Challenges facing Geotechnical Engineers in Ireland

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Public procurement practices

- are they fit-for-purpose?

Implementing Eurocode 7

- some personal views

Public procurement of infrastructure projects

Obsession with ‘value for money’.

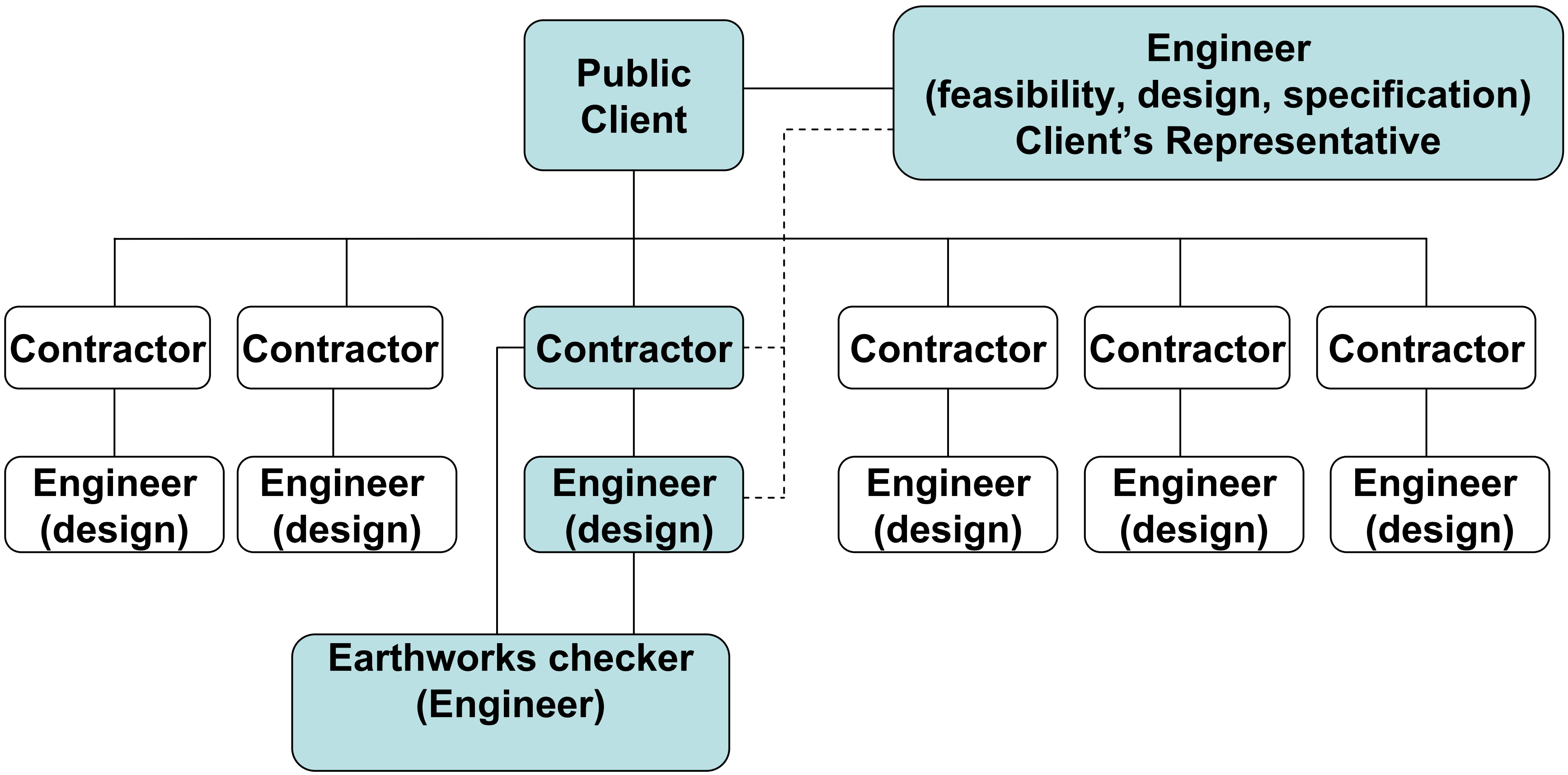
What does it mean?

- Drive down prices.
- Transfer risk.
- Let someone else pay if something goes wrong.

Should the Public Client be encouraging below cost selling of professional services by consulting engineers and contractors?

If fees/profits are insufficient to ensure a quality service, who loses out in the end?

Design & Construct National Road Project



Is this effective use of national engineering resources?

Can such waste of effort lead to value for money in the long term?

Engineer as Lead Designer is diminished.

The Engineer who conceived the original design is effectively sidelined as designer once the contract is awarded and is left looking on as Client's Representative.

The new Engineer as designer is employed by the Contractor, who drives the design process. This Engineer owes a primary duty to the Contractor to ensure that the project is designed and constructed to comply with the specification.

The link between the Engineer as designer and the Client is effectively severed.

The traditional relationship between Engineer and Contractor has been turned on its head.

Is this good for Engineering?

Transfer of risk

Good engineering involves managing and minimizing risk.

On major infrastructural projects, effective management of geotechnical risk is central to technical and economic success.

Geotechnical risk needs to be managed effectively from feasibility right through to operation.

Do the present methods of procurement facilitate a life cycle approach to geotechnical risk management?

Is it good engineering to create high geotechnical risks at feasibility and specimen design stage and to simply transfer them on to a contractor?

The transfer of such risks is predicated on the contractor managing them. If he cannot do so, will the risks just bounce back to the employer?

Effective management of geotechnical risk imposes a responsibility on all parties not to just transfer it on and sit back.

Eurocode 7 (EC7) is upon us and must be implemented by 2010.

What follows are my personal observations.
It is not an introduction to EC7.

What is good about EC7?

Good geotechnical practice **shall** be obligatory.

Cl. 2.8 There **shall** be a **Geotechnical Design Report**.
Supervision, monitoring & maintenance requirements for the completed structure **shall** be provided to the client.

Cl. 3.4 The results of a geotechnical investigation **shall** be compiled in a **Ground Investigation Report** which **shall** form part of the **Geotechnical Design Report**.

Cl. 2.7 The form of the **Observational Method** is defined clearly.

EC7 Design by Calculation is generally consistent with other Eurocodes.

Ultimate Limit States (ULS) and Serviceability Limit States (SLS)
are considered separately.

Partial Factor approach is used as in other Eurocodes.

Partial Factors are denoted by the symbol γ, not to be confused with
γ denoting bulk unit weight (weight density in EC7).

γ_F on actions, γ_E on effects of actions
γ_M on material strength parameters
γ_R on resistances

In discussing EC7 Design by Calculation for ULS, I will restrict myself
to simple problems where all loads are permanent loads.

I will not discuss piles or anchors, where the partial factors set in the
Irish National Annex are greater than the EC7 recommended minimum values
(and rightly so).

Ultimate Limit States in EC7

STR internal failure or excessive deformation of the structure

GEO failure or excessive deformation of the ground

EQU loss of equilibrium of the structure or ground as a rigid body

UPL loss of equilibrium of structure or ground due to uplift water pressure

HYD hydraulic heave, piping, internal erosion

Different partial factors are specified for each limit state.

EQU, **UPL** & **HYD** Limit states

My personal view

UPL is a special case of **EQU** if soil strength is ignored (it should be)

HYD (hydraulic heave) is a special case of **UPL**

HYD (piping, internal erosion) is quite different – a sediment transport issue

EQU should include **UPL** and **HYD (hydraulic heave)** so that all these loss of equilibrium problems can be treated in a consistent manner using a single set of partial factors.

HYD (piping, internal erosion) should be treated as a separate limit state

Apply **EQU**, **UPL** & **HYD** to uplift of ground by water thrust using EC7 partial factors

OFS = (Resistance Force)/(Disturbing Force)

EQU **1.1** (Unfav. Perm. Actions) ↑ ≤ **0.9** (Fav. Perm. Actions) ↓

OFS = 1.1/0.9 = **1.22**

UPL **1.0** (Unfav. Perm. Actions) ↑ ≤ **0.9** (Fav. Perm. Actions) ↓

OFS = 1.0/0.9 = **1.11**

HYD **1.35** (Unfav. Perm. Actions) ↑ ≤ **0.9** (Fav. Perm. Actions) ↓

HYD eq. (2.9a) Total stress approach

1.35 (upward water pressure) ↑ ≤ **0.9** (Total vertical stress) ↓

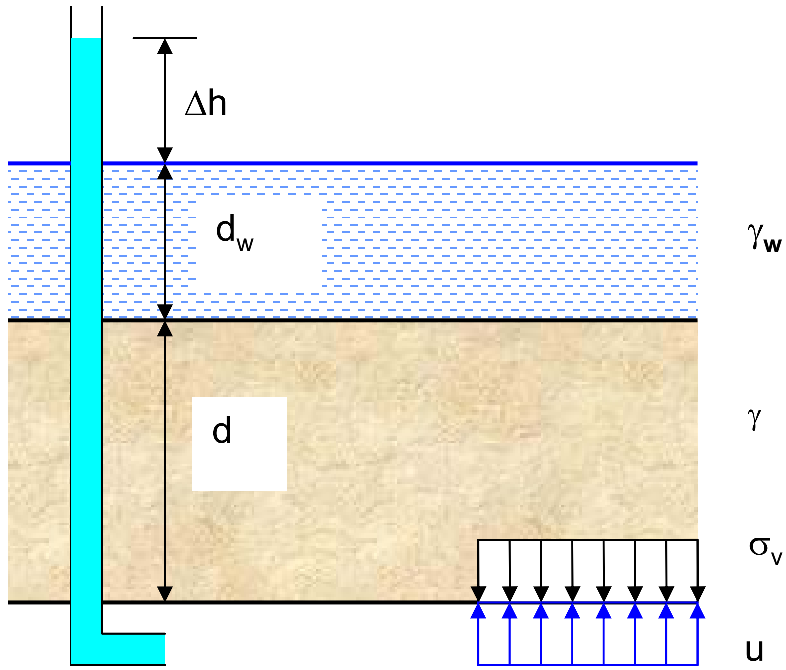
OFS = 1.35/0.9 = **1.5**

HYD eq. (2.9b) Effective stress approach

1.35 (seepage force) ↑ ≤ **0.9** (Effective vertical stress) ↓

Seepage Force is not a force but a pressure difference.
Effective vertical stress is not a stress but a stress difference.
OFS = ??? It cannot be calculated directly from the partial factors.

