Example 2.5:Embankment on soft peat

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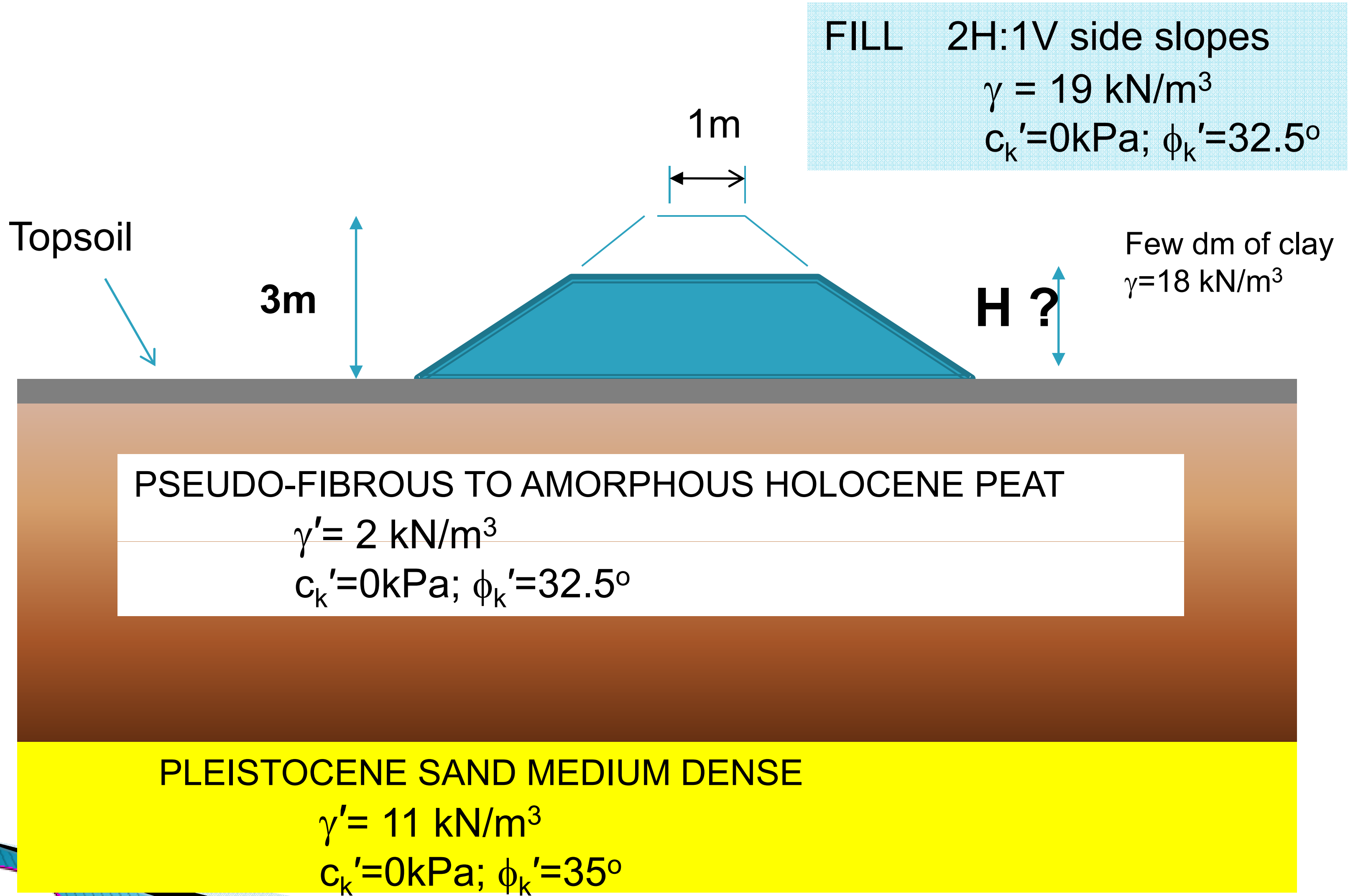
Example 2.5 DESIGN SITUATION



GROUND INVESTIGATION INFORMATION

Information supplied

2 No. Borehole logs

5 No vane tests to DIN 4094:2002 (75mm dia.)

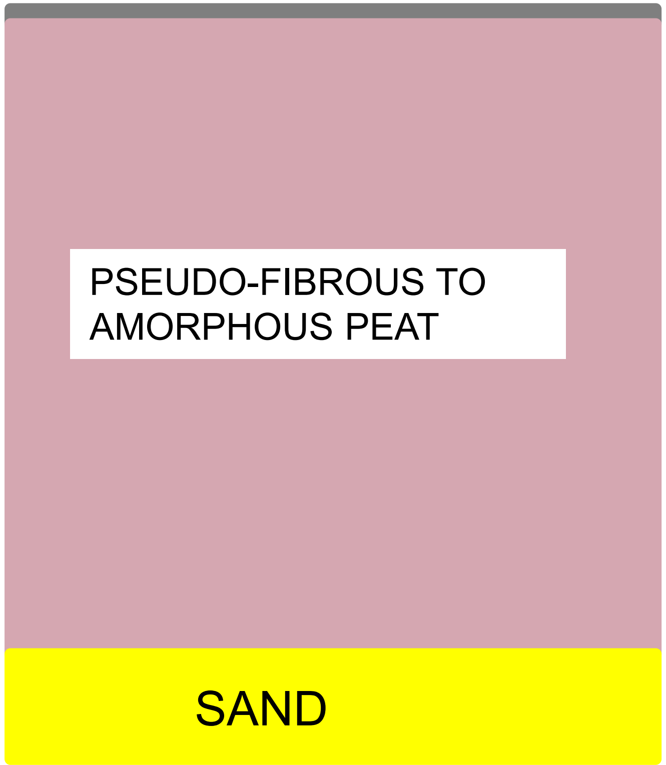
Vanes at spacing of 40m to 50m on centerline.

