

Clays: Plasticity and Consistency

Text: Das. (2010). *Principles of Geotechnical Engineering*, § 4.1 - 4.7

When clay minerals are present in fine-grained soil, the soil can be remoulded in the presence of moisture without crumbling. This cohesive nature is caused by the adsorbed water surrounding the clay particles.



<http://sageproject.wikispaces.com/TAFE+-+Soil+Testing+On+Site>

Measures of Consistency

The Atterberg Limits:

In the early 1900s the Swedish scientist Albert Atterberg developed a method to describe the consistency of fine-grained soils with varying water contents.

At a low moisture content, clay soil behaves like a brittle solid.

At a range of intermediate moisture contents the behaviour is semi-solid and then plastic, where the "remoulding" behaviour is dominant.

At high moisture content a clay soil becomes more or less a liquid, ie it flows and is viscous rather than plastic.



http://www.123rf.com/photo_1379858_dry-surface-texture.html



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<http://www.environment.nsw.gov.au/Heritage/research/heraldry/creating.htm>

<http://www.hortus5.com/journal/conquering-clay-soil.html>

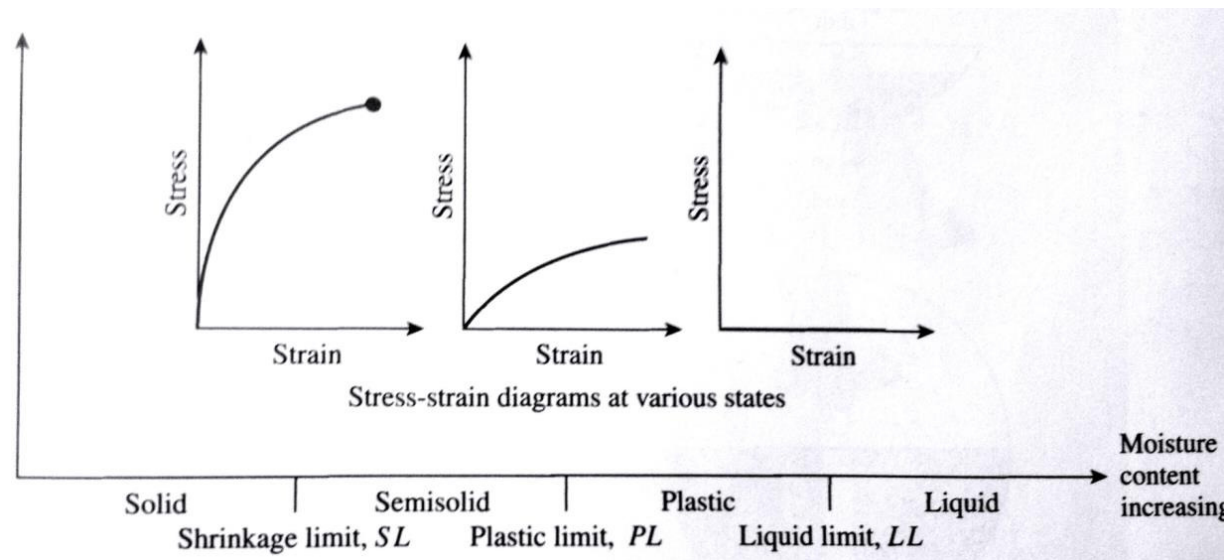


Measures of Consistency

The Atterberg Limits

Transitions between these states are not clear, but they can be consistently identified by three distinct limit states:

- A *shrinkage limit* that divides brittle solid from semi-solid;
- A *plastic limit* dividing semi-solid from plastic behaviour; and
- A *liquid limit* between plastic and liquid behaviour.



The Casagrande Methods

In the 1930s the Austrian-American engineer Arthur Casagrande developed an apparatus to measure the liquid limit. This is now universally applied in soil mechanics and geotechnology and is known as the Casagrande apparatus.

Casagrande also developed general techniques for measuring the plastic and shrinkage limits.

Together with the liquid limit, and based on Atterberg's theory, these techniques provide a practical definition of soil consistency.