EQU, UPL & HYD applied to uplift of ground by water thrust using EC7 partial factors

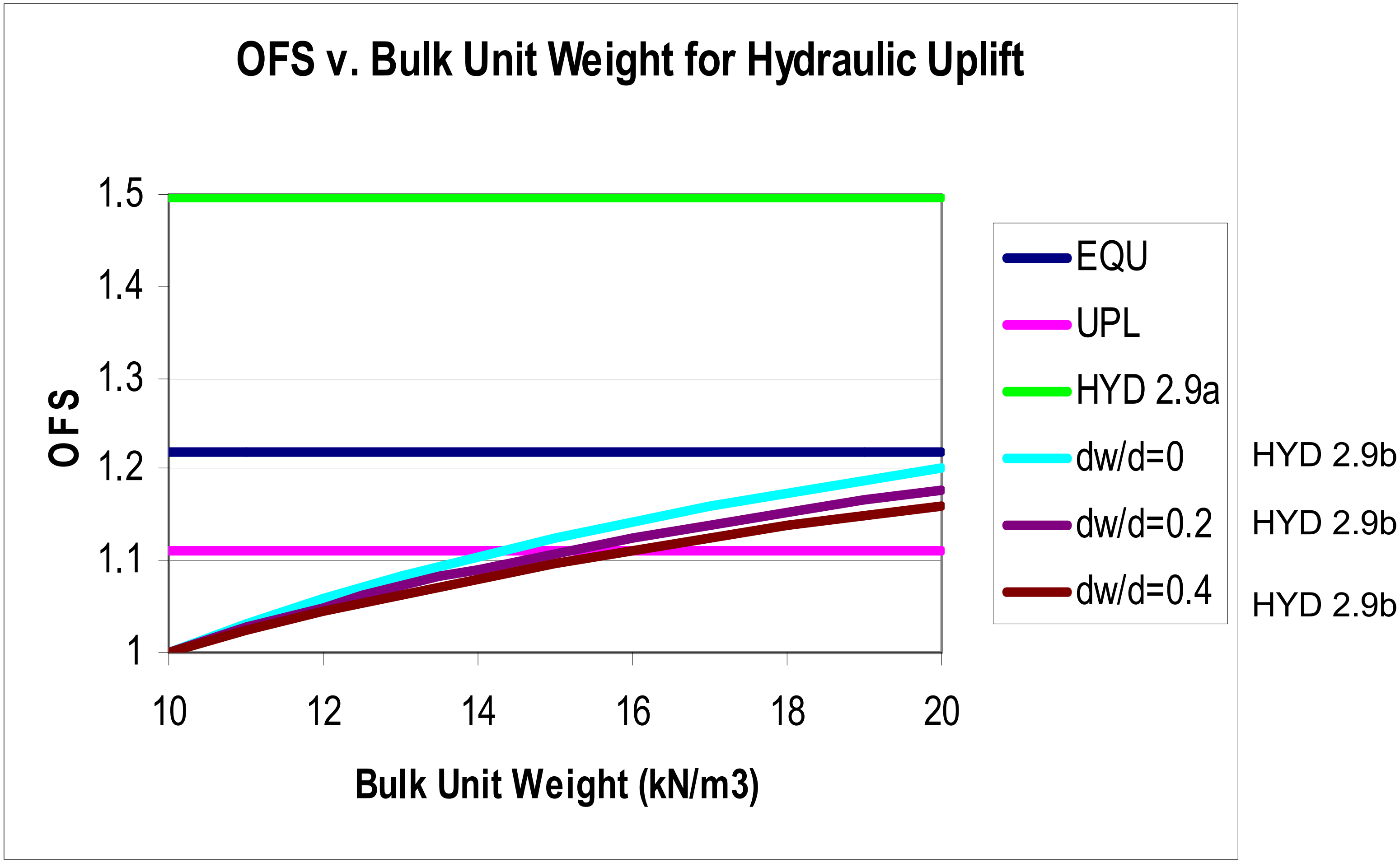


EQU OFS = 1.1/0.9 = **1.22**

UPL OFS = 1.0/0.9 = **1.11**

HYD eq. (2.9a) Total stress approach OFS = 1.35/0.9 = **1.5**

HYD eq. (2.9b) Effective stress approach OFS varies but is **≤ 1.2**


OFS v. Bulk Unit Weight for Hydraulic Uplift
OFS
1.5
1.4
1.3
1.2
1.1
1
10
12
14
16
18
20
Bulk Unit Weight (kN/m3)
EQU
UPL
HYD 2.9a
dw/d=0
dw/d=0.2
dw/d=0.4
HYD 2.9b
HYD 2.9b
HYD 2.9b

EC7 Design by calculation for STR & GEO Ultimate Limit States

Where the strength of the soil is relevant, partial factors are included in the Ultimate Limit State calculations using three Design Approaches.

I explore the three Design Approaches by looking at the Ultimate Limit State (ULS) for some standard problems where all loads are permanent loads.

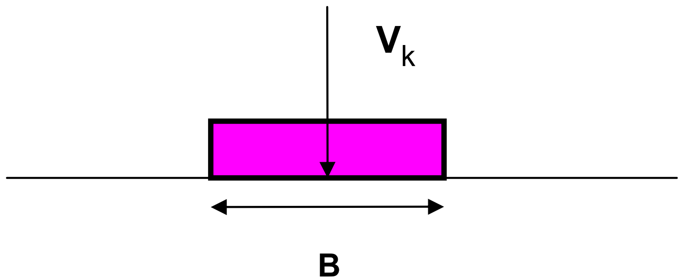
I assume that

(1) the characteristic loads in EC7 are the working loads in present practice;

(2) the characteristic strength parameters in EC7 are the design strength parameters in present practice.

The focus is on the Overall Factor of Safety (OFS) achieved for each DA.

Ultimate Bearing Capacity of a Strip Foundation on surface of Undrained Clay



γ, c_u
$\gamma_d = \gamma_k = \gamma$
$(c_u)_d = (c_u)_k / \gamma_M$

γ_M: Material factor

OFS approach: $\mathbf{q}_{ult} = (\pi+2)c_u$ $\mathbf{q}_{safe} = \mathbf{q}_{ult}/OFS$

EC7 Characteristic Action = $q_k = V_k/B$
EC7 Characteristic Resistance = $(\pi+2)(c_u)_k$

EC7 Design Action = $q_d = \gamma_F q_k$
EC7 Design Resistance = $\{(\pi+2)(c_u)_k\}/\gamma_R$ or $(\pi+2)\{(c_u)_k/\gamma_M\}$

Strip Foundation, width B, on surface of undrained clay
Central Point Dead Load

$\mathbf{q}_{ult} = (\pi+2)c_u$ $\mathbf{q}_{safe} = \mathbf{q}_{ult}/OFS$

What is OFS for each EC7 Design Approach?

