Introduction to the Structural Eurocodes

Dr Andrew Bond

Geocentrix Ltd

www.geocentrix.co.uk/attic

Outline of lecture

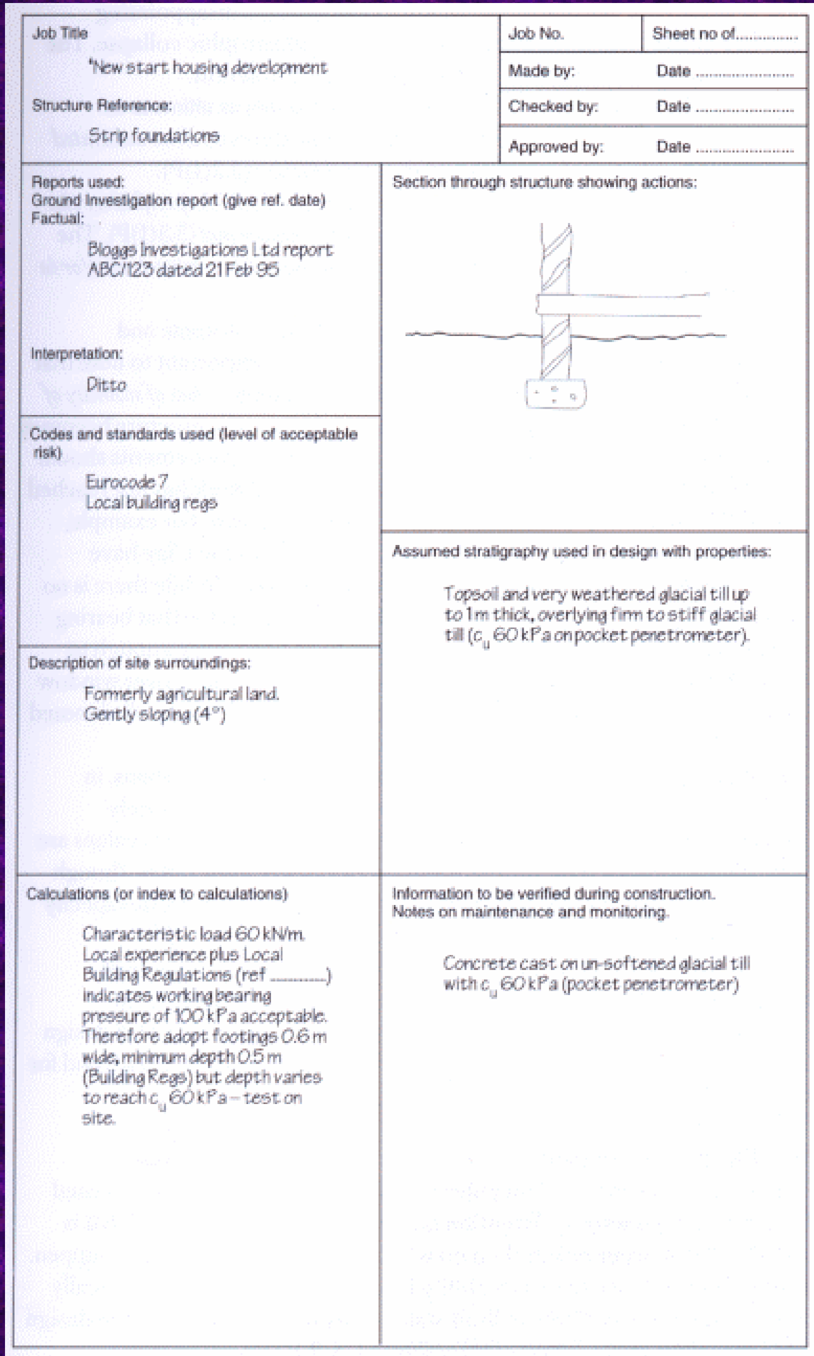
- ✔ Part 1
  - ✔ What are the Structural Eurocodes?
  - ✔ Basis of design
  - ✔ Verification of safety
- ◆ Part 2
  - ◆ Geotechnical design
  - ◆ Comparison with traditional methods
  - ◆ Conclusions

Geotechnical design

Introduction to the Structural Eurocodes

Geotechnical Design Report

- The assumptions, data, calculations and results of the verification of safety and serviceability shall be recorded in a Geotechnical Design Report
- The Report shall include a plan of supervision and monitoring, as appropriate
- An extract of the Report containing the supervision, monitoring and maintenance requirements ... shall be provided to the owner/client



Job Title: "New start housing development"	Job No.	Sheet no of............
Structure Reference: Strip foundations	Made by:	Date ....
	Checked by:	Date ....
	Approved by:	Date ....