Casagrande apparatus for plastic limit tests (left) and UNE student undertaking a limit test (RGG)



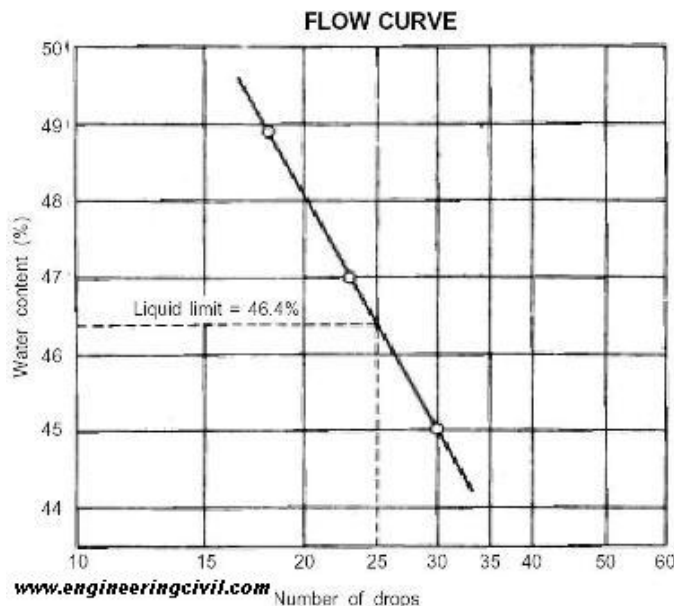
The Casagrande Methods

The Liquid Limit

The liquid limit is defined as the moisture content at which a prepared soil sample develops a standardised form of liquid behaviour.

The limit is found by gradually increasing the moisture content and observing the sample's behaviour.

The liquid limit or LL is then interpolated between observed states.



The Casagrande Methods

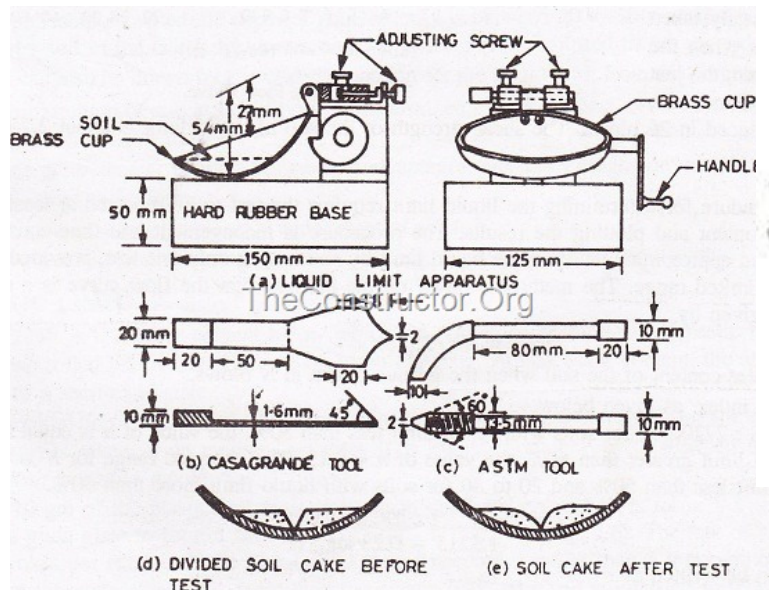
The Liquid Limit

The soil sample is prepared by sieving for fines $< 425 \mu\text{m}$, known as the Casagrande fines. These are then moist-cured for 12 hours.

A small amount (about a palm full) of the prepared fine soil is placed in the Casagrande apparatus and levelled with a spatula. A groove is then cut in the pat with a standard "grooving tool".

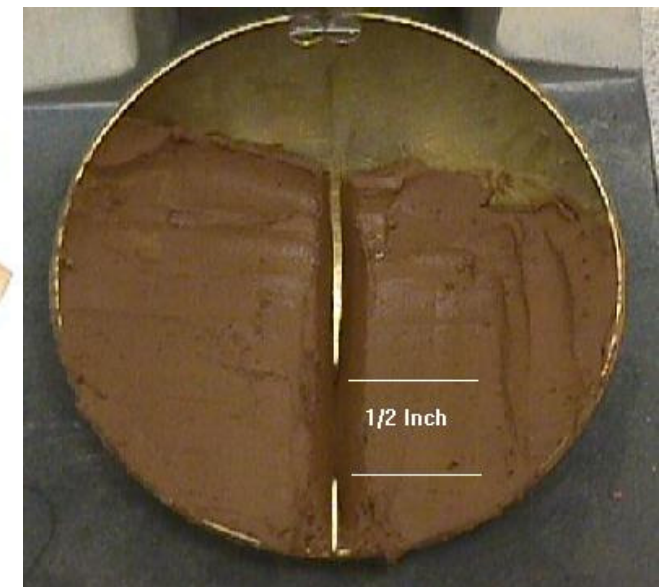
The apparatus is then operated by turning the handle. This taps the soil in the cup, causing it to flow into the groove. The number of taps required to close the groove over a 10 - 12 mm length is noted.