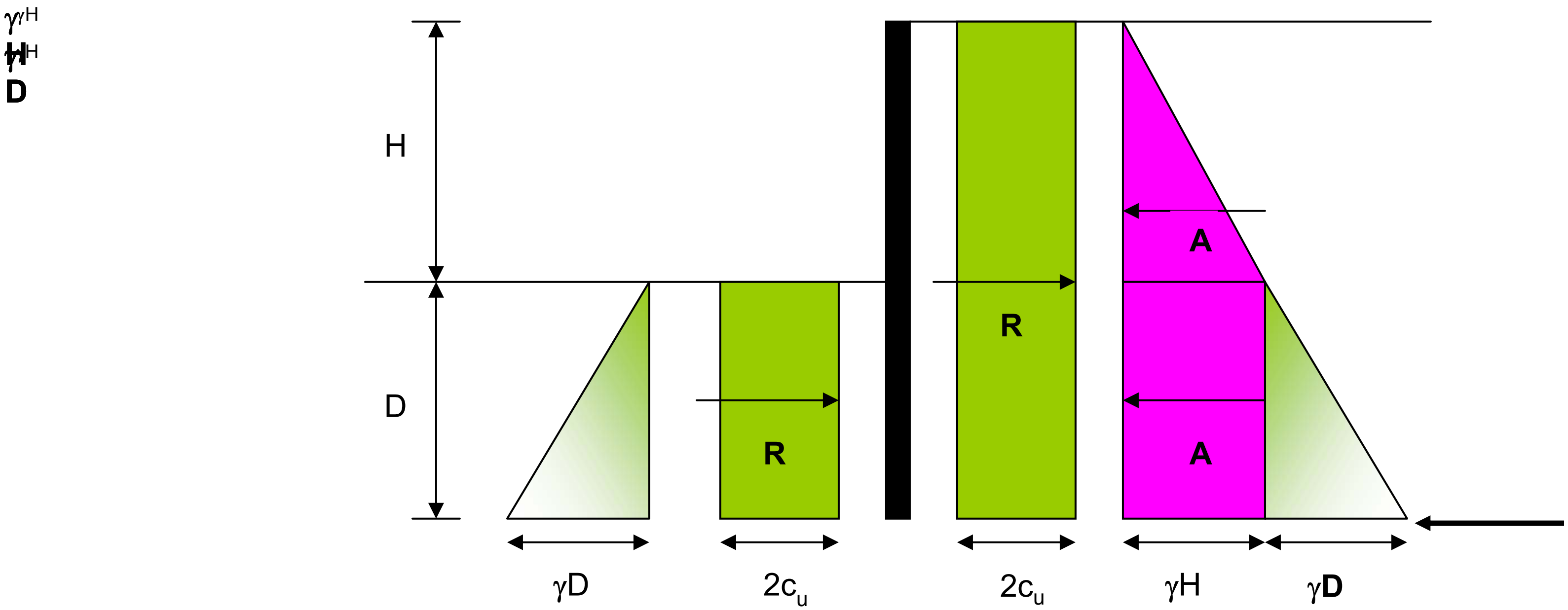
DA1-1	$\mathbf{1.35}\ q_k = (\pi+2)\mathbf{\{}(c_u)_k/\mathbf{1.0}\mathbf{\}}$	OFS = 1.35
DA1-2	$\mathbf{1.0}\ q_k = (\pi+2)\mathbf{\{}(c_u)_k/\mathbf{1.4}\mathbf{\}}$	OFS = 1.4
DA2	$\mathbf{1.35}\ q_k = \mathbf{\{}(\pi+2)(c_u)_k\mathbf{\}}/\mathbf{1.4}$	OFS =1.35x1.4 = 1.89
DA3	$\mathbf{1.35}\ q_k = (\pi+2)\mathbf{\{}(c_u)_k/\mathbf{1.4}\mathbf{\}}$	OFS =1.35x1.4 = 1.89

These OFS values are minimum values.

As imposed load increases as a proportion of total load, the OFS increases.

As eccentricity of load due to imposed load increases, the OFS increases.

Embedded Cantilever Retaining Wall in undrained clay (Burland & Potts)
Horizontal retained surface, no surcharge, Rankine pressures



Unfavourable Actions due to weight of retained soil of height H
Favourable Actions due to weight of embedded soil of depth D (self-cancelling)

Characteristic Action Moment about bottom = $0.5\gamma H^2(H/3+D) + 0.5\gamma HD^2$

Characteristic Resistance Moment about bottom = $\{(H+D)^2 + D^2\}(c_u)_k$

Embedded Cantilever Retaining Wall in undrained clay (Burland & Potts)
Horizontal retained surface, no surcharge, Rankine pressures

Action Moment = $0.5\gamma H^2(H/3+D) + 0.5\gamma HD^2$

Resistance Moment = $\{(H+D)^2 + D^2\}c_u$

What is OFS for each EC7 Design Approach?

DA1-1 $\mathbf{1.35}(\text{Action M})_k = \{(H+D)^2 + D^2\}\mathbf{\{}(c_u)_k/\mathbf{1.0}\mathbf{\}}$ OFS = 1.35

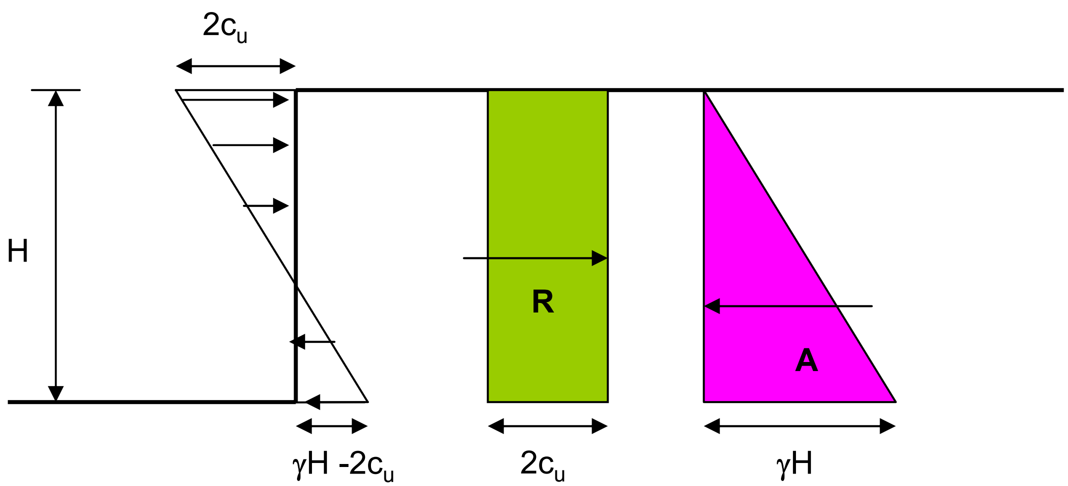
DA1-2 $\mathbf{1.0}(\text{Action M})_k = \{(H+D)^2 + D^2\}\mathbf{\{}(c_u)_k/\mathbf{1.4}\mathbf{\}}$ OFS = 1.4

DA2 $\mathbf{1.35}(\text{Action M})_k = \mathbf{\{}\{(H+D)^2 + D^2\}(c_u)_k\mathbf{\}}/\mathbf{1.4}$ OFS =1.35x1.4 = 1.89

DA3 $\mathbf{1.0}(\text{Action M})_k = \{(H+D)^2 + D^2\}\mathbf{\{}(c_u)_k/\mathbf{1.4}\mathbf{\}}$ OFS = 1.4

Note that $\mathbf{OFS_{DA3} = OFS_{DA1\text{-}2}}$ due to γ_F=**1.0** on LHS (action through ground).

Unsupported vertical cut in undrained clay
Rankine pressures



Characteristic Action Force = $0.5\gamma H^2$

Characteristic Resistance Force = $2H(c_u)_k$

Unsupported vertical cut in undrained clay
Rankine pressures

Action Force = $0.5\gamma H^2$

Resistance Force = $2Hc_u$

What is OFS for each EC7 Design Approach?

DA1-1	$\mathbf{1.35}(0.5\gamma H^2)_k = 2H\{(c_u)_k/\mathbf{1.0}\}$	OFS = 1.35
DA1-2	$\mathbf{1.0}(0.5\gamma H^2)_k = 2H\{(c_u)_k/\mathbf{1.4}\}$	OFS = 1.4
DA2	$\mathbf{1.35}(0.5\gamma H^2)_k = \{2H(c_u)_k\}/\mathbf{1.1}$	OFS =1.35x1.1 = 1.485
DA3	$\mathbf{1.0}(0.5\gamma H^2)_k = 2H\{(c_u)_k/\mathbf{1.4}\}$	OFS = 1.4

Note that $\mathbf{OFS_{DA3} = OFS_{DA1\text{-}2}}$ due to γ_F=**1.0** on LHS (action through ground).

OFS Summary for undrained clay examples

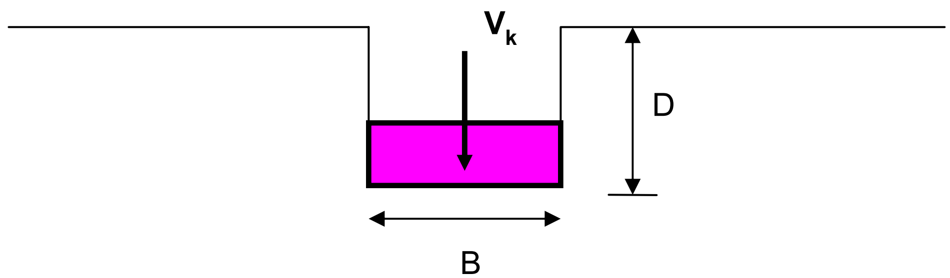
	Strip	Wall	Slope
DA1-1	1.35	1.35	1.35
DA1-2	1.4	1.4	1.4
DA2	1.89	1.89	1.485
DA3	1.89	1.4	1.4

DA1-2 is the controlling case for DA1.

DA2 gives the highest OFS in all three cases.

Which approach gives outcomes closest to present practice?

Strip Foundation, width B, at depth D in dry sand/gravel
Central Point Dead Load



$\mathbf{q}_{ult} = \gamma D N_q + 0.5\gamma B N\gamma$ $\mathbf{q}_{safe} = \mathbf{q}_{ult}/OFS$

$N_q = e^{\pi \tan\phi'} \tan^2(45+\phi'/2)$ $N_\gamma = 2(N_q-1)\tan\phi'$

Consider two cases
(a) Strip at surface (N_γ term only)
(b) Square pad at large depth, D >> B (N_q term only)

Strip Foundation, width B, on surface of sand/gravel
Central Point Dead Load

$\mathbf{q}_{ult} = 0.5\gamma B N_\gamma$ $\mathbf{q}_{safe} = \mathbf{q}_{ult}/OFS$ $\tan\phi_d' = \dfrac{\tan\phi_k'}{\mathbf{1.25}}$

What is OFS for each EC7 Design Approach?