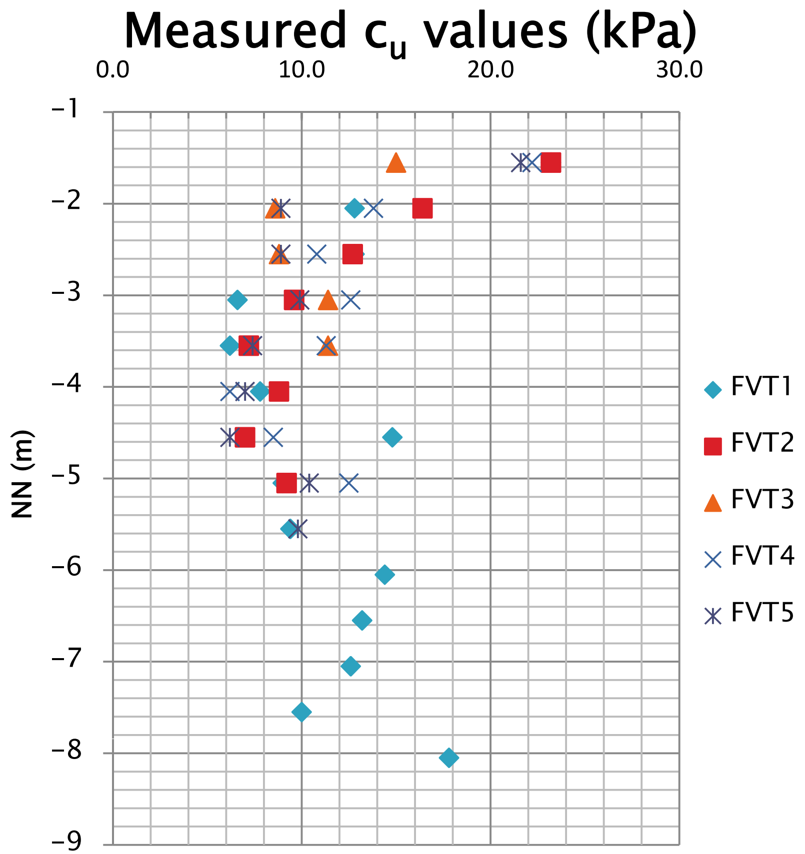
Comment

- *No information on method of construction of boreholes*
- *No laboratory test data*
- *No desk study (previous experience)*
- *Correlation factors for c_{uvane}?*

MEASURED c_U VALUES

Stratification





OBJECTIVES

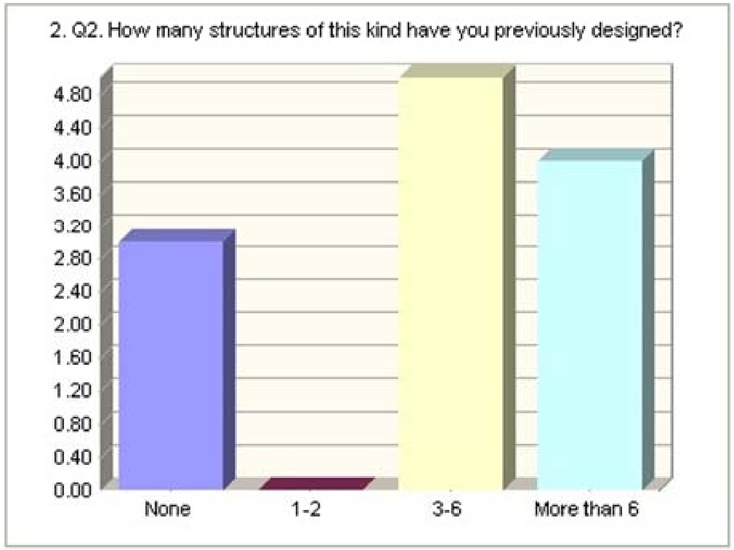
- DETERMINE THE HEIGHT OF EMBANKMENT FOR INITIAL STAGE

Design assumptions

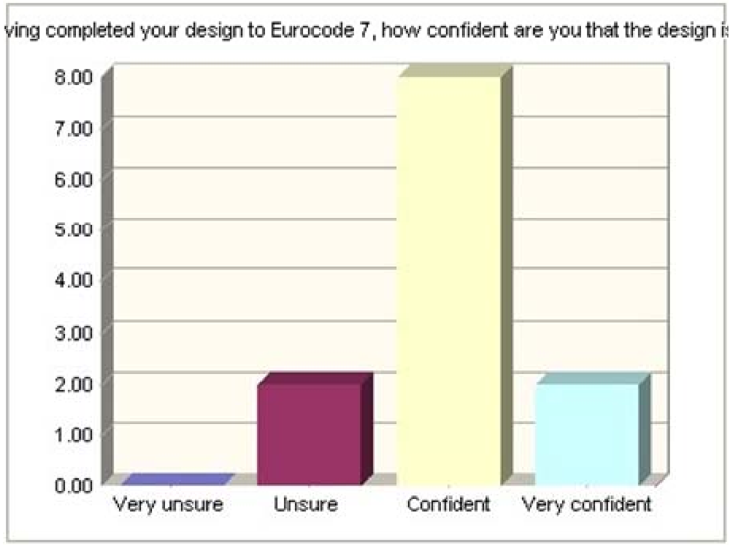
- *Topsoil not to be removed*
- *No hydraulic fill at the rear*
- *No serviceability requirements*
- *No accidental design situations*
- *No construction traffic to be considered*.