Reports used:
Ground Investigation report (give ref. date)
Factual:
Bloggs Investigations Ltd report ABC/123 dated 21 Feb 95

Interpretation:
Ditto

Section through structure showing actions:

Codes and standards used (level of acceptable risk)
Eurocode 7
Local building regs

Assumed stratigraphy used in design with properties:
Topsoil and very weathered glacial till up to 1 m thick, overlying firm to stiff glacial till (c_u 60 kPa on pocket penetrometer).

Description of site surroundings:
Formerly agricultural land.
Gently sloping (4°)

Calculations (or index to calculations)
Characteristic load 60 kN/m.
Local experience plus Local Building Regulations (ref ....) indicates working bearing pressure of 100 kPa acceptable.
Therefore adopt footings 0.6 m wide, minimum depth 0.5 m (Building Regs) but depth varies to reach c_u 60 kPa – test on site.

Information to be verified during construction.
Notes on maintenance and monitoring.
Concrete cast on un-softened glacial till with c_u 60 kPa (pocket penetrometer)

- Description of the ground conditions
- Description of the proposed construction, including actions
- Design values of soil and rock properties, including justification, as appropriate
- Statements of the level of acceptable risks
- Geotechnical design calculations and drawings

Verification of limit states STR/GEO

- (P) To ensure stability and adequate strength in the structure and in the ground, one of three Design Approaches shall be used for the STR and GEO ultimate limit states...

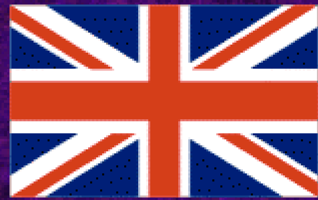
EN 1997-1 §2.4.7.2

Design Approaches

- Design approach 1
  - Original method from ENV 1997-1
  - Load and material factor approach using two separate combinations of partial factors
- Design approach 2
  - Load and resistance factor approach
- Design approach 3
  - Load and material factor approach

EN 1997-1 Annex A

Design Approach 1



- Partial factors for STR *and* GEO limit states:
  - Combination 1: A1+M1+R1
    - $\gamma \geq 1.0$ on actions
  - Combination 2: A2+M2+R1
    - $\gamma \geq 1.0$ on ground properties
- But for piles and anchorages…
  - Combination 1: A1+M1+R1
    - $\gamma \geq 1.0$ on actions
  - Combination 2: A2+(M1 or M2)+R2
    - $\gamma \geq 1.0$ on resistances