DA1-1 $\mathbf{1.35}\ \mathbf{q}_k = 0.5\gamma B(N_\gamma)_k$ OFS = 1.35

DA1-2 $\mathbf{1.0}\mathbf{q}_k = 0.5\gamma B\mathbf{(N_\gamma)_d}$ OFS = $(N_\gamma)_k/(N_\gamma)_d$

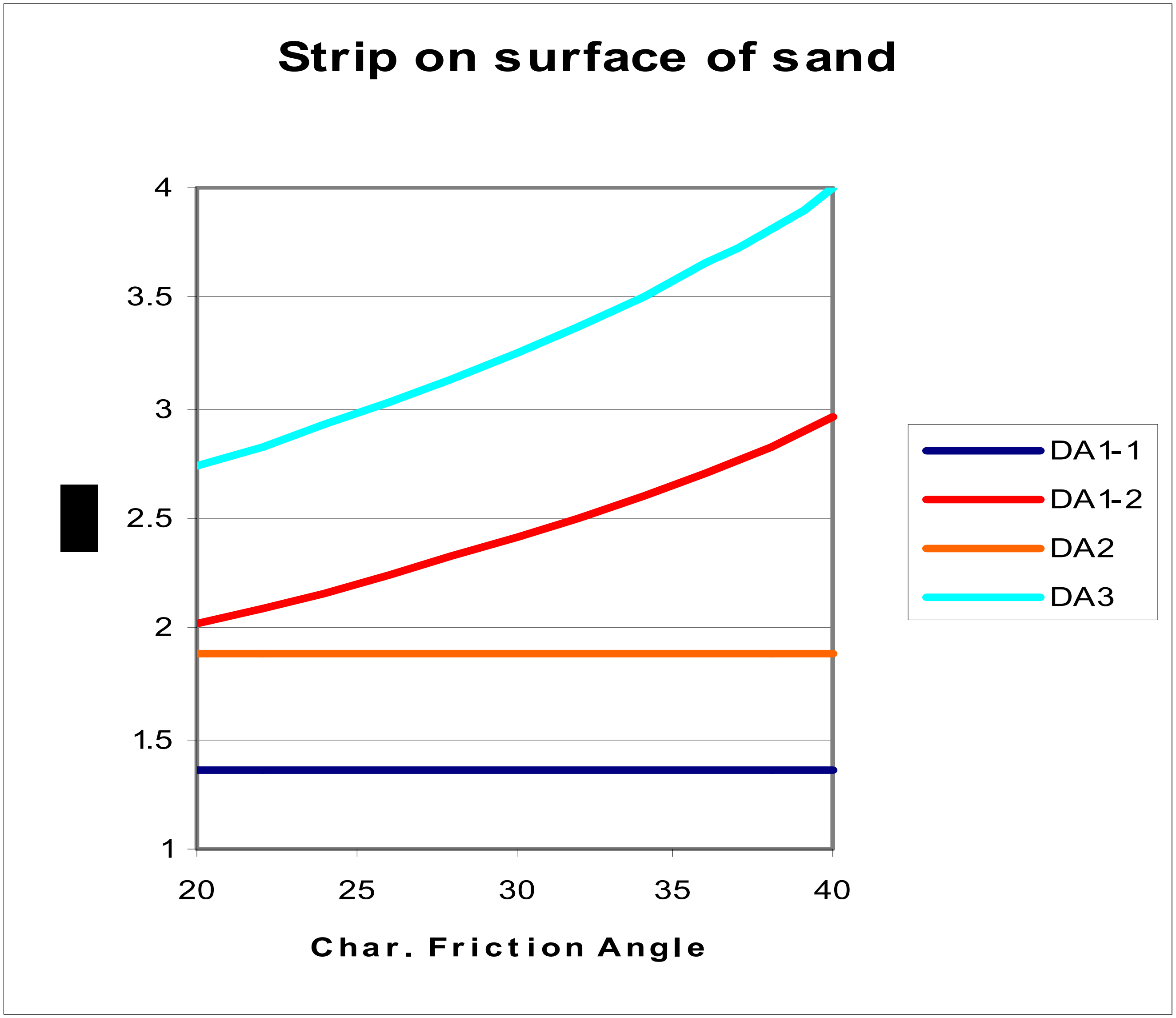
DA2 $\mathbf{1.35}\ \mathbf{q}_k = \{0.5\gamma B(N_\gamma)_k\}/\mathbf{1.4}$ OFS =1.35x1.4 = 1.89

DA3 $\mathbf{1.35}\ \mathbf{q}_k = 0.5\gamma B\mathbf{(N_\gamma)_d}$ OFS = $1.35(N_\gamma)_k/(N_\gamma)_d$

These OFS values are minimum values.

As imposed load increases as a proportion of total load, the OFS increases.

As eccentricity of load due to imposed load increases, the OFS increases.


Strip on surface of sand
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

Square Foundation at large depth D in sand/gravel
Central Point Dead Load

$\mathbf{q}_{ult} = \gamma D(1+\sin\phi')N_q$ $\mathbf{q}_{safe} = \mathbf{q}_{ult}/OFS$ $s_q = 1+\sin\phi'$

What is OFS for each EC7 Design Approach?

DA1-1 $\mathbf{1.35}\ \mathbf{q}_k = \gamma D(1+\sin\phi'_k)(N_q)_k$ OFS = 1.35

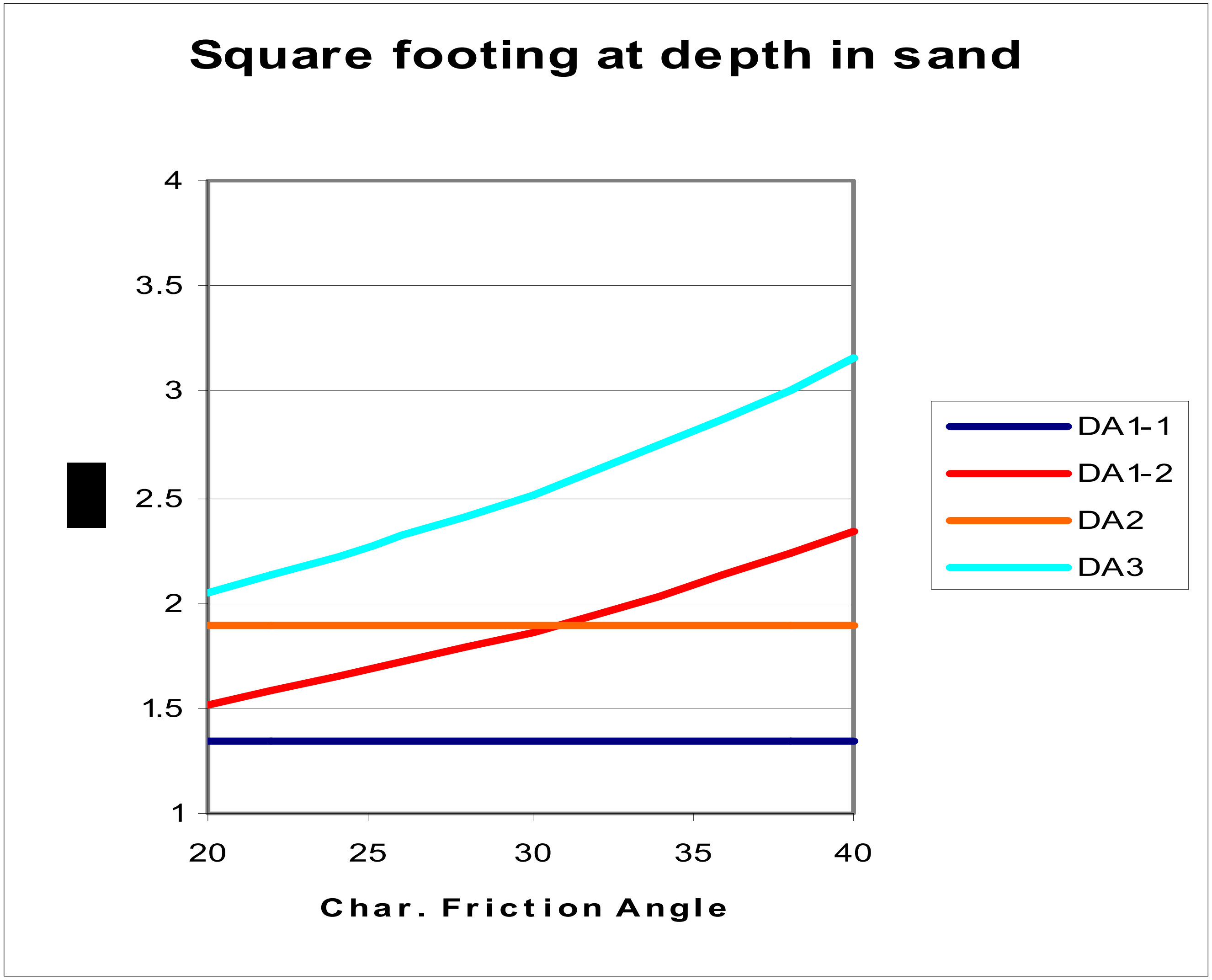
DA1-2 $\mathbf{1.0}\ \mathbf{q}_k = \gamma D\mathbf{(1+\sin\phi'_d)(N_q)_d}$ $\text{OFS} = \dfrac{(1+\sin\phi'_k)(N_q)_k}{(1+\sin\phi'_d)\,(N_q)_d}$