<http://www.shriadinathscientific.in/soilcement-concrete-testingequipments.html>



Count the taps

<http://people.wku.edu/matthew.dettman/matt/prof/ce410/II.htm>



Liquid Limit Test

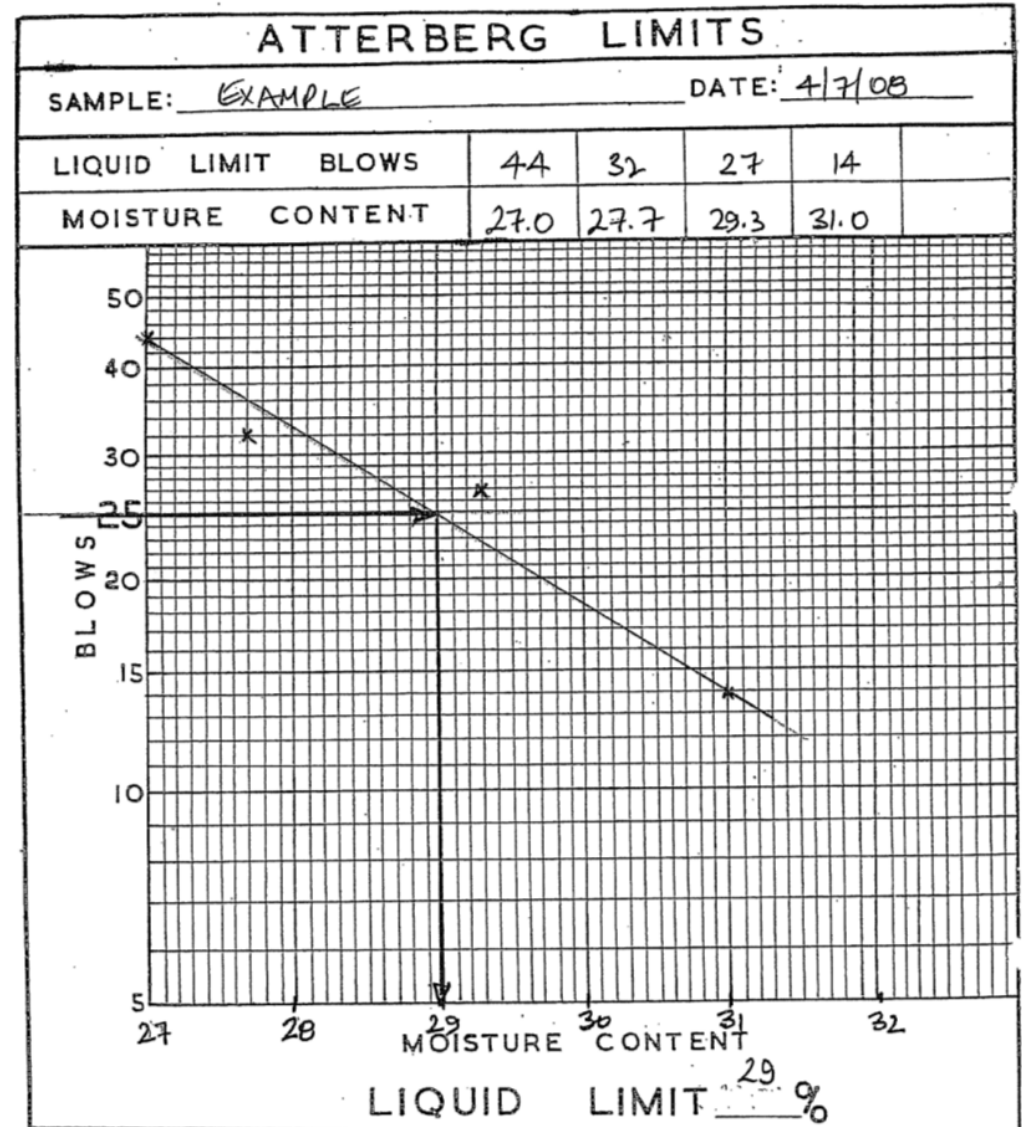
3 or 4 samples are tested in the Casagrande apparatus

Water is added between tests

Samples are retained and tested for moisture content by weighing, drying and weighing again

Moisture content is recorded against no. of taps (blows).

