The CRISP Consortium

DETERMINATION OF CRITICAL STATE SOIL PARAMETERS USING LABORATORY TESTS

Original notes by Professor Mike Gunn, South Bank University, London, UK
Produced by the CRISP Consortium Ltd

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1.1 PARAMETERS TO BE DETERMINED

$$\left.\begin{array}{l} M \\ \Gamma \\ \lambda \end{array}\right\} \text{Define critical states} \quad \left\{\begin{array}{l} q = Mp' \\ v = \Gamma - \lambda \ln p' \end{array}\right.$$

κ elastic volumetric compressibility

($v = v_\kappa - \kappa \ln p'$)

\- one other elastic parameter

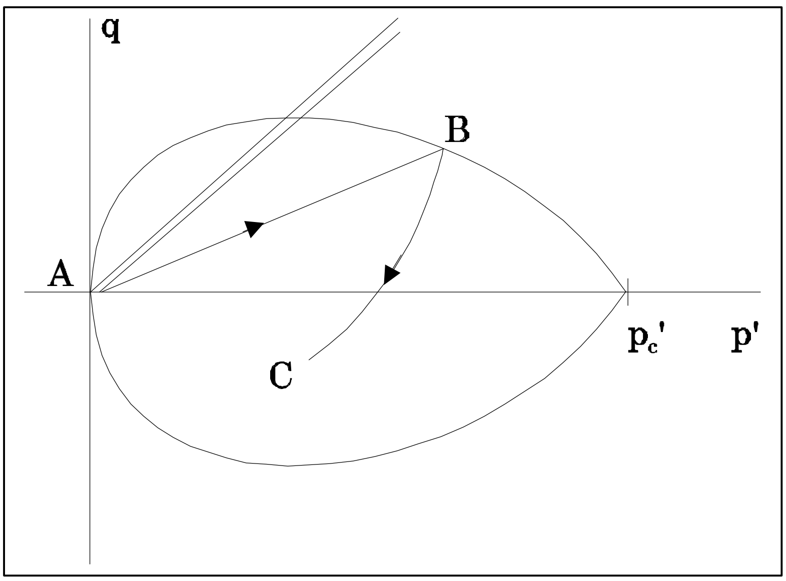
p_c' size of Cam-clay yield locus

<u>Note:</u>

Whereas M, Γ, λ, κ are assumed (in Critical State theory) to be soil properties which do not change, p_c' depends on the past loading of the soil.

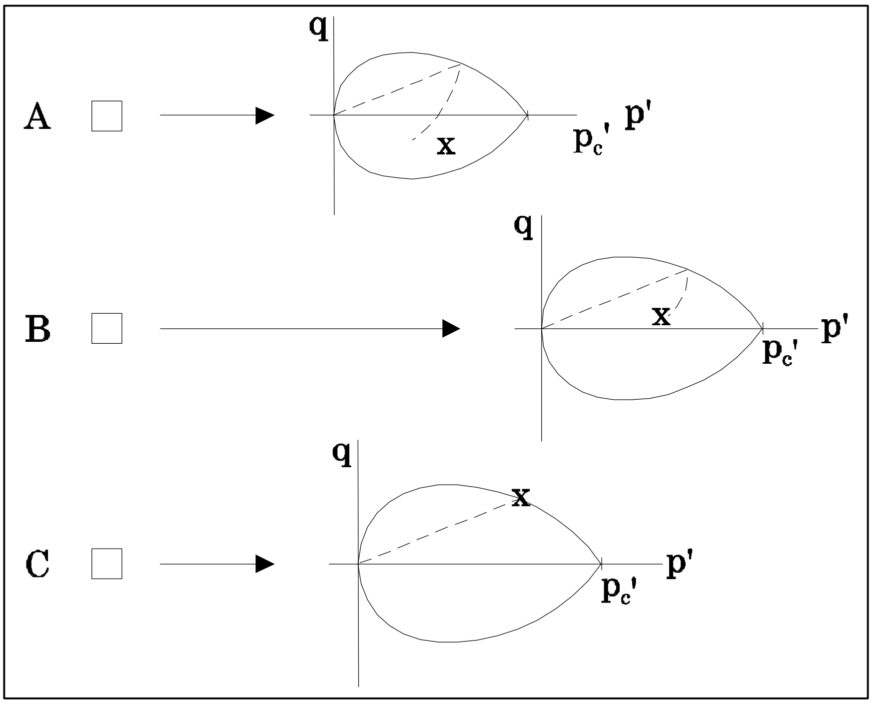
In a soil deposit p_c' will vary with depth.