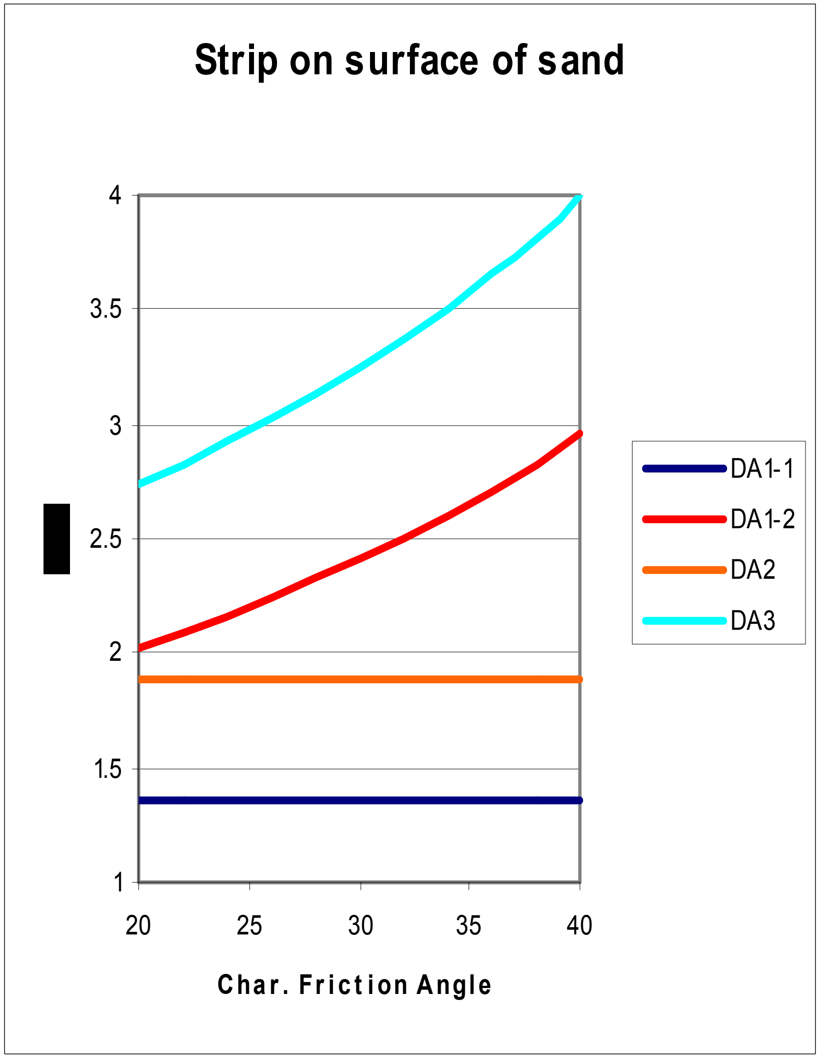
DA2 $\mathbf{1.35}\ \mathbf{q}_k = \{\gamma D(1+\sin\phi'_k)(N_q)_k\}/\mathbf{1.4}$ OFS =1.35x1.4 = 1.89

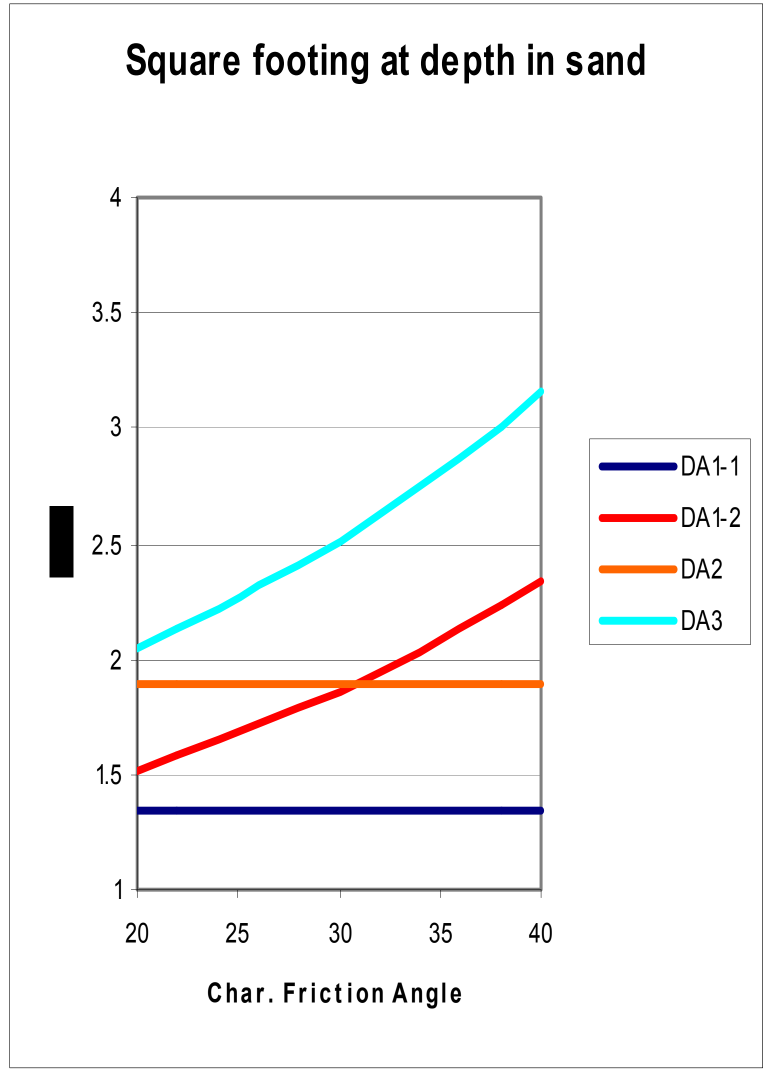
DA3 $\mathbf{1.35}\ \mathbf{q}_k = \gamma D\mathbf{(1+\sin\phi'_d)(N_q)_d}$ $\text{OFS} = 1.35\text{x}\text{OFS}_{DA1-2}$

These OFS values are minimum values.

As imposed load increases as a proportion of total load, the OFS increases.


Square footing at depth in sand
4
3.5
3
2.5
2
1.5
1
[redacted]
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

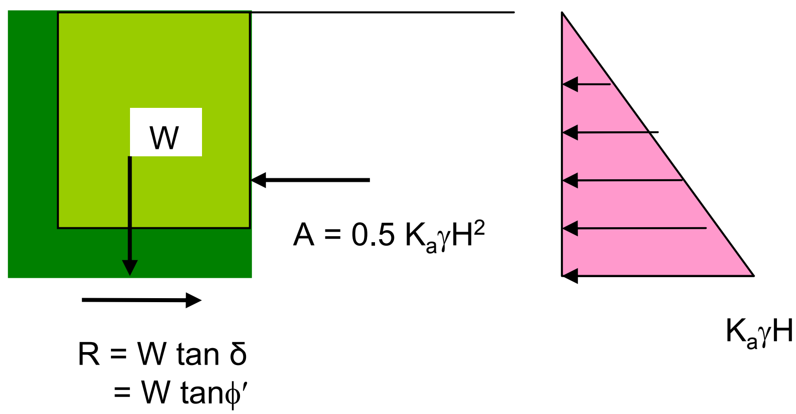

Strip on surface of sand
[redacted]
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3


Square footing at depth in sand
[redacted]
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

Gravity Retaining Wall on rough base ($\delta = \phi'$) in sand/gravel

Rankine pressures, horizontal retained surface

Failure by sliding



$K_a = \tan^2(45 - \phi'/2)$

$(K_a)_k = \tan^2(45 - \phi_k'/2)$

Characteristic Unfavourable Action $A_k = 0.5(K_a)_k \gamma H^2$
Characteristic Favourable Action W_k
Characteristic Resistance $R_k = W_k \tan\phi_k'$

EC7 requires $A_d \leq R_d$

Gravity Retaining Wall on rough base ($\delta=\phi'$) in sand/gravel
Rankine pressures, horizontal retained surface
Failure by sliding

Action = $0.5K_a\gamma H^2$ $W_d = \mathbf{1.0}W_k$ Resistance = $W_d\tan\phi'$

What is OFS for each EC7 Design Approach?