The liquid limit LL is the moisture content corresponding to 25 taps of the apparatus.



The Casagrande Methods

The Plastic Limit

The plastic limit is defined as the moisture content at which a prepared soil sample exhibits a standardised form of plastic behaviour.

The limit is found by gradually *decreasing* the moisture content and observing the sample's behaviour.

The plastic limit or PL is then obtained by measuring the moisture content of at least 4 or 5 repeated tests.



The Casagrande Methods

The Plastic Limit

Cured Casagrande fines $< 425 \mu\text{m}$ are also used in the plastic limit test.

A much smaller amount (about a fingertip) of the prepared fine soil is rolled into a thread on a sheet of glass or glazed ceramic. A car bonnet also works well.

The sample is rolled and re-rolled, allowing air-drying to take place over a few minutes. When the sample has dried to the point where it just begins to crumble at a diameter of 3 mm the sample is placed in an airtight container to prevent further drying.

The process is repeated. At least 4 - 5 samples are then tested for moisture content = PL



<http://www.utest.com.tr/en/markaurunlerx.asp?akid=73&ankid=60>



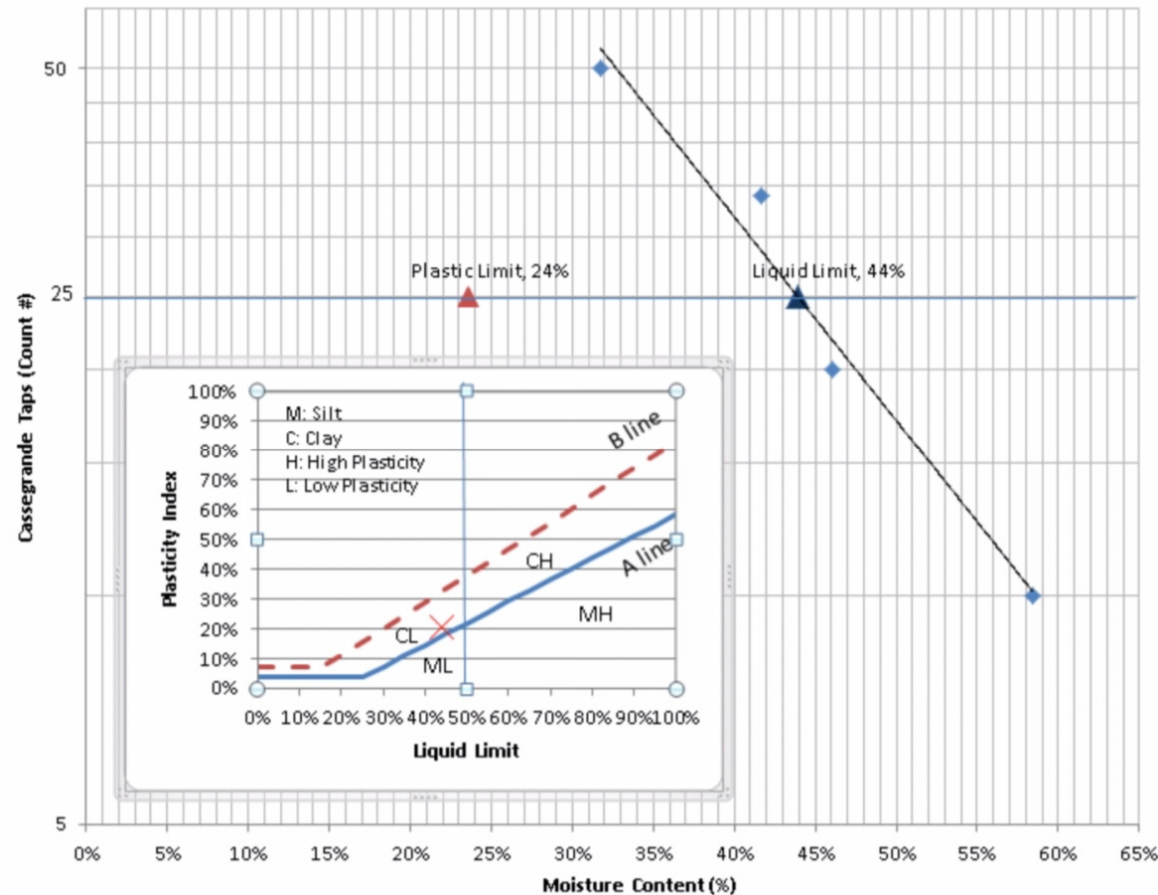
students doing plastic limit tests (RGG)