RESPONSES

Q2 How many structures of this kind have you previously designed?



Q3 Having completed your design to EC7, how confident are you that the design is sound?



RESPONSES

Q4 Which calculation model did you use to determine the maximum height of the embankment?

Annex D from EN1997-1
Alternative given in NA
Alternative given in National Standard
Terzaghi
Meyerhof
Brinch-Hansen
Limiting equilibrium (Slip circle/method of slices)
Limiting equilibrium (wedge mechanism)
Finite element analysis
Finite difference analysis
Other (Specify)

NO RESPONSES
(LATER COMMENTS INDICATE SLIP CIRCLE AND BEARING CAPACITY MODELS)

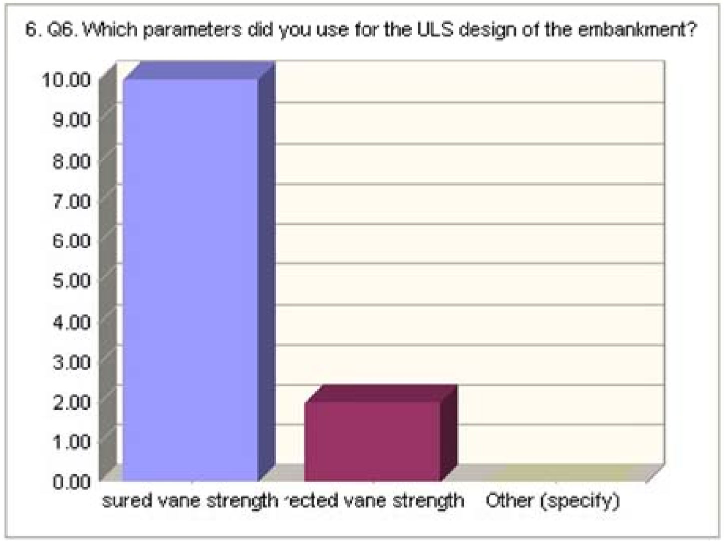
Q5 If you used the slip circle method, what variant of this method did you use?

Bishop with horizontal interslice forces
Bishop with variable inclined interslice forces
Spencer/Bishop with constantly inclined interslice forces
Janbu with horizontal interslice forces
Janbu with variably inclined interslice forces
Janbu with constantly inclined interslice forces
Morgenstern and Price
Other (Specify)

NO FORMAL RESPONSES (later responses, Bishop's variable interslice forces and bearing capacity)

RESPONSES

Q6 Which parameters did you use for the ULS design of the embankment?

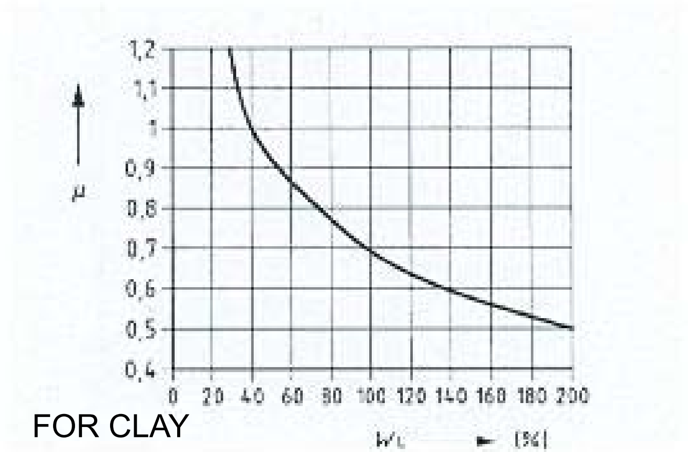


2 No of the 12No submissions used corrected shear strengths

Q7 What corrections did you use to derive soil parameter values (if used) for the USL verification?

a) Annex-I from EN-1997-2

(no correction specifically for peat, which depends on size of vane, plot for clay sometimes used.).



b) DIN 1055-2

RESPONSES

Q7a Any other correlations?

NO RESPONSE

Q8 What assumptions did you make in choosing these correlations?

a) None – would have researched more if given more time
b) None but also did not reduce g following 2.4.7.1(5). Arguably might have used lower strength and lower factors
c) Peat is NC (required to use the correction factors from Eurocode
d) Ys=y'+10y=ys-1 kN/m?
e) Correction factor of 0.5 to account for fibrous nature of peat

RESPONSES

Q9 How did you account for the location of boreholes/vane profiles relative to embankment?

Did of consider borehole/profile location	2No.
Considered nearest borehole/profile only	0 No.
Considered 'average' of all boreholes/profiles	6 No.
Considered trend of all boreholes/profiles, biased towards nearest	0No
Other	3 No.

