanes, tornadoes, and earthquakes!”

(Jones and Holtz, 1973)

NEED FOR UNSATURATED SOIL MECHANICS

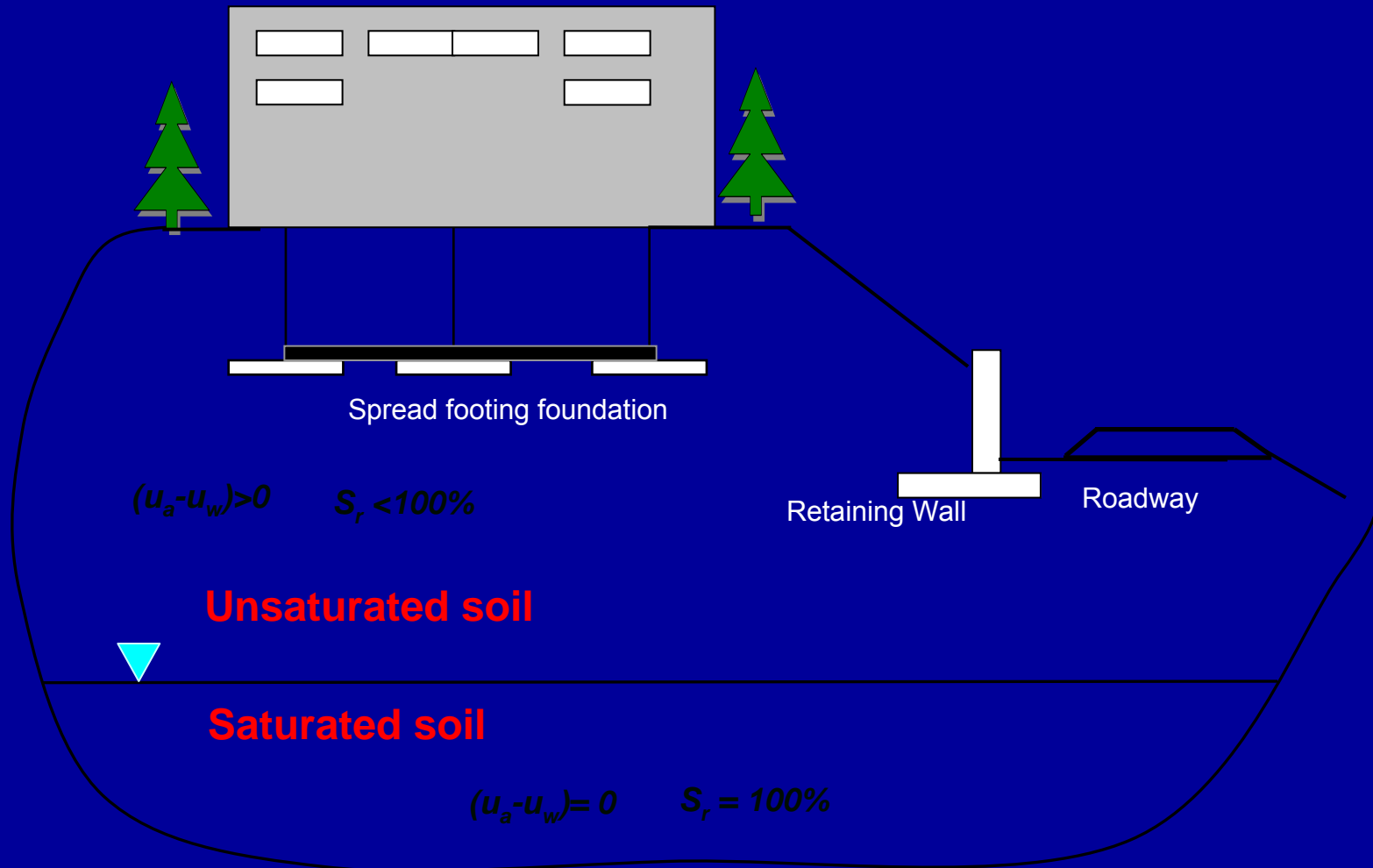
Krohn and Slosson (1980)

“\$7 billion are spent every year in the USA as a result of damage to all type of structures built on expansive soils”.

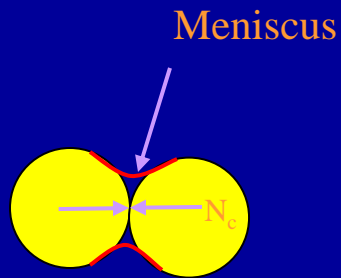
Snethen (1986):

“Expansive soils “hidden disaster”: economically, one of the USA costliest natural hazards. More than one fifth of American families live on such soils.”

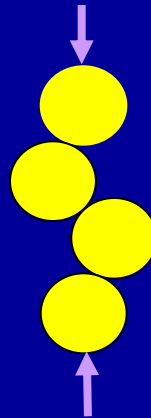
Near Ground Surface Structures



EFFECT OF MATRIC SUCTION ($u_a - u_w$)

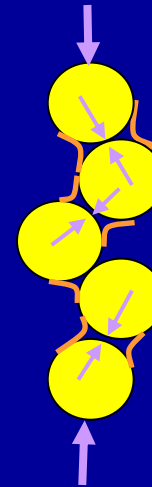


**Interparticle force
due to capillarity**



Unstable

(after Burland and Ridley 1996)