Plasticity Index

The *plasticity index* is the difference (in %) of the plastic and liquid limits:

$$\text{Plasticity Index: PI} = \text{LL} - \text{PL}$$

The plasticity index is an indication of the reactivity (eg expansiveness) of the soil. Combined with the LL it provides a diagnostic of the soil type:



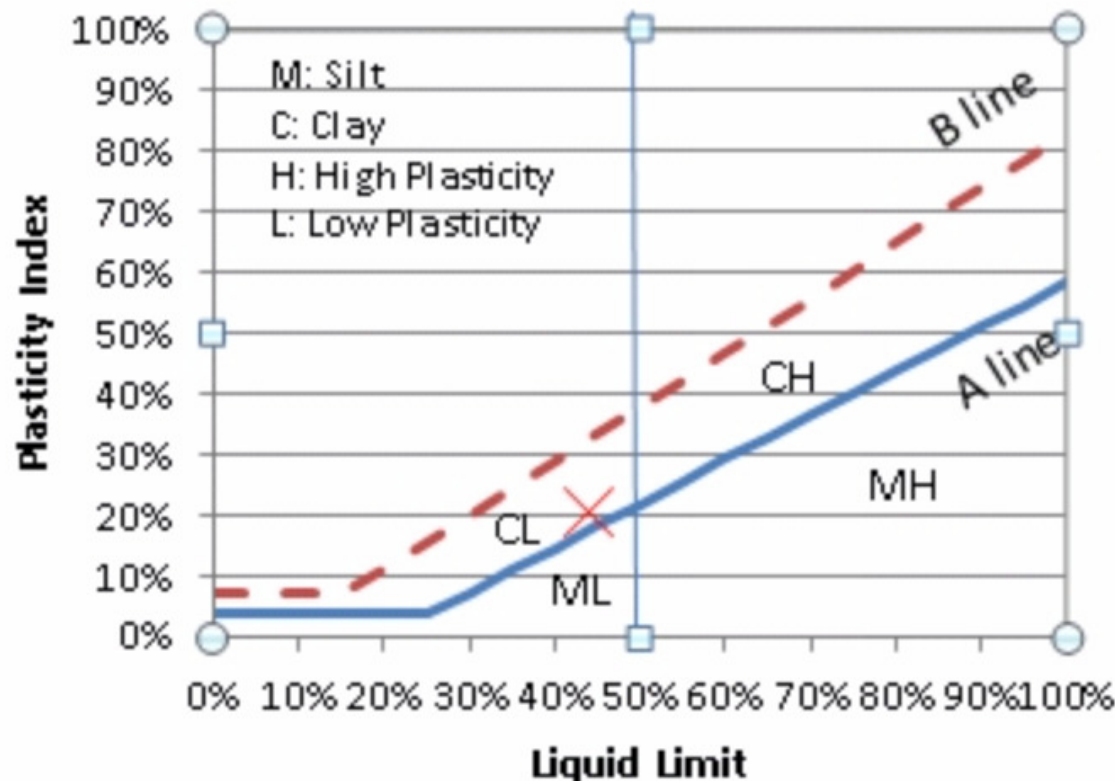
Plasticity Chart

Casagrande's Plasticity Chart is now used in the Unified Soil Classification System.

The *A line* represents a threshold between silt (M) and clay (C) soil.

Moisture content of 50% divides low (L) from high (H) reactive soils.

Soils above the B line are regarded as having unusually high plasticity. This may indicate errors in technique or a highly reactive clay and should be checked.