EN 1997-1 Annex A

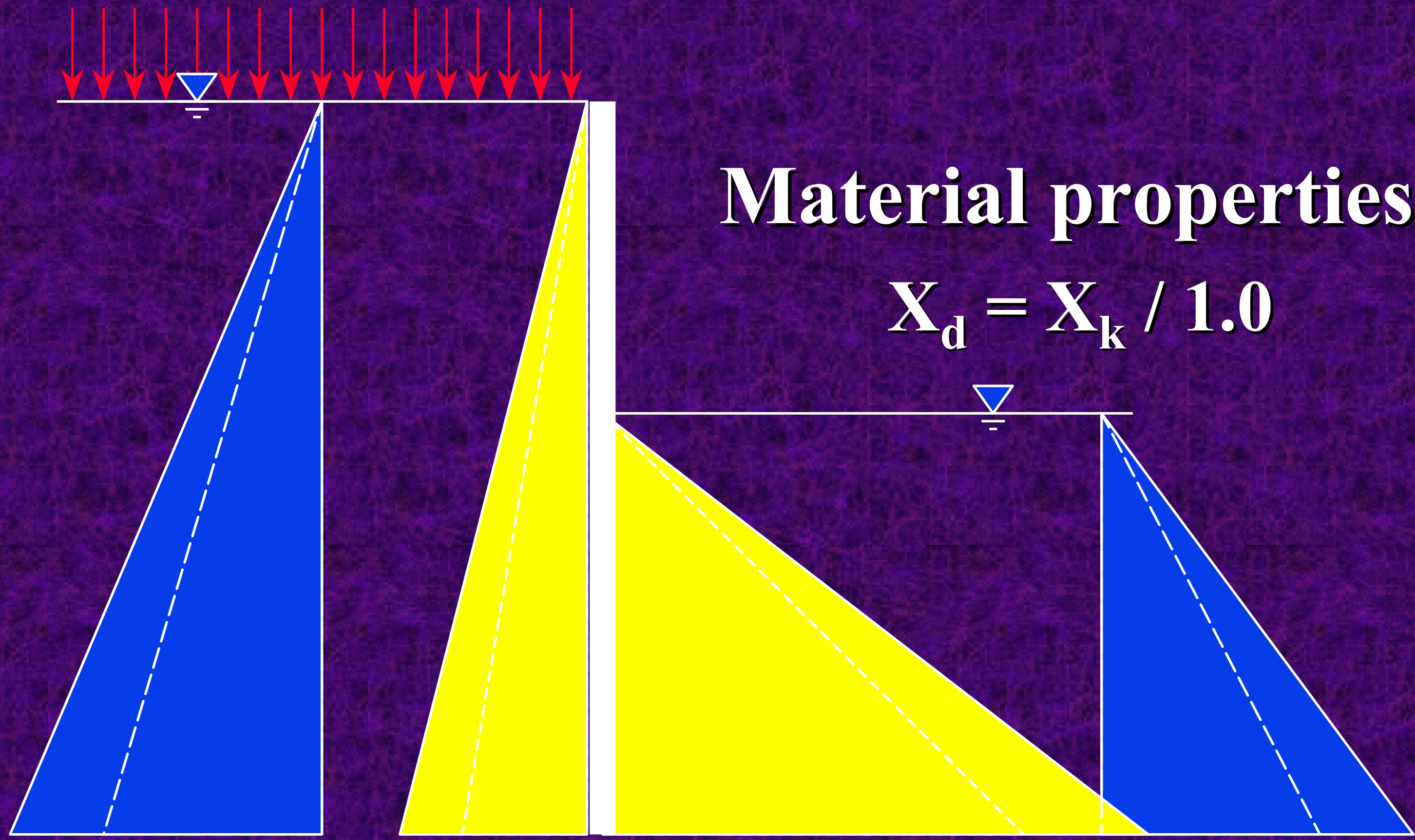
Partial factors on actions (γ_F) and action effects (γ_E)

Action		Symbol	EQU	STR/GEO	
				A1	A2
Permanent	Unfavourable	γ_G	1.1	1.35	1.0
	Favourable		0.9	1.0	1.0
Variable	Unfavourable	γ_Q	1.5	1.5	1.3
	Favourable		0	0	0

EN 1997-1 (Draft G, Feb 2001 + UK modification) A.1.1 & A.2.1

Set A1 partial factors

Actions: $F_d = \gamma_F F_k$



Material properties:

$X_d = X_k / 1.0$

Partial material factors (γ_M)

Ground property	Symbol	EQU	STR/GEO	
			M1	M2
Shearing resistance	γ_ϕ	1.25	1.0	1.25
Effective cohesion	$\gamma_{c'}$	1.25	1.0	1.25
Undrained strength	γ_{cu}	1.4	1.0	1.4
Unconfined strength	γ_{qu}	1.4	1.0	1.4
Unit weight	γ_σ	1.0	1.0	1.0