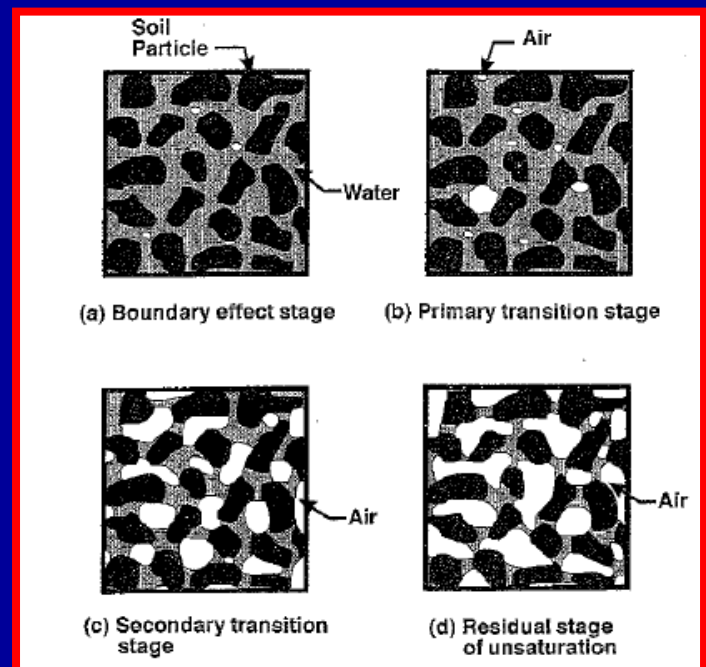
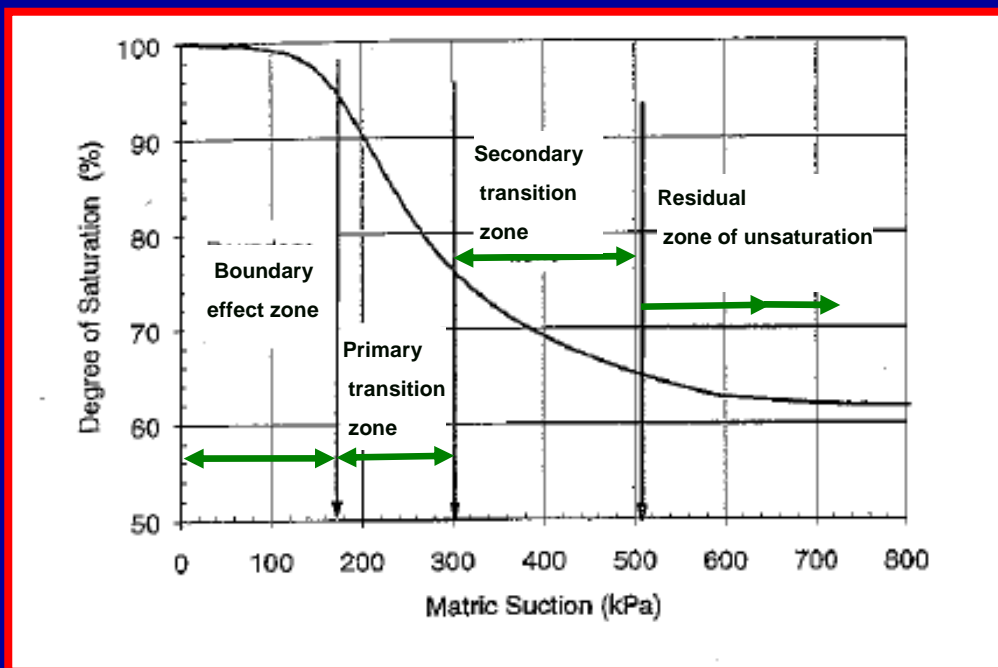


Stable

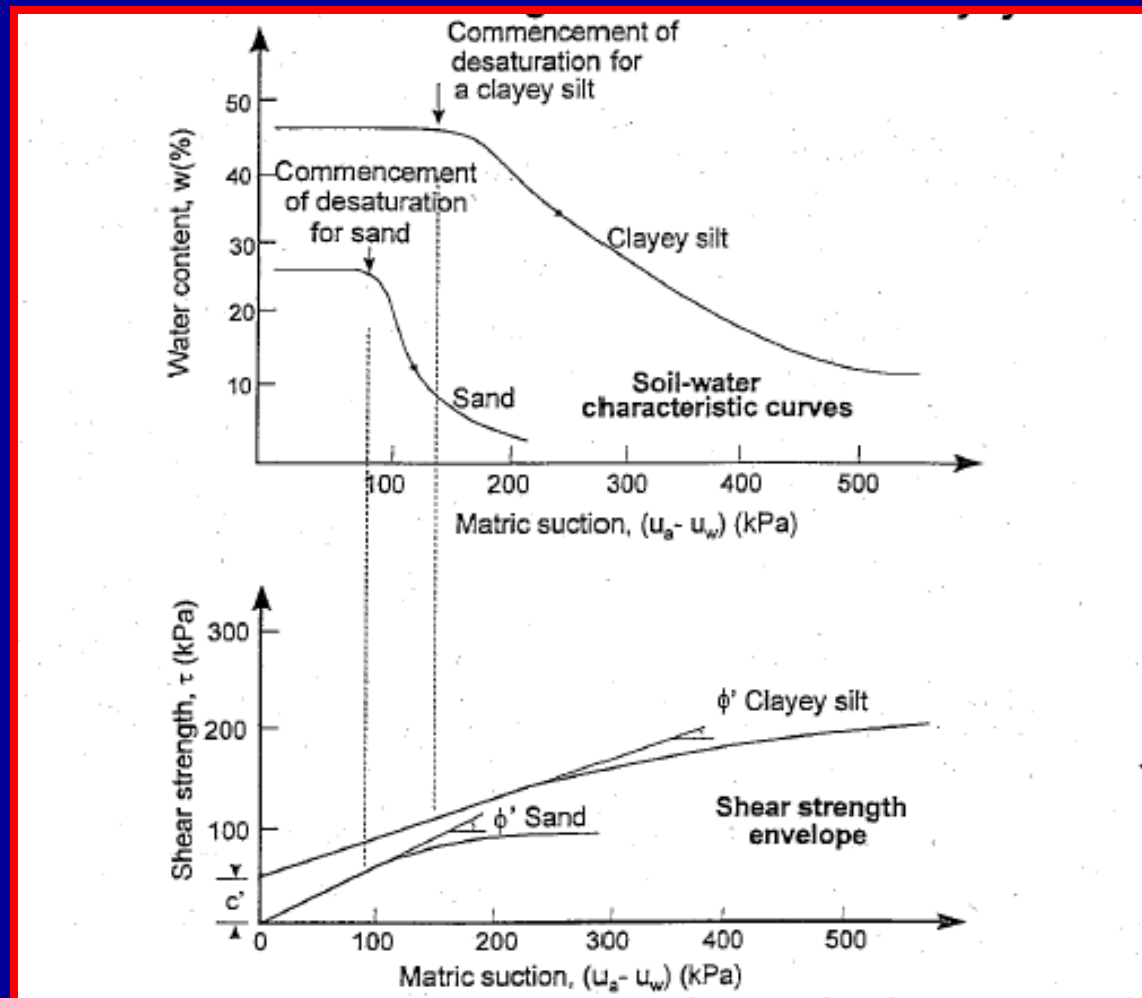
(after Burland and Ridley 1996)

SOIL WATER CHARACTERISTIC CURVE

- It defines the relationship between the amount of water in the soil and the suction.