Activity

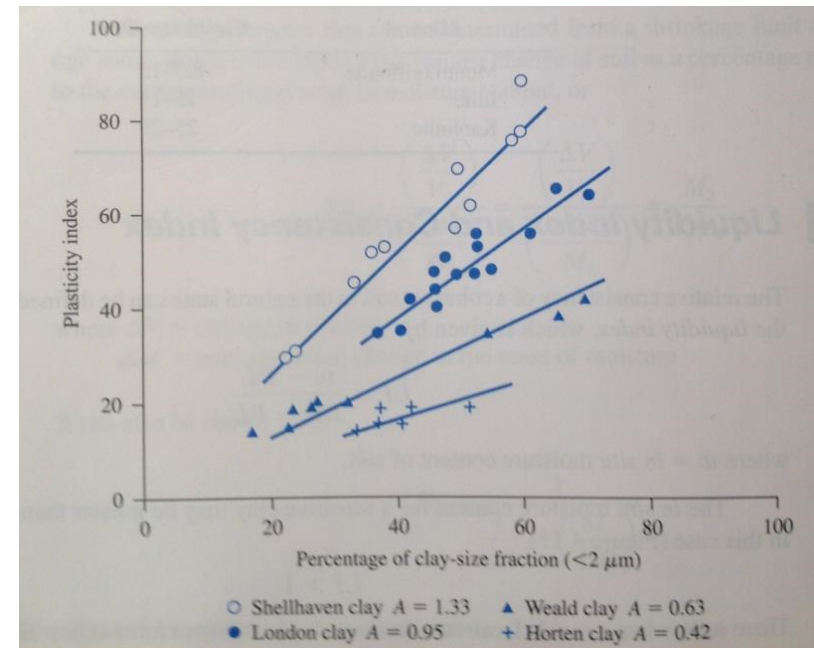
Because the plasticity of soil is caused by the adsorbed water that surrounds the clay particles, we can expect that the type of clay minerals and their proportional amounts in a soil will affect the liquid and plastic limits

Skempton (1953) observed that the plasticity index of a soil increases linearly with the percentage of clay size fraction, and varies systematically with the type of clay.

Skempton defined a soil's *activity* as the slope of the best fit line of PI against clay %:

$$A = \frac{PI}{\% \text{ clay by mass} - C}$$

Where $A \times C$ is the line intercept. The % clay is found by a grading curve or sedimentation test.



The Casagrande Methods

The Shrinkage Limit

The shrinkage limit is defined as the moisture content at which drying shrinkage ceases.

The limit is found by measuring the mass and volume of a soil sample before and after drying. Assuming the lost volume corresponds to an evaporated volume of water, the limit is calculated as:

$$SL = 100\% \times \left[\frac{M_1 - M_2}{M_2} - \frac{\rho_w (V_1 - V_2)}{M_2} \right]$$

This combines the standard moisture content calculation with an estimated change in moisture content at the shrinkage limit.



