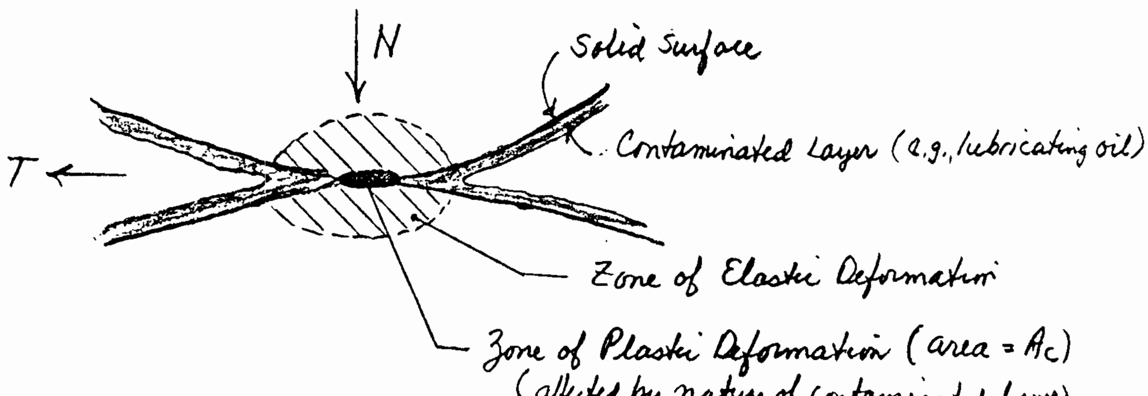
IV STRENGTH GENERATION IN SOILS (= 1.361 Part II 2, Sect. 2.6)

1. FRICTIONAL RESISTANCE

1) Terzaghi-Bowden-Tabor Adhesion theory (developed for metals) (1940s)

All surfaces are rough at microscopic scale. Therefore get contacts at asperities



- Normal force = $N = A_c \cdot \bar{\bar{\sigma}}_Y$, where $\bar{\bar{\sigma}}_Y$ = yield stress
  Shear force = $T = A_c \cdot \bar{\bar{\tau}}$, where $\bar{\bar{\tau}}$ = shear strength due to primary valence bonding

- Increasing $N \rightarrow$ increasing $A_c \rightarrow$ increasing T
  Decreasing $N \rightarrow$ decreasing A_c due to elastic rebound $\rightarrow$ decreasing T
  } Constant coef. of friction $= T/N = \bar{\bar{\tau}}/\bar{\bar{\sigma}}_Y = \tan\phi'_\mu$

- Tests on Quartz by Bromwell (1966) (Sheet A)
  Ultrasmooth surfaces, $\phi'_\mu = 10 - 35°$ is function of surface contamination
  Regular, rough surfaces, $\phi'_\mu = 25 \pm 5°$ independent of contamination

2) Granular Soils

$$\sigma' = \bar{\bar{\sigma}} \cdot a_c \text{, where } \bar{\bar{\sigma}} \approx 10{,}000 \text{ atm at typical stress levels}$$

(For $\sigma' = 1$ atm, $a_c = 0.01\%$)

3) Cohesive Soils

a) Are there mineral to mineral contacts in clays at typical σ' levels (say $\sigma' \geq 1$ atm)?

- Ladd (1961) back calculated likely values of contact shear stresses → $\bar{\bar{\tau}} \approx$ 100's of atm. ∴ must have primary valence bonding at min.-min. contacts
- Mitchell (1993 book), but based on research in 1960's using rate process theory → activation energy of bonding

Material	Activation Energy (kcal/mol)	Calorie x 4.2 = J = N·m
Water	4-5	
Ice	10-15	
Metals & Concrete	≥ 50	
Soil	30±5	Sands & clays, both wet & dry!

b) Conclusion: clays develop a frictional resistance (ϕ') due to primary valence bonding at contacts. However, get wide variation in ϕ' due to wide variation in $\bar{\bar{\sigma}} \cdot a_c / \sigma'$ ratio (Part A V) i.e. surface forces affect ratio and ability to reform broken contacts

