UPL and HYD in EC7

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Imperial College, 31 August 2017

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UPL and HYD

- UPL
  - Uplift
  - Buoyancy problems
  - Generally static water
- HYD
  - Hydraulic heave
  - Disturbance of the soil caused by upward seepage of water
- Internal erosion

Fundamental limit state requirement

$$E_d \le R_d$$

$$E\{\; F_d \;;\; X_d \;; a_d\} = E_d \le R_d = R\{\; F_d \;;\; X_d \;; a_d\}$$

$$E\{\gamma_F F_{rep}; X_k/\gamma_M; a_d\} = E_d \le R_d = R\{\gamma_F F_{rep}; X_k/\gamma_M; a_d\}$$

or $E\{\gamma_F F_{rep}; X_k/\gamma_M; a_d\} = E_d \le R_d = R_k/\gamma_R = R_n\phi_R$ (LRFD)

or $\gamma_E E_k = E_d \le R_d = R_k/\gamma_R$

so in total

$$\gamma_E E\{\gamma_F F_{rep}; X_k/\gamma_M; a_d\} = E_d \le R_d = R\{\gamma_F F_{rep}; X_k/\gamma_M; a_d\}/\gamma_R$$

E = action effects

F = actions (loads)

R = resistance (=capacity)

X = material properties

a = dimensions/geometry

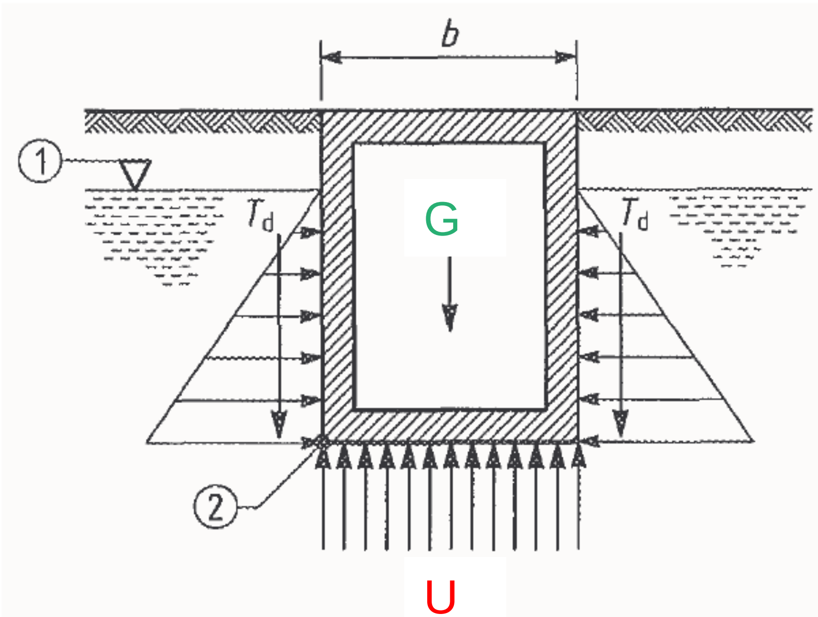
d = design (= factored)

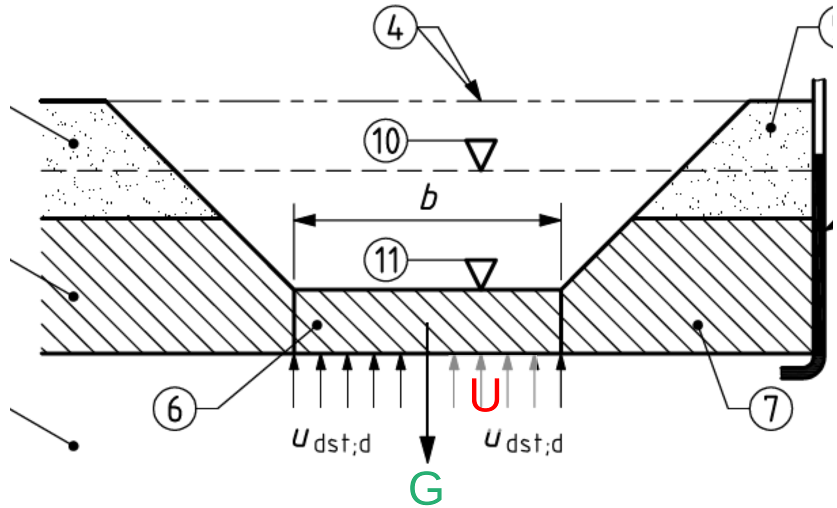
k = characteristic (= unfactored)