Others

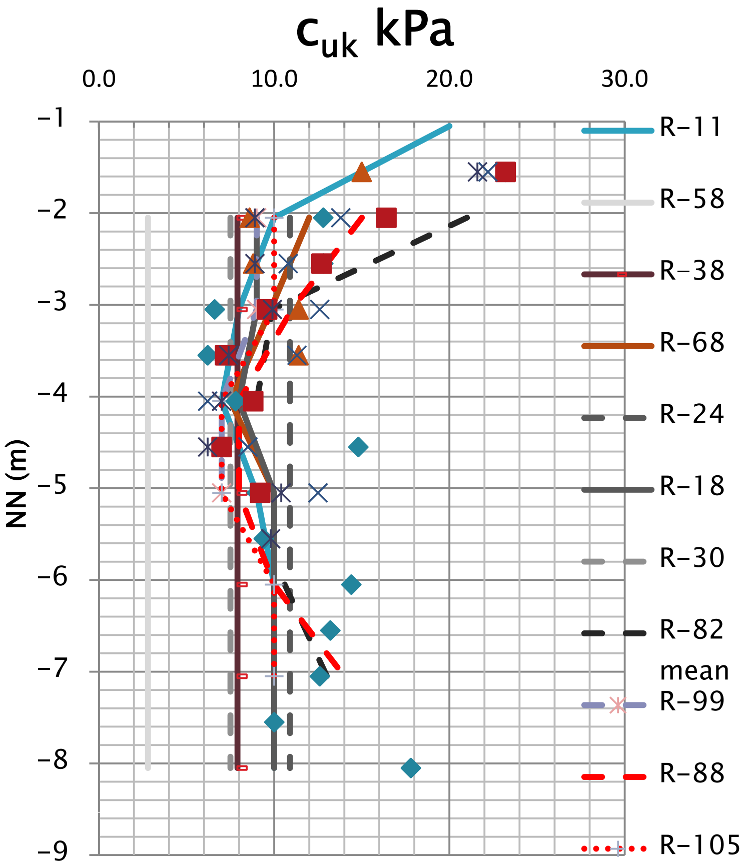
a) Looked for the profile showing the lowest strength
b) Pessimistic scenario using judgement
c) Statistical analysis

Q10 Explain reply to Q9

Explanations

a) Embankments has limited ability to transfer loads, hence ULS must be on lowest strength
b) No information given
c) Adopted a conservative approach due to uncertainty wrt strength
d) Locations plan not given, therefore 'average' soil properties considered.

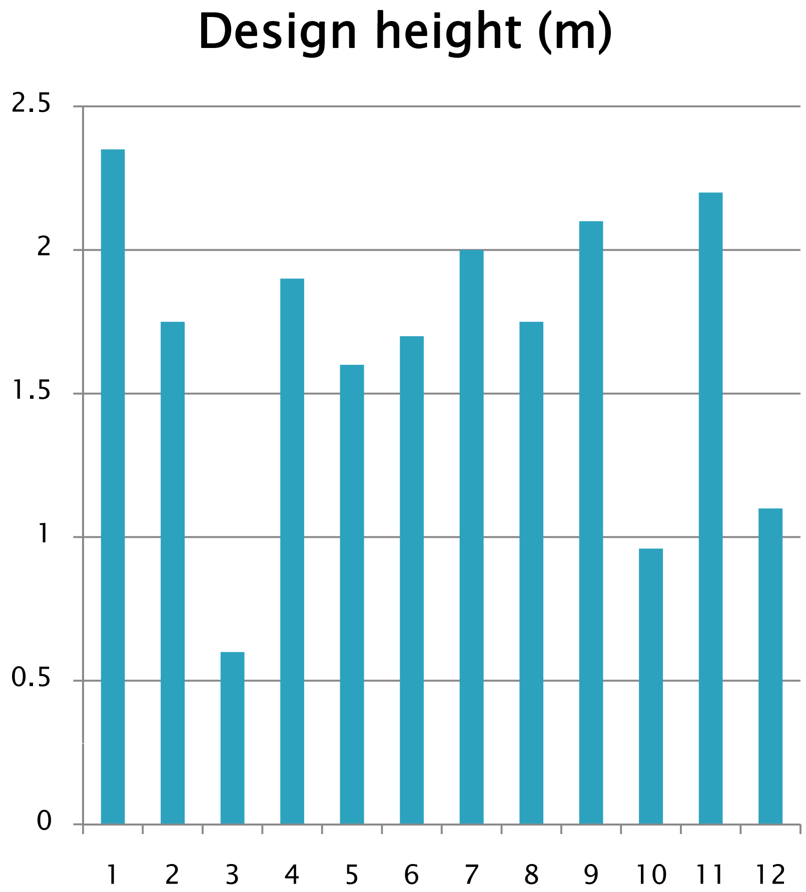
RESPONSES – 11 to 14 Development of $c_{u;k}$



7 No. by eye; 4 No. by stats

1 No. used Schneider + SD

RESPONSES 15 & 16 – Design height



National Annex

➢UK	3 No.
➢German	2No.
➢Italy	3 No.
➢Ireland	1 No.
➢Portugal	1 No.
➢National std	1No.
➢Other	1 No.

Design Approaches

➢DA1	2 No.
➢DA1:C2	7 No.
➢DA2	1 No.
➢DA2*	1 No.
➢DA3	1 No.
➢DA2 & DA3	1 No.
➢Other	1 No.