http://www.humboldtmg.com/astm_liquid_limit_atterberg.html

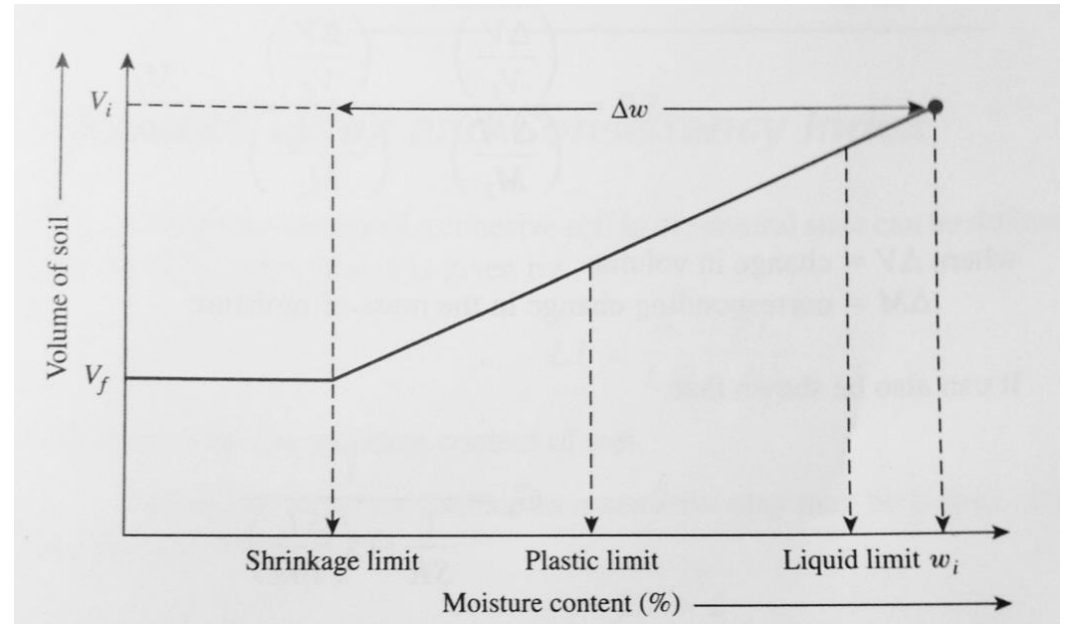
The Casagrande Methods

The Shrinkage Limit

Cured Casagrande fines $< 425 \mu\text{m}$ are also used in the shrinkage limit test.

A ceramic dish of known mass and volume is filled with a pat of soil. The sample is weighed, dried and weighed again.

A measured volume of oil is added to fill the dish. This represents the change in volume, so $V_2 = V_1 - \Delta V$



Shrinkage and Porosity

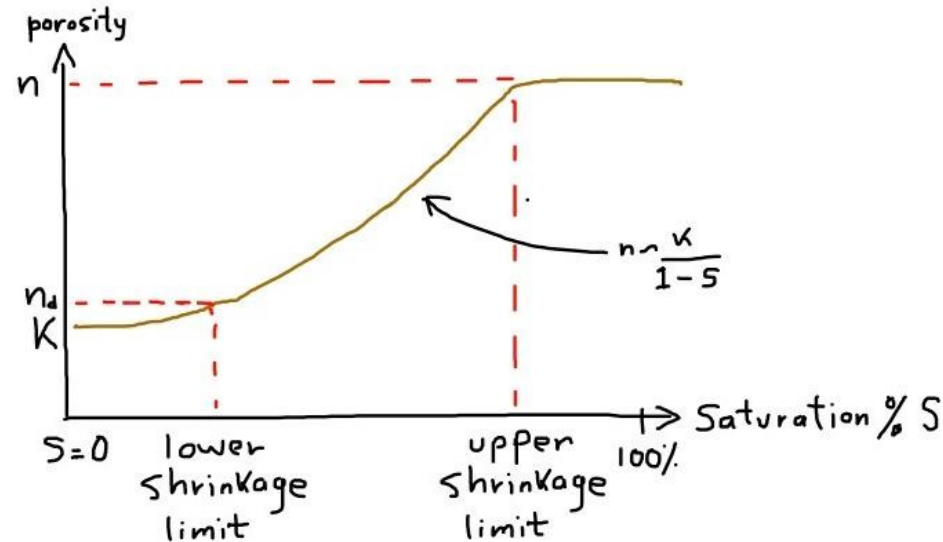
Drying shrinkage tends to occur such that the total air voids volume is constant or increases only slightly as water is removed (Dexter, 1988).

$$V_a = V_v - V_w \approx \text{constant } k$$

$$n(1 - S) \approx k$$

$$n \approx \frac{k}{1 - S}$$

The constant k can be identified with the dry porosity n_d :



Shrinkage and Porosity

The shrinkage test gives a good measure of the dry density of the prepared soil. This enables a *dry porosity* to be estimated from the dry density:

$$\rho_d = \rho_s \frac{1}{1 + e_d}$$

$$e_d = \frac{\rho_s - \rho_d}{\rho_d}$$

$$n_d = \frac{e_d}{1 + e_d}$$

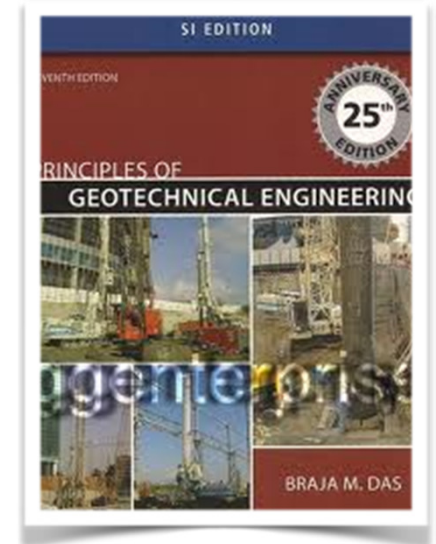
This porosity relates only to the condition of the soil after preparation for Casagrande tests, ie maximum 0.425 mm particles, moist cured overnight.

