Eurocode 7 – Today and Tomorrow

Ground structures – Slope and Retaining wall design in the Netherlands

Adriaan van Seters
Hein Jansen

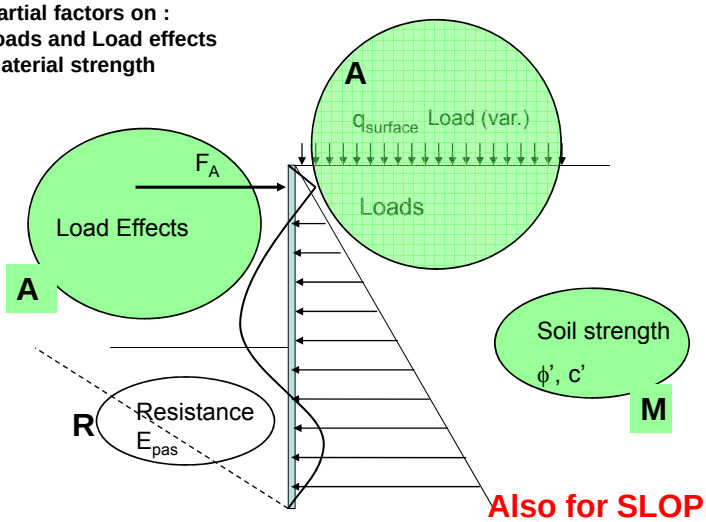
Fugro Ingenieursbureau BV
The Netherlands

Contents

- Design Approach 3
- Safety and reliability in EN-1990
- Probabilistic Analyses for retaining structures
- Partial Factors
- Calculation method for retaining structures
- Example
- Slope stability

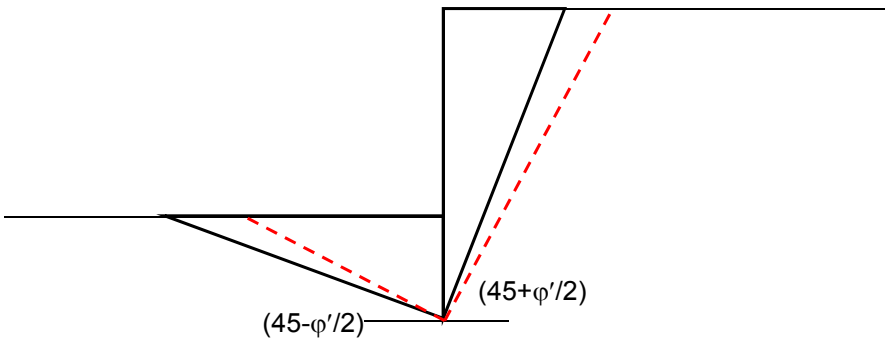
The Netherlands use Design Approach 3

OB 3: partial factors on :
- A on Loads and Load effects
- M on Material strength



Also for SLOPES

Material Factors applied to Sheetpiles



Characteristic values φ'_{char}

Design values φ'_{d} $\quad tan\varphi'_{d} = tan\varphi'_{char} / \gamma_{\varphi}$

Safety and Reliability in Eurocode 7

old NEN 6700		new Eurocode 0 (NEN-EN 1990)		
Class	β	Class	β	Example
1	3,2	CC1/RC1	3,3	Family house Buildings < 3 stories
2	3,4			
3	3,6	CC2/RC2	3,8	Offices, apartments Traffic bridges
-	-	CC3/RC3	4,3	High rise buildings > 70 m Stadions, Concert halls Primary dikes, railway bridges

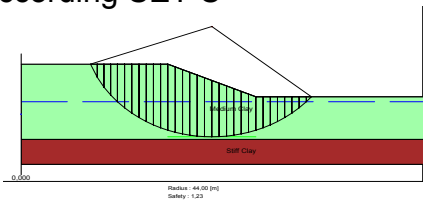
Distinction between CC/RC-Classes in Eurocode EN-1990 given by LOADFACTORS γF (for Class CC2/RC2)

for: CC1/RC1: $\gamma = 0{,}9 * \gamma F$
CC3/RC3: $\gamma = 1{,}1 * \gamma F$

FOR GROUND STRUCTURES – SLOPES, SHEET PILES

Eurocode EN 1990:

- Loadfactors to be used are according SET C
- permanent loads γ = 1.0
- variable loads γ = 1.3

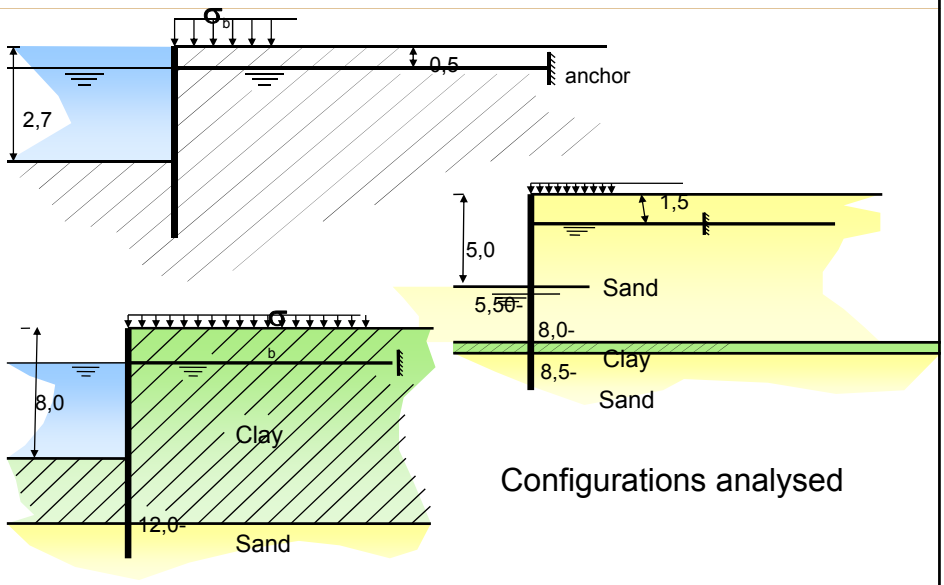


Main load = soil weight → **both** stabilising and destabilising

→ Therefore γ = 1.0 is correct, but no difference for various CC/RC-Classes

→ In NL – Differentiate in Material Factors per CC/RC

Probabilistic Analyses in 1990 and 2005



Configurations analysed

www.fugro.com

Probabilistic Analyses

Probabilistic analyses Level II and Level III (Monte Carlo)

- stochastic parameters (geometry, soil parameters)
- average value μ and standard deviation σ

  ($\rightarrow$ variation coefficient $V = \sigma / \mu$)
- Combined with Reliability index β = 3,3 / 3,8 / 4,3 (EN 1990)

influence factors α follow from probabilistic analyses

www.fugro.com

Probabilistic Analyses

Probabilistic analyses

influence factor α is dependent on:

- influence of parameter on failure mode
- type of failure mode
- number of stochastic parameters

$$\sum(\alpha^2) = 1.0$$

Partial factors

Partial factor $\gamma = \dfrac{1-1.64 \cdot V}{1-\alpha \cdot \beta \cdot V}$

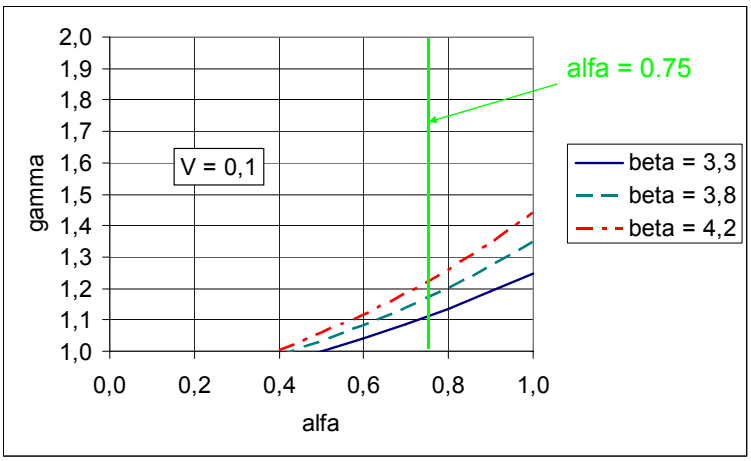
formula based on characteristic (5 %) values of parameters