RESPONSES– Q 17 to 18 (Partial factors, H, DA)

	γ_G	γ_Q	$\gamma_{\phi'}$	$\gamma_{c'}$	γ_{cu}	γ_{Rv}	γ_{Rh}	γ_{Rd}	DA	H
8	1.0		1.25	1.25	1.25				DA3	2.35
11	1.0	1.3	1.25	1.4	1.4	1.0	1.0	1.0	DA1:C2	
58	1.0	1.3	1.25	1.25	1.4		1.4			0.6
38	1.35	1.5	1.0	1.0	1.0	1.0	1.0	1.0	DA1 C1 & C2	1.9
68	1.35	1.5	1.0	1.0					DA1 C1 &C2	1.6
24	1.35				1.0	1.4			DA2	1.7
18	1.0	1.3	1.25	1.25	1.4	1.0	1.0	1.0	DA1.C2	2.0
30	1.35					1.4			DA2&3	1.75
82									Stat	2.1
99	1.35				1.0	1.4			DA2	0.96
88	1.0		1.25	1.25	1.4			1.1	DA1.C2	2.2
105	1.0	1.3	1.25		1.4	1.8		1.1	DA1.C2	1.1/1.4

RESPONSES- Partial Factors- 2nd Combination

	γ_G	γ_Q	$\gamma_{\phi'}$	$\gamma_{c'}$	γ_{cu}	γ_{Rv}	γ_{Rh}	γ_{Rd}	
8									
11									
58	1.0	1.3	1.25	1.25	1.4		1.4		
38	1.0	1.3	1.25	1.25	1.4	1.0	1.0	1.0	
68	1.0	1.3	1.25	1.25					
24									
18									
30	1.0		1.25		1.25				
82									
99									
88									
105									

Responses Q19 & Q20

Q 19 Other assumptions

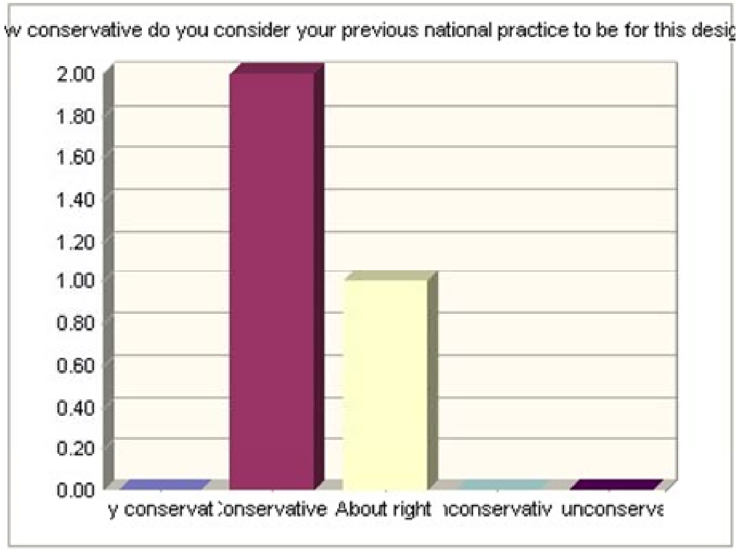
- GWL
- Mohr-Coulomb for fill & Sand; undrained for peat & topsoil
- Base of embankment 13m wide and I_P=20, no correction
- Relative position of embankment and FV

Q20 What additional data required?

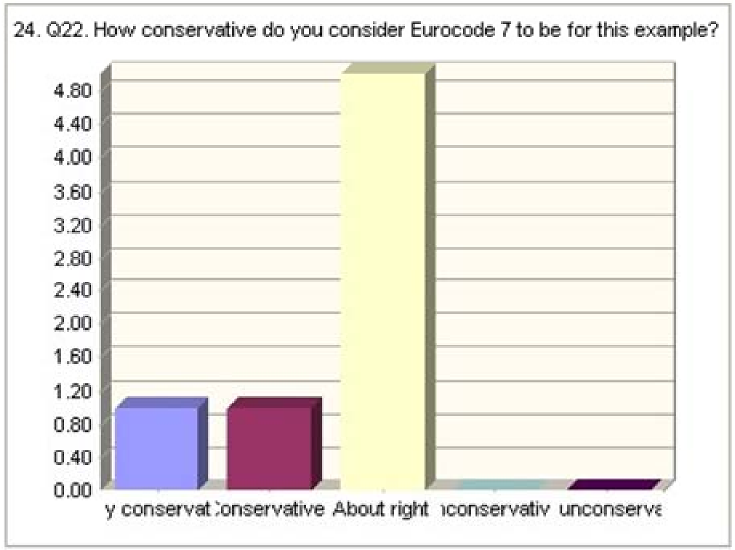
- GWL & Piez data
- Deformability of soil
- Other tests on peat eg DMT or CPT
- Correction factor (4 No.)
- I_P

Responses Q21 & Q22

Q21 – How conservative your previous national practice

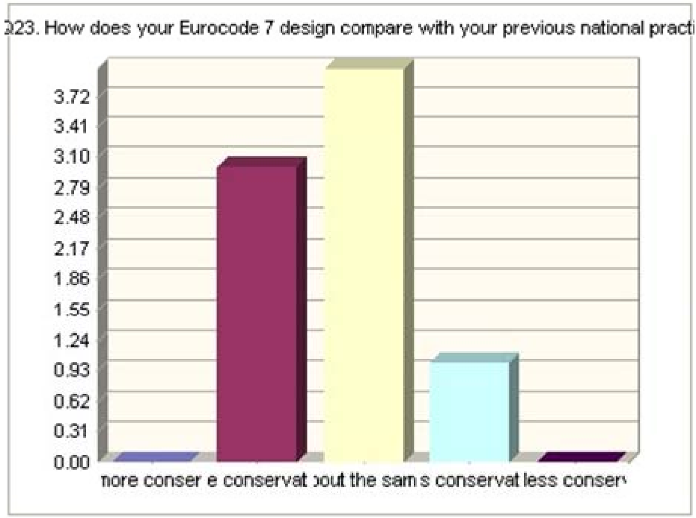


Q22 – How conservative EC7



Responses Q23

Q23 – How does EC7 compare with previous national practice.