SOIL WATER CHARACTERISTIC CURVE & SHEAR STRENGTH



SHEAR STRENGTH

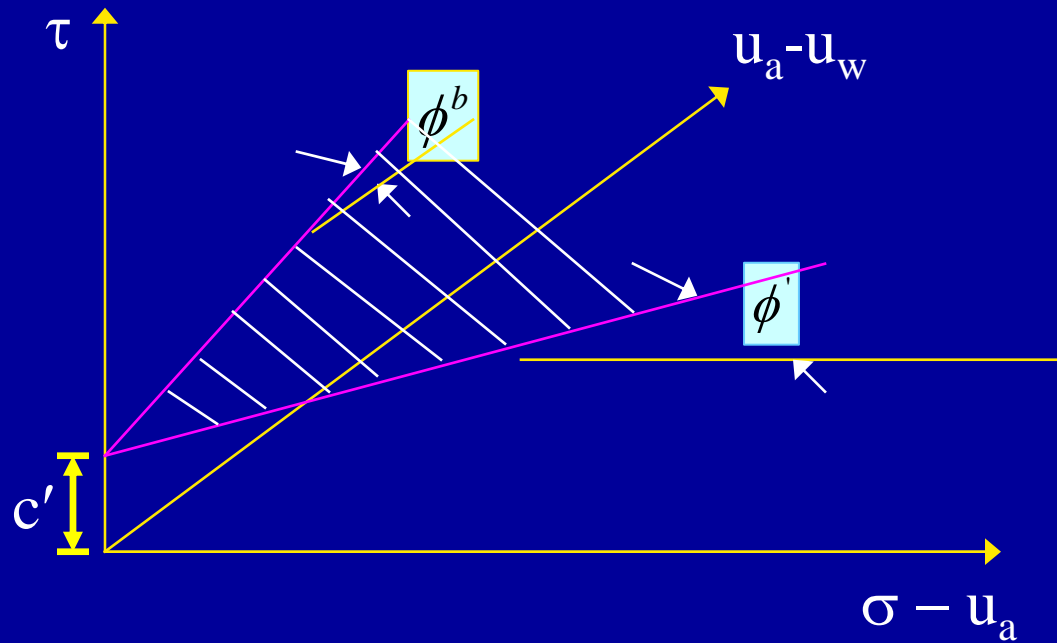
SATURATED
SOIL

$$\tau_{ff} = c' + (\sigma_f - u_w) \tan \phi'$$

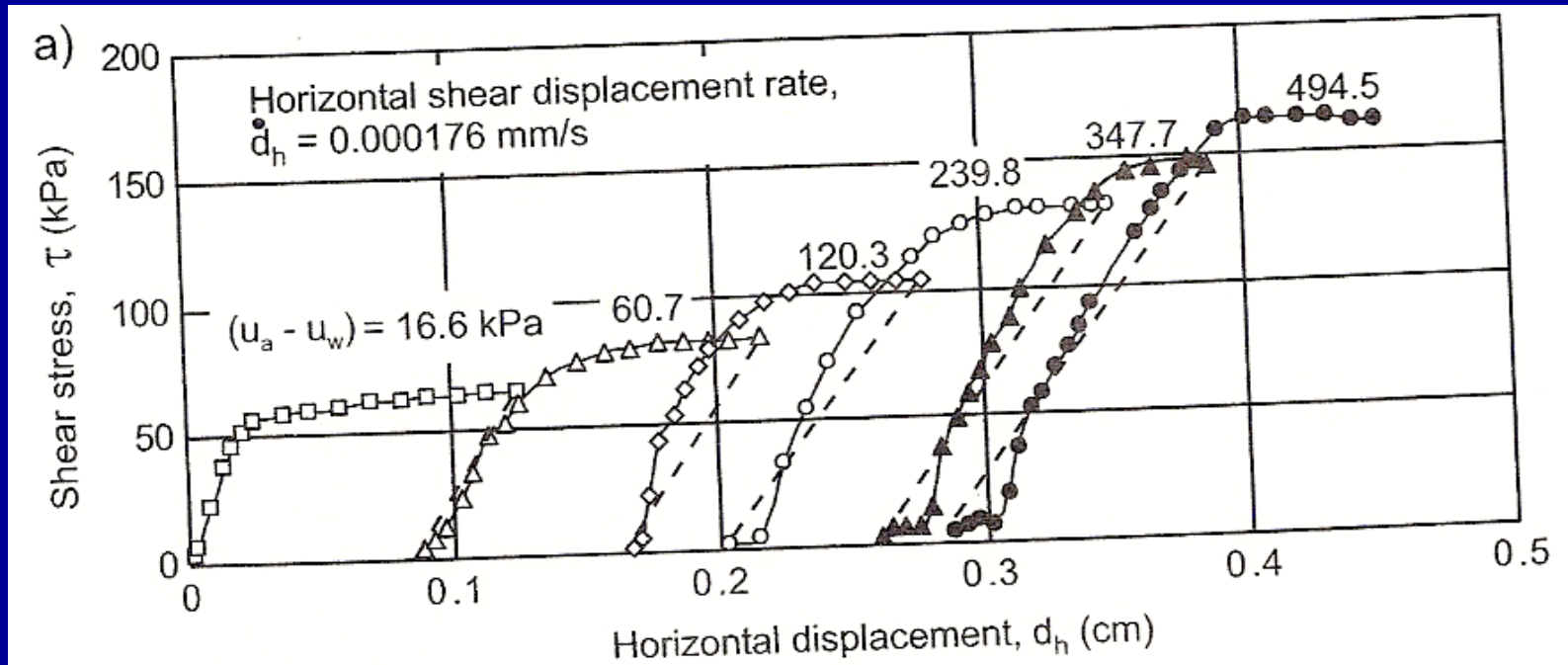
UNSATURATED
SOIL

$$\tau = c' + (\sigma_n - u_a) \tan \phi' + (u_a - u_w) \tan \phi^b$$

EXTENDED MOHR-COULOMB FAILURE ENVELOPE FOR UNSATURATED SOIL



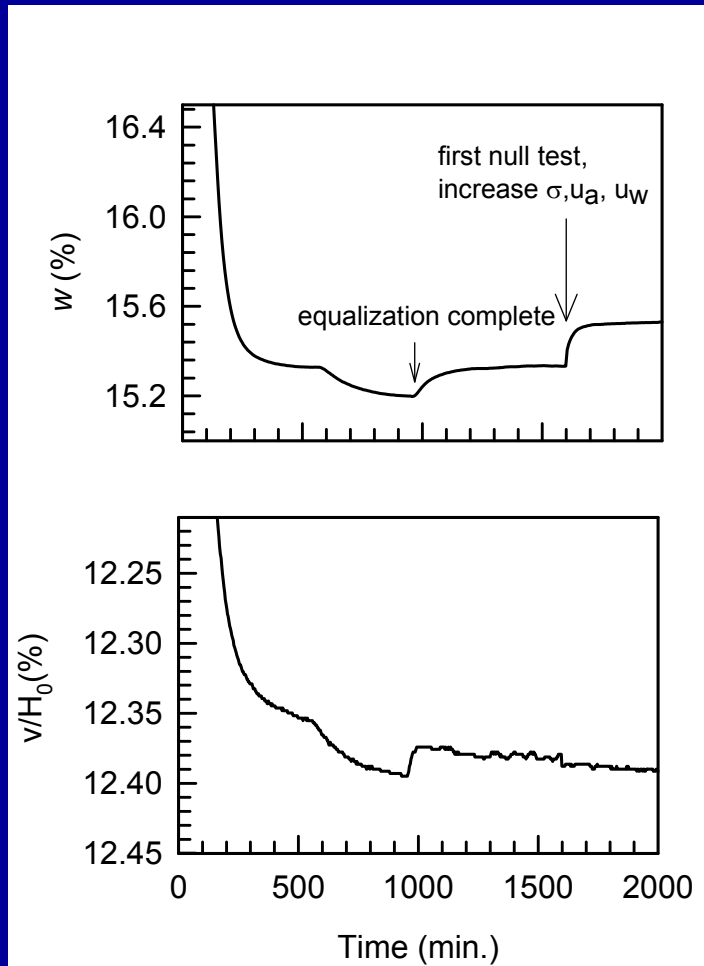
INCREASE IN SHEAR STRENGTH WITH SUCTION



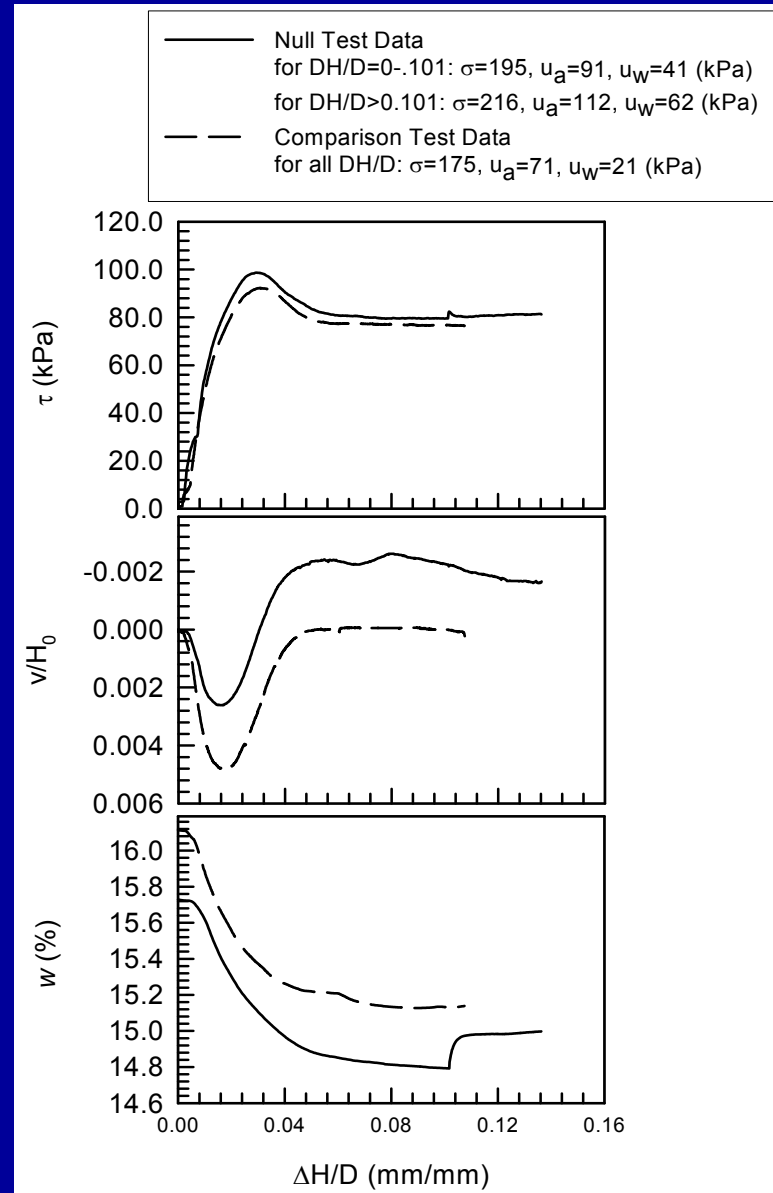
Gan et al. (1988)

NULL TEST RESULTS

Equalization Phase



Shearing Phase



UNSATURATED SOIL TESTING

STRENGTH & COMPRESSIBILITY TESTS

❖ TRIAXIAL TEST

❖ DIRECT SHEAR TEST

❖ OEDOMETER TEST

UNSATURATED SOIL TESTING

MEASUREMENT OF MATRIC SUCTION

❖ TENSIO METER →



2100F, Soilmoisture Probe

❖ FILTER PAPER METHOD

❖ PRESSURE PLATE →

❖ AXIS TRANSLATION TECHNIQUE



BEARING CAPACITY

- Footings are placed well above the groundwater table
- Water table may rise due to excessive watering of the vegetation surrounding the building
- Measurement of in-situ suction may be valuable