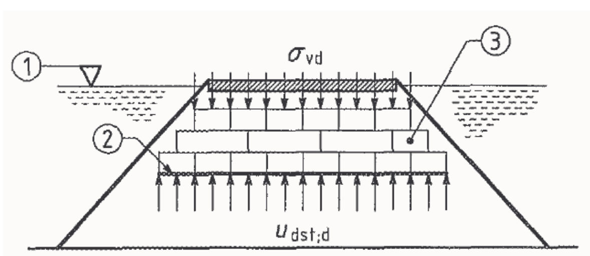
rep = representative

Existing EC7 – Uplift (UPL)

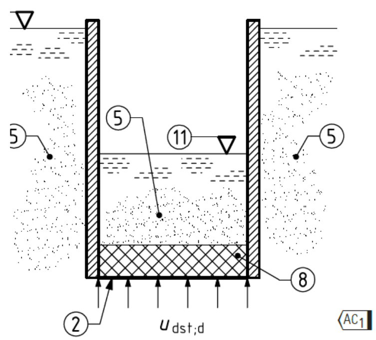
$$\gamma_{dst} U_k \leq \gamma_{stb} G_k$$

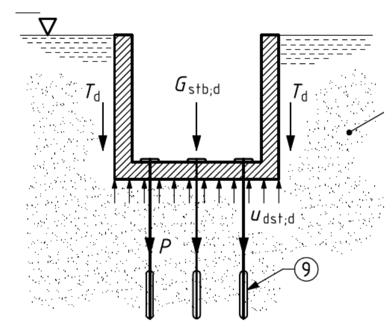






b) Uplift of a lightweight embankment during flood





e) Structure anchored to resist uplift