A typical element of soil in the field follows a stress path as shown below:



AB virgin compression

BC unloading (due to erosion or water table changes) to produce over consolidated state.



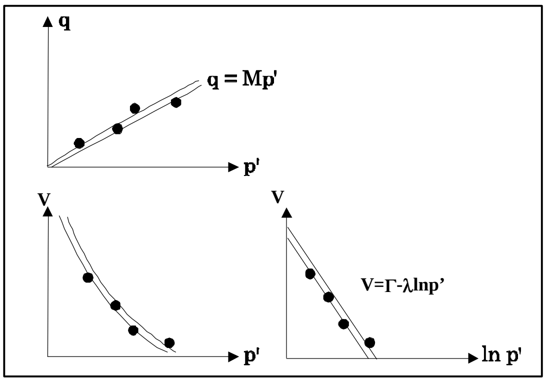
In each case ‘x’ indicates the current effective stresses.

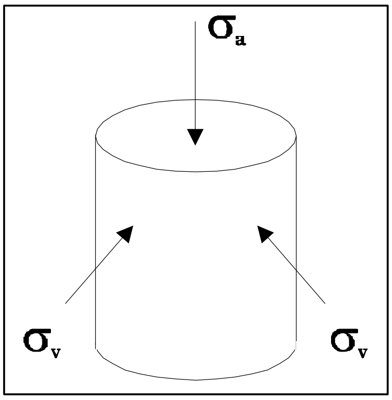
The distance between ‘x’ and the yield surface in each case determines (together with the stress path direction when the soil is loaded) the amount of elastic straining before plastic yielding starts.

Hence it is important to obtain accurate estimates of pc’ if we are going to use CSSM to predict strains and ground movements.

1.2 TRIAXIAL TESTS

If we plot the end points of triaxial tests in (p’, q) and (ln p’, v) plots then we can determine M, Γ and λ.



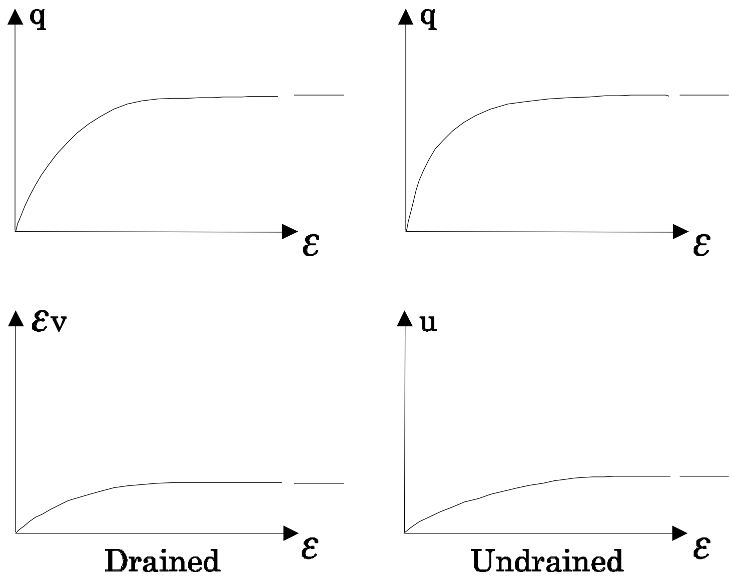


The tests can be drained or undrained (slow, with pore pressure measurement).