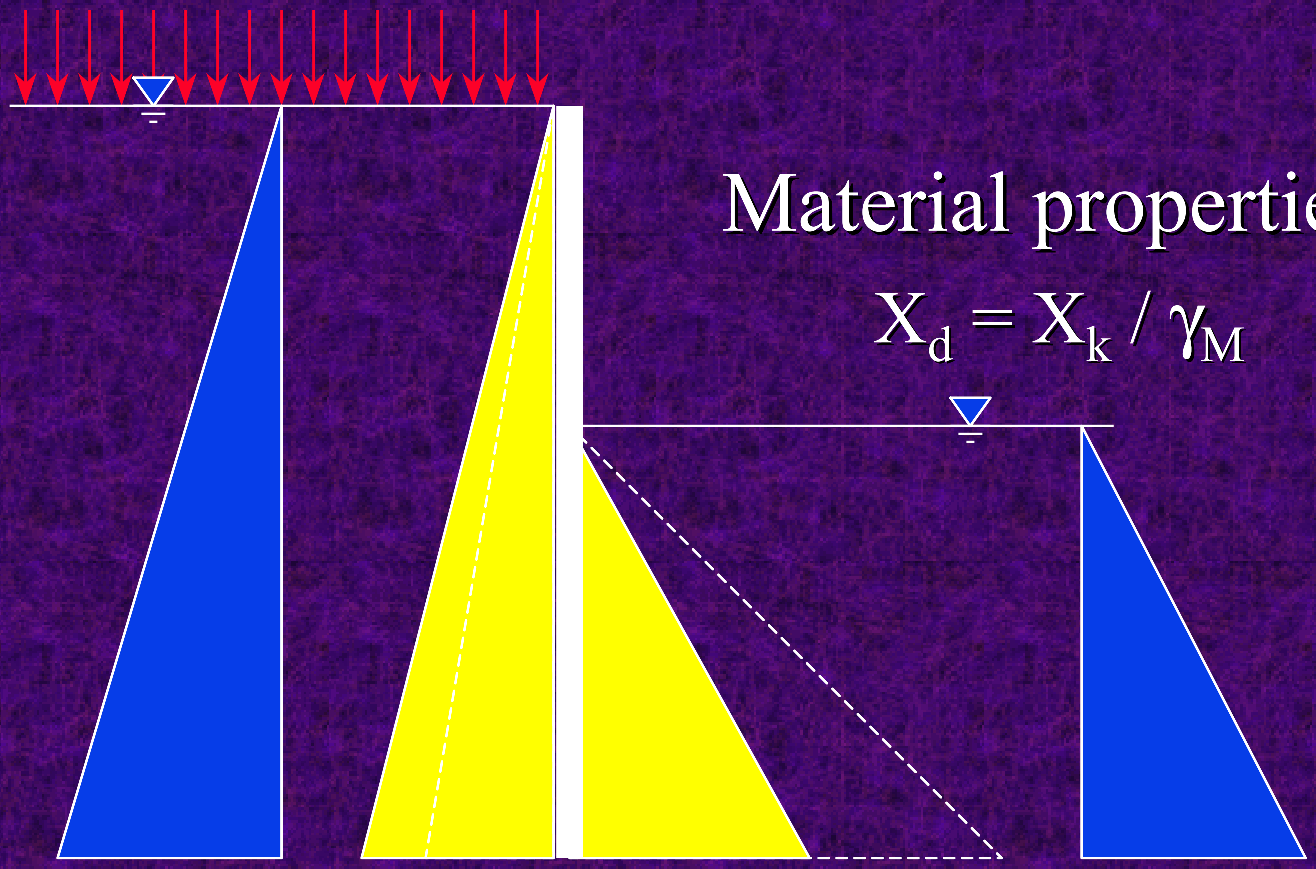
EN 1997-1 (Draft G, Feb 2001 + UK modification) A.1.2 & A.2.2

Set M2 partial factors

Actions: $F_d = \gamma_F F_k$

Material properties:

$X_d = X_k / \gamma_M$



Design Approach 2

- Partial factors for STR *and* GEO limit states:
  - Combination 1: A1+M1+R3
    - $\gamma \geq 1.0$ on action effects and resistances
- But for slopes and overall stability…
  - Combination 1: A2+M2+R1 (same as DA1)
    - $\gamma \geq 1.0$ on actions and ground properties
  - Combination 2: (A1 or A2)+M2+R1
    - $\gamma \geq 1.0$ on ground properties