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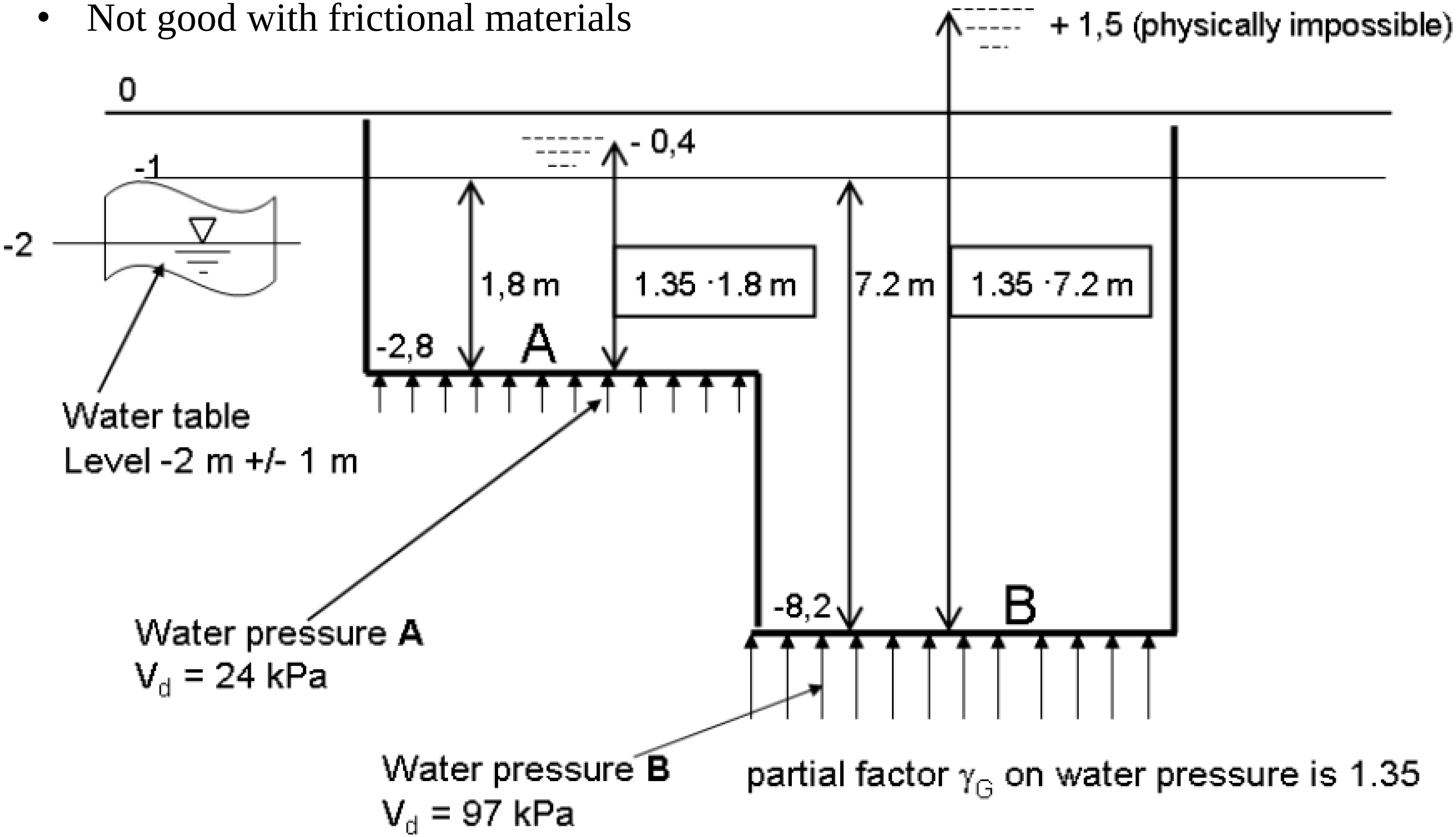
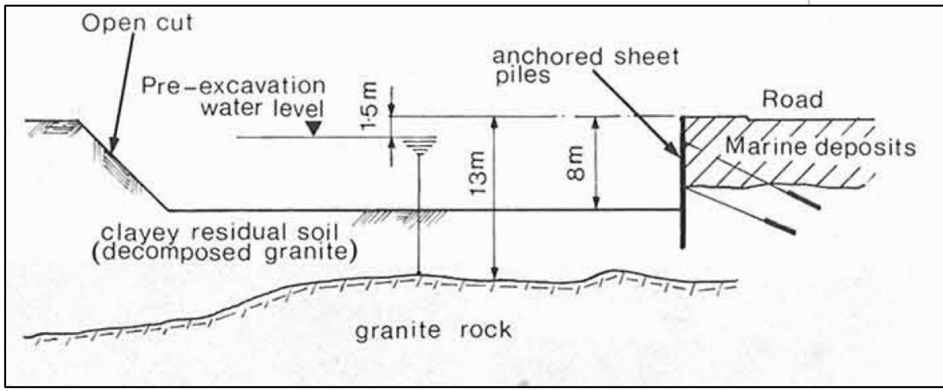
Problems with factoring water pressure

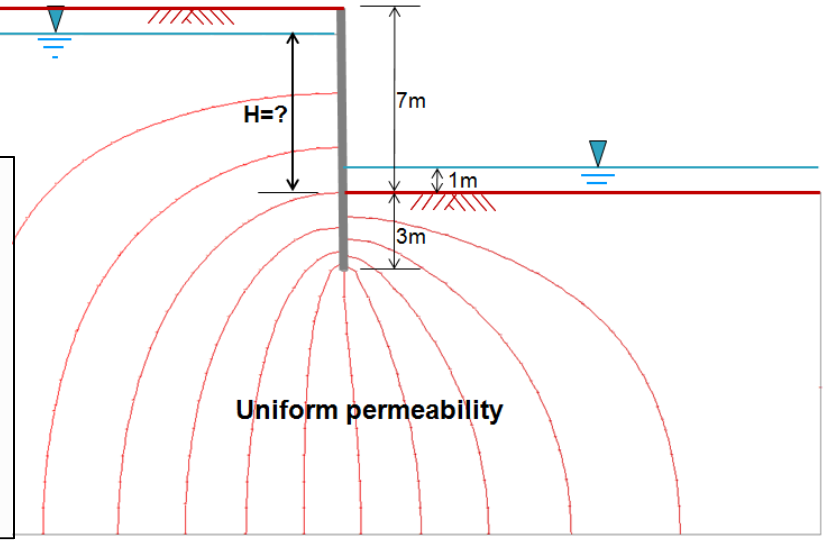
- Leads to impossible situations
- Not good with frictional materials