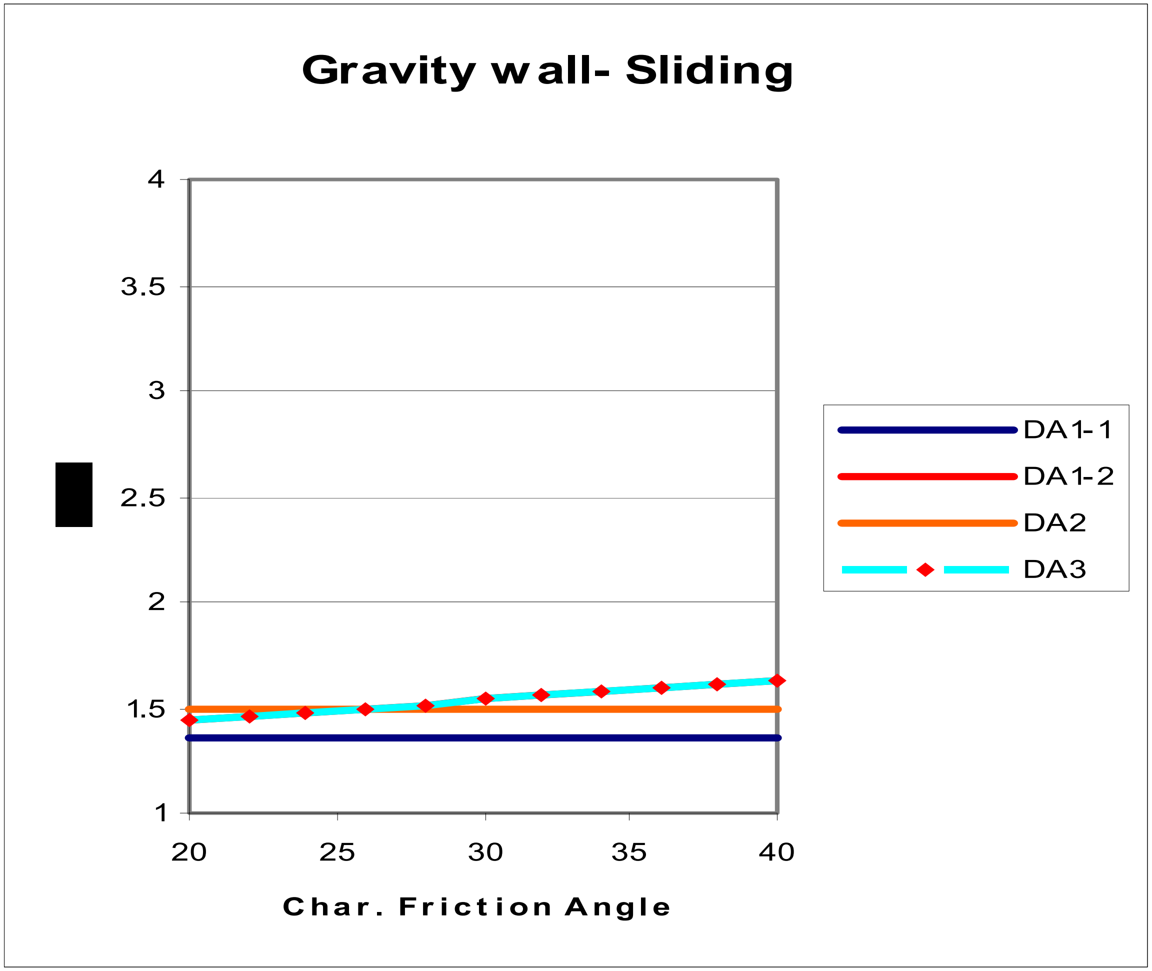
DA1-1 $\mathbf{1.35}(0.5(K_a)_k\gamma H^2) = W_d\tan\phi'_k$ OFS = 1.35

DA1-2 $\mathbf{1.0}(0.5\mathbf{(K_a)_d}\gamma H^2) = W_d\mathbf{\tan\phi'_d}$ OFS = $1.25(K_a)_d/(K_a)_k$
where $\tan\phi'_d = (\tan\phi'_k)/\mathbf{1.25}$

DA2 $\mathbf{1.35}(0.5(K_a)_k\gamma H^2) = (W_d\tan\phi'_k)/\mathbf{1.1}$ OFS =1.35x1.1 = 1.485

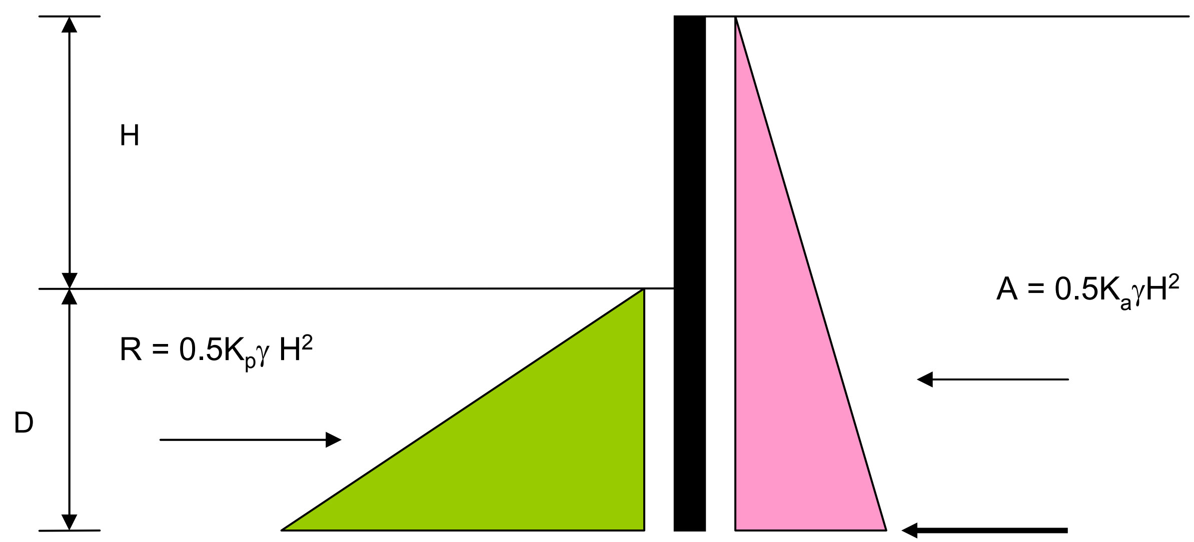
DA3 $\mathbf{1.0}(0.5\mathbf{(K_a)_d}\gamma H^2) = W_d\mathbf{\tan\phi'_d}$ OFS = $1.25(K_a)_d/(K_a)_k$

Note that $\mathbf{OFS_{DA3} = OFS_{DA1\text{-}2}}$ due to γ_F=**1.0** on LHS in DA-3
(action through ground).


Gravity wall- Sliding
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

Embedded Cantilever Retaining Wall in sand/gravel

Horizontal retained surface, no surcharge, Rankine pressures



Characteristic Action Moment about bottom = $(K_a)_k\gamma(H+D)^3/6$

Characteristic Resistance Moment about bottom = $(K_p)_k\gamma D^3/6$

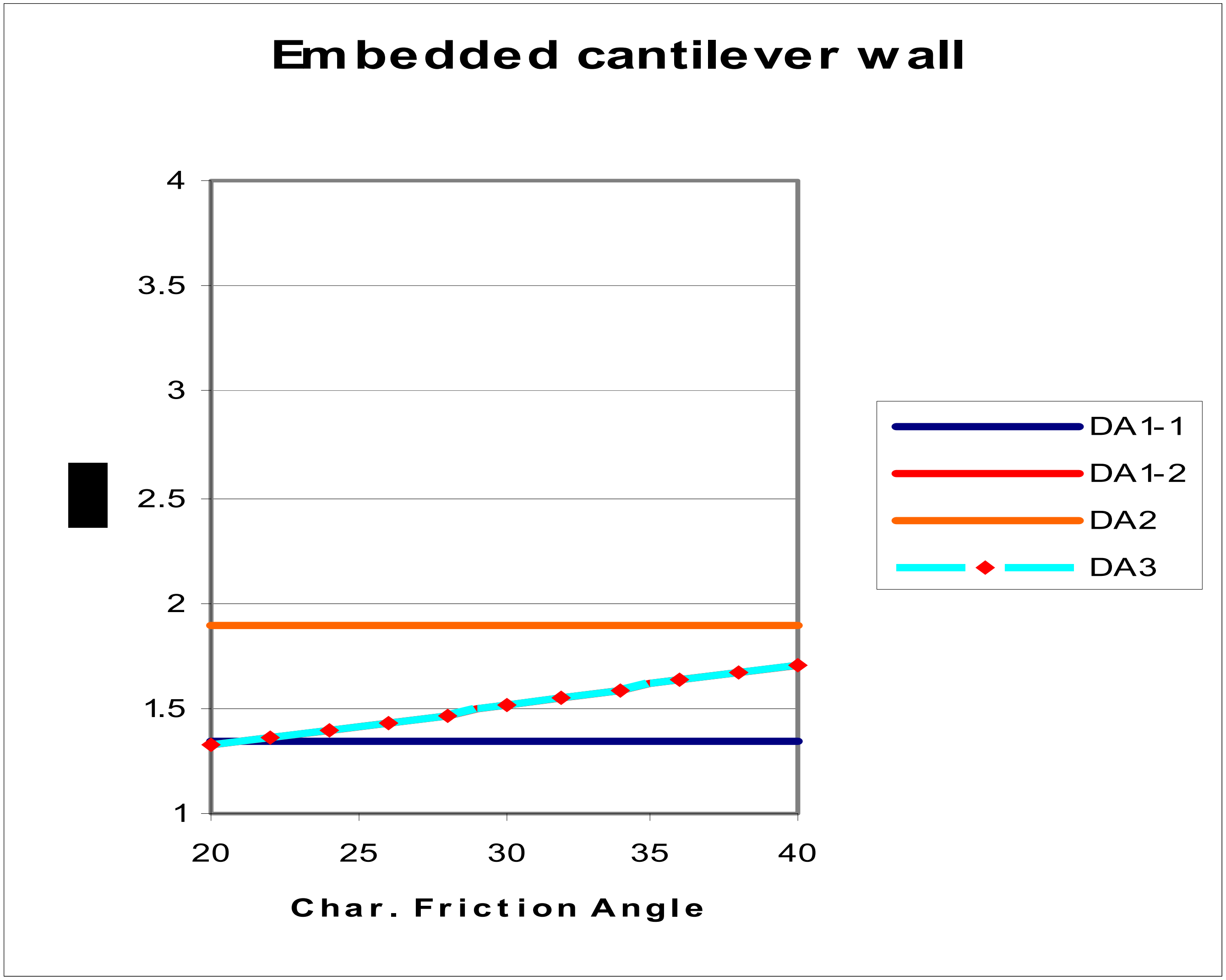
Embedded Cantilever Retaining Wall in sand/gravel
Horizontal retained surface, no surcharge, Rankine pressures

Action Moment = $K_a\gamma(H+D)^3/6$ Resistance Moment = $K_p\gamma D^3/6$

What is OFS for each EC7 Design Approach?

