Lessons learned from Cambridge (UK) Soil Models.

Andrew N. Schofield GeoVirginia 2013

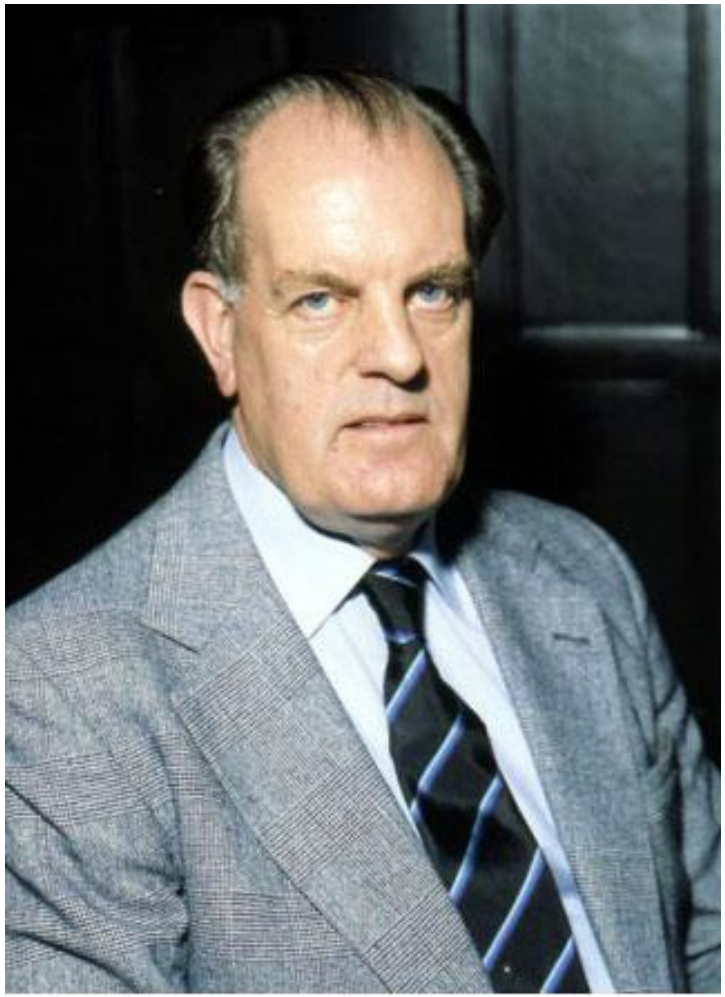
Trench & Tunnel heading damage

1) Tunnel faces can be supported by compressed air, or as in Crossrail, by earth pressure balance.

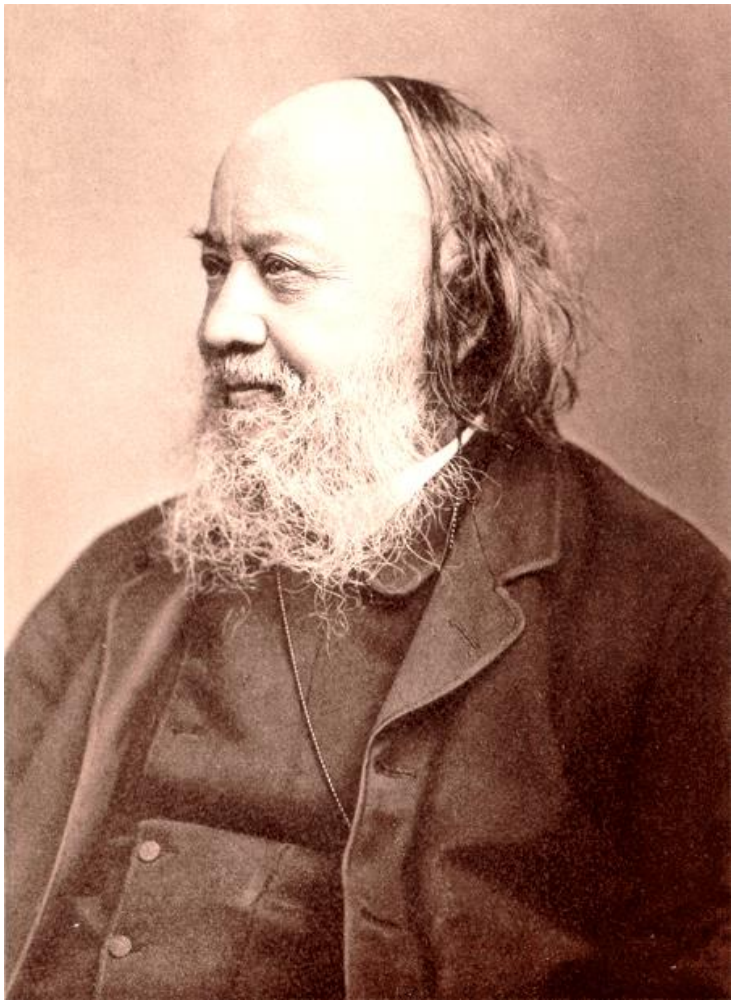
2) A trench for a sewer pipe with a backdrop has a deep cut face without heading support pressure.