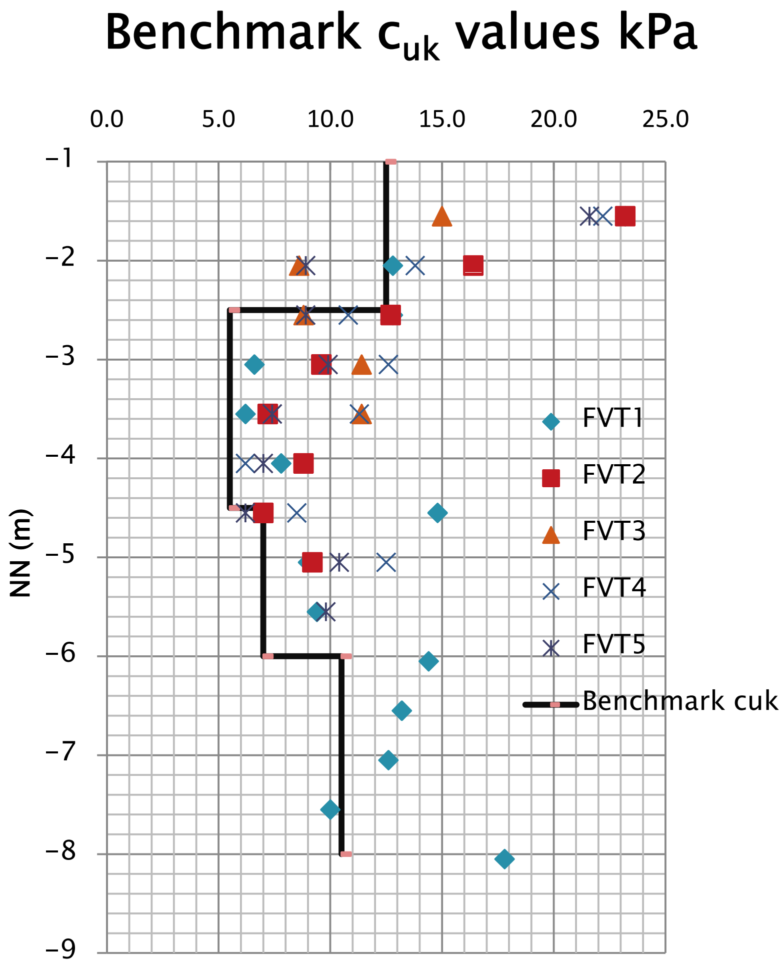


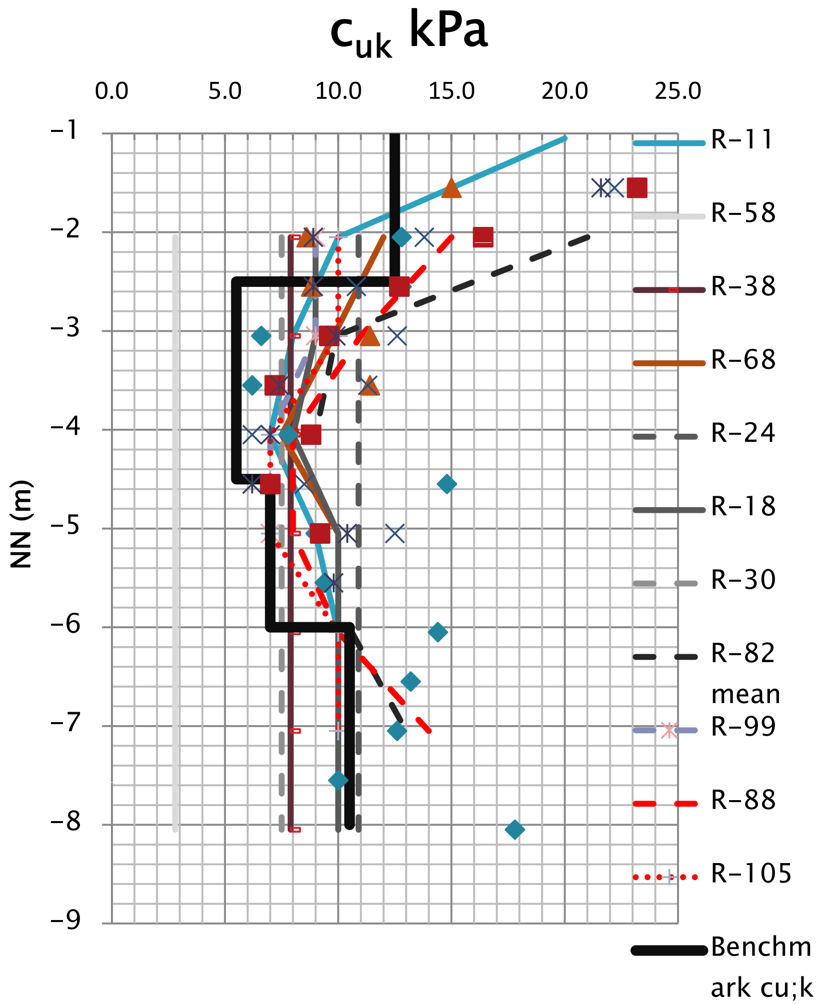
Responses Q24 – Other relevant information

- Local experience of reduction required in c_{uvane} (2 No.)