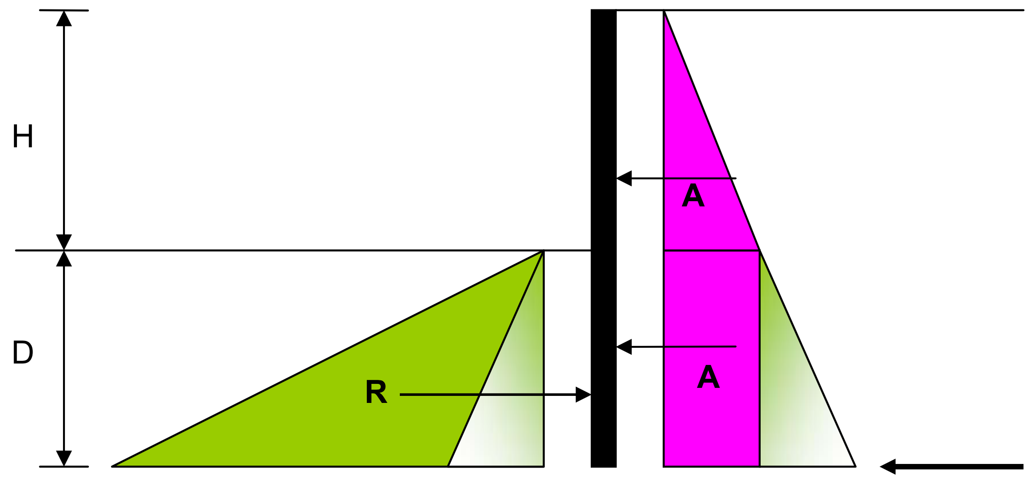
DA1-1	$\mathbf{1.35}(K_a)_k\gamma(H+D)^3/6 = (K_p)_k\gamma D^3/6$	OFS = 1.35
DA1-2	$\mathbf{1.0(K_a)_d}\gamma(H+D)^3/6 = \mathbf{(K_p)_d}\gamma D^3/6$	OFS = $(K_p)_k^2/(K_p)_d^2$
DA2	$\mathbf{1.35}(K_a)_k\gamma(H+D)^3/6 = (K_p)_k\gamma D^3/6/\mathbf{1.4}$	OFS =1.35x1.4 = 1.89
DA3	$\mathbf{1.0(K_a)_d}\gamma(H+D)^3/6 = \mathbf{(K_p)_d}\gamma D^3/6$	OFS = $(K_p)_k^2/(K_p)_d^2$

Note that $\mathbf{OFS_{DA3} = OFS_{DA1\text{-}2}}$ due to γ_F=**1.0** on LHS (action through ground).


Embedded cantilever wall
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

Embedded Cantilever Retaining Wall in sand/gravel (Burland & Potts)

Horizontal retained surface, no surcharge, Rankine pressures



Characteristic Action Moment about bottom = $0.5(K_a)_k\gamma H^2(D+H/3) + 0.5(K_a)\gamma HD^2$

Characteristic Resistance Moment about bottom = $(K_p-K_a)_k\gamma D^3/6$

Embedded Cantilever Retaining Wall in sand/gravel (Burland & Potts)
Horizontal retained surface, no surcharge, Rankine pressures

Action Moment = $0.5K_a\gamma H^2(D+H/3) + 0.5K_a\gamma HD^2$

Resistance Moment = $(K_p-K_a)\gamma D^3/6$

What is OFS for each EC7 Design Approach?

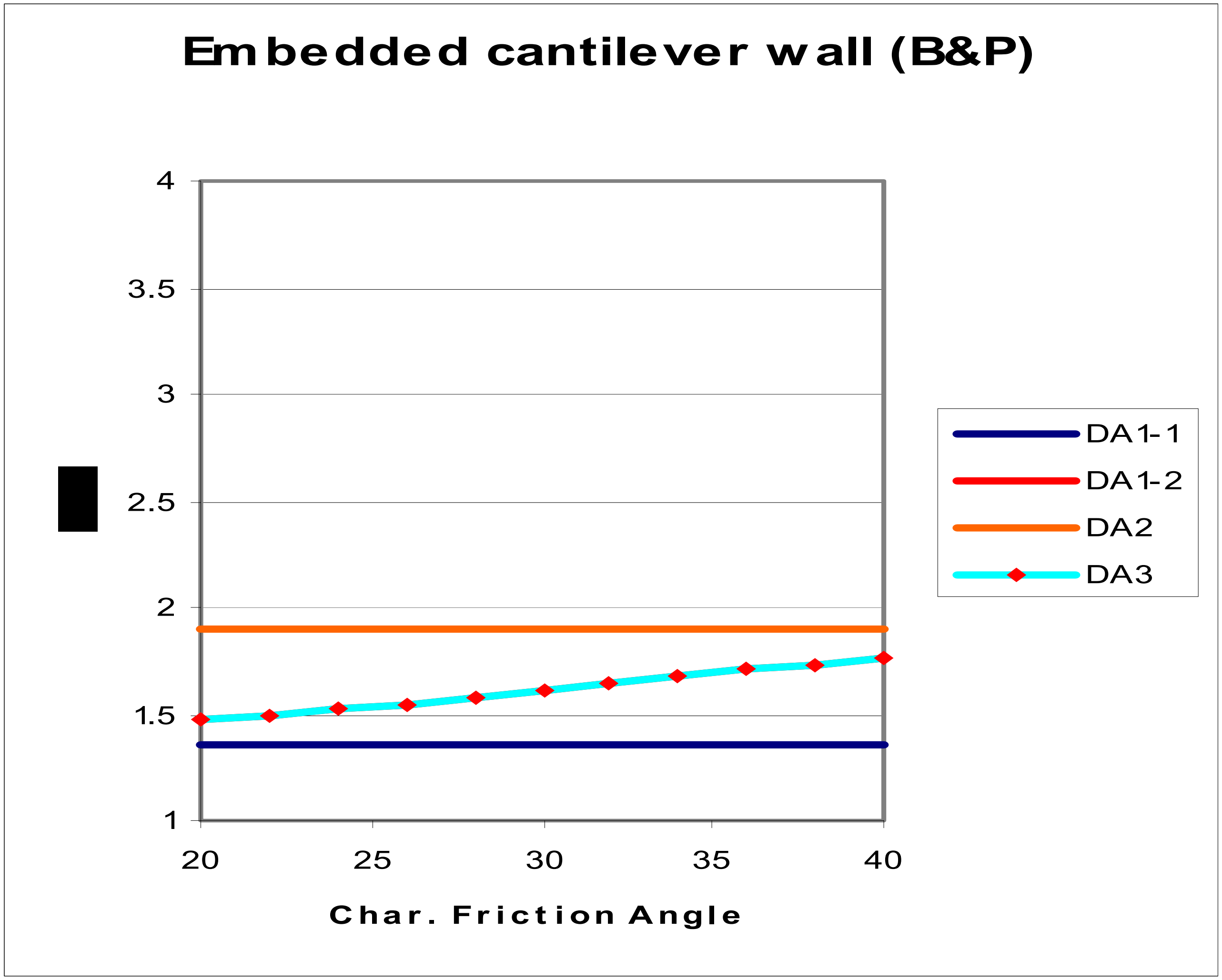
DA1-1 **1.35**(Action M)$_k$ = (Resistance M)$_k$ OFS = 1.35

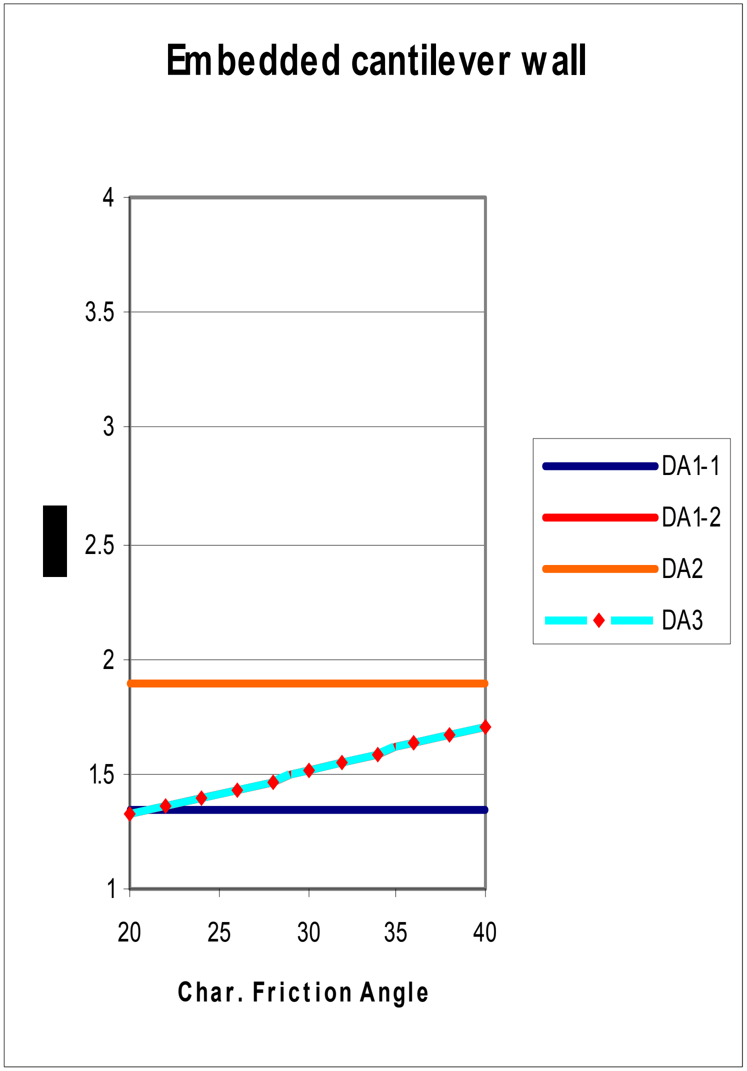
DA1-2 **1.0(Action M)$_d$** = **(Resistance M)$_d$** OFS = $\frac{(K_p)_k^2 - 1}{(K_p)_d^2 - 1}$