3) Centrifuge model tests with authentic soil states revealed new heading damage mechanisms.

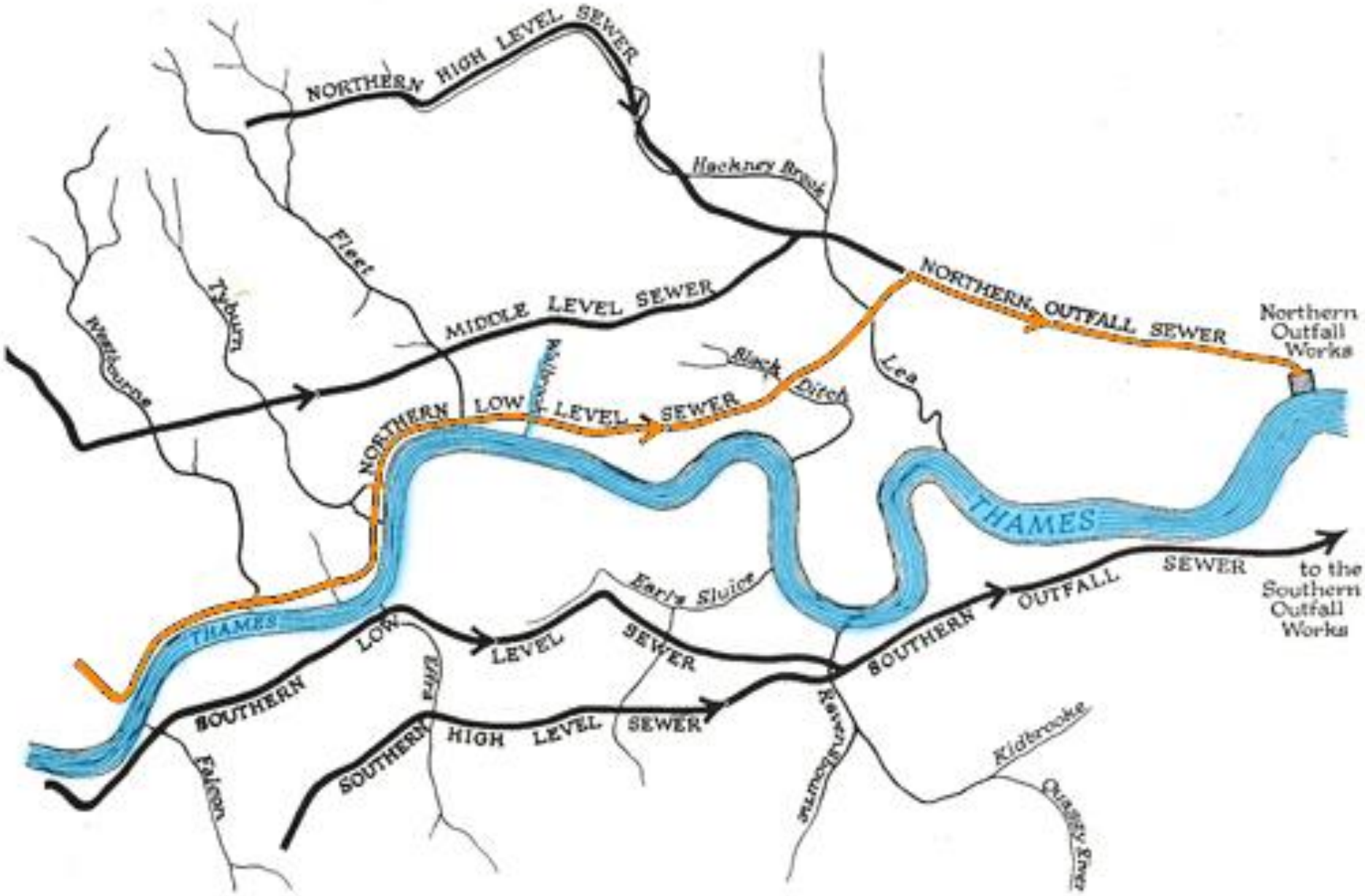
Crossrail – 550 tonne tunnelling machine Elizabeth being lowered into 40m deep shaft at Limmo Peninsula