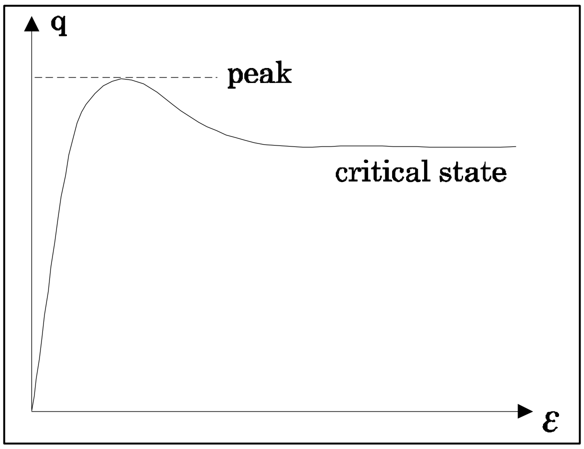
<u>Note</u>

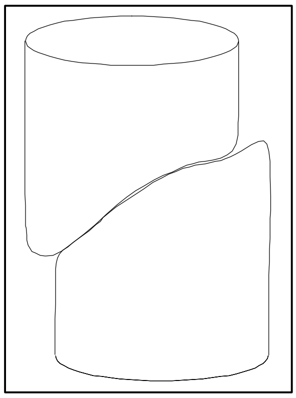
the test samples must be consolidated to a known effective pressure at the start of the tests.

the tests must be continued to large strains to ensure that samples are close to the critical state (in which the samples undergo continuing shear with no change in stress or volume).



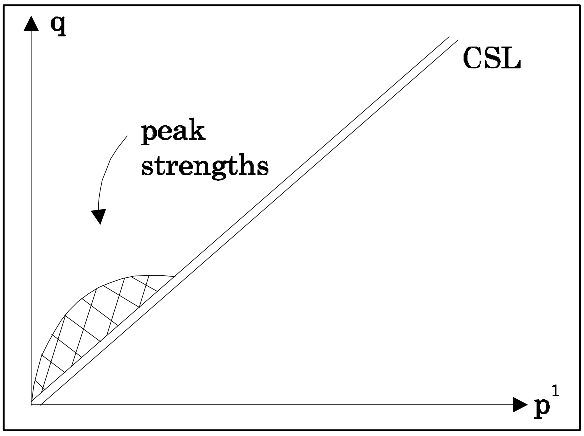
Some samples (particularly heavily over-consolidated ones) fail <u>before</u> the critical state is reached.





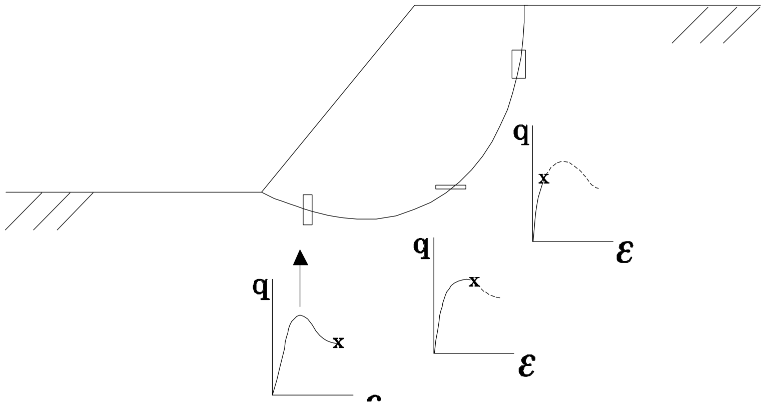
If we could conduct very careful strain - controlled tests on these samples we would see the critical state at a lower stress than the peak.

Peak strengths correspond to points which plot above the Critical State Line in a (p’, q) plot.