Simpson, B, Vogt, N & van Seters AJ (2011) Geotechnical safety in relation to water pressures. Proc 3rd Int Symp on Geotechnical Safety and Risk, Munich.

HYD – Equation 2.9





$u_{dst;d} \leq \sigma_{stb;d}$ (2.9a) – **total stress (at the bottom of the column)**

$S_{dst;d} \leq G'_{stb;d}$ (2.9b)" – **effective weight (within the column)**

$$\gamma_{G;dst}\, u_{dst;k} \leq \gamma_{G;stb}\, \sigma_{stb;k} \qquad (2.9a)$$

$$\gamma_{G;dst}\, S_{dst;k} \leq \gamma_{G;stb}\, G'_{stb;k} \qquad (2.9b)$$

Apply $\gamma_{G;dst}$ = 1.35 to:	Apply $\gamma_{G;stb}$ = 0.9 to:	H
Pore water pressure $u_{dst;k}$	Total stress $\sigma_{stb;k}$	2.78
Seepage force $S_{dst;k}$	Buoyant weight $G'_{stb;k}$	6.84

Existing EC7 - Internal erosion

(6)P The critical hydraulic gradient for internal erosion shall be established taking into consideration at least the following aspects:

— direction of flow;

— grain size distribution and shape of grains;

— stratification of the soil.

- No further advice or instruction.
- Nothing about safety margins needed.

Factors of safety for HYD

Williams B P & Waite D (1993) The design and construction of sheet-piled cofferdams. Special publication 95. London: Construction Industry Research and Information

2.0.

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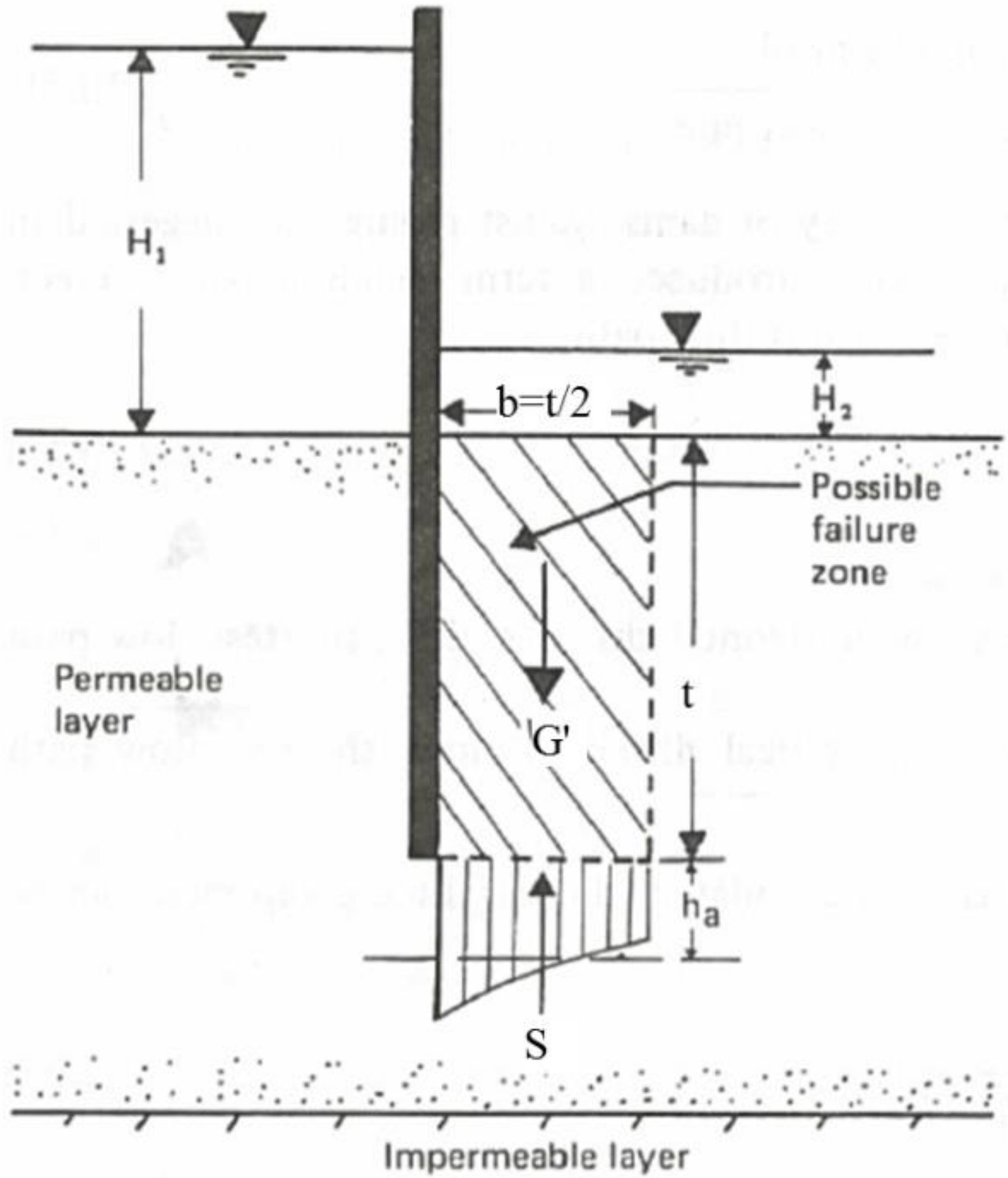
dition.