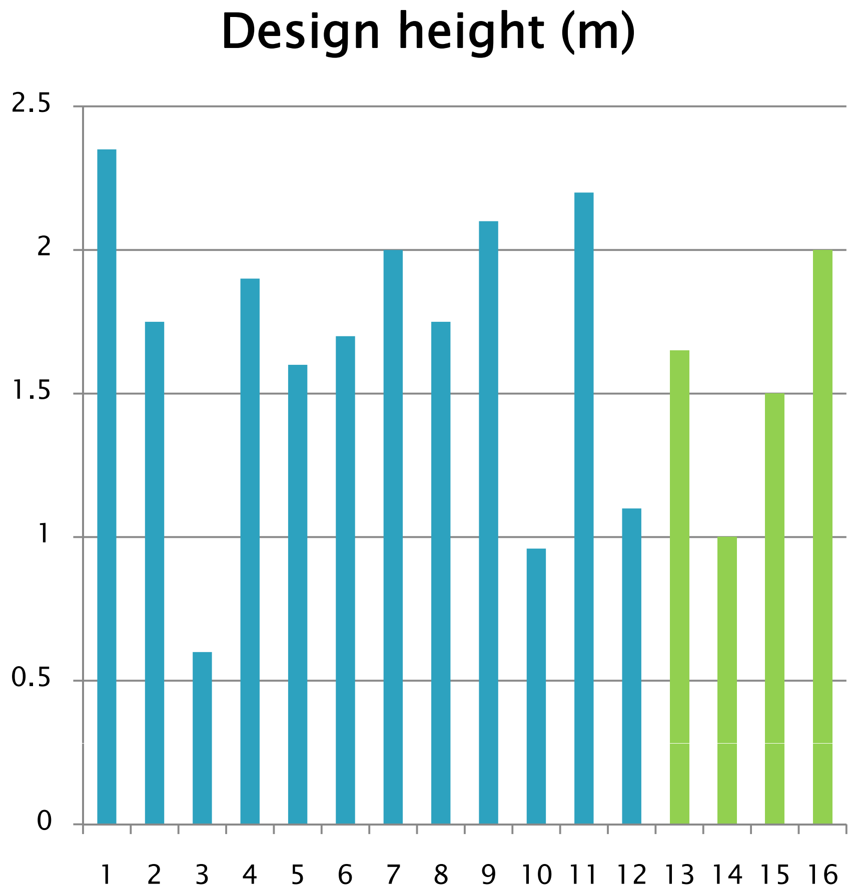
Benchmark

Applied correction factor of 0.8 to c_{uvane} to get $c_{u\text{-derived}}$





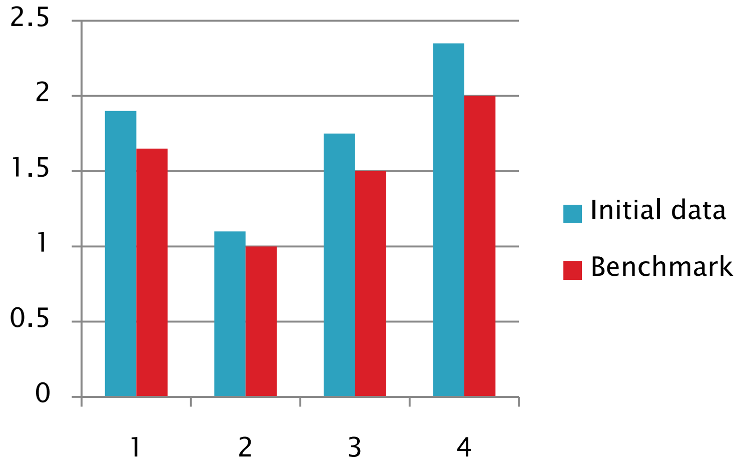
Benchmark – Design height



Methods of analysis

Method of slices 2 No.

Branch-Hansen 1 No.



Comparison of individual contributor

Method of slices

Simple case, assuming no surcharge load.

$$\tau_{mob} = \frac{c'}{F} + N'\frac{\mathrm{Tan}\varphi'}{F} = \frac{c'}{\gamma_{m;mob}} + N'\frac{\mathrm{Tan}\varphi'_k}{\gamma_{m;mob}}$$

$$\gamma_{m;mob} = \frac{1}{\sum \gamma_G W Sin\alpha} \sum \frac{[c'_k b + (\gamma_G W - \gamma_G u b) Tan\varphi'_k] Sec\alpha}{1 + \frac{Tan\alpha Tan\phi'_k}{\gamma_{m;mob}}}$$

Table 2-1 Equations of Statics Satisfied

Method	Moment Equilibrium	Force Equilibrium
Ordinary or Fellenius	Yes	No
Bishop's Simplified	Yes	No
Janbu's Simplified	No	Yes
Spencer	Yes	Yes
Morgenstern-Price	Yes	Yes
Corps of Engineers – 1	No	Yes
Corps of Engineers – 2	No	Yes
Lowe-Karafiath	No	Yes
Janbu Generalized	Yes (by slice)	Yes
Sarma – vertical slices	Yes	Yes