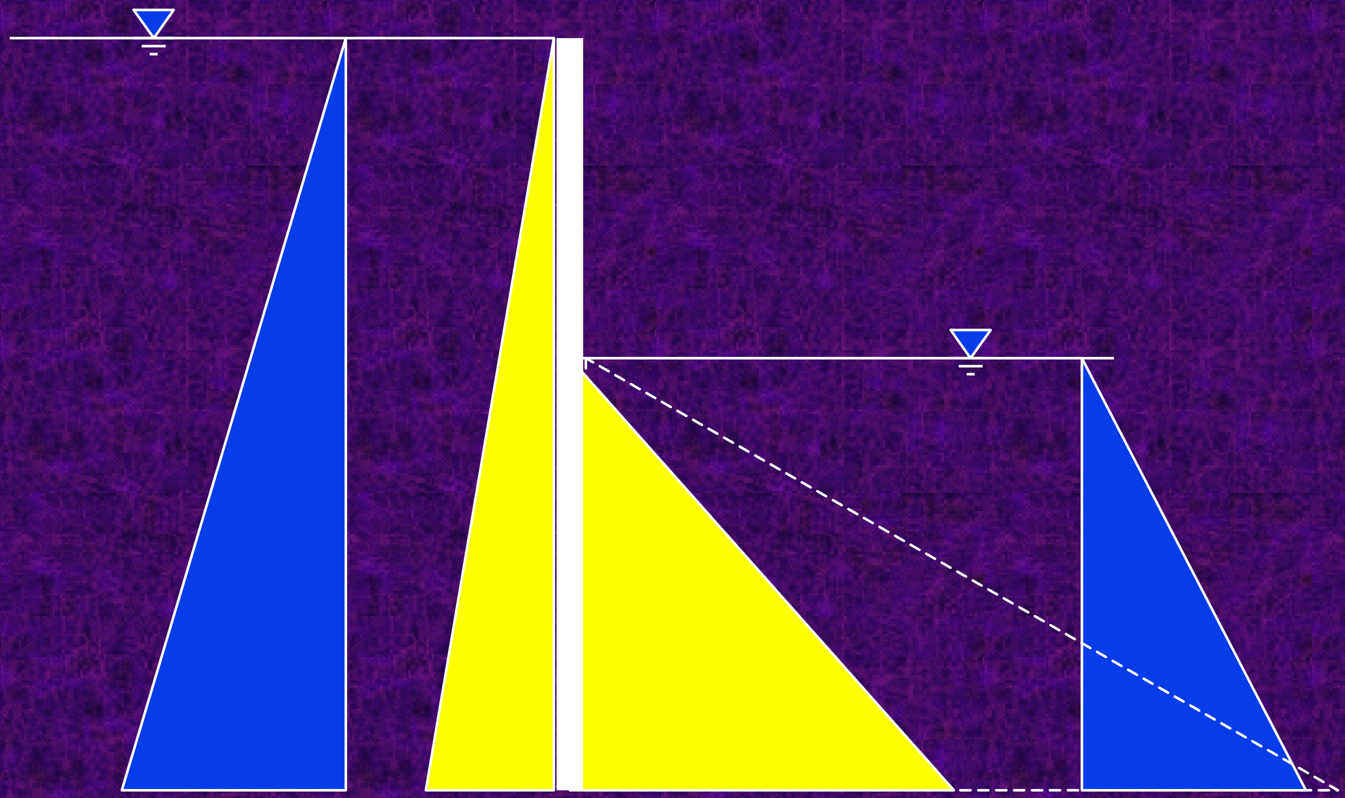
EN 1997-1 Annex A

Partial resistance factors - retaining structures

Resistance	Symbol	STR/GEO		
		R1	R2	R3
Bearing capacity	γ_{Rv}	1.0	1.0	1.4
Sliding resistance	γ_{Rh}	1.0	1.0	1.1
Earth resistance	γ_{Re}	1.0	1.0	1.4

EN 1997-1 (Draft G, Feb 2001 + UK modification) A.2.3.2.1

Set R3 partial factors



Partial resistance factors - piled foundations (bored piles)

Resistance	Symbol	STR/GEO		
		R1	R2	R3
Base	γ_b	1.25	1.6	1.1
Shaft (compression)	γ_s	1.0	1.3	1.1
Total/combined (compression)	γ_t	1.15	1.5	1.1
Shaft (tension)	$\gamma_{s,t}$	1.25	1.6	1.15

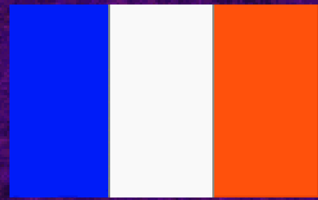
EN 1997-1 (Draft G, Feb 2001 + UK modification) A.2.3.2.1

Partial resistance factors - piled foundations (driven piles)

Resistance	Symbol	STR/GEO		
		R1	R2	R3
Base	γ_b	1.0	1.3	1.1
Shaft (compression)	γ_s	1.0	1.3	1.1
Total/combined (compression)	γ_t	1.0	1.3	1.1
Shaft (tension)	$\gamma_{s,t}$	1.25	1.6	1.15

EN 1997-1 (Draft G, Feb 2001 + UK modification) A.2.3.2.2

Design Approach 3



- Partial factors for STR *and* GEO limit states:
  - Combination 1: (A1 or A2)+M2+R1
    - $\gamma \geq 1.0$ on structural actions only (A1)
    - $\gamma \geq 1.0$ on ground properties

EN 1997-1 Annex A

Comparison with traditional methods

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