Sir Denis Rooke
1924-2008

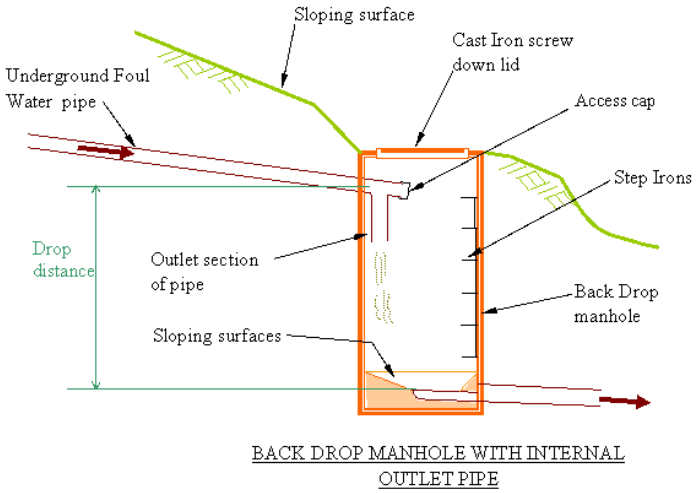


Sir Edwin Chadwick
1800-1890

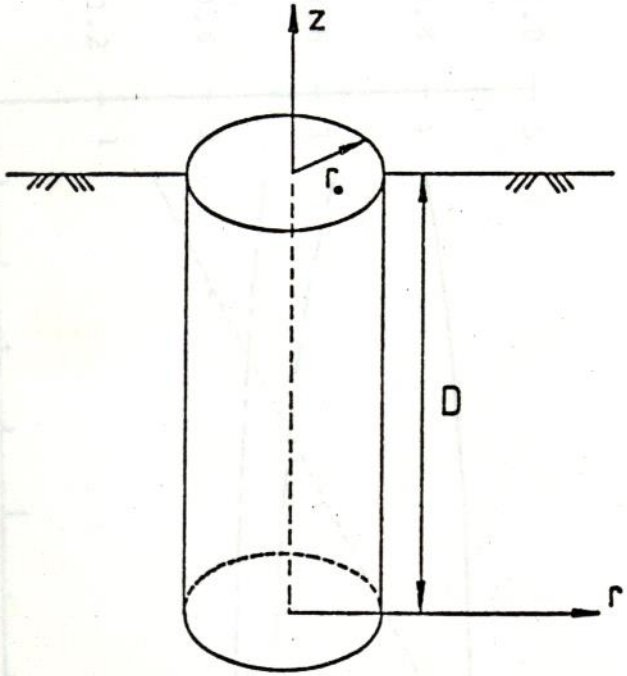


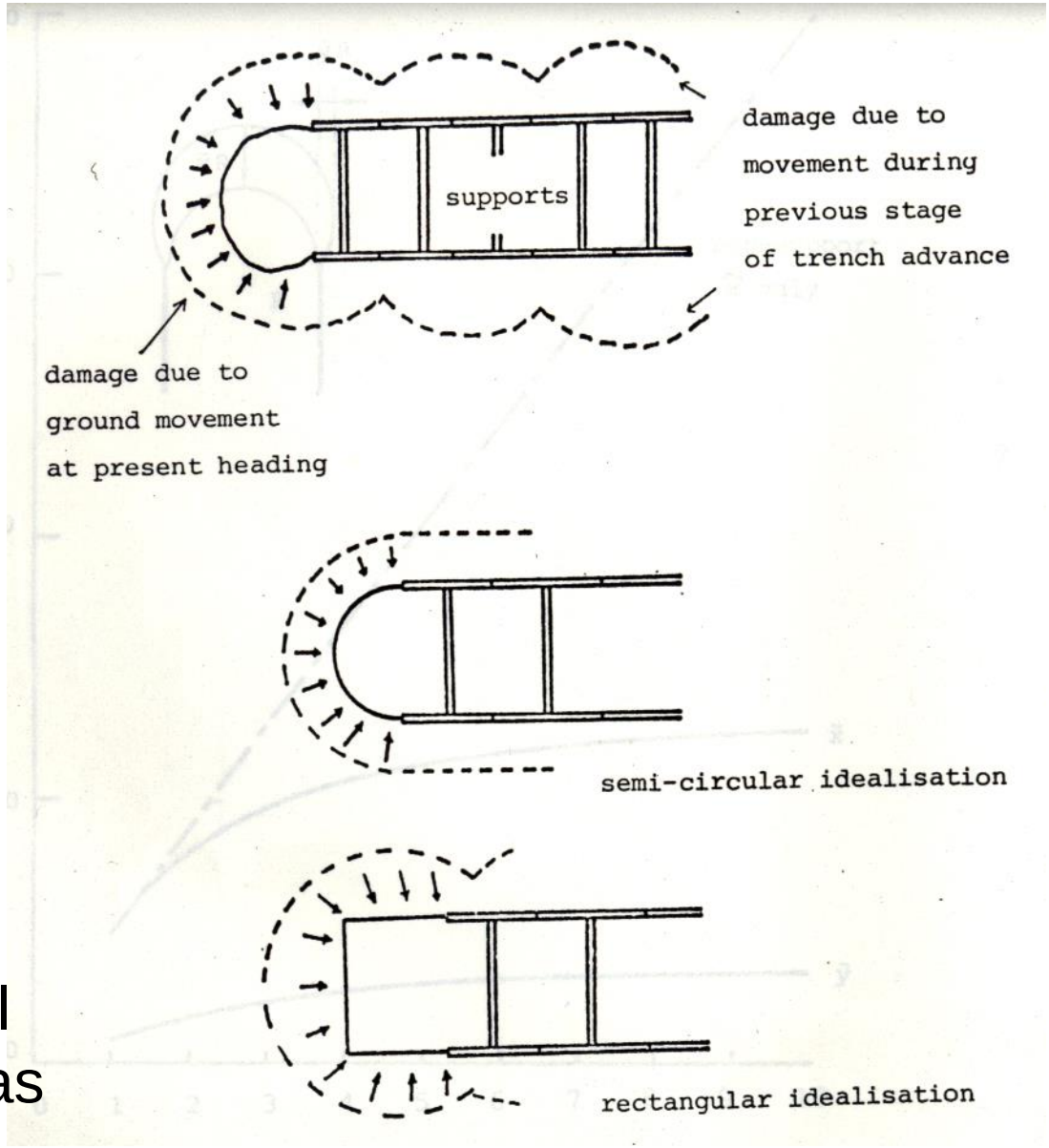
Bazalgette's sewer system. Image: N. Barton, "Lost Rivers of London" (Modified)

A backdrop will reduce sewer flow rate, but will cause deep trench-heading damage