BEARING CAPACITY

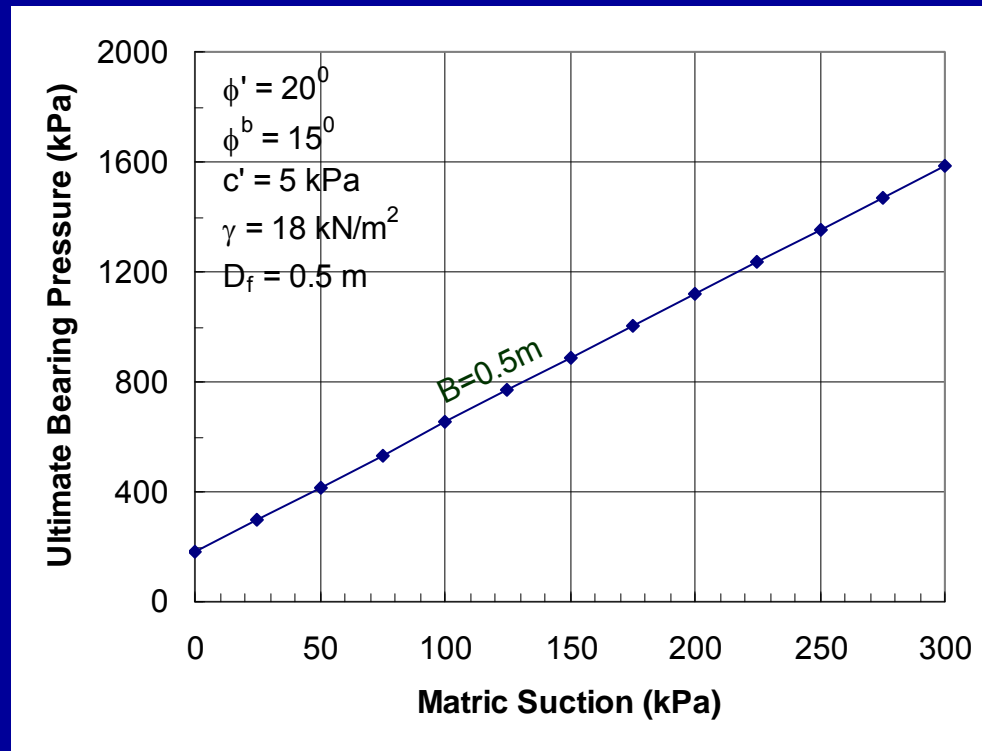
- Extension of Saturated Soil Mechanics

$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_{\gamma}$$

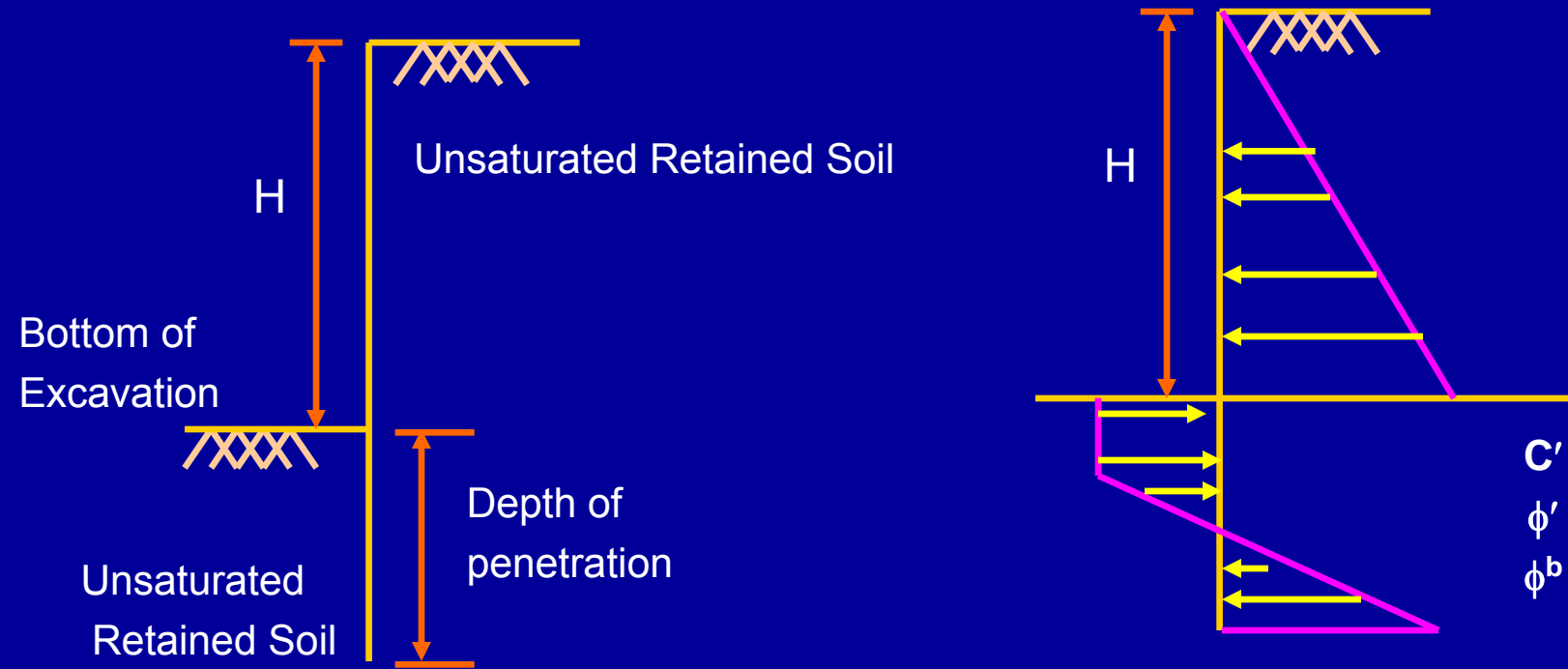
Where:

$$c = c' + (u_a - u_w) \tan \phi^b$$

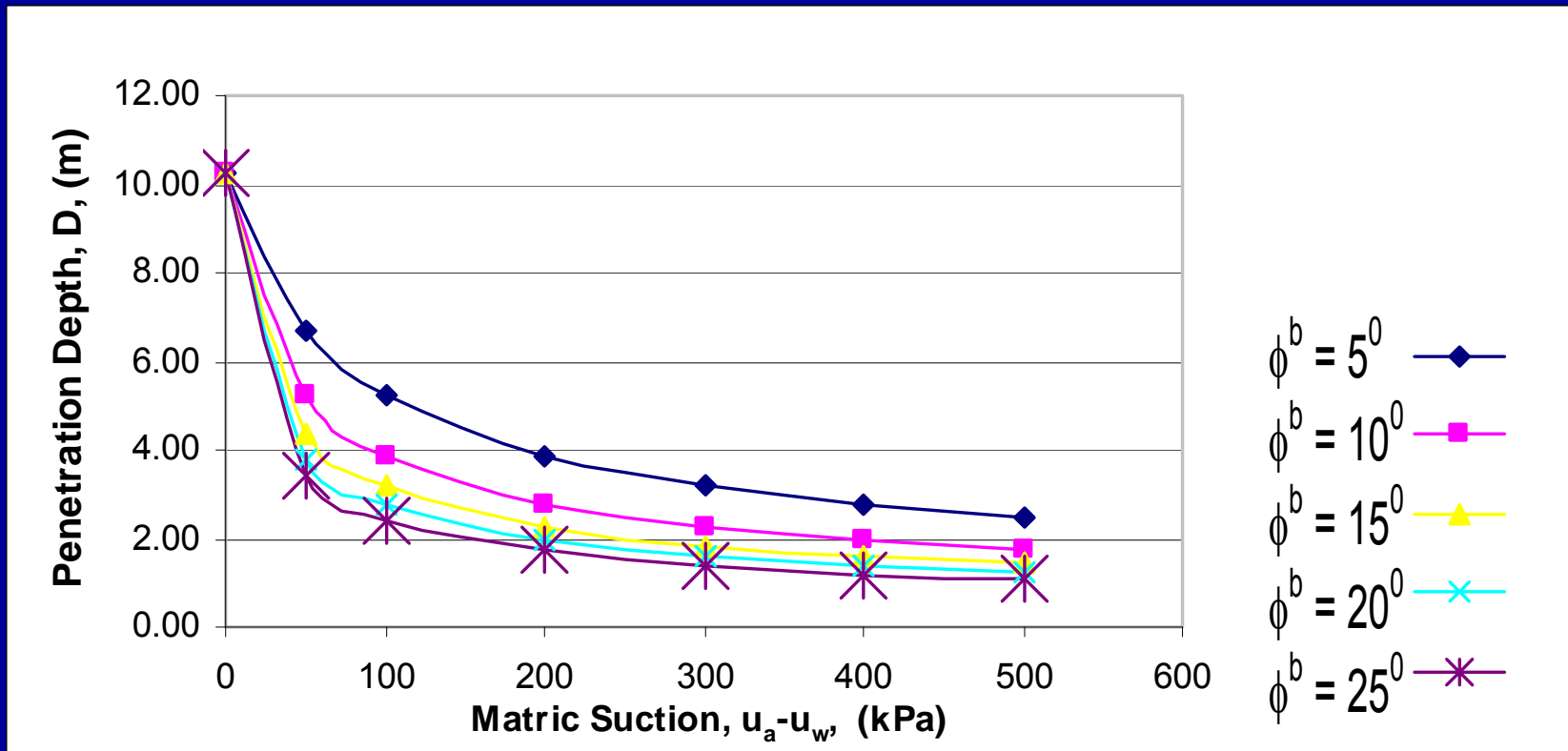
BEARING CAPACITY OF A STRIP FOOTING FOR VARIOUS MATRIC SUCTION VALUES



EXCAVATION SUPPORT SYSTEM IN UNSATURATED SOIL



EXCAVATION SUPPORT SYSTEM IN UNSATURATED SOIL

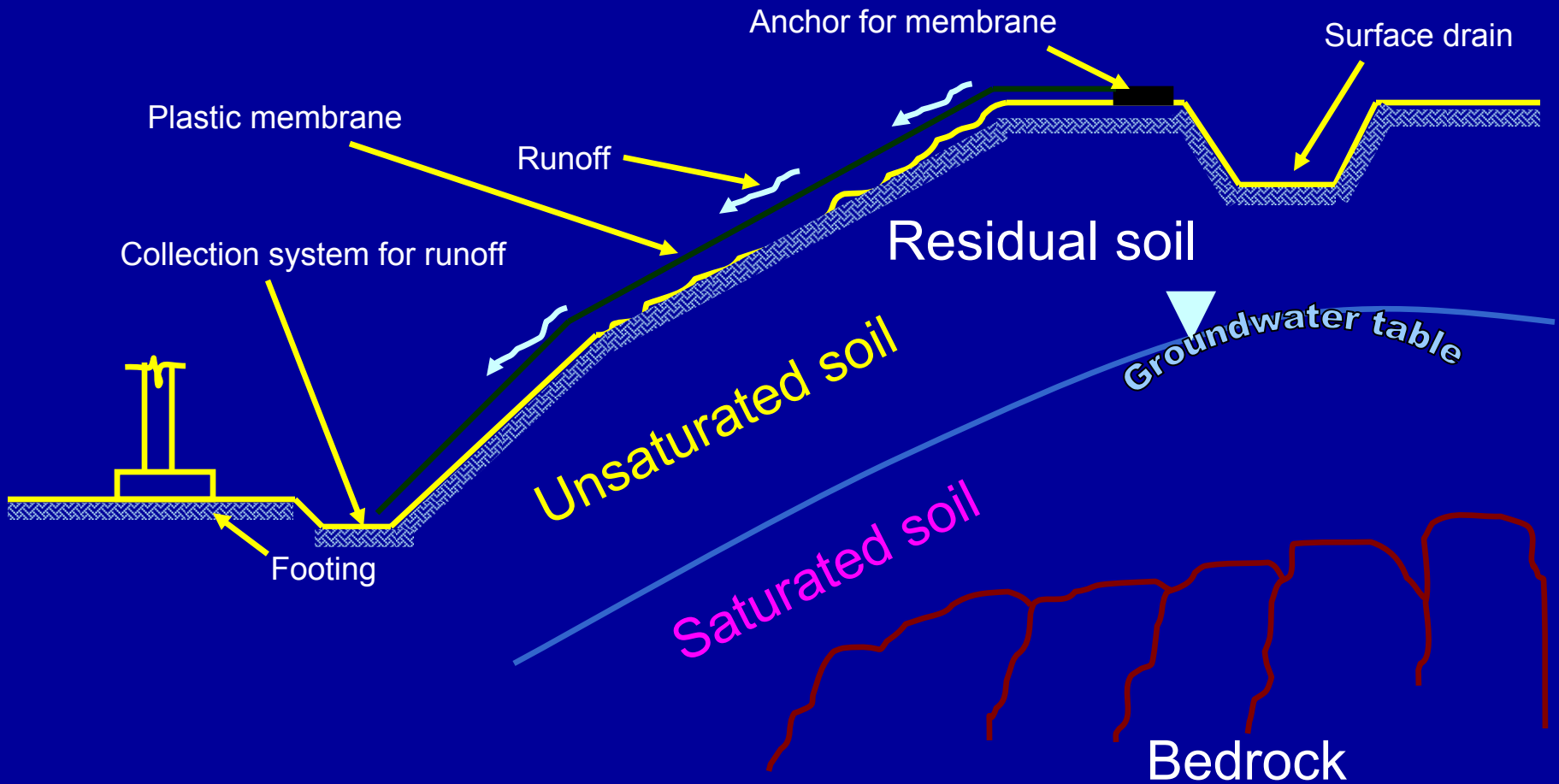


Variation in Depth of Penetration (D) With Matric Suction

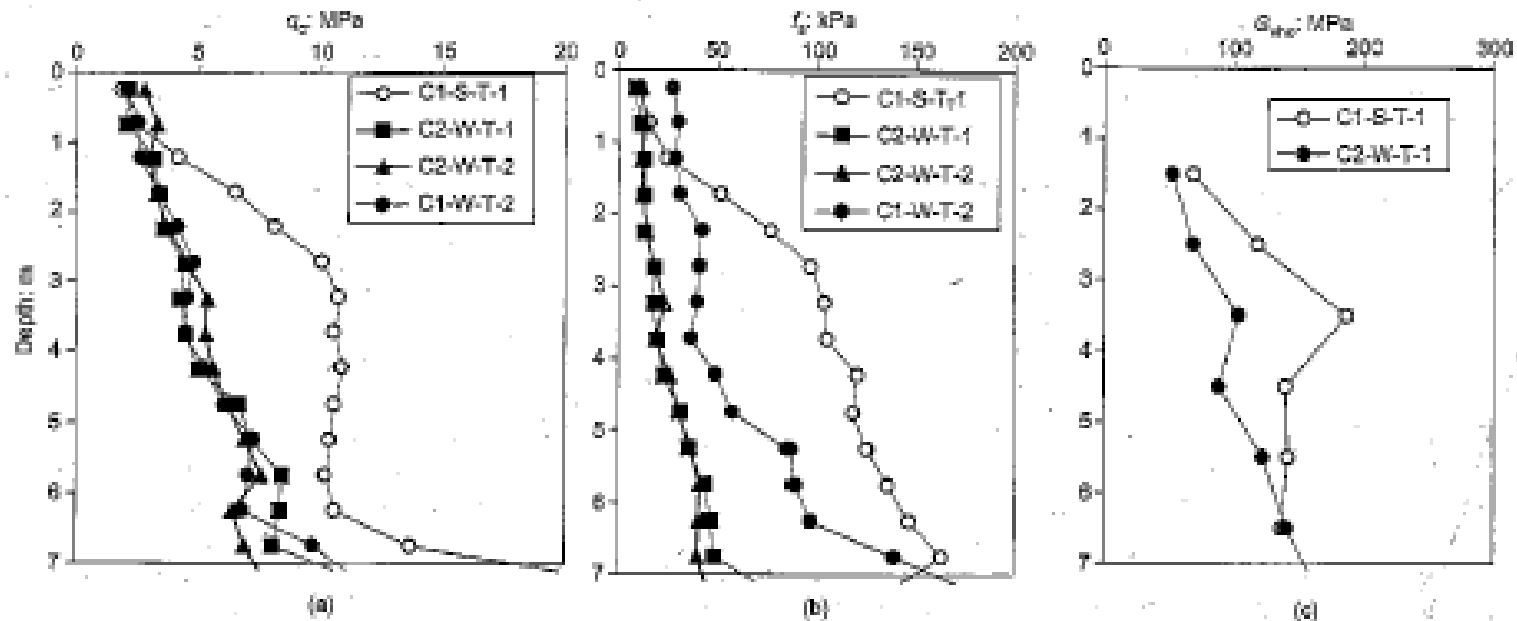
NATURAL UNSATURATED SOIL-SLOPE STABILITY

- Shear strength equation for unsaturated soil conveniently separates environmental boundary conditions from stress related loading. $\tau = c' + (\sigma_n - u_a) \tan \phi' + (u_a - u_w) \tan \phi^b$
- Major problem - determine the reduction in suction and positive pore pressure increase as a function of precipitation history.