This may obviously bear no relation to the native soil, but is another indication of the reactivity of the fine components of the soil.

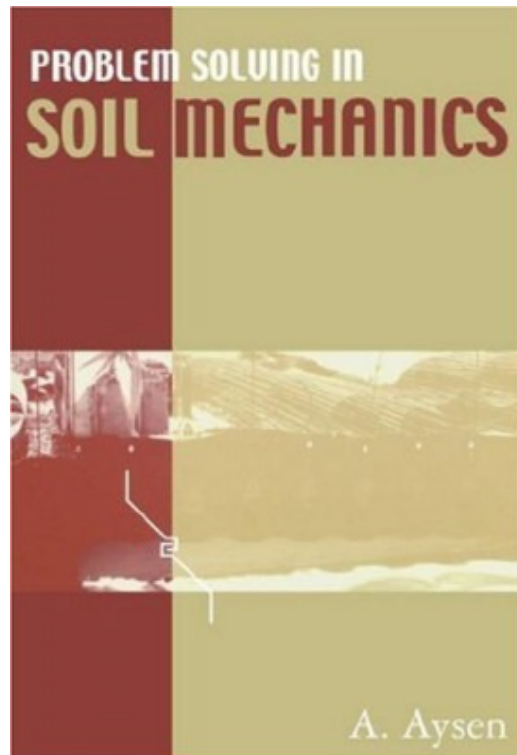
Readings

§s 4.1 - 4.7 Das

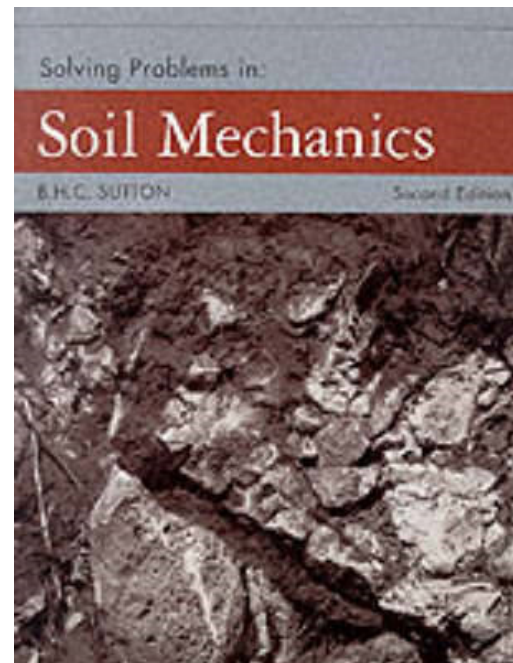
Keywords: Liquid Limit, Plastic Limit, Shrinkage Limit.



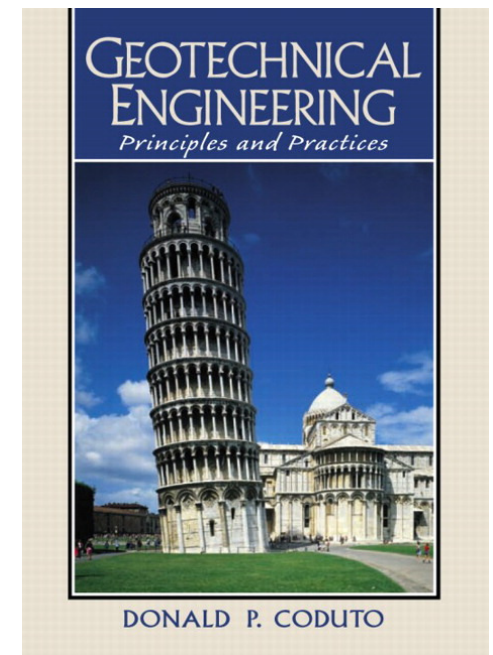
<http://www.bookdepository.com/Solving-Problems-Soil-Mechanics-BHC-Sutton/9780582089716>



<http://www.ebay.com/ctg/Problem-Solving-Soil-Mechanics-A-Aysen-2004-Paperback-/52853454>



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<http://www.tower.com/foundation-design-principles-practices-donald-p-coduto-hardcover/wapi/100501083>