sheet pile design in sand:
probabilistic analyses result in α_φ = 0.7 to 0.8
for friction angle φ'

with V_φ = 0.1 → $\gamma_\varphi = \dfrac{1-1.64 \cdot 0.1}{1-0.75 \cdot 3.8 \cdot 0.1} = 1{,}169$

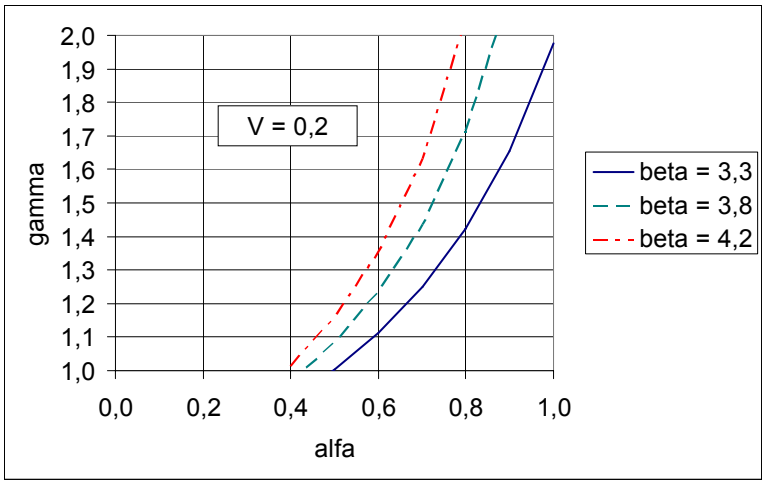
Partial Factor for φ'

General trend V = 0.1 – assumed variation for tan (φ)



Partial Factor for c'

General trend V = 0.2 – assumed variation for cohesion c'



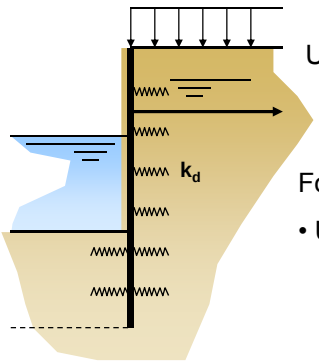
Partial Factors for Retaining Walls (flexible)

Soilparameter	Symbol	Set M2		
		Reliability Class		
		RC1 (β = 3,3)	RC2 (β = 3,8)	RC3 (β = 4,3)
Friction angle tan φ'	$\gamma_{\varphi'}$	1,15	1,175	1,20
Effective cohesion	$\gamma_{c'}$	1,15	1,25	1,40
Undrained Shear strength	γ_{cu}	1,5	1,6	1,65
Volume unit weight	γ_g	1,0	1,0	1,0

Geometric offsets:

- retaining height: 10 % extra, max 0.5 m (acc EC7)
- waterlevel: extra 0.25 m difference between both sides

DIMENSIONING OF SHEETPILE WALL



Use Beam-Column method with linear soil springs

For each calculation phase – 5 calculations

- ULS - Vary spring stiffness (high/low) and vary waterlevel at excavation (high/low) – 4 calcs
- SLS-calculation

CALCULATION SCHEME

Phase	Scheme **A** Always design values (d) Incl Material Factors	Scheme **B** Design values (d) in applicable phase, but characteristic values (char) in previous phases
1	d ↓	char → d ↓
2	d ↓	char → d ↓
3	d ↓	char → d ↓
…	d ↓	char → d ↓