DA2 **1.35**(Action M)$_k$ = (Resistance M)$_k$/**1.4** OFS =1.35x1.4 = 1.89

DA3 **1.0(Action M)$_d$** = **(Resistance M)$_d$** OFS = OFS_{DA1-2}

Note that $\mathbf{OFS_{DA3} = OFS_{DA1-2}}$ due to γ_F=**1.0** on LHS (action through ground).


Embedded cantilever wall (B&P)
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3


Embedded cantilever wall
4
3.5
3
2.5
2
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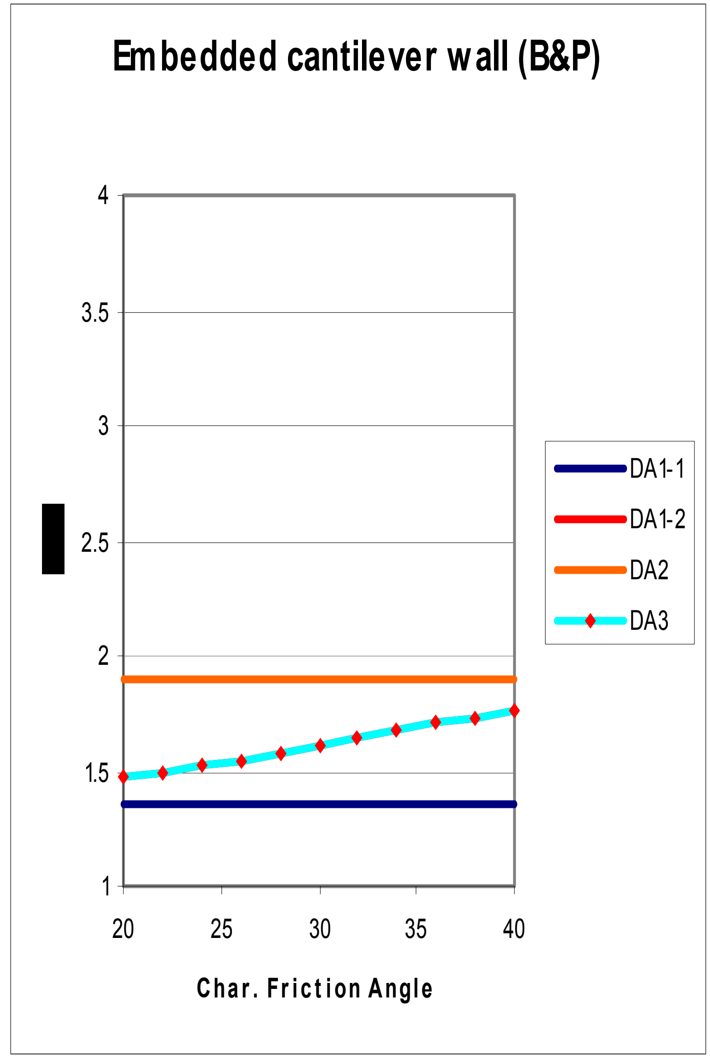
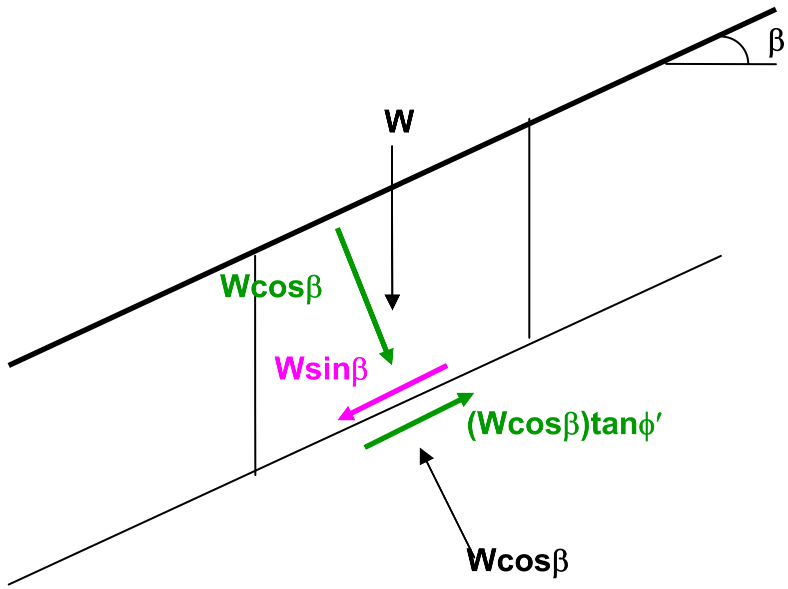
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3


Embedded cantilever wall (B&P)
4
3.5
3
2.5
2
1.5
1
20
25
30
35
40
Char. Friction Angle
DA1-1
DA1-2
DA2
DA3

Infinite Slope at angle β° to horizontal in dry sand/gravel



Unfavourable Characteristic Action = Wsinβ
Favourable Characteristic Action = Wcosβ
Characteristic Resistance = (Wcosβ)tanϕ_k'

EC7 requires $A_d \leq R_d$

Infinite Slope at angle $\beta°$ to horizontal in dry sand/gravel

Action = $W\sin\beta$ Resistance = $(W\cos\beta)\tan\phi'$ OFS = $(\tan\phi')/(\tan\beta)$

What is OFS for each EC7 Design Approach?

DA1-1	$\mathbf{1.35}W\sin\beta = (W\cos\beta)\tan\phi_k'$	OFS = 1.35
DA1-2	$\mathbf{1.0}W\sin\beta = (W\cos\beta)\{(\tan\phi_k')/\mathbf{1.25}\}$	OFS = 1.25
DA2	$\mathbf{1.35}W\sin\beta = \{(W\cos\beta)(\tan\phi_k')\}/\mathbf{1.1}$	OFS =1.35x1.1 = 1.485
DA3	$\mathbf{1.0}W\sin\beta = (W\cos\beta)\{(\tan\phi_k')/\mathbf{1.25}\}$	OFS = 1.25

Note that $\mathbf{OFS_{DA3} = OFS_{DA1\text{-}2}}$ due to γ_F=**1.0** on LHS (action through ground).

As both $W\sin\beta$ and $W\cos\beta$ come from a single source, soil weight W, it may be appropriate to apply the same partial factor to each, yielding OFS = 1.1 in DA2.

OFS Summary for sand/gravel examples

	Surface Strip	Deep Square	Gravity Wall	Embed	Embed (B&P)	Slope
DA1-1	1.35	1.35	1.35	1.35	1.35	1.35
DA1-2	$f_1(\phi_k')$	$f_2(\phi_k')$	$f_3(\phi_k')$	$f_4(\phi_k')$	$f_5(\phi_k')$	1.25
DA2	1.89	1.89	1.485	1.89	1.89	1.485
DA3	$1.35f_1(\phi_k')$	$1.35f_1(\phi_k')$	$f_3(\phi_k')$	$f_4(\phi_k')$	$f_5(\phi_k')$	1.25

DA1-2 is the controlling case for DA1, except for slope.

In DA1-2 and DA3, the OFS varies with ϕ', except for slope.

The highest OFS is not associated with any single DA.

Which DA leads to outcomes closest to present practice?

Some observations on ULS problems in sand/gravel

- Except for the dry infinite slope, DA1-2 leads to a higher OFS than DA1-1 and is the controlling DA1 case.

- Applying γ_M=1.25 to tanϕ_k' gives rise to OFS increasing with ϕ_k' in DA1-2 and DA3 for foundation and retaining wall problems.

- The practice in DA1 of applying partial factors >1 either to the Actions (DA1-1) or to the Soil Strength (DA1-2) but not to both is at variance with the other Eurocodes. It appears to be not consistent with a partial factor approach.

- DA2 is a simple approach giving rise to OFS = γ_F x γ_R

- Yet another Design Approach, combining the treatment of Actions as in DA3 and Resistances as in DA2, might be worth considering.

Final Comments on EC7

EQU/UPL/HYD needs to be addressed in a consistent manner**.**

Hydraulic Heave by an effective stress approach should be assigned to history.

Only **DA2** offers a consistent Overall Factor of Safety independent of soil strength.

I can see how Europe is leaning towards DA2.

- It respects the EC1 partial factors for structures.
- OFS is easily calculated.
- OFS can be set by adjusting the partial factors on resistance.