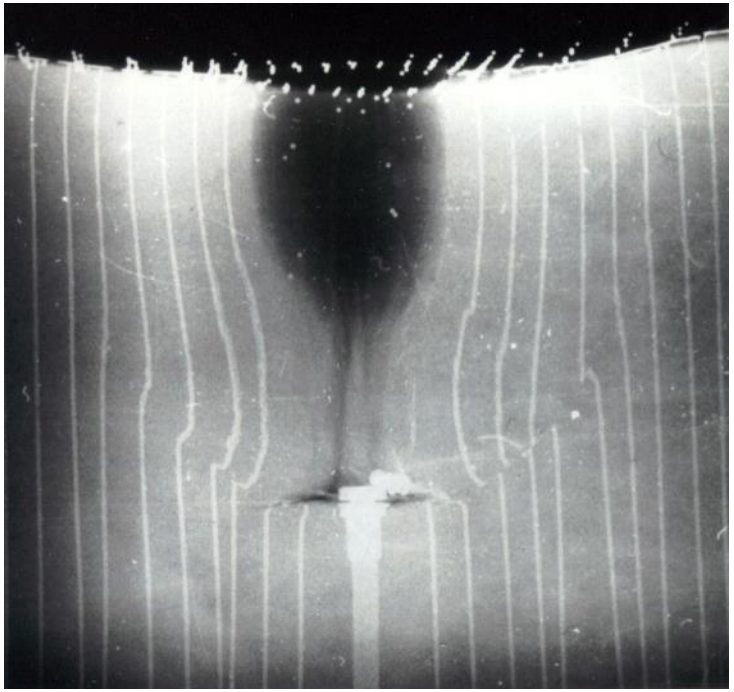


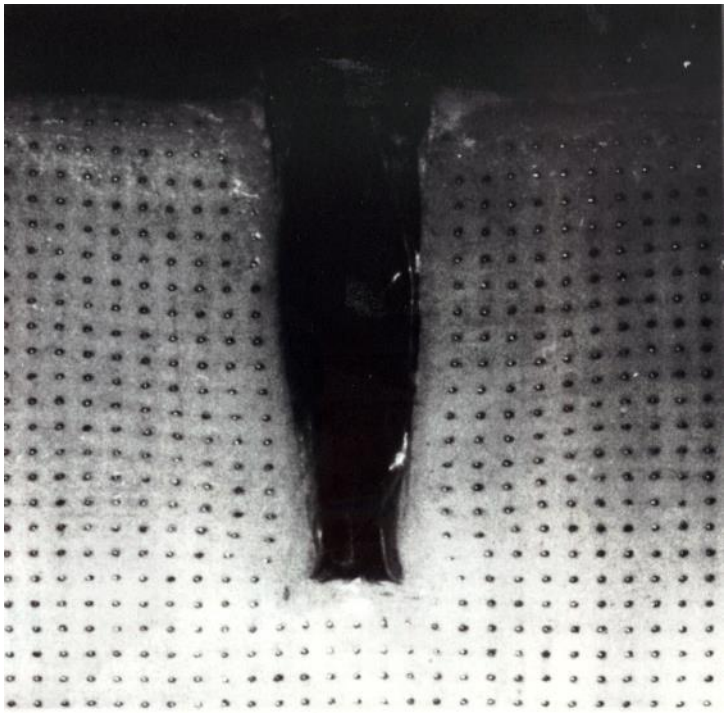
BACK DROP MANHOLE WITH INTERNAL OUTLET PIPE

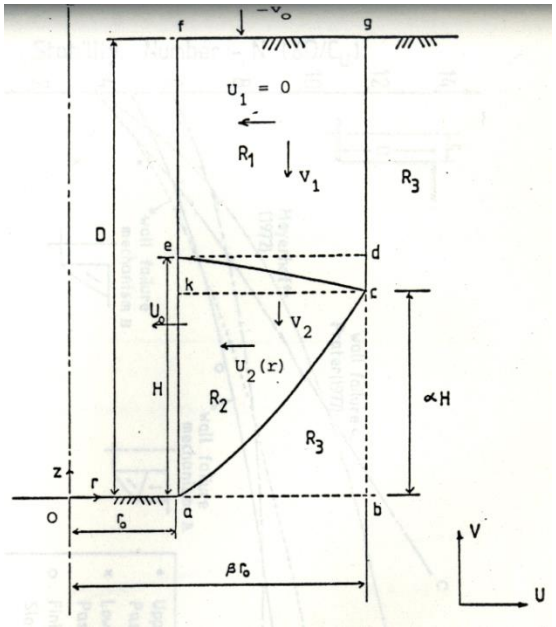




Kusakabe's model tests for British Gas







1980 centrifuge-model test by PhD research student Osamu Kusakabe (now Professor, Tokyo Institute of Technology) showed axisymmetric circular shaft failure mechanism.

Alternative soil strength models and theories

Terzaghi's Equation

Strength on a slip surface =(slip friction)+(cohesion).

$\tau=\sigma'\tan\phi'+c'$.

Taylor's CS+Interlocking

$\tau=\sigma'\tan\phi_d+\sigma'(dy/dx)$.

Cam-clay Strength

=(aggregate CS friction) + (interlocking).

An increment $d\varepsilon$ of plastic distortion unloading and reloading soil grains will dissipate "frictional" work $dW = M\ p'\ d\varepsilon$.