tangle.

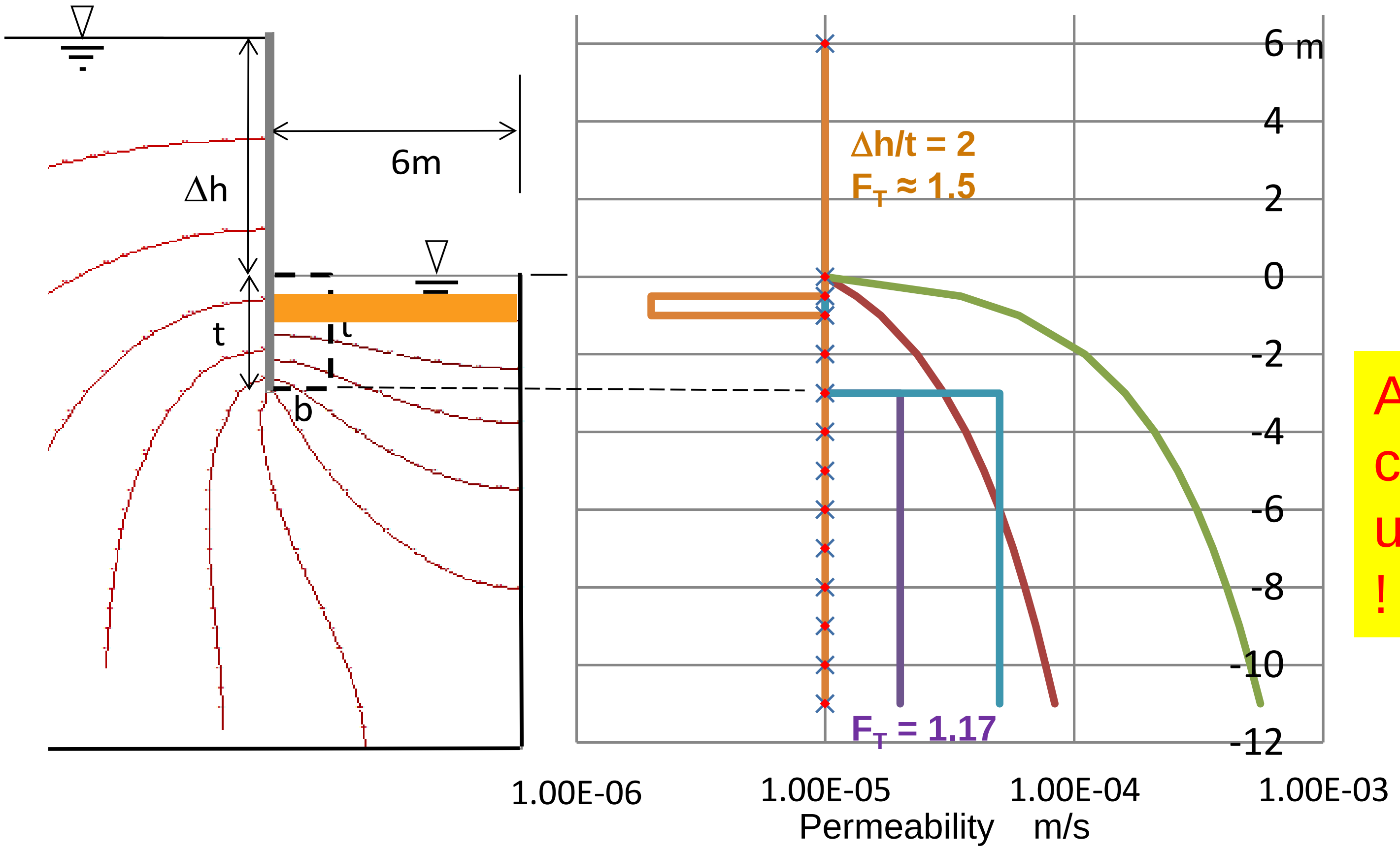
ation for

seepage berm toe	i ≤ 0.8	FS ≥ 1.0	berms less than 100 ft (30.5 m)	berms less than 100 ft (30.5 m)

Das (1983) Fig 2.47

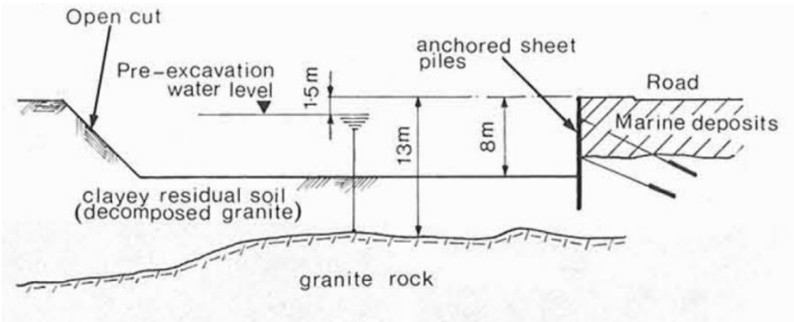
Essential to assess correct water pressures (permeabilities)

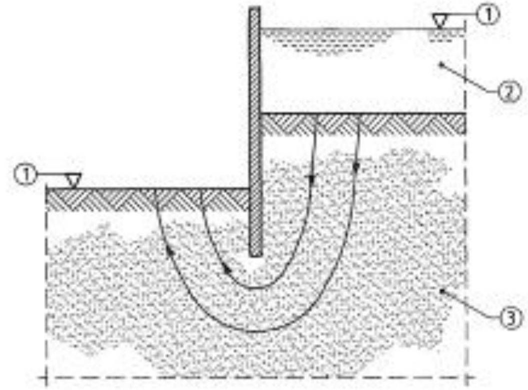
…then F_T seems to be irrelevant



All other cases unstable !