Scheme A → too conservative

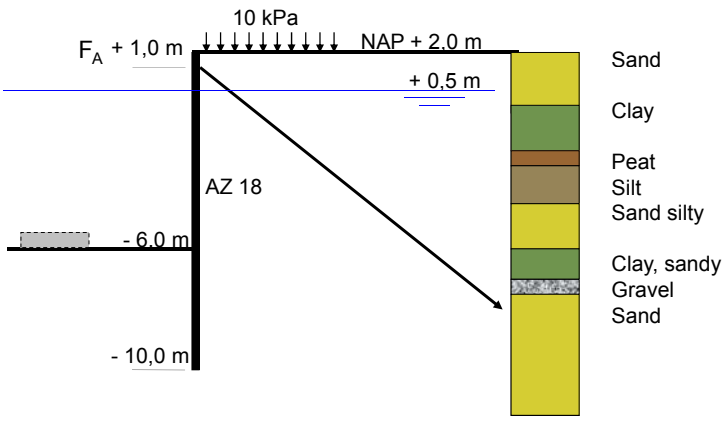
Scheme B → enough safety (ex 1 case), based on PROB sums

EXAMPLE

Phases

1. Excavate to NAP + 0,7 m
2. Install Anchor
3. Excavate to NAP -6,0 m (wet)
4. Underwater concrete

+ pump out water



EXAMPLE

PHASE	SLS [char-values]		ULS – scheme **A**		ULS – scheme **B**		ULS = **SLS x 1,2**	
	M_{rep}	$F_{A;rep}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$
1. Excavate to 0.7 m								
2. Install anchor								
3. Excavate to – 6 m	139	116	260	149				
4. Under water concrete + pumping	190	131	**287**	**177**				

EXAMPLE

PHASE	SLS [char-values]		ULS – scheme **A**		ULS – scheme **B**		ULS = **SLS x 1,2**	
	M_{rep}	$F_{A;rep}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$
1. Excavate to 0.7 m								
2. Install anchor								
3. Excavate to – 6 m	139	116	260	149	**264**	**141**		
4. Under water concrete + pumping	190	131	**287**	**177**	190	138		

EXAMPLE

PHASE	SLS [char-values]		ULS – scheme **A**		ULS – scheme **B**		ULS = **SLS x 1,2**	
	M_{rep}	$F_{A;rep}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$	M_d	$F_{A;d}$
1. Excavate to 0.7 m								
2. Install anchor								
3. Excavate to – 6 m	139	116	260	149	**264**	**141**	167	139
4. Under water concrete + pumping	190	131	287	177	190	138	228	**157**

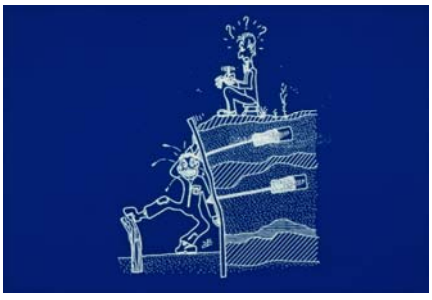
Slope Stability

Partial Factors - Slopes

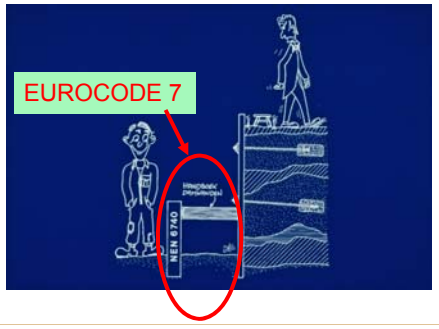
SOIL PARAMETER	Symbol	Default EC7	Slope Stability Set M2		
			Reliability Class		
			RC1	RC2	RC3
Friction angle tan φ'	$\gamma_{\varphi'}$	1,25	1,2	1,25	1,3
Cohesion c'	$\gamma_{c'}$	1,25	1,3	1,45	1,6
Undrained shear strength c_u	γ_{cu}	1,4	1,5	1,75	2,0
Volume unit weight	γ_g	1,0	1,0	1,0	1,0

Material factors are based on PROB sums in the 90's

Developments in Geotechnics….



With Trial and Error….



But now with Eurocode…

Thank You

a.vseters@fugro.nl