Example 2.5: Embankment on soft peat

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Example 2.5  DESIGN SITUATION

FILL  2H:1V side slopes
\[ \gamma = 19 \text{kN/m}^3 \]
\[ c_k' = 0 \text{kPa}; \phi_k' = 32.5^\circ \]

Topsoil
Few dm of clay
\[ \gamma = 18 \text{kN/m}^3 \]

PSEUDO-FIBROUS TO AMORPHOUS HOLOCENE PEAT
\[ \gamma' = 2 \text{kN/m}^3 \]
\[ c_k' = 0 \text{kPa}; \phi_k' = 32.5^\circ \]

PLEISTOCENE SAND MEDIUM DENSE
\[ \gamma' = 11 \text{kN/m}^3 \]
\[ c_k' = 0 \text{kPa}; \phi_k' = 35^\circ \]
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

PSEUDO-FIBROUS TO AMORPHOUS PEAT

SAND

Measured $c_u$ values (kPa)

NN (m)

FVT1

FVT2

FVT3

FVT4

FVT5

2nd International Workshop on Evaluation of Eurocode 7, Pavia, Italy, April 2010
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?
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)
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?

Q8 What assumptions did you make in choosing these correlations?

NO RESPONSE

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   2 No.

Considered nearest borehole/profile only   0 No.

Considered ‘average’ of all boreholes/profiles   6 No.

Considered trend of all boreholes/profiles, biased towards nearest   0 No.

Considered nearest No.

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 $c_{uk}$

7 No. by eye; 4 No. by stats

1 No. used Schneider + SD
RESPONSES 15 & 16 – Design height

National Annex

- UK: 3 No.
- German: 2 No.
- Italy: 3 No.
- Ireland: 1 No.
- Portugal: 1 No.
- National std: 1 No.
- 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)

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## RESPONSES – Partial Factors – 2\textsuperscript{nd} Combination

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Responses Q19 & Q20

Q19 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.)
Applied correction factor of 0.8 to $c_{uvane}$ to get $c_u$-derived

Benchmark $c_{uk}$ values kPa

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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.

\[
\tau_{\text{mob}} = \frac{c'}{F} + N' \frac{\tan \phi'}{\gamma_{m;\text{mob}}} = \frac{c'}{\gamma_{m;\text{mob}}} + N' \frac{\tan \phi'}{\gamma_{m;\text{mob}}}
\]

\[
\gamma_{m;\text{mob}} = \frac{1}{\sum \gamma_G W \sin \alpha \sum \frac{c_k b + (\gamma_G W - \gamma_G W) \tan \phi_k}{1 + \tan \alpha \tan \phi_k}}
\]

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 ?)

\( \gamma_G \gamma_H \leq \frac{5.14c_{u;k}}{\gamma_{cu}}/R_{R:e} \) ?
Issues

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