TEMPORARY EXCAVATION

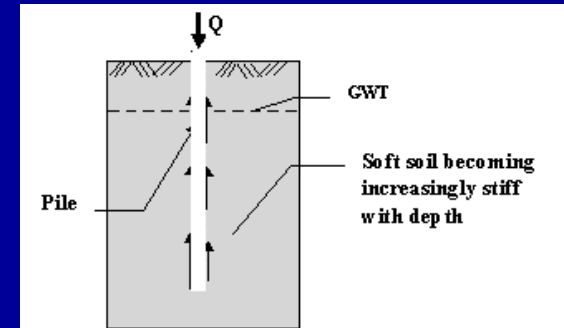


SEASONAL DEPENDANCE OF IN-SITU TEST PARAMETERS



EXAMPLES OF UNSATURATED INTERFACES

❖ PILES EMBEDDED IN UNSATURATED SOIL



❖ RETAINING WALLS WITH UNSAT. SOIL BACK FILL



❖ BURIED PIPE



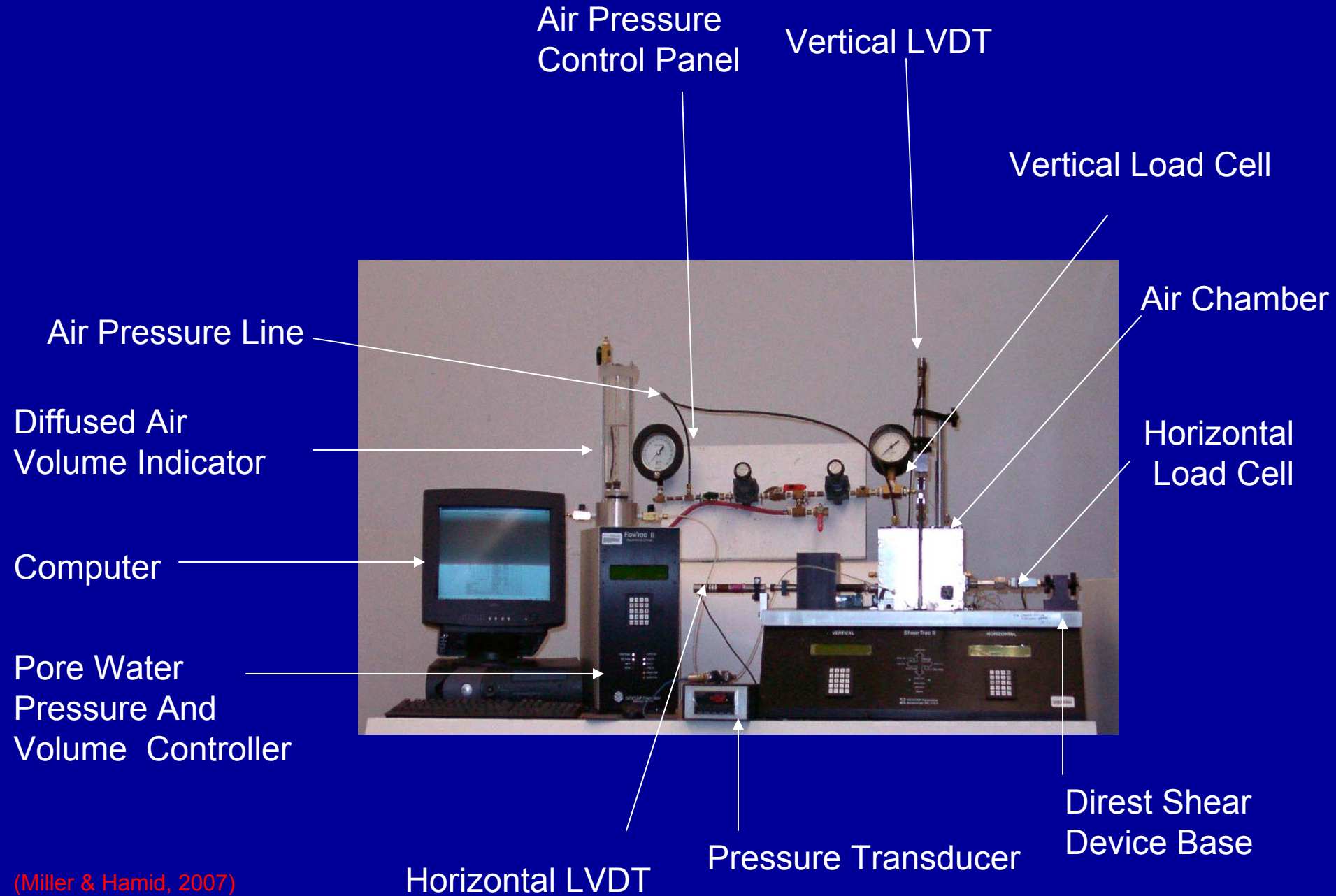
EXTENDED MOHR-COULOMB FAILURE CRITERION

INTERFACE STRENGTH IN UNSATURATED SOIL:

$$\tau_s = c'_a + (\sigma_n - u_a) \tan \delta' + (u_a - u_w) \tan \delta^b$$

LABORATORY TESTING FOR INTERFACE
STRENGTH PARAMETERS c'_a, δ, δ^b

UNSATURATED INTERFACE DIRECT SHEAR APPARATUS



Air Pressure
Control Panel

Vertical LVDT

Vertical Load Cell

Air Chamber

Horizontal
Load Cell

Direct Shear
Device Base

Pressure Transducer

Horizontal LVDT

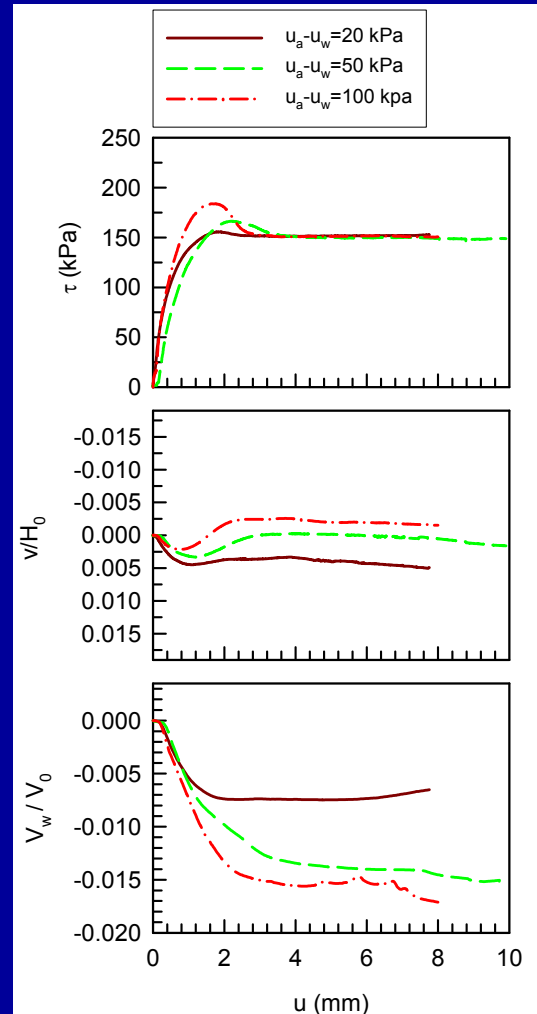
Air Pressure Line

Diffused Air
Volume Indicator

Computer

Pore Water
Pressure And
Volume Controller

INCREASE IN INTERFACE SHEAR STRENGTH WITH SUCTION



THANK YOU