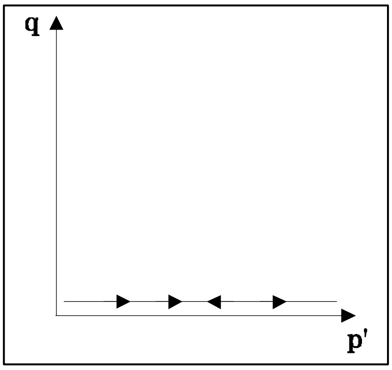


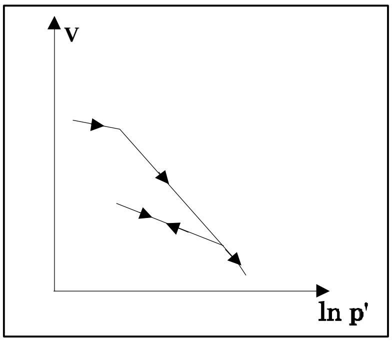
q
CSL
peak
strengths
p'

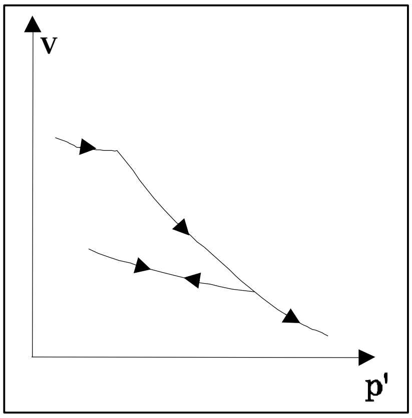
It is unwise to rely on peak strengths in design as the average <u>mobilised</u> strength will always be less than the peak.



We can also find λ and κ by drained isotropic loading and unloading in the triaxial apparatus.







1.3 STRESS PATH TESTS

Different types of test (triaxial compression, triaxial extension) may give different values of M.

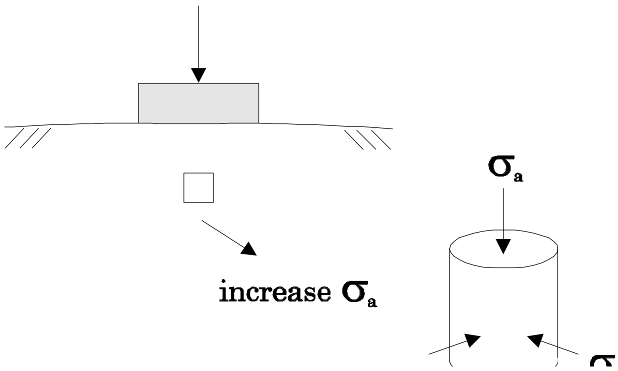
λ (and particularly κ) may vary with stress level / degree of unloading.

For these reasons we usually:

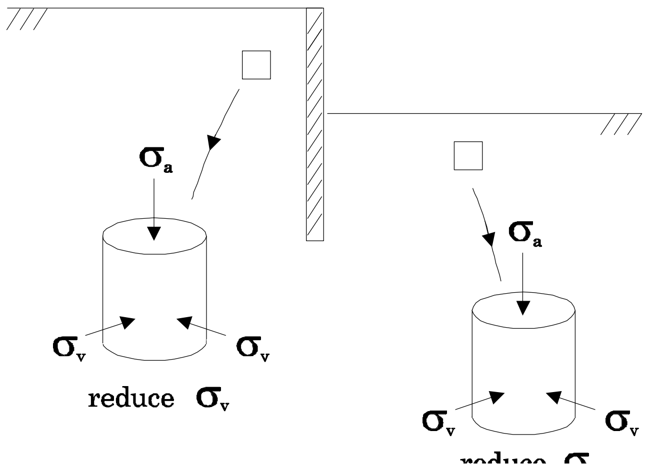
reconsolidate the soil sample to its field effective stresses

apply a stress path in the triaxial test corresponding to the expected stress path during construction in the field.

Footings and slabs



Embedded retaining walls



1.4 OEDOMETER TESTS

According to Cam-clay theory, one-dimensional loading also gives a "λ - line" in a (V, ln p') plot.