Table 2-2 Interslice force characteristics and relationships

Method	Interslice Normal (E)	Interslice Shear (X)	Inclination of X/E Resultant, and X-E Relationship
Ordinary or Fellenius	No	No	No interslice forces
Bishop's Simplified	Yes	No	Horizontal
Janbu's Simplified	Yes	No	Horizontal
Spencer	Yes	Yes	Constant
Morgenstern-Price	Yes	Yes	Variable; user function
Corps of Engineers – 1	Yes	Yes	Inclination of a line from crest to
Corps of Engineers – 2	Yes	Yes	Inclination of ground surface at top of slice
Lowe-Karafiath	Yes	Yes	Average of ground surface and slice base inclination
Janbu Generalized	Yes	Yes	Applied line of thrust and moment equilibrium of slice
Sarma – vertical slices	Yes	Yes	$X = C + E \tan \phi$

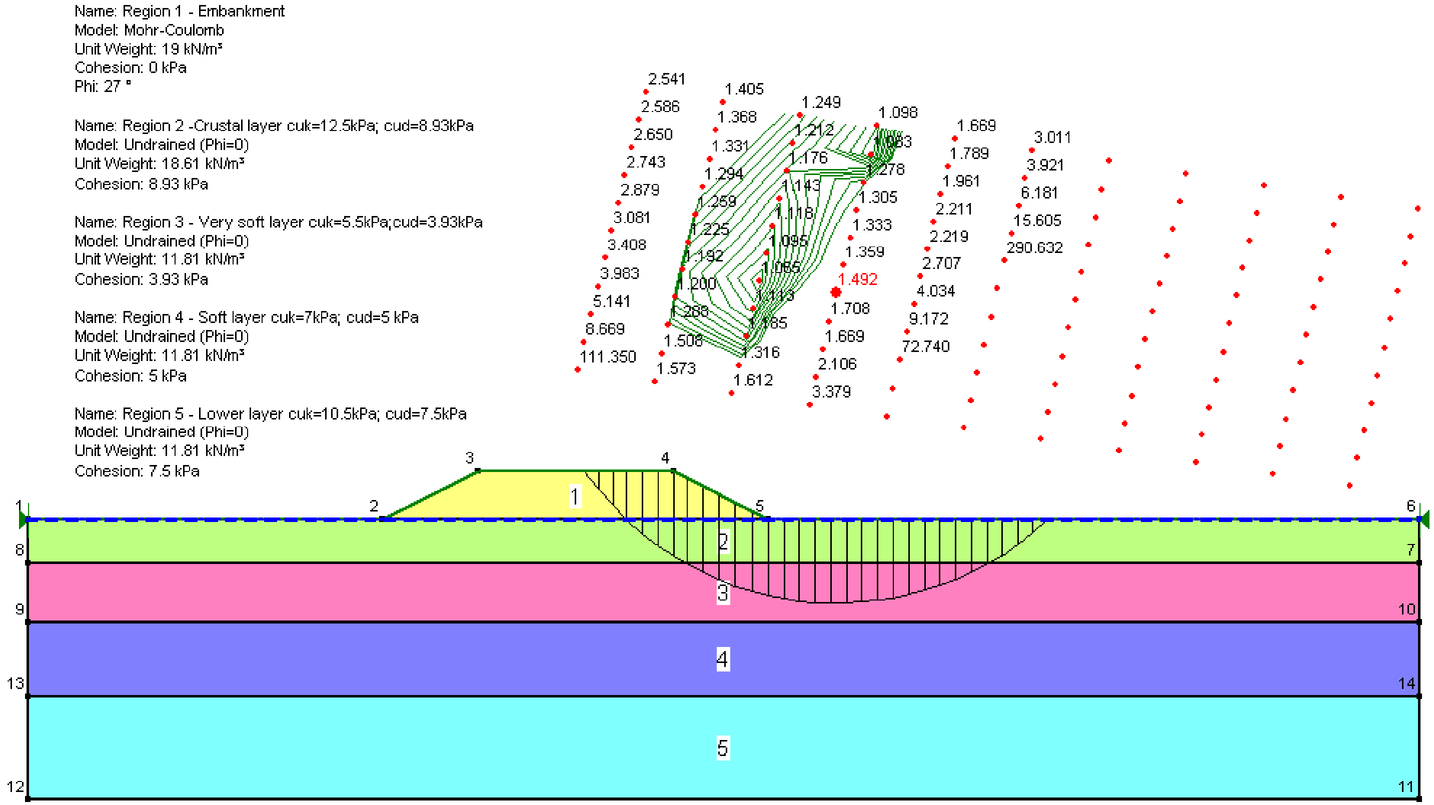
From SLOPE/W Manual

Design Example

$c_{u;d} = c_{u;k}/1.4$ using benchmark values

Bishop's method of slices

Design height = 1.6m



Bearing capacity –
simplified relationship

Approx– dealing with
stresses (FORCES ?)

$\gamma_G \gamma H \leq (5.14 c_{u;k}/\gamma_{cu})/R_{R;e}$?

Issues

- Correlation factors and local experience
- Use of bearing capacity equations (Table A.14 , earth resistance and $\gamma_{R;e}$)
- DA1.C2 versus DA3
- Differences in application of partial factors
- Effect of different calculation models.
- Tension cracks in embankment?

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