The HYD problem – water seeping



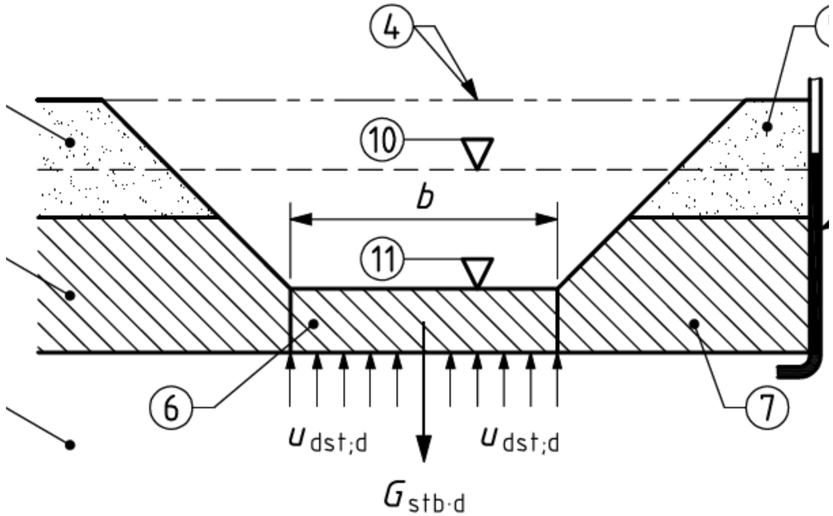


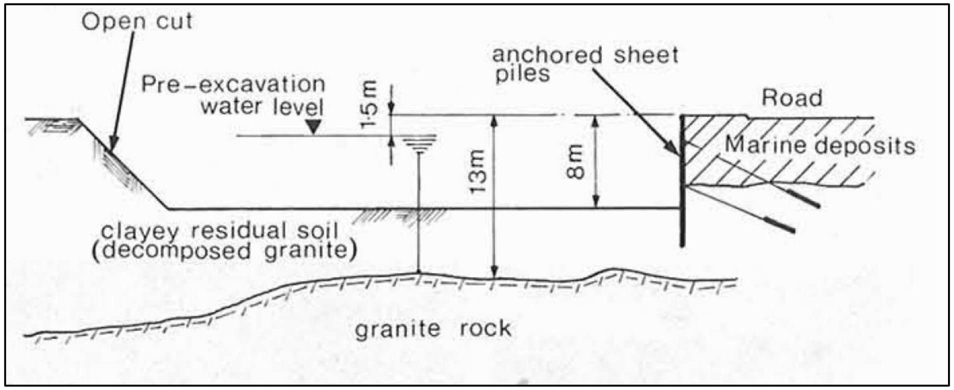
- What are the real limit states – what are we afraid of ?
- Wall stability may be a dominating issue and, but this is dealt with separately.
- We don't want effective stress to fall to zero. $\sigma' \geq 0$
- In fact, we don't want the design value of effective stress, calculated for a continuum, to get close to zero:
  - The real material is likely to be less continuous (possibly gap graded)
  - There are usually performance requirements: people need to walk or drive vehicles on the surface.
  - $\sigma' \geq$??

$$\sigma'_d \geq \alpha.\gamma_d z \qquad \text{or} \qquad u_{e;d} = u_d - \gamma_w z \leq \gamma_d z(1-\alpha) + q_d$$

- α should be a material-dependent parameter (eg gap graded soils)

A possibility to combine UPL and HYD?





- Sometimes difficult to distinguish.
- Material-dependent parameter α $\sigma'_d \geq \alpha . \gamma'_d z$

	γ kN/m³	β	α	γ_{UPL}	F_T
Dense sand (Germany)	20	2	0.18	1.10	**1.4**
Loose sand (Germany)	18	1.8	0.36	1.25	**1.8**
Silty, layered sand	18	1.8	0.54	1.43	**2.5**
Stiff clay (Germany)	20	2	0.175	**1.1**	1.39 *
NC clay (Germany)	16	1.6	0.15	**1.1**	1.35 *
Stiff clay (UK)	20	2	0.275	**1.2**	1.59
NC clay (UK)	16	1.6	0.225	**1.2**	1.48

Is this a good idea? Comments welcome.

Internal erosion – critical gradient or velocity

PT1: An equation should be proposed in order to check this criterion in terms of hydraulic gradient or seepage velocity:

$i_d < i_{c;d}$ or $v_d < v_{c;.d}$.

$i_{c;d}$ and $v_{c;.d}$ are material-dependent parameters

- Which is the better form? PT2 chose hydraulic gradient.
- Might be worth considering which is the better constant as material grading varies unpredictably.
- Is critical gradient dependent on direction?
- How to derive its value?
  - International Levee Handbook?
  - Cross-over between geotechnics and dam design.
- How to give safety margins in practical cases?

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Thanks for your attention.

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