Also, it is easy to show that:

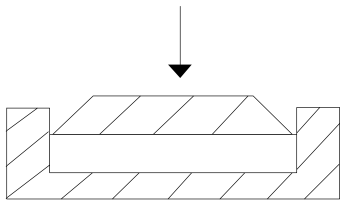
$$l = \frac{C_c}{2.3}$$

$$k = \frac{C_s}{2.3}$$

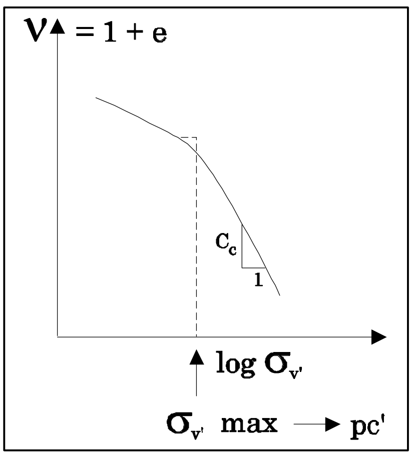
where C_c and C_c are obtained by the standard interpretation of the oedometer test.

(NB: ln (10) = 2.303)

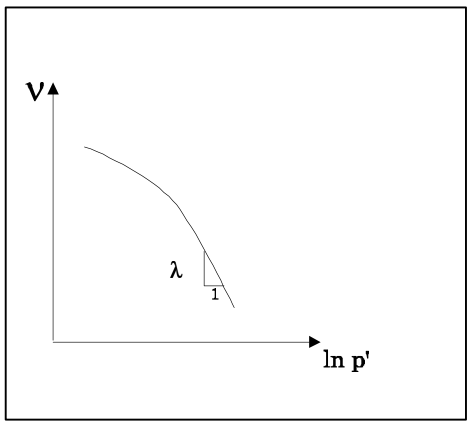
schematic of apparatus



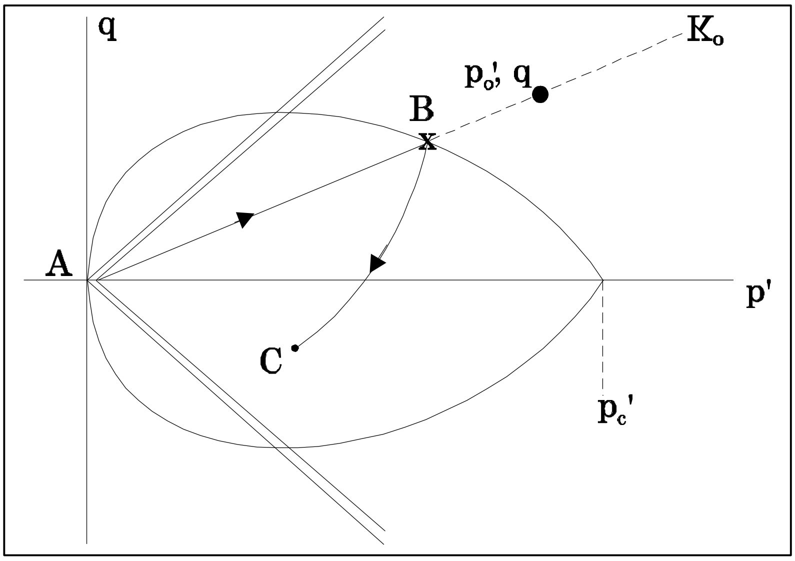
"conventional" plot e, log(σ'_v)



CSSM plot v, ln p'



1.5 Size of Yield Surface



To get size of current yield surface:

assume K_o for normally consolidated state $K_o = 1\text{-}\sin\phi'$

where $K_o = \sigma'_h / \sigma_v'$

$$p_o' = \left(\frac{1+2K_o}{3}\right)s_v'_{max}$$

$q_o = (1 - K_o)\,\sigma_v'_{max}$

rearrange equation for yield surface:

$q = Mp' \ln\left(\frac{p_c'}{p'}\right)$

$\Rightarrow p_c' = p' \exp\left(\frac{q}{Mp'}\right)$

substitute $p' = p_o$

and $q = q_o$

to get p_c'

1.6 INDEX TESTS

These are done to establish the moisture contents corresponding to the Plastic Limit (PL) and Liquid Limit (LL) of the soil.

If we assume that the strength of the soil at the Plastic Limit is 100 times the strength at the Liquid Limit, then:

$$l = \frac{V_L - V_p}{\ln 100} = \frac{(w_L - w_p)G_s}{\ln 100}$$

or

$$l = \frac{\mathrm{PI\ x\ G_s}}{160}$$

where PI is % Plasticity Index.