EC7 Workshop, Pavia, April 2010

Water pressures

Brian Simpson, *Arup Geotechnics*

with assistance from:

Andrew Bond, Norbert Vogt, Adriaan Seters

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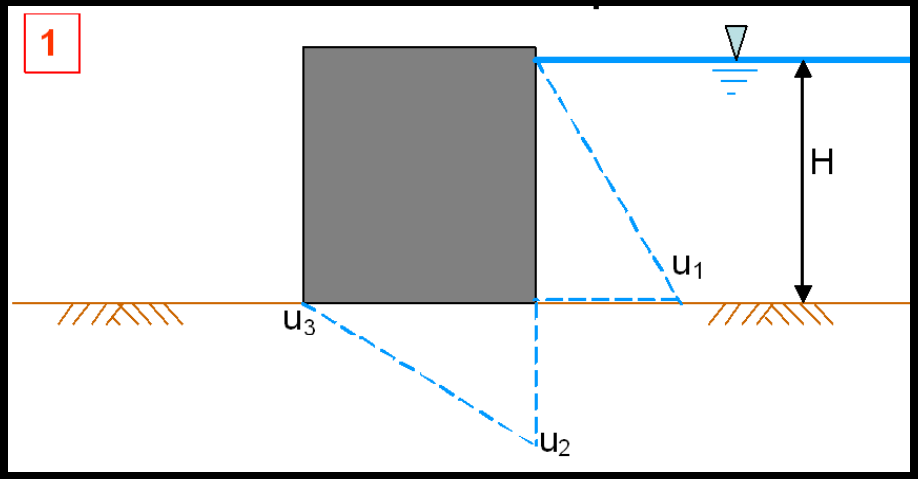
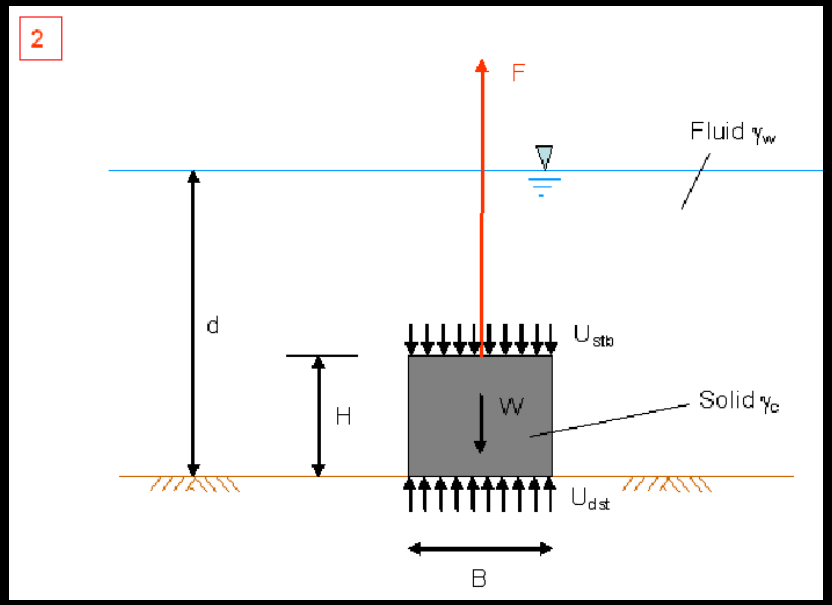
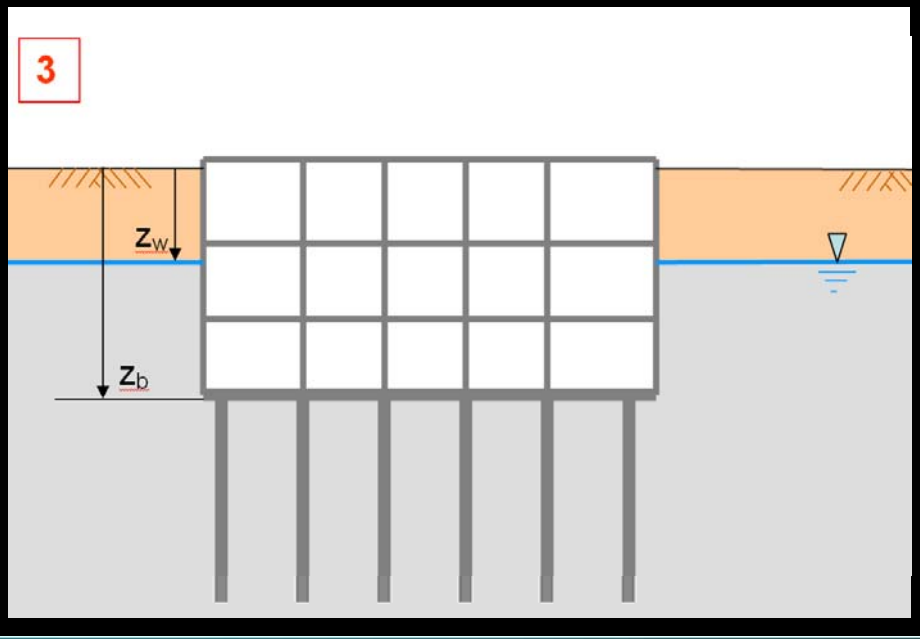
Three simple (????) problems







- Concentrating here on safety related to water pressure.
- Other issues complicate matters further:
  - DA's, materials, resistances, calculations models

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Extracts from EN1997-1

2.4.2 Actions

(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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Extracts from EN1997-1

2.4.6.1 Design values of actions

(1)P The design value of an action shall be determined in accordance with EN 1990:2002.

(2)P The design value of an action (F_d) shall either be assessed directly or shall be derived from representative values using the following equation:

$$F_d = \gamma_F \cdot F_{rep} \qquad (2.1a)$$

with

$$F_{rep} = \psi \cdot F_k \qquad (2.1b)$$

…

(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.

…

(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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Extracts from EN1997-1

2.4.7.3.2 Design effects of actions

(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.

- DA2* - or DA1* ??

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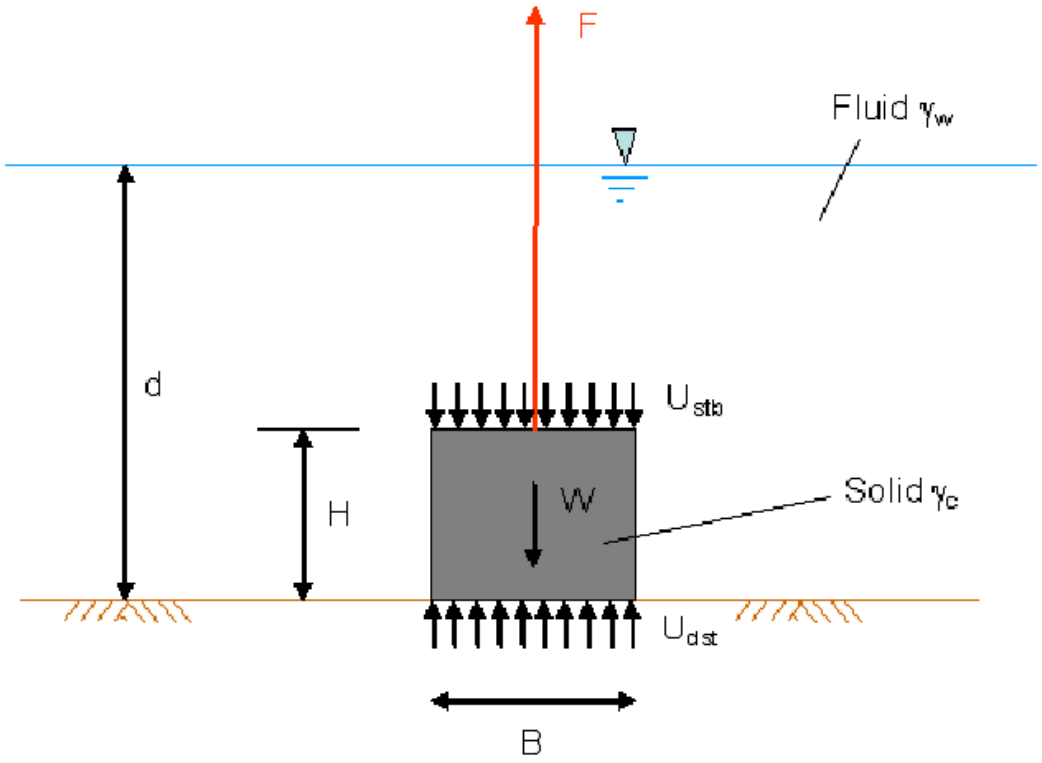

The figure shows an anchor block, for which W (total weight) is a favourable force and F is unfavourable.

H = height of block
B = breadth of block
d = depth of water
F = external force applied to block
γ_c = weight density of block material (e.g. concrete)
γ_w = weight density of water

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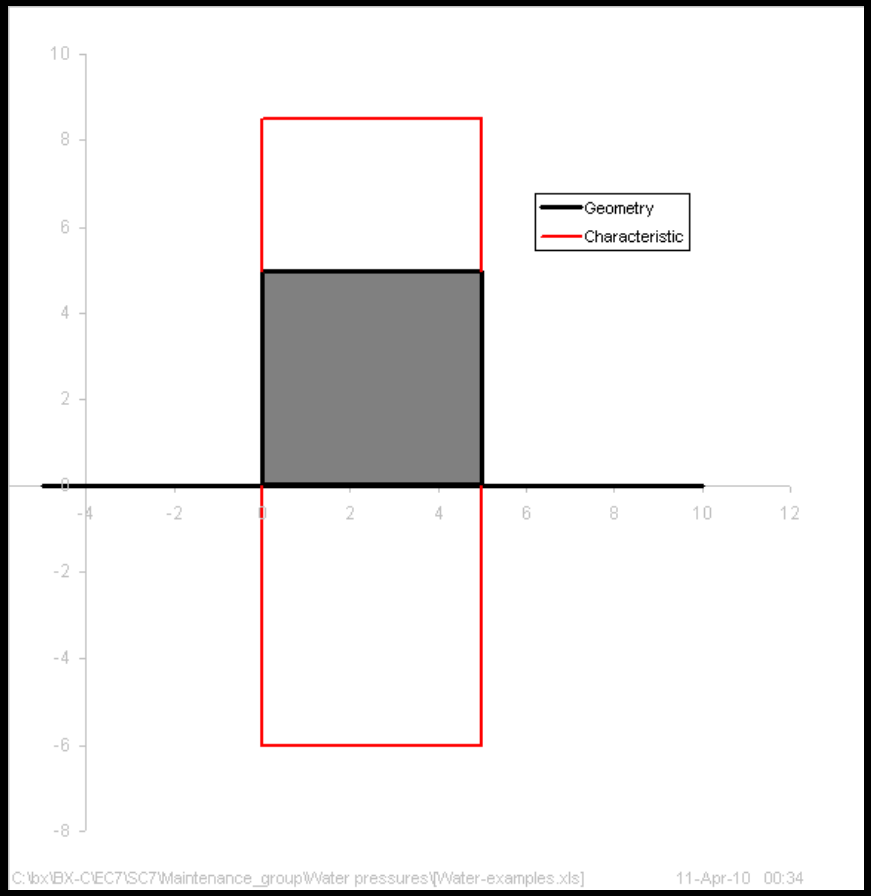

- Single source?
- Buoyant weight?

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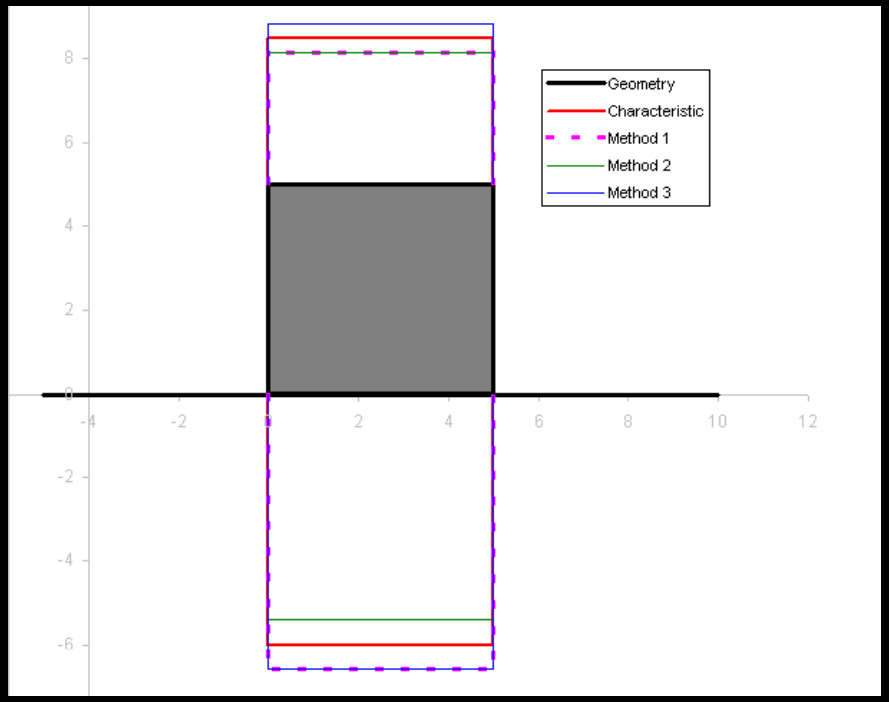

- Method 1 – γ_{dst} (>1) and γ_{stb} (<1)
  - $W * \gamma_{G;stb} + U_{stb} * \gamma_{G;stb} \geq U_{dst} * \gamma_{G;dst} + F * \gamma_{Q;dst}$
- Method 2 – γ_{stb} and γ_{stb}
  - $(W - \Delta U) * \gamma_{G;stb} \geq F * \gamma_{Q;dst}$ (buoyant weight method)
- Method 3 – γ_{dst} and γ_{dst}
  - $W * \gamma_{G;stb} - \Delta U * \gamma_{G;dst} \geq F * \gamma_{Q;dst}$
  - relative water pressure method - “single source”

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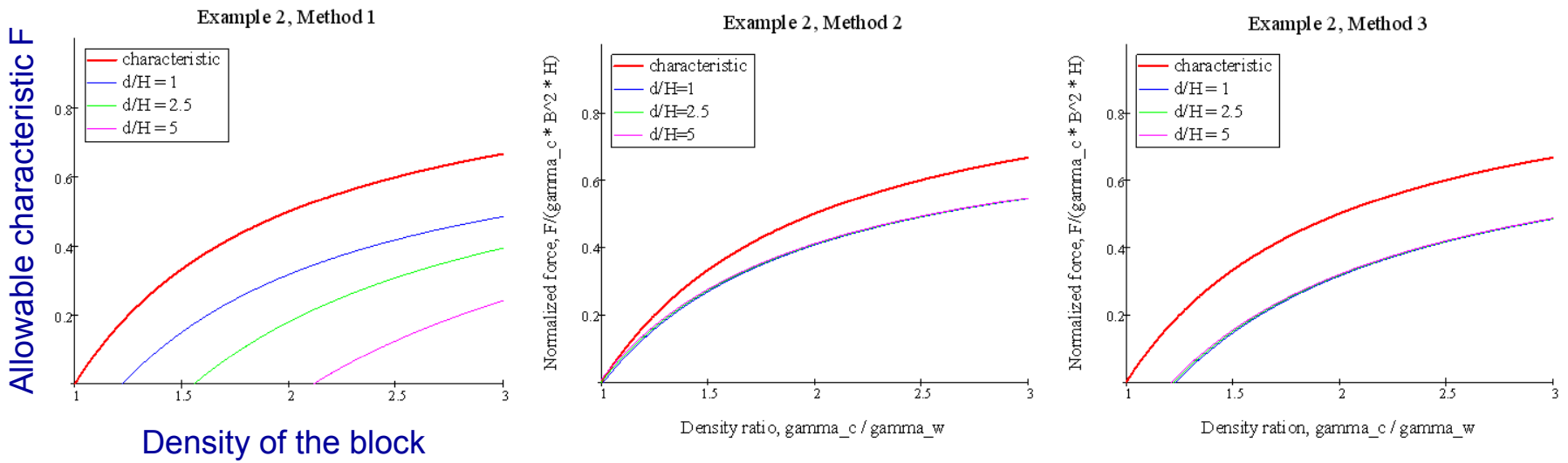
Example 2: consequences for uplift



Observation: in Method 1, the acceptable force depends on the depth of water in which it sits

- Method 1 – γ_{dst} and γ_{stb}
- Method 2 – γ_{stb} and γ_{stb}
- Method 3 – γ_{dst} and γ_{dst}

- $W * \gamma_{G;stb} + U_{stb} * \gamma_{G;stb} \geq U_{dst} * \gamma_{G;dst} + F * \gamma_{Q;dst}$
- $(W - \Delta U) * \gamma_{G;stb} \geq F * \gamma_{Q;dst}$ (buoyant weight method)
- $W * \gamma_{G;stb} - \Delta U * \gamma_{G;dst} \geq F * \gamma_{Q;dst}$
- relative water pressure method - “single source”

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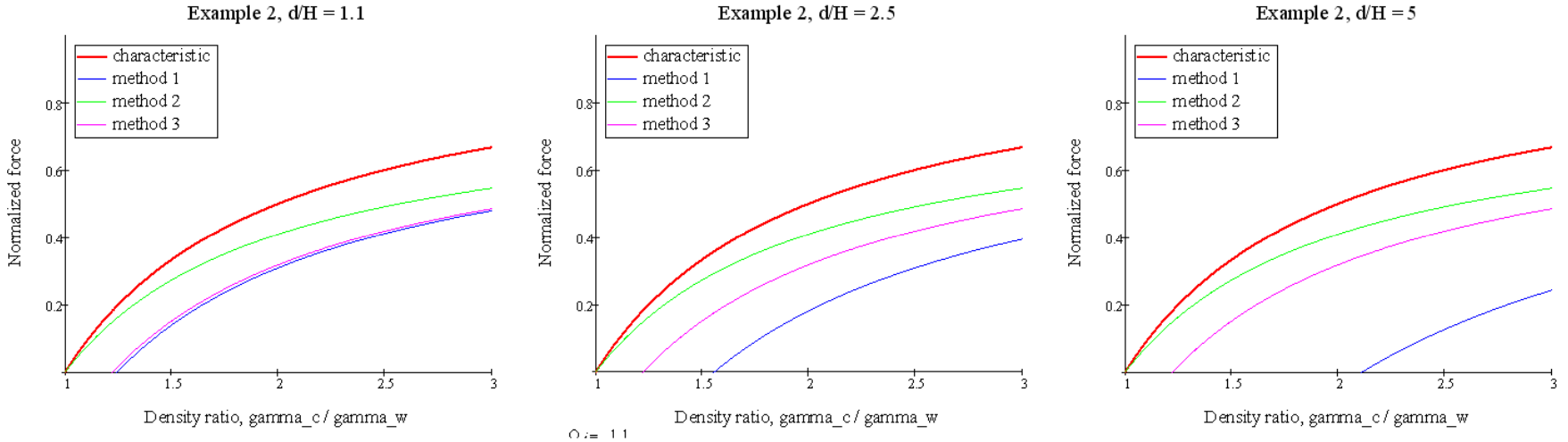

Observation: in Method 1, the acceptable force decreases as the depth of water increases Factoring water pressures.
Observation: in Method 2, the acceptable force approaches the characteristic force as the density of the block approaches that of water
Observation: Method 3 may be better, but still factoring the density of water.

- Method 1 – γ_{dst} and γ_{stb}
  - $W * \gamma_{G;stb} + U_{stb} * \gamma_{G;stb} \geq U_{dst} * \gamma_{G;dst} + F * \gamma_{Q;dst}$
- Method 2 – γ_{stb} and γ_{stb}
  - $(W - \Delta U) * \gamma_{G;stb} \geq F * \gamma_{Q;dst}$ (buoyant weight method)
- Method 3 – γ_{dst} and γ_{dst}
  - $W * \gamma_{G;stb} - \Delta U * \gamma_{G;dst} \geq F * \gamma_{Q;dst}$
  - relative water pressure method - “single source”

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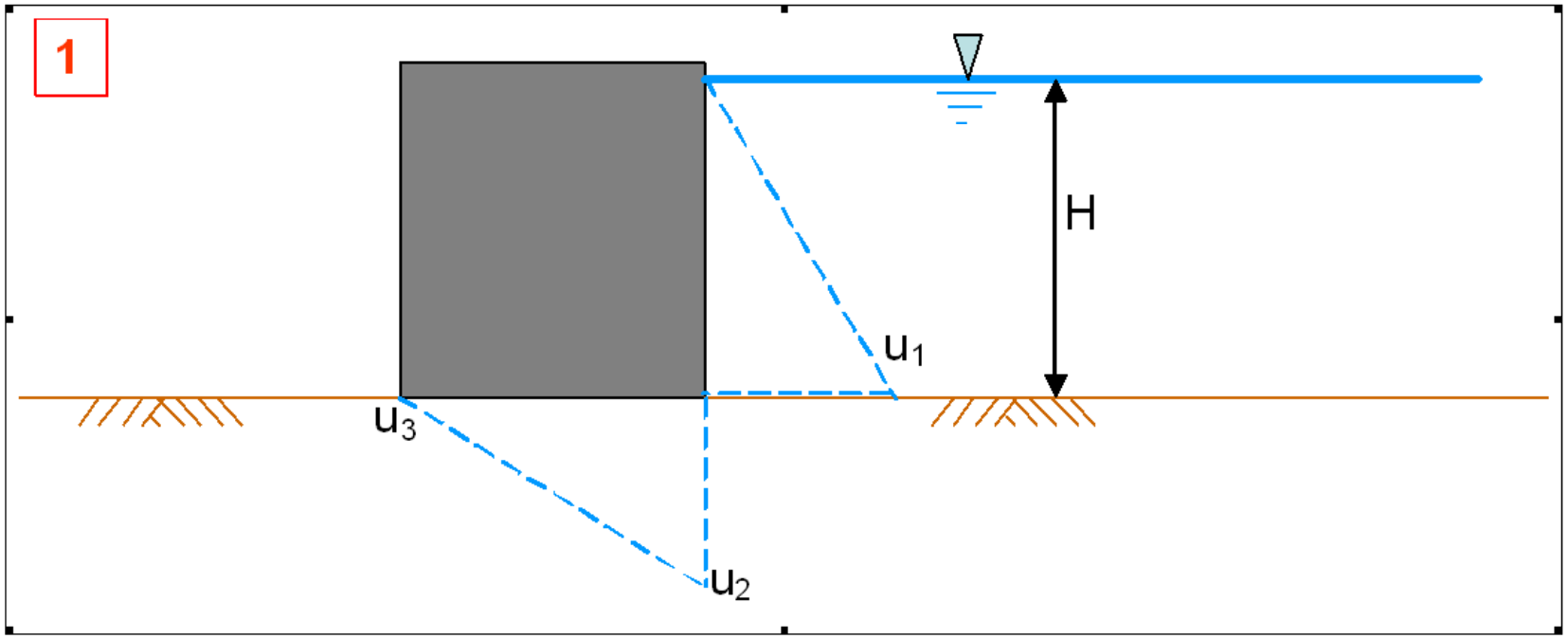

A wall or caisson supporting only water which can rise to the top of the caisson, at which point it overflows. The natural ground water level on the downstream side of the wall is at ground level. It has been determined that it is reasonable to assume a linear distribution of water pressure beneath the structure, as shown.

H = height of block
B = breadth of block
γ_c = weight density of block material (e.g. concrete)
γ_w = weight density of water

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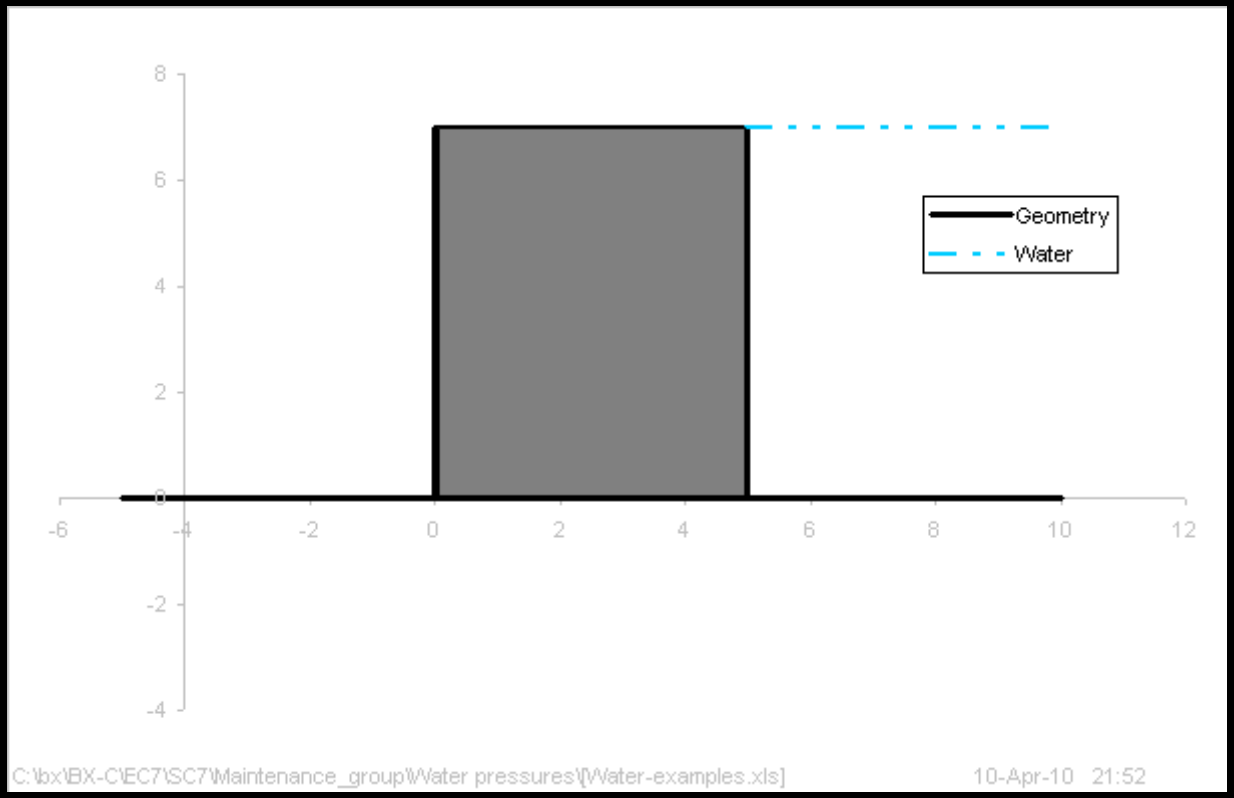
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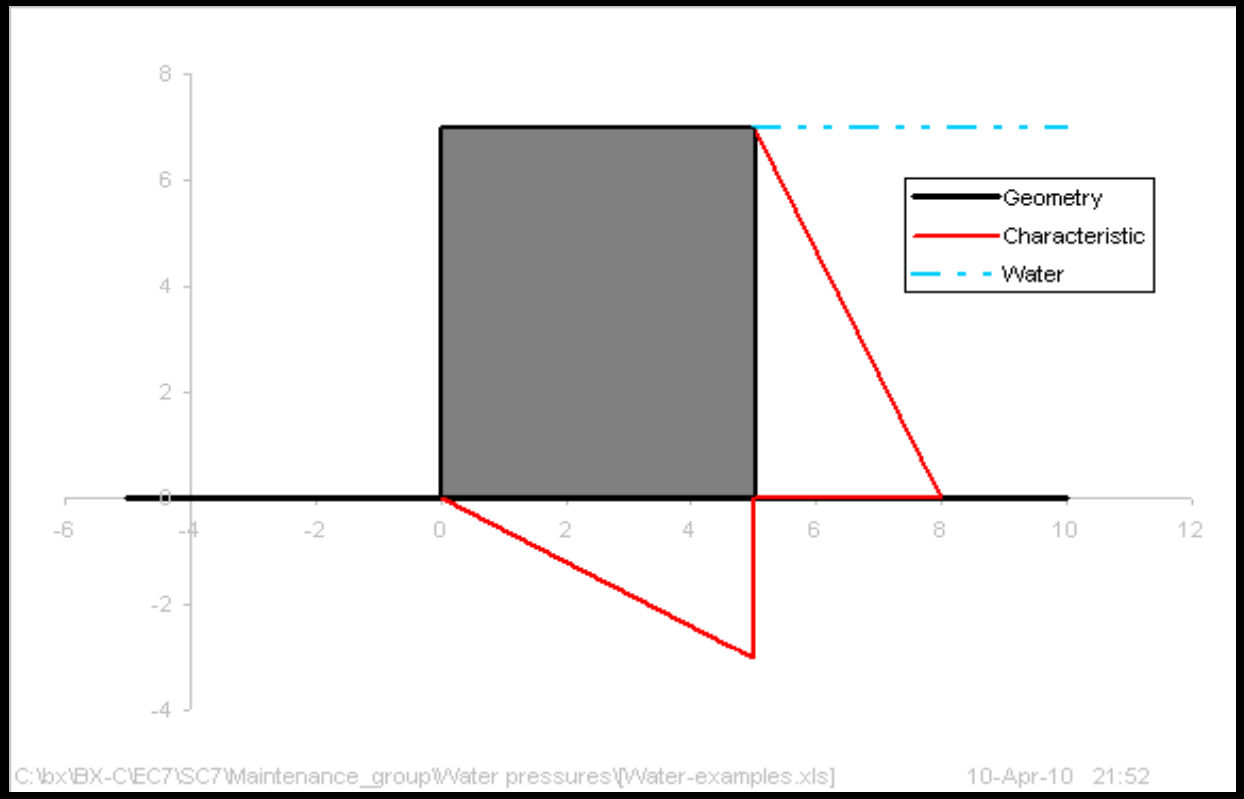
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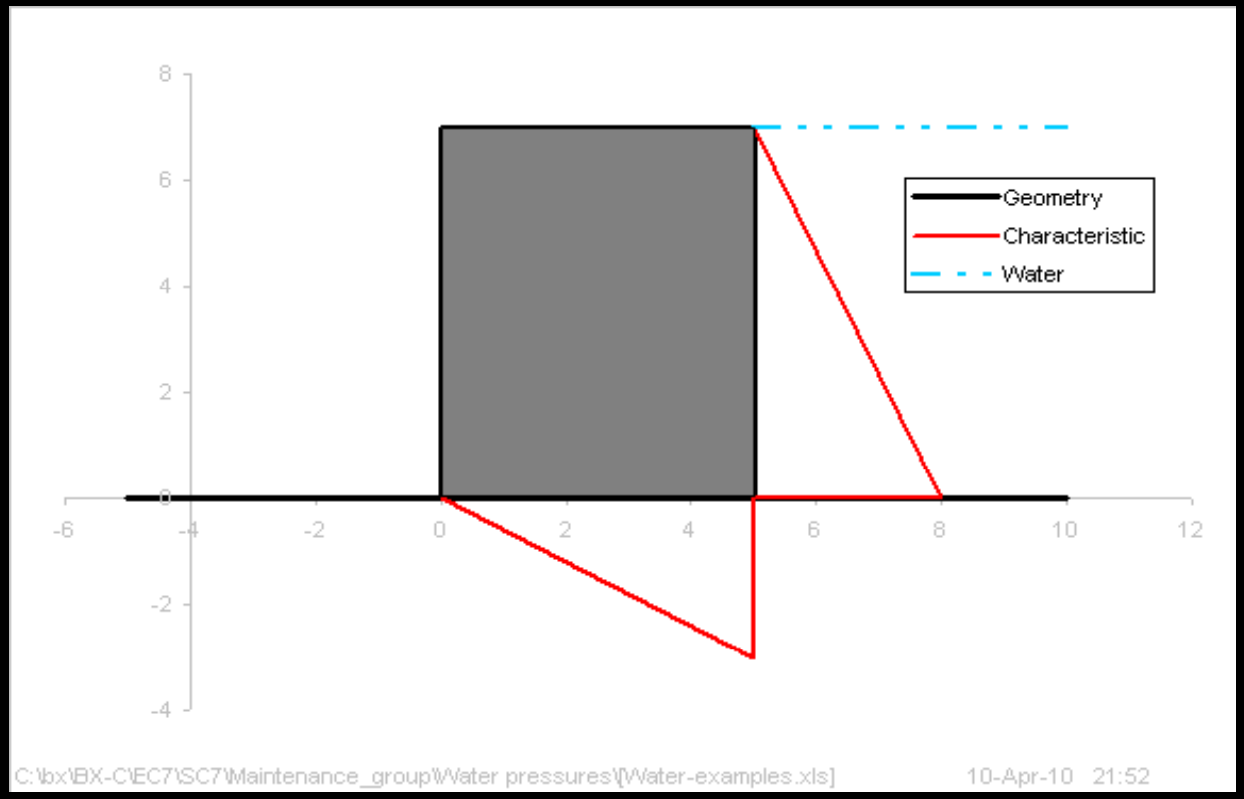

- Which limit states are relevant?
  - Sliding – GEO
  - Bearing capacity – GEO
  - Internal strength – STR
  - EQU? Toppling?

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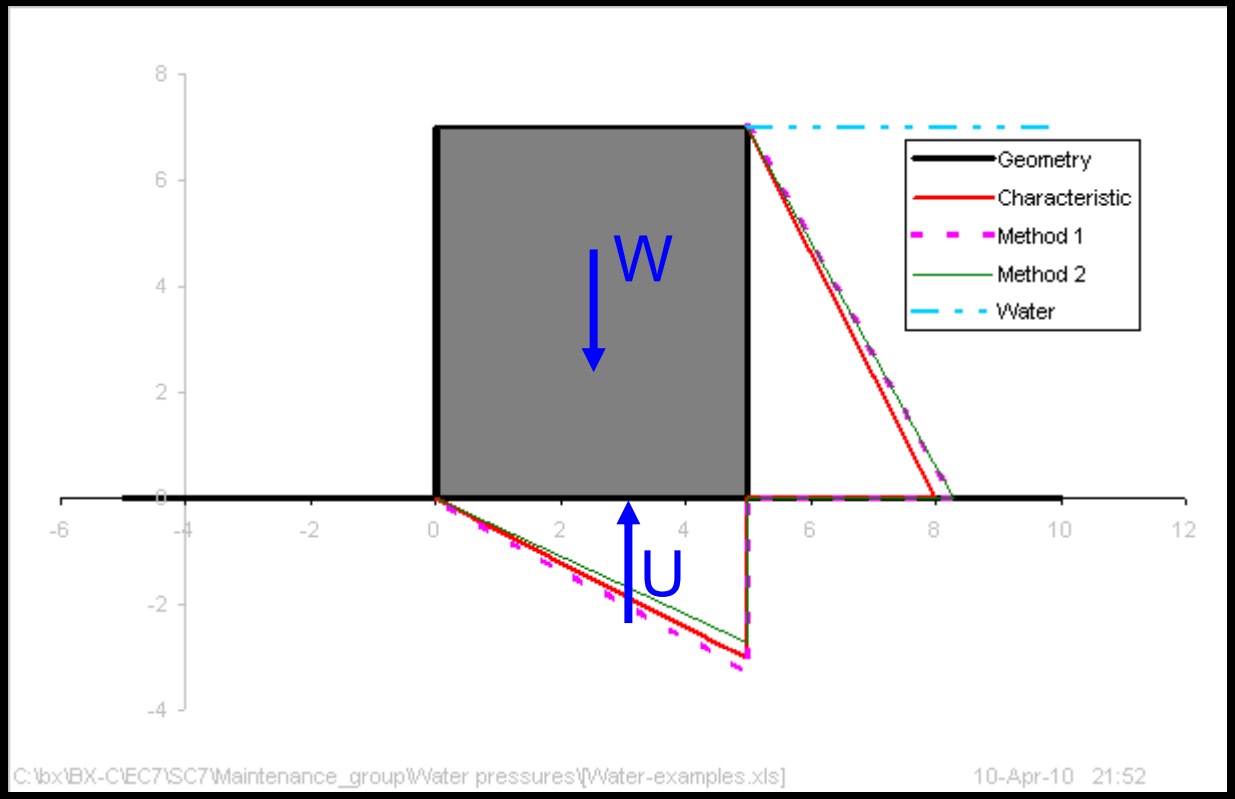

- Do we factor water pressure?
- "Single source"? Same factors on horizontal and vertical at a point?
- Effect of factoring buoyant weight? $\gamma_{stb}(W_k-U_k)$

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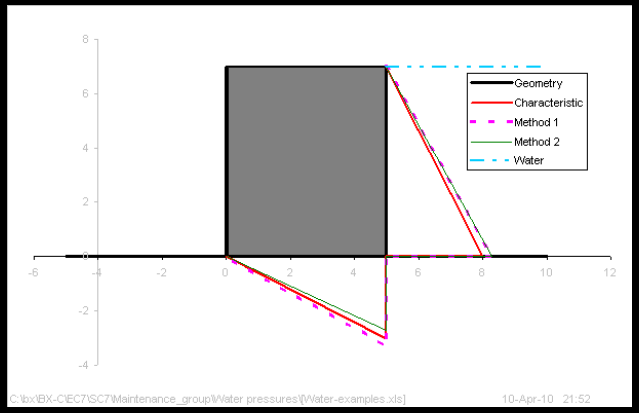
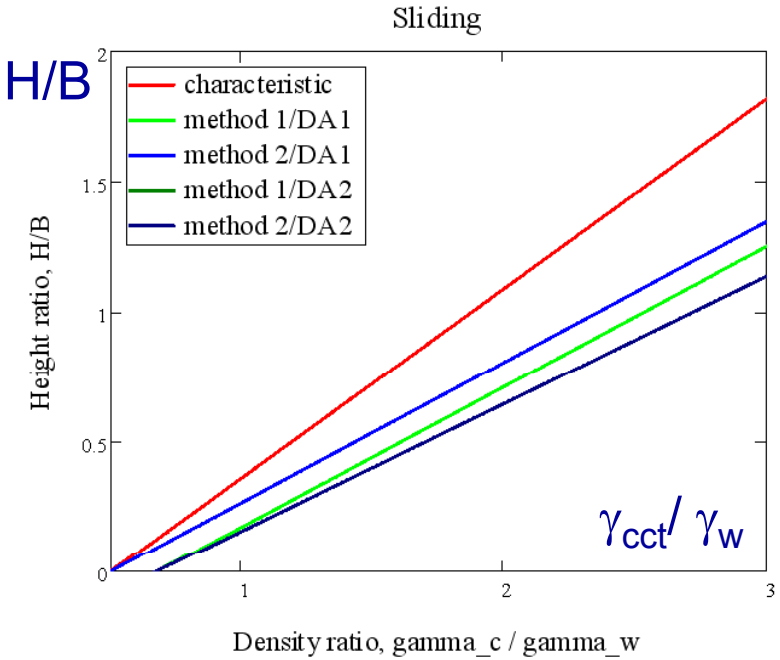
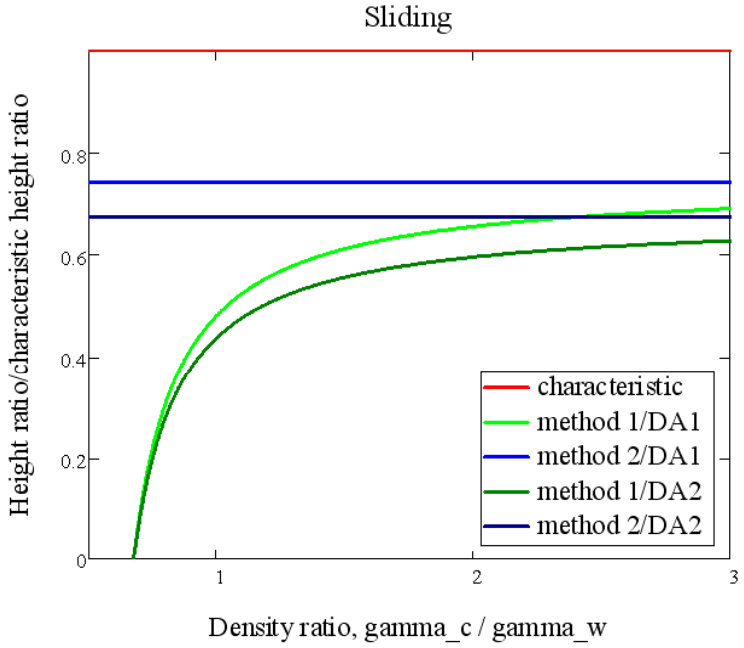


Example 1: consequences for sliding





Observation: as the density of the block reduces towards and below that of water, so the acceptable height reduces dramatically

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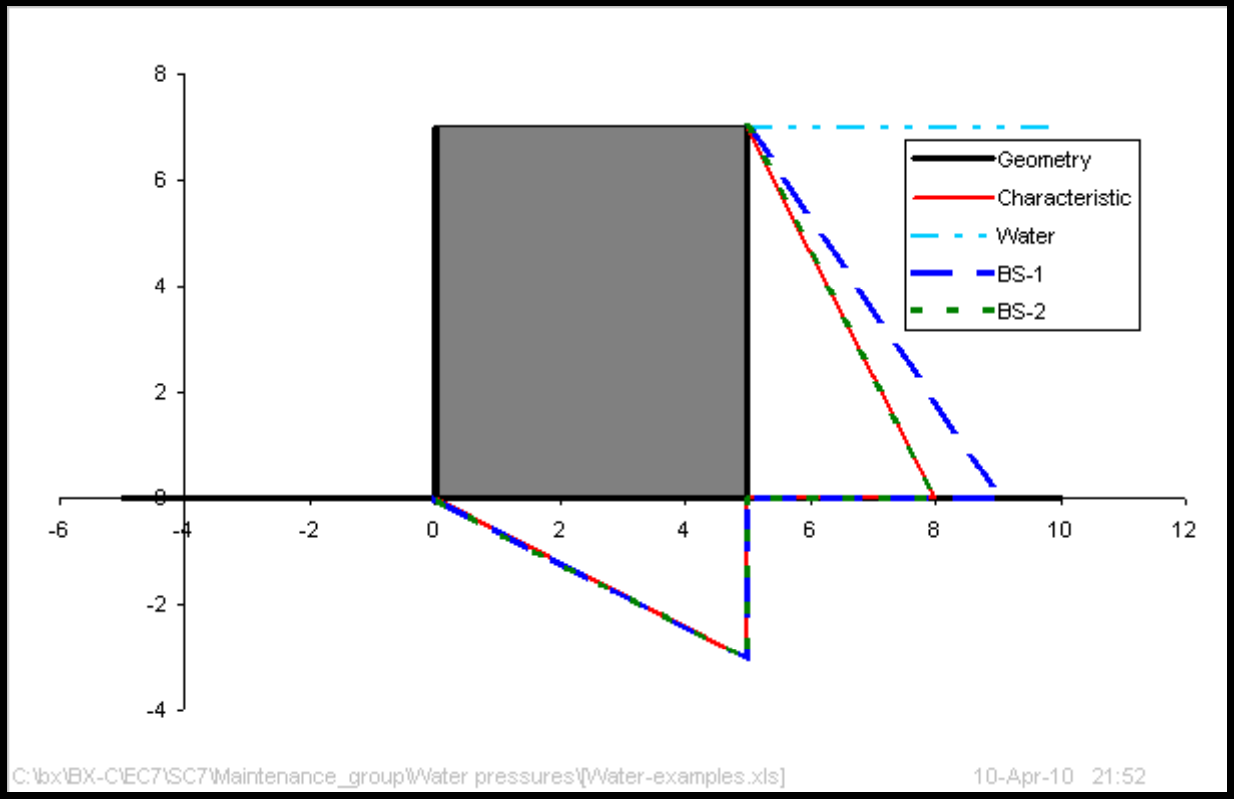

- Two combinations (DA1)
- Same water pressures for all calculations.
- Not “single source” (in any of the plots)
- For all methods, results very dependent on factor values, including material or resistance factors for BC.

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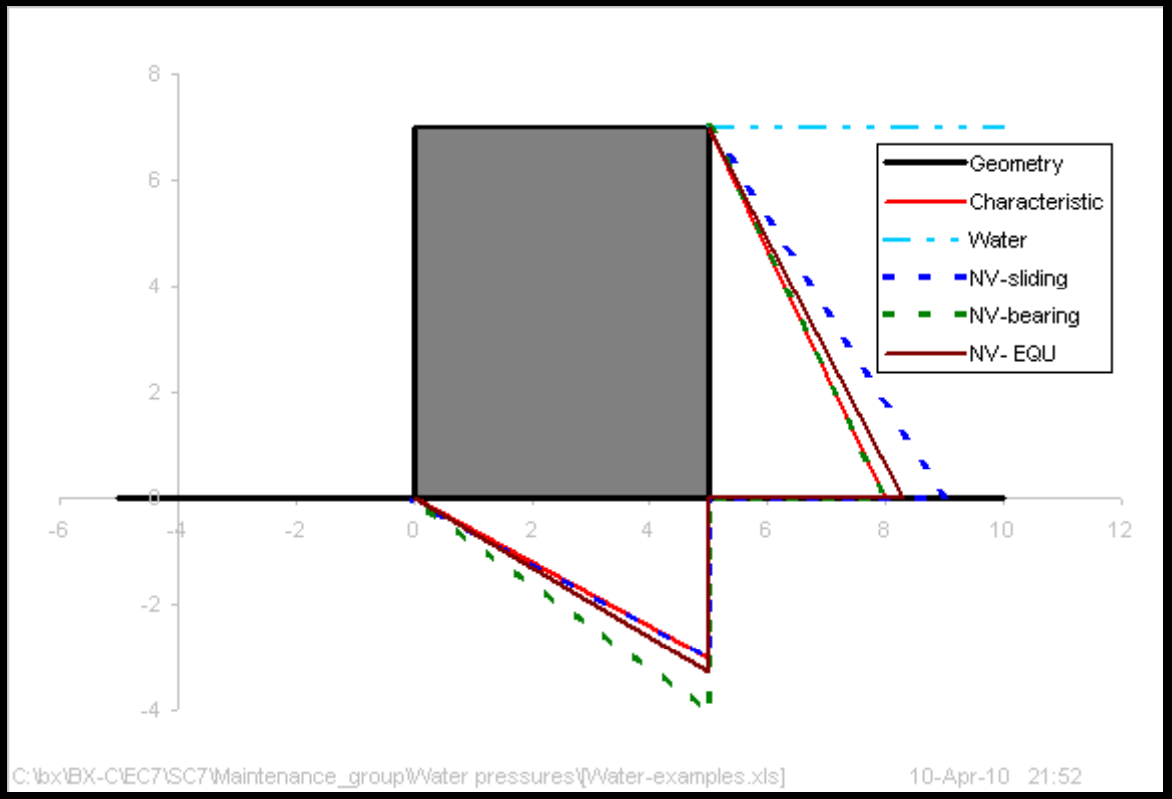

- Different water pressures for each limit state?
- No water pressures less than characteristic
- Not simply using the most critical?

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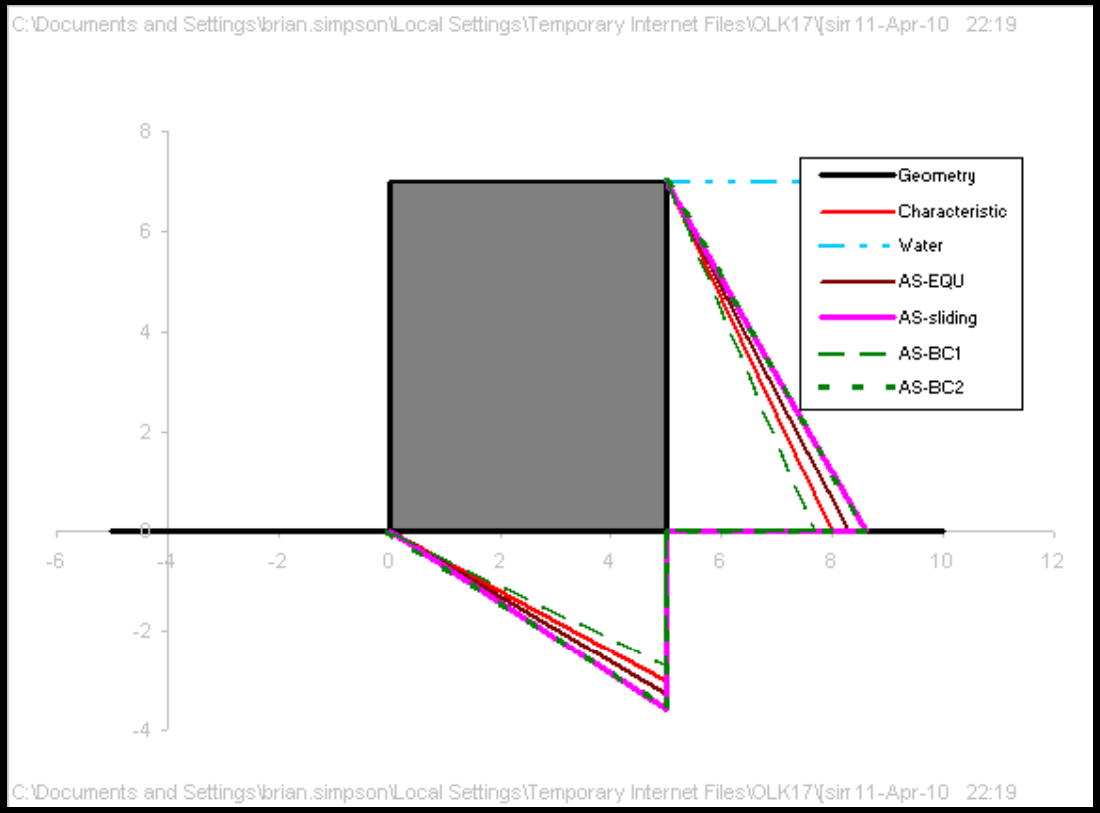

- γ_G lower for water pressure?
- Water pressure less than characteristic considered
- This one is “single source”.

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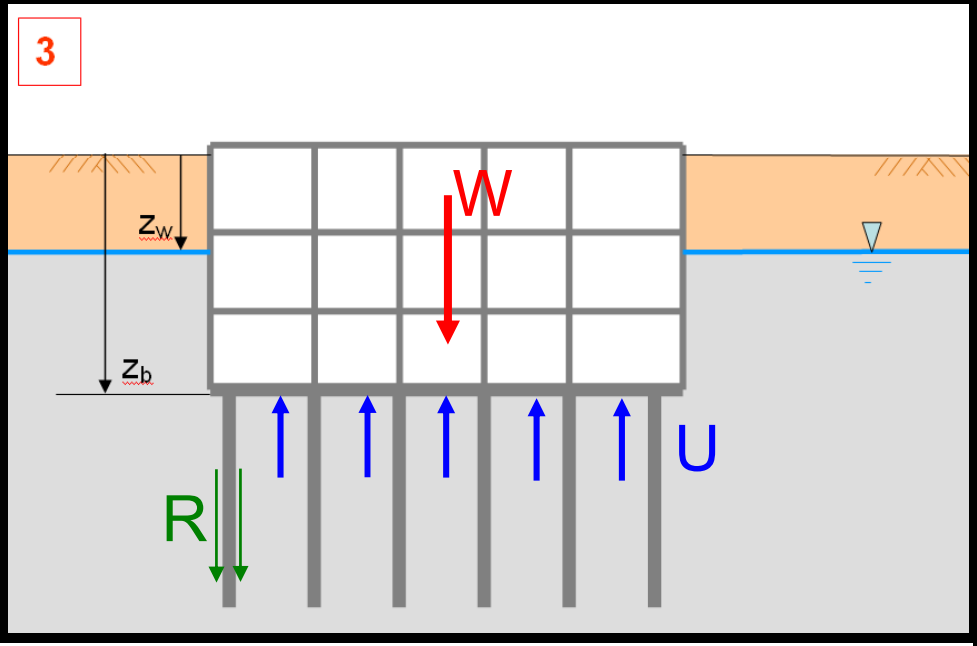
Example 3

- How many piles?
- How to compute design BM?



An urban deep basement. The principal concern addressed here is holding the basement down against the upward pressure of the water beneath it, using bored piles in tension.

The geology consists of gravel over clay with the observed water level at the surface of the clay. Other future construction in the area might, in theory, cause the water table to rise, but this is thought to be unlikely. However, calculations suggest that at the worst the rise could be 1.0 to 1.5m. No holding-down force is provided by the ground in shear on the walls. There is no drainage beneath the basement.

The plan area of the basement is A, and its characteristic weight is W_k (a permanent action, uniformly distributed). The characteristic *geotechnical* resistance of each pile in tension is R_{kg} and there is no interaction between piles or group effect to be considered. No load testing will be carried out for the piles.

u_b is the water pressure at depth z_b. The weight density of water is γ_w.

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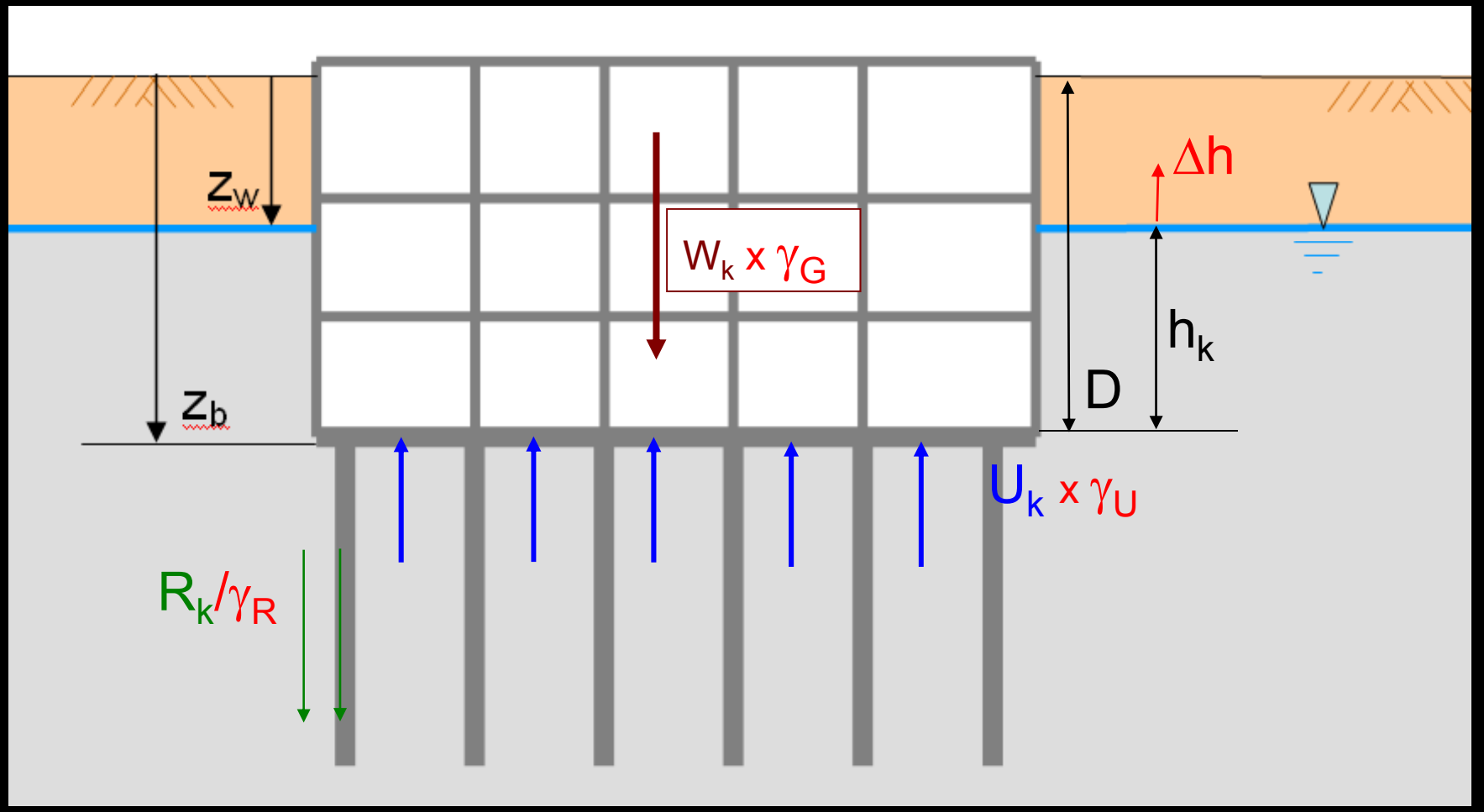

$\gamma_G = \gamma_{F,inf}$ or $\gamma_{F,stb}$

$\gamma_U = \gamma_{F,sup}$ or γ_{dst}

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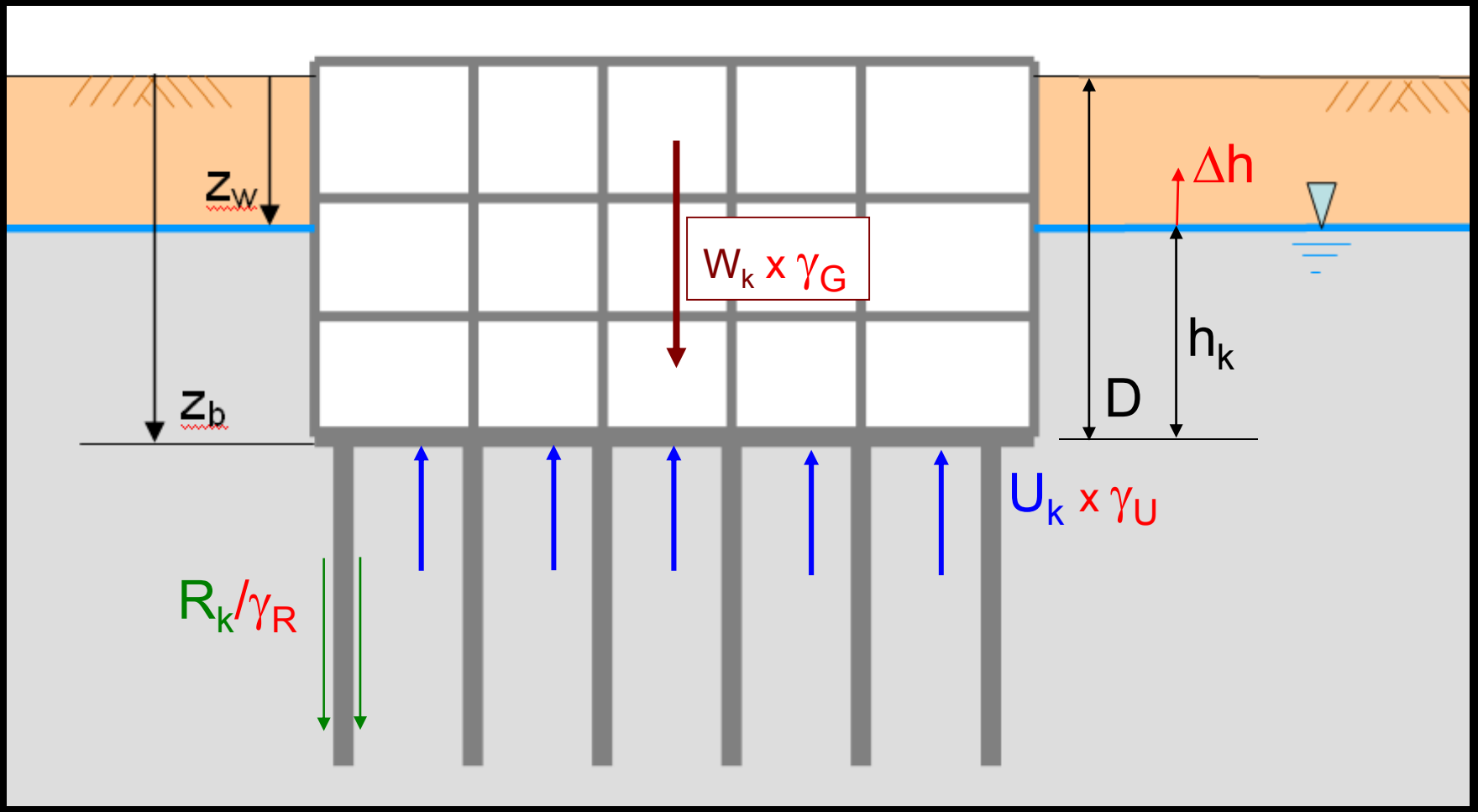

- Water head ratio h_k/D
  - How much water pressure
- Weight ratio $W_k/(vol \times \gamma_w)$
  - How heavy is the building
- Anchorage ratio nR_k/W_k
  - How much anchorage

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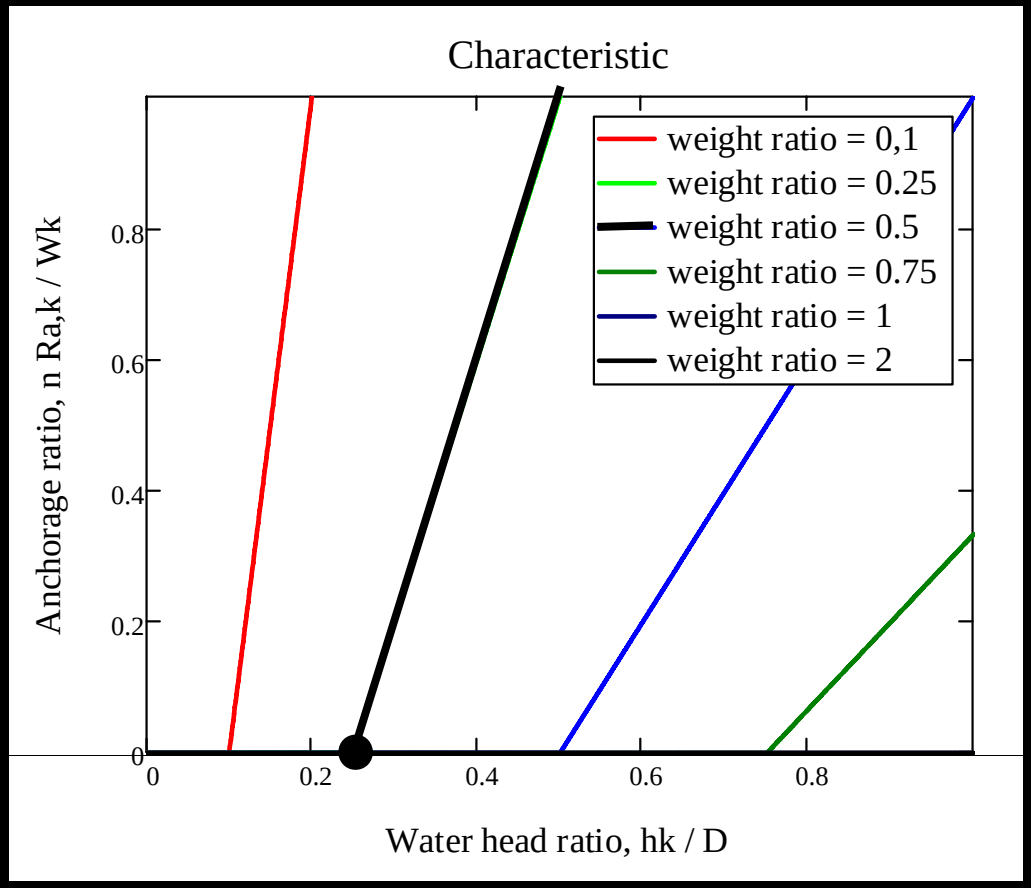
Example 3 – Characteristic situation



- Anchorage ratio nR_k/W_k
  - How much anchorage
- Water head ratio h_k/D
  - How much water pressure
- Weight ratio $W_k/(vol \times \gamma_w)$
  - How heavy is the building

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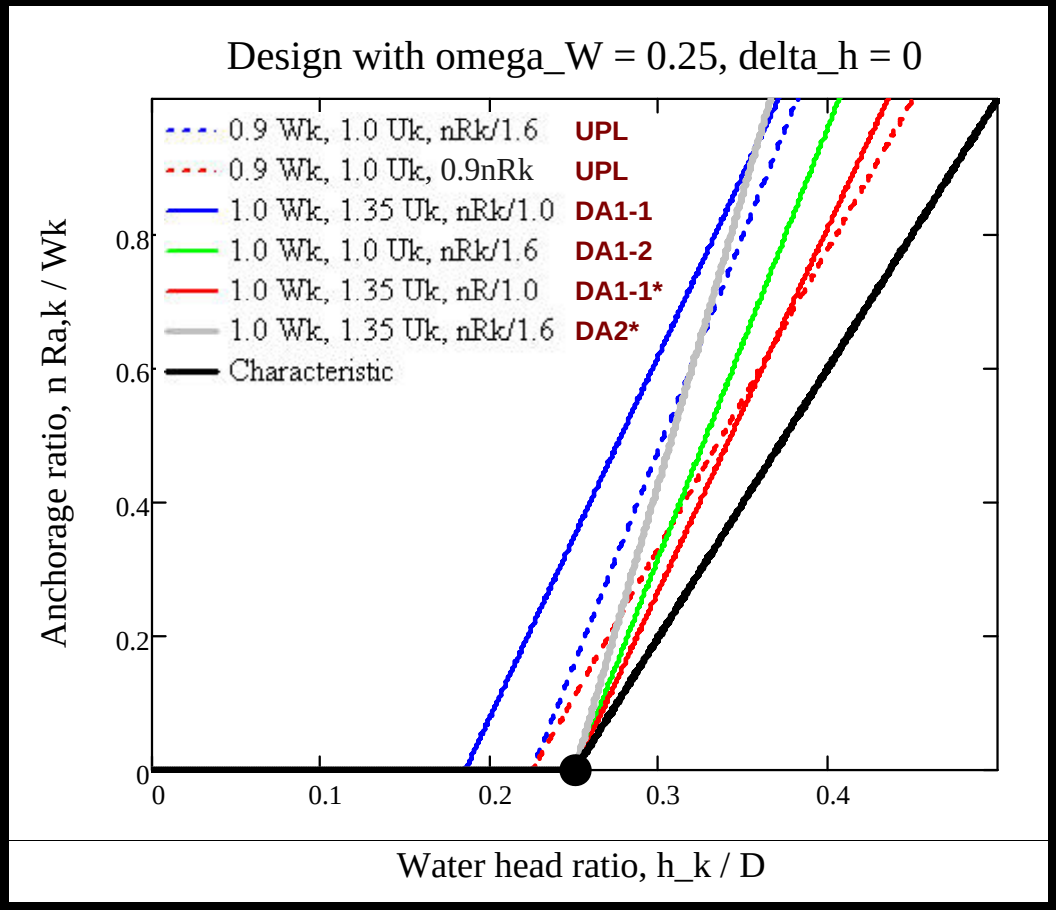
Weight ratio 0.25. $\Delta h=0$.



- For high water heads, all methods give some safety.
  - How much is needed?
- Near the balance point, safety is only provided by increasing the water pressure.

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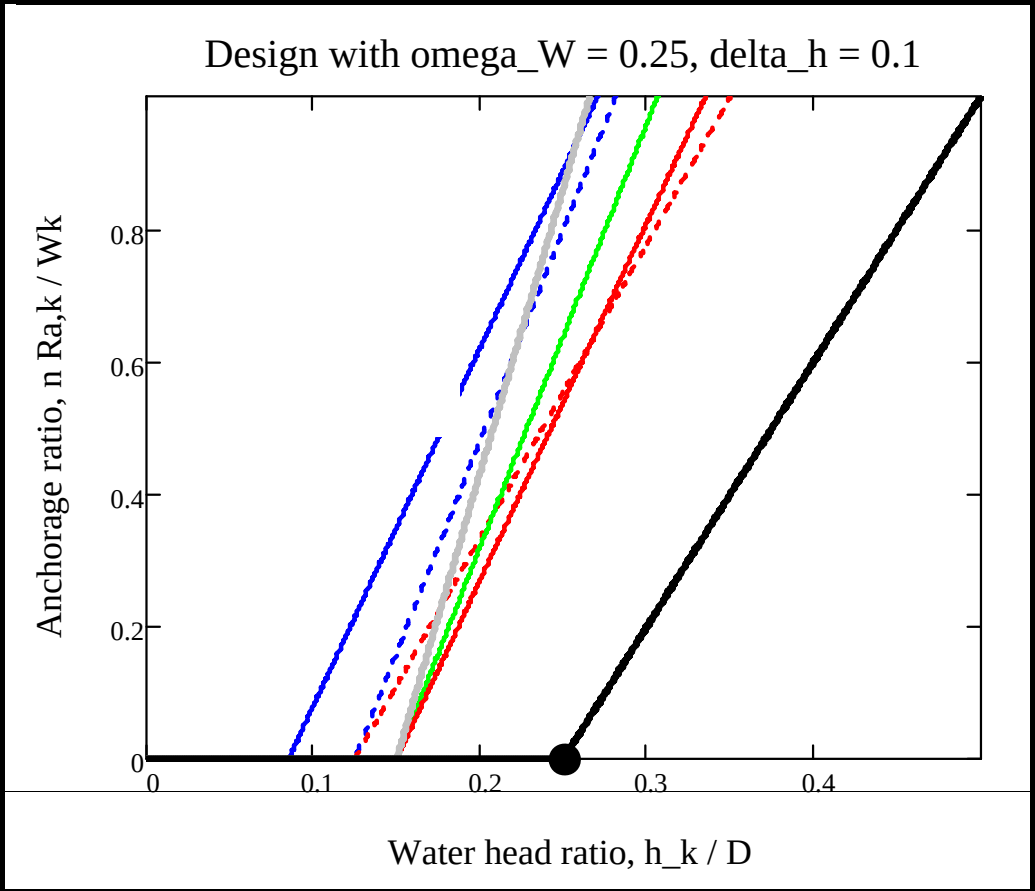
Weight ratio =0.25. Δh=0.1



- Increasing the head by Δh provides a safety margin.
- But would this be used in addition to other safety factors?

0.9 Wk, 1.0 Uk, nRk/1.6	UPL
0.9 Wk, 1.0 Uk, 0.9nRk	UPL
1.0 Wk, 1.35 Uk, nRk/1.0	DA1-1
1.0 Wk, 1.0 Uk, nRk/1.6	DA1-2
1.0 Wk, 1.35 Uk, nR/1.0	DA1-1*
1.0 Wk, 1.35 Uk, nRk/1.6	DA2*
Characteristic	

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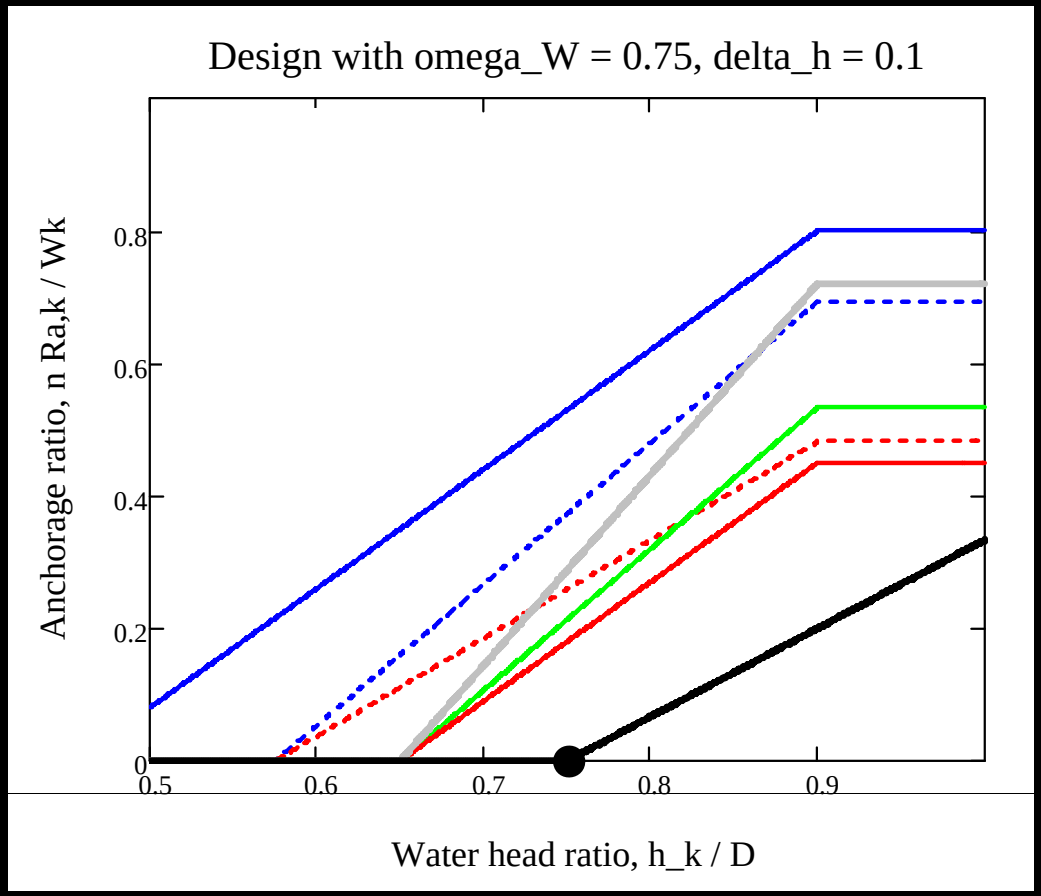
Weight ratio = 0.75 (heavy building). Δh=0.1.



- Similar pattern.
- Factoring water pressures starting to dominate effect of Δh.

0.9 Wk, 1.0 Uk, nRk/1.6	UPL
0.9 Wk, 1.0 Uk, 0.9nRk	UPL
1.0 Wk, 1.35 Uk, nRk/1.0	DA1-1
1.0 Wk, 1.0 Uk, nRk/1.6	DA1-2
1.0 Wk, 1.35 Uk, nR/1.0	DA1-1*
1.0 Wk, 1.35 Uk, nRk/1.6	DA2*
Characteristic	

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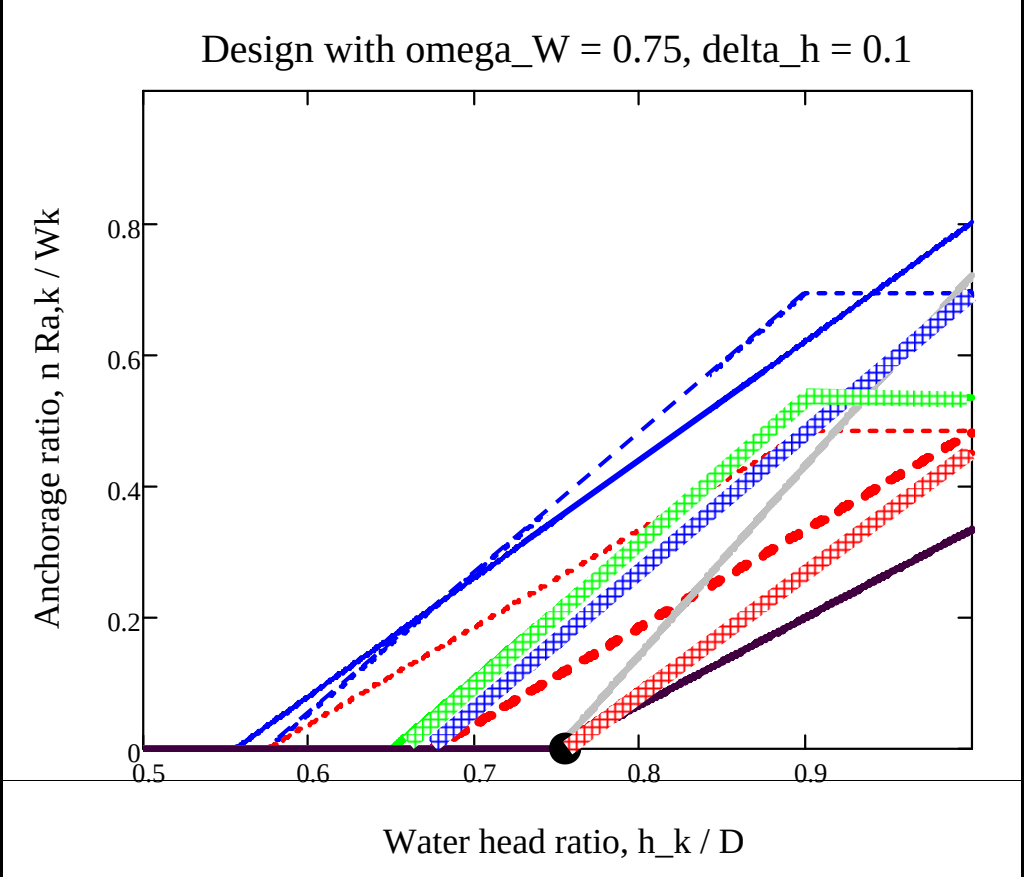
Weight ratio = 0.75 - *my preference*
Δh=0.1 or γ^*



- DA1-1* becomes critical for bending moment.

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Some thoughts

- Avoid factoring water pressures – always??
- Margins better than factors.
- Perhaps factor *differential* water pressure.
- Single source?
- Can we retain physical reason?
- Apply a lot of common sense.