2. COHESIVE RESISTANCE (True Cohesion)

1) Very controversial since difficult to measure or even define

2) However one can list potential sources of true cohesion

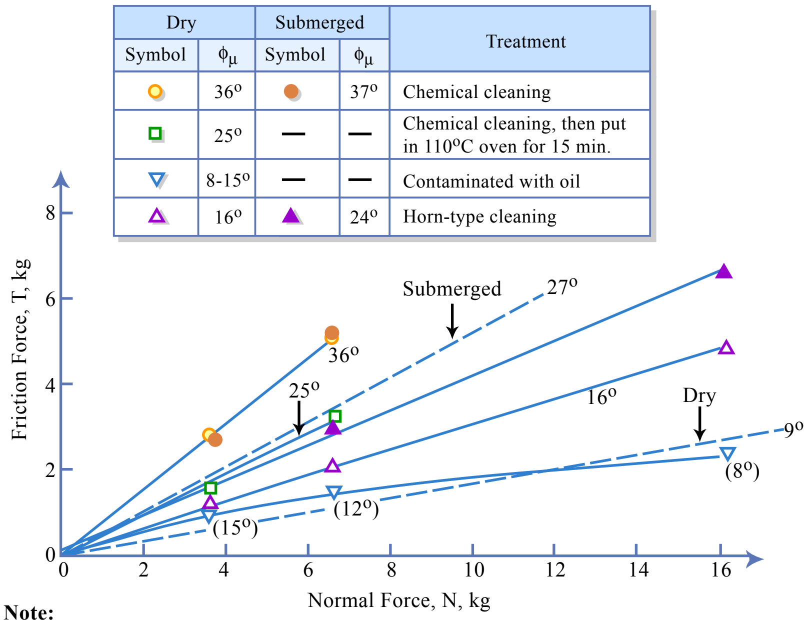
a) Cementation due to carbonates, Fe/Al oxides, amorphous silica
- Difficult to quantify, but certainly occurs → brittle behavior

Calcareous sands, calcareous clay shales, Champlain clays, (Will give examples in Parts C & D)

b) When physico-chemical $\bar{\bar{\sigma}}_a > \bar{\bar{\sigma}}_r$, so that added energy required to break contacts during shearing (Energy diagrams Part A III)

c) Adsorbed water ?? Some still promote "ice-like" behavior

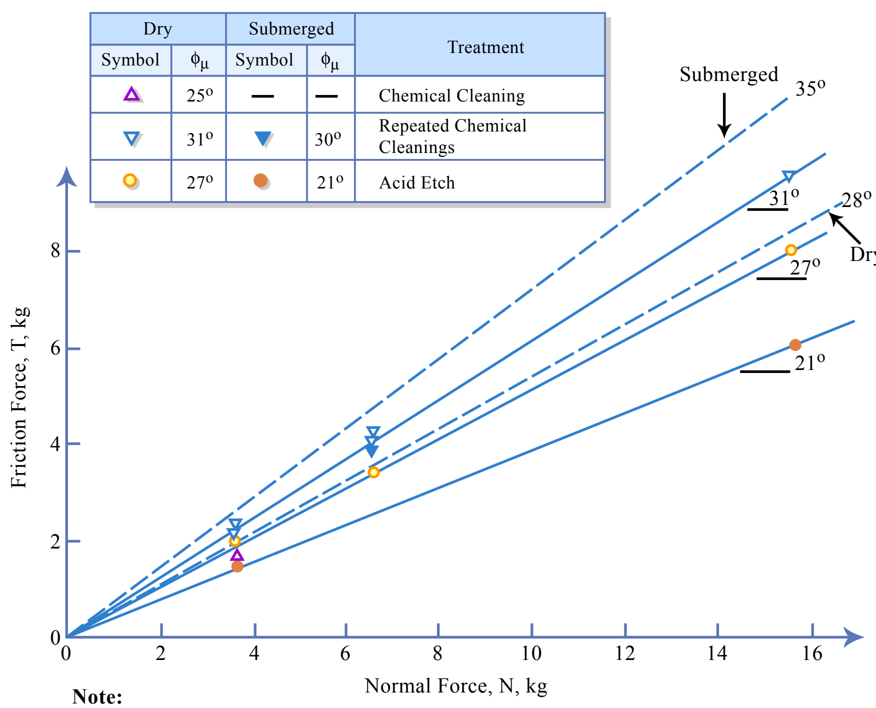
NOTE: Unconfined shear strength of ovendried remolded clay can be high. Can't be due to adsorbed water; must be caused by $\bar{\bar{\sigma}}_a > \bar{\bar{\sigma}}_r$



Note:
Dashed curves are from Horn and Deere (1962)

Results of Atmospheric Friction Tests on Smooth Quartz Surface

Figure by MIT OCW.



Note:
Dashed curves are from Horn and Deere (1962)
Geot. 12(4), 319-335

Results of Atmospheric Friction Tests on Rough Quartz Surfaces

Figure by MIT OCW.

Adapted from Bonaparte & Mitchell (1981) UC Berkeley NASA Contractor Report 3365

Bromwell (15) = PhD thesis by L.G. Bromwell (1966) on "Friction of Quartz in a High Vacuum" to predict behavior of lunar soils (CCL's 1st PhD student)

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