Water pressures –safety in design

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Geotechnical safety in relation to water pressures

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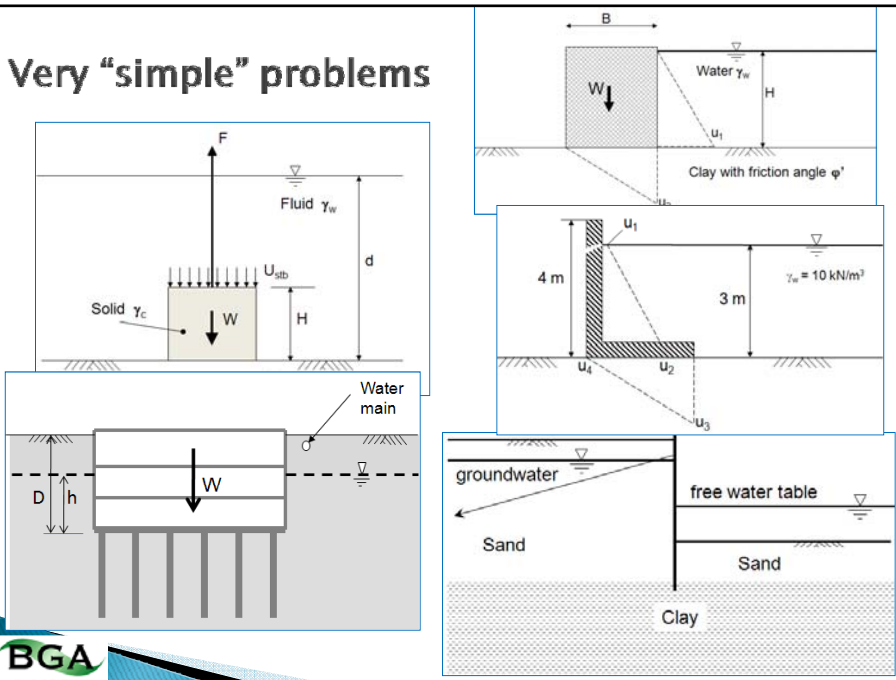
Very “simple” problems



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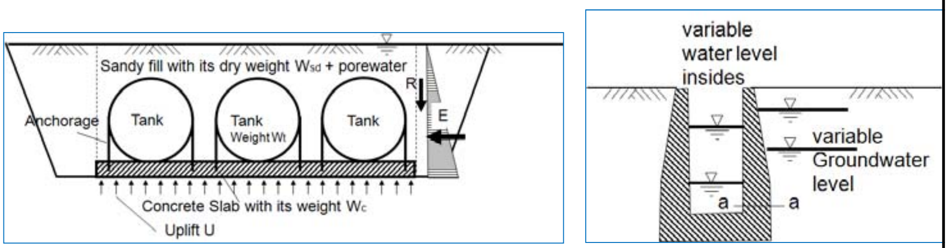
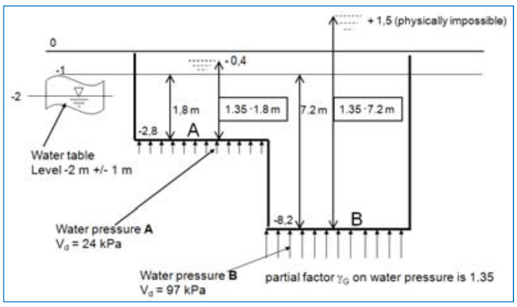
Slightly more realistic problems





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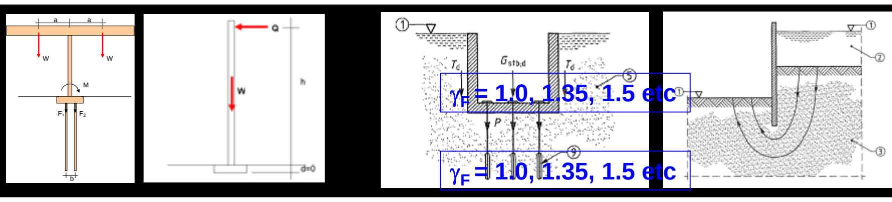
2.4.7 Ultimate limit states – EQU, UPL, HYD

2.4.7.1 General

(1)P Where relevant, it shall be verified that the following limit states are not exceeded:

— loss of equilibrium of the structure or the ground, considered as a rigid body, in which the strengths of structural materials and the ground are insignificant in providing resistance (EQU);



— loss of equilibrium of the structure or the ground due to uplift by water pressure (buoyancy) or other vertical actions (UPL); $\gamma_{F,dst}$ = 1.1, $\gamma_{F,stb}$ = 0.9

— hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients (HYD).

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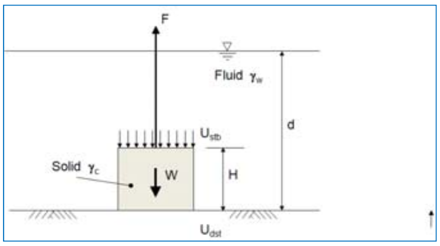
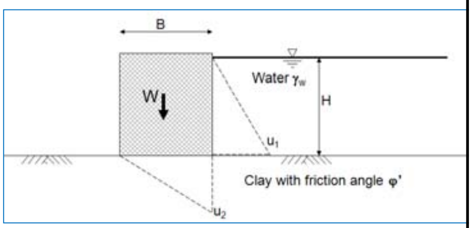
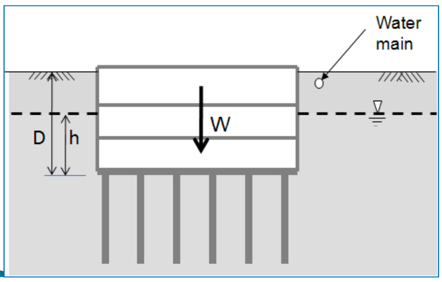
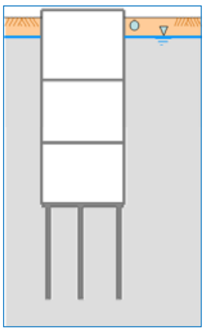
Robustness – allow for "secondary actions"









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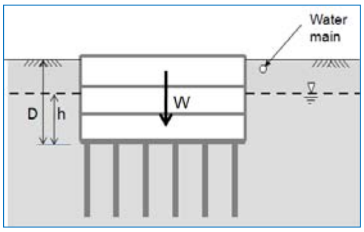
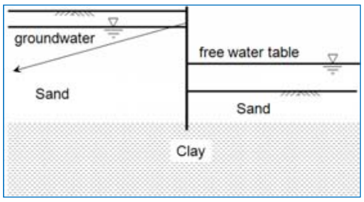
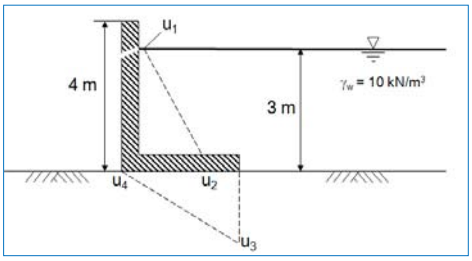
Explicitly accommodate the worst water pressures that could reasonably occur







1m rise in water level multiplies BM by about 2.5 – outside the range allowed by factors on the water pressure or water force.

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Explicitly accommodate the worst water pressures that could reasonably occur

(6)P When dealing with ground-water pressures for limit states with severe consequences (generally ultimate limit states), design values shall represent the most unfavourable values that could occur during the design lifetime of the structure. For limit states with less severe consequences (generally serviceability limit states), design values shall be the most unfavourable values which could occur in normal circumstances.

(7) In some cases extreme water pressures complying with 1.5.3.5 of EN 1990:2002, may be treated as accidental actions.

(8) Design values of ground-water pressures may be derived either by applying partial factors to characteristic water pressures or by applying a safety margin to the characteristic water level in accordance with 2.4.4(1)P and 2.4.5.3(1)P.

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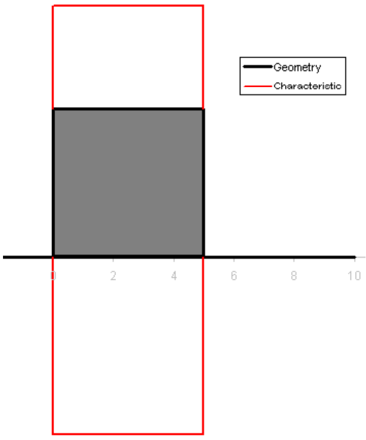
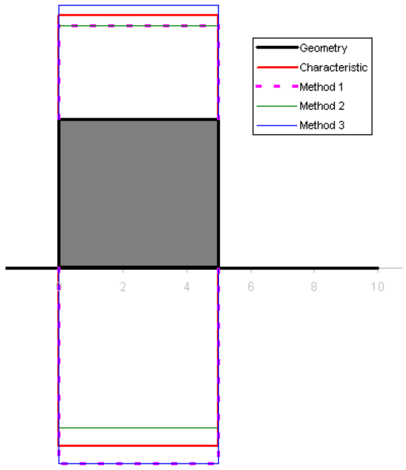
Application of partial factors to the density of water should generally be avoided.





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2.4.2 – Actions
The "single source principle"

(9)P Actions in which ground- and free-water forces predominate shall be identified for special consideration with regard to deformations, fissuring, variable permeability and erosion.

NOTE Unfavourable (or destabilising) and favourable (or stabilising) permanent actions may in some situations be considered as coming from a single source. If they are considered so, a single partial factor may be applied to the sum of these actions or to the sum of their effects.

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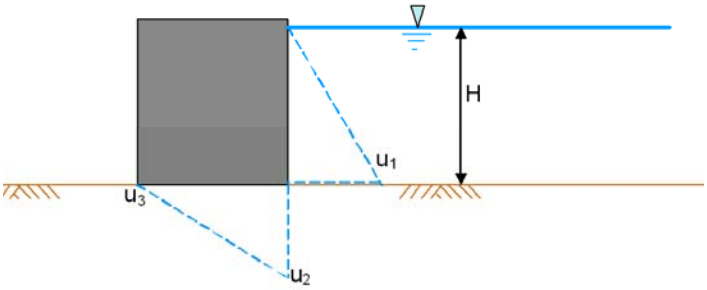
Partial factors on the density of water?



- Should generally be avoided
- Use unfactored water pressures and forces?
- Don't factor density but factor pressures (AvS)?
- Don't factor pressures but factor forces (NV)?
- At some point, equilibrium is not preserved. But the question is – where?

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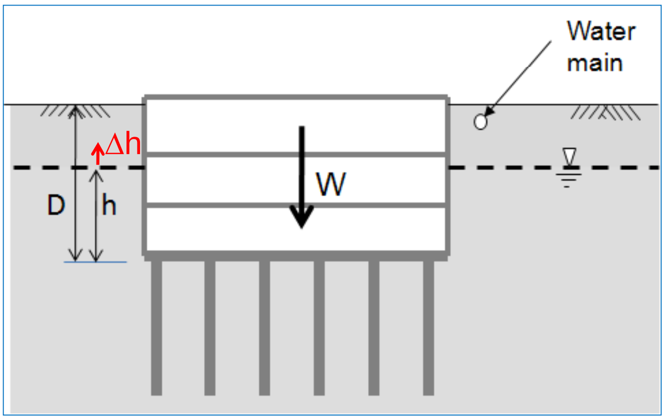
Use of an offset in water level?



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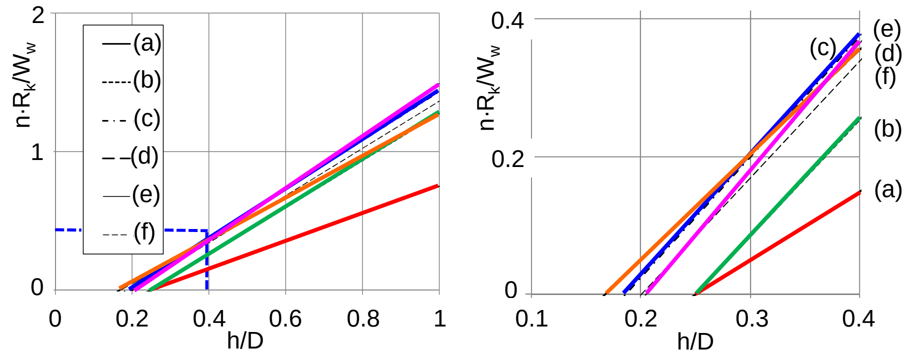
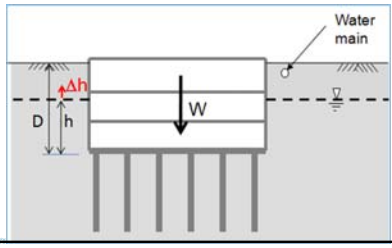


Number of piles required (normalised). (a) unfactored, (b) pile resistance factored, (c) γ_G = 1.35 on water pressure, (d) water table adjusted, (e) UPL,



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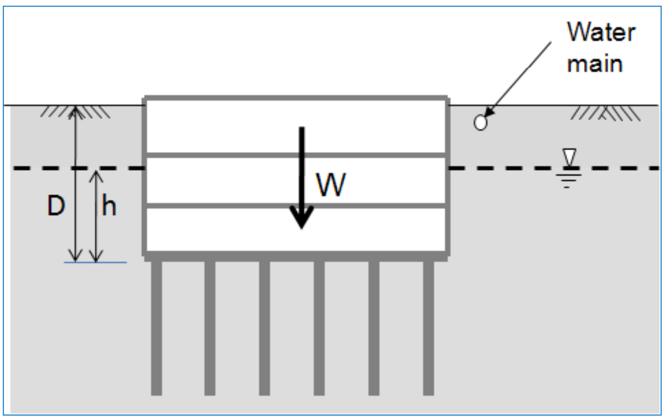
Reduced factor on favourable weight for UPL?

The possibility of a reduced factor on favourable weight, perhaps between 0.8 and 0.9 should be considered.



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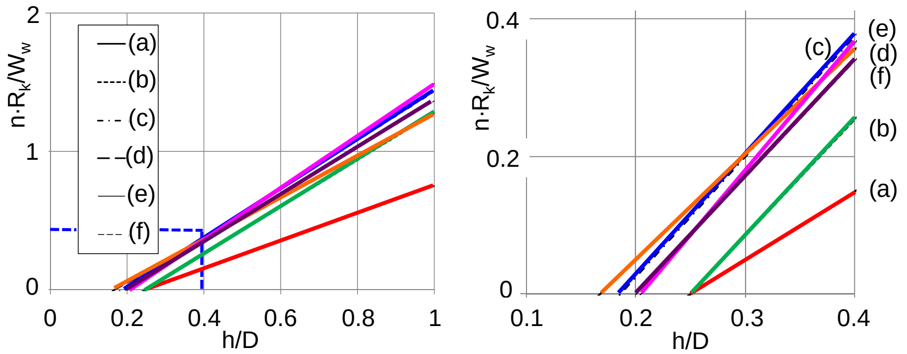
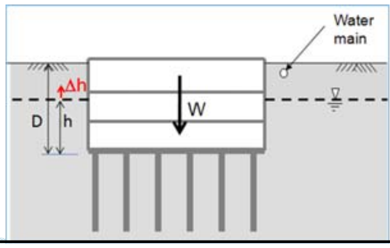
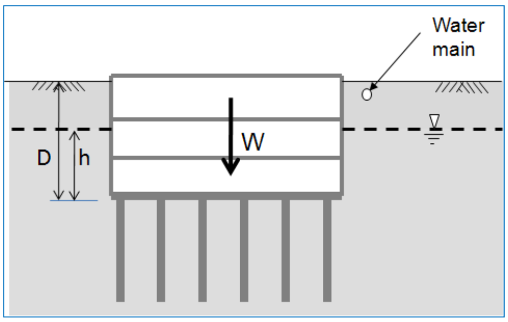


Number of piles required (normalised). (a) unfactored, (b) pile resistance factored, (c) γ_G = 1.35 on water pressure, (d) water table adjusted, (e) UPL, (f) $\gamma_{G;fav}$ = 0.8 on weight.



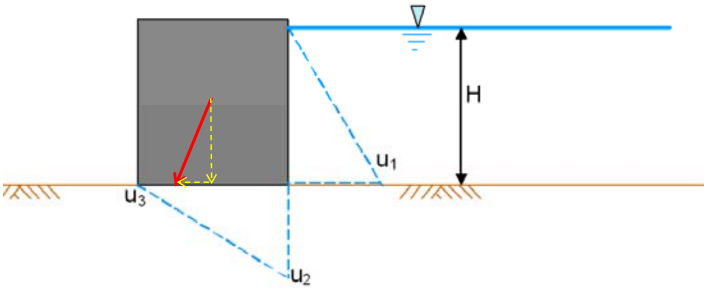
The "star" approach – DA2* – DA1* ?

EC7 2.4.7.3.2(2)
In some design situations, the application of partial factors to actions coming from or through the soil (such as earth or water pressures) could lead to design values which are unreasonable or even physically impossible. In these situations, the factors may be applied directly to the effects of actions derived from representative values of the actions.



Apply only to structural bending moments etc, or more generally?

The "star" approach



- Depending on other factors, it might be necessary to enhance the loads (or load effects such as an uplifting force), even when they are very certain.
- Problem in cases where it is directly equivalent to factoring water pressures

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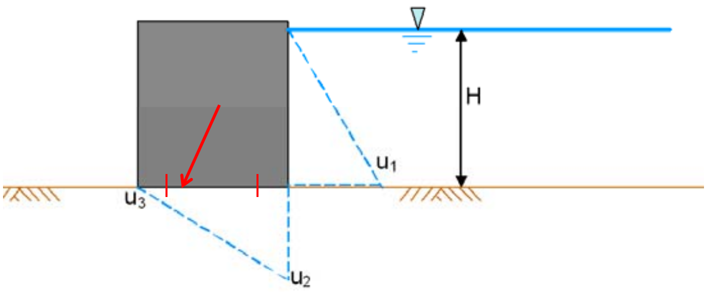
Uplift problems



- A "middle 2/3rds" rule could be considered.

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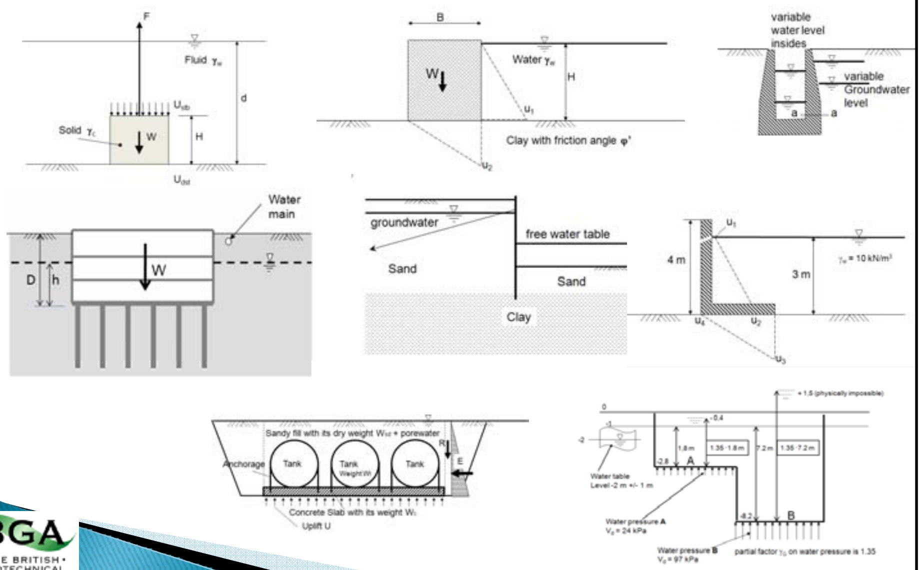
Engineering expertise



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