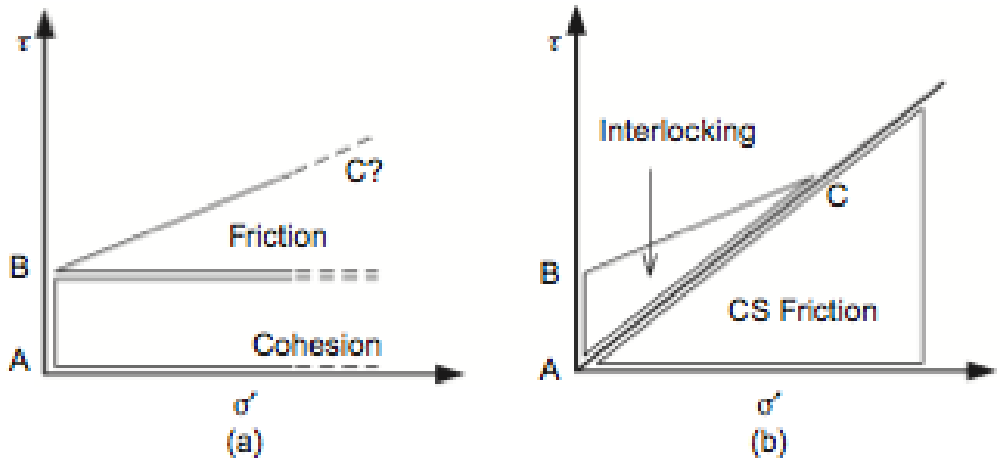


Fig. 1. Alternative models for soil strength

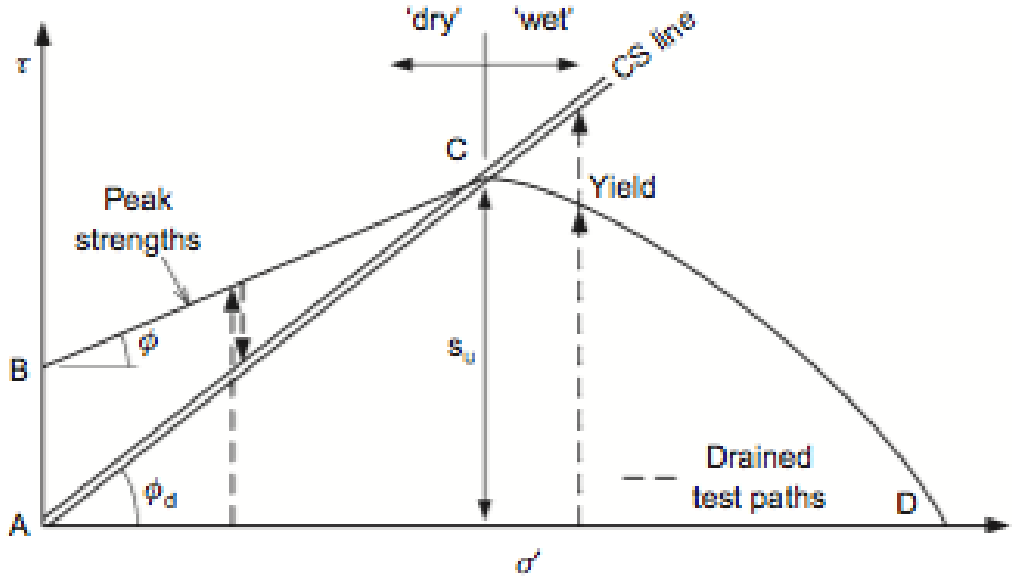


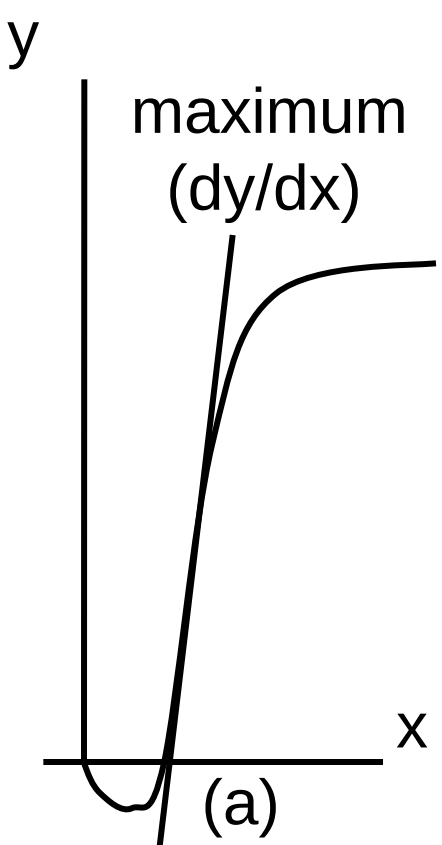
Fig. 2. Observed soil behaviour, in critical state framework

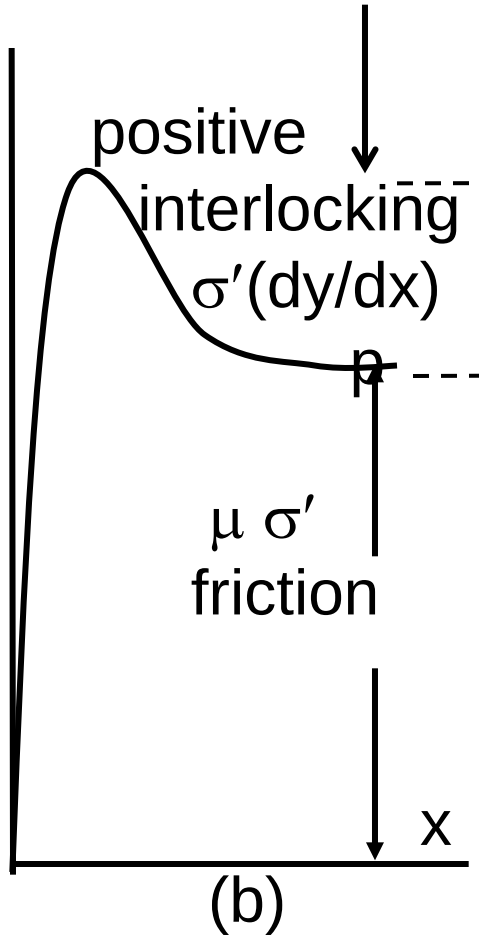
Schofield, A. N. (2006). Ge´otechnique 56, No. 5, 357–358

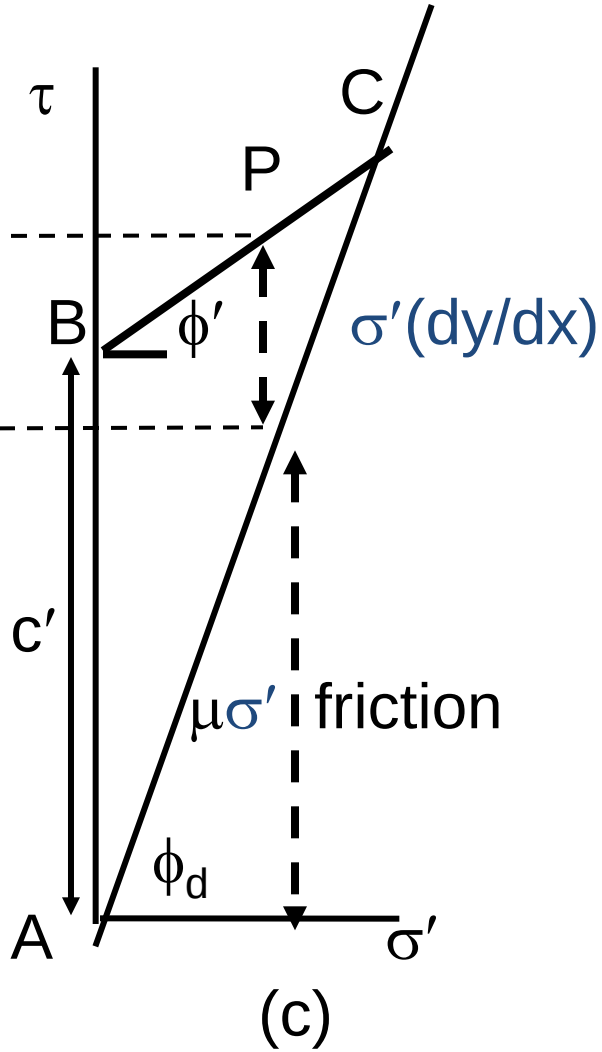
Grain-aggregate mechanics in typical slopes at rest.

- The typical effectively stressed grain-aggregate in CS critical states with $v_\lambda = v + \lambda \ln p' = \Gamma$ is a heap of sand at rest in an hour-glass.
- No dust is seen in an hour glass. Any grain damage would have made dust hence internal-friction in sand must dissipate energy by elastic collisions of grains without damaging the grains.

Interlocking in Taylor's MIT shear box tests







Taylor's interlocking strength component.
$\tau = \mu\ \sigma' + \sigma'(dy/dx)$

strength = friction + interlocking

Peak drained strength at P; see Schofield (2006) Géotechnique