

## Shear Strength: CU and CD Triaxial Tests

**Q1.** Consolidated undrained (CU) triaxial tests were performed on two specimens of overconsolidated clay at different consolidation stresses and the following results were obtained:

	Specimen I	Specimen II
Consolidation Stress, $\sigma_3$	150 kPa	300 kPa
Maximum Principal Stress Difference, $(\sigma_1 - \sigma_3)_{\max}$	197 kPa	295 kPa
Excess pore water pressure at failure, $\Delta u_f$	78 kPa	121 kPa

Plot the total and effective Mohr's circles at failure for both specimens and determine:

- a) the total shear strength parameters,  $c_T$  and  $\phi_T$ ;
- b) the effective shear strength parameters, and  $c'$  and  $\phi'$
- c) Describe the steps in the graphical solution for a) and b).

**Solution:**

If use  $\Delta u_f = +78$  kPa and  $+121$  kPa for specimen 1 and specimen 2 respectively:

For Specimen 1,

$$\sigma_3 = 150 \text{ kPa}$$

$$(\sigma_1 - \sigma_3)_f = 197 \text{ kPa}$$

$$\Delta u_f = +78 \text{ kPa}$$

and thus,

$$\sigma_{1f} = (\sigma_1 - \sigma_3)_f + \sigma_3 = 197 + 150 = 347 \text{ kPa.}$$

Effective stresses are:

$$\sigma'_3 = \sigma_3 - \Delta u_f = 150 - 78 = 72 \text{ kPa}$$

$$\sigma'_{1f} = \sigma_{1f} - \Delta u_f = 347 - 78 = 269 \text{ kPa}$$

For Specimen 2,

$$\sigma_3 = 300 \text{ kPa}$$

$$(\sigma_1 - \sigma_3)_f = 295 \text{ kPa}$$

$$\Delta u_f = 121 \text{ kPa}$$

and thus,

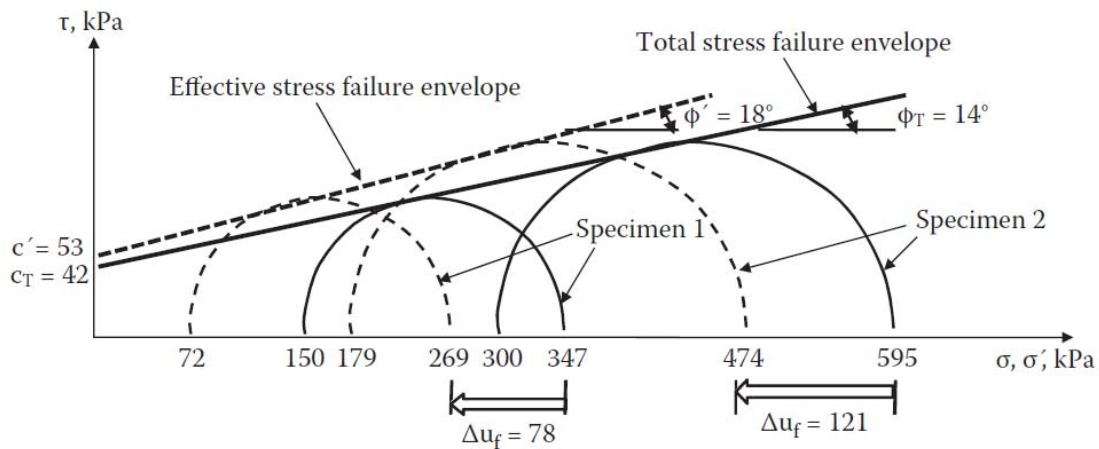
$$\sigma_{1f} = (\sigma_1 - \sigma_3)_f + \sigma_3 = 295 + 300 = 595 \text{ kPa}$$

Effective stresses are

$$\sigma'_3 = \sigma_3 - \Delta u_f = 300 - 121 = 179 \text{ kPa}$$

$$\sigma'_{1f} = \sigma_{1f} - \Delta u_f = 595 - 121 = 474 \text{ kPa}$$

From those values, Mohr's circles at the failure are drawn as shown in the Figure. The total stress failure envelope is drawn tangent to the total stress Mohr's circles (solid lines), and the effective stress failure envelope is drawn tangent to the failure circles in effective stresses (dotted lines). Accordingly,  $c_T = 42 \text{ kPa}$ ,  $\phi_T = 14^\circ$  for the total stress, and  $c' = 53 \text{ kPa}$ ,  $\phi' = 18^\circ$  for the effective stress are scaled off the plot.



If use  $\Delta u_f = -78$  kPa and  $-121$  kPa for specimen 1 and specimen 2 respectively.

For specimen 1:

$$\sigma_{1f} = (\sigma_1 - \sigma_3)_f + \sigma_3 = 197 + 150 = 347 \text{ kPa}$$

$$\sigma'_3 = \sigma_3 - \Delta u_f = 150 - (-78) = 228 \text{ kPa}$$

$$\sigma'_{1f} = \sigma_{1f} - \Delta u_f = 347 - (-78) = 425 \text{ kPa}$$

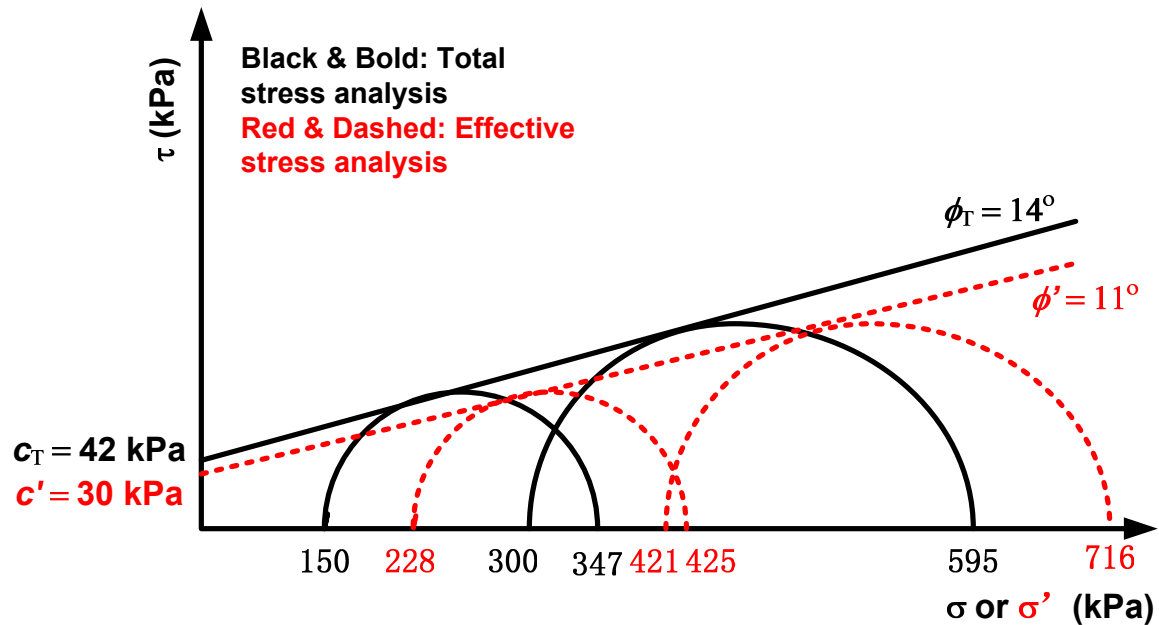
For specimen 2:

$$\sigma_{1f} = (\sigma_1 - \sigma_3)_f + \sigma_3 = 295 + 300 = 595 \text{ kPa}$$

$$\sigma'_3 = \sigma_3 - \Delta u_f = 300 - (-121) = 421 \text{ kPa}$$

$$\sigma'_{1f} = \sigma_{1f} - \Delta u_f = 595 - (-121) = 716 \text{ kPa}$$

Procedures for determining the  $c_T$  and  $\phi_T$  and  $c'$  and  $\phi'$  are similar to the previous solution:



Reasonable variances in the determined  $c_T / \phi_T$  and  $c' / \phi'$  values are allowed considering the individual bias.

**Q2.** For a normally consolidated clay, it was found that  $\phi_T = 16^\circ$  and  $\phi' = 28^\circ$ . If a similar specimen is sheared with  $\sigma_3 = 120$  kPa in consolidated undrained (CU) test with pore water pressure measurements:

- Plot the effective and total stress Mohr circles for the failure condition;
- Estimate the principal stress difference at failure,  $(\sigma_1 - \sigma_3)_f$ , and the induced excess pore water pressure at failure,  $\Delta u_f$

c) Describe the steps in the graphical solution for a) and b).

**Solution:**

1. Since the clay is normally consolidated, draw the total and effective stress failure envelopes through the origin ( $c' = 0$ ,  $c_T = 0$ ) with  $\phi_T = 16^\circ$  and  $\phi' = 28^\circ$ , respectively, as seen in the Figure.
2. Draw the total stress failure Mohr's circle with  $\sigma_3 = 120$  kPa, which touches the total stress failure envelope and read  $\sigma_{1f} = 205$  kPa on the graph. And thus the principal stress difference at failure is  $(\sigma_1 - \sigma_3)_f = 205 - 120 = 85$  kPa (diameter of the Mohr's circle).
3. With the same diameter as the total stress failure Mohr's circle, draw the effective stress failure Mohr's circle, which touches the effective stress failure envelope and read  $\sigma'_3 = 48$  kPa and  $\sigma'_{1f} = 133$  kPa on the graph.
4. The induced excess pore water pressure at failure is the magnitude of horizontal shift between the two Mohr's circles, and thus  $\Delta u_f = 205 - 133 = 72$  kPa as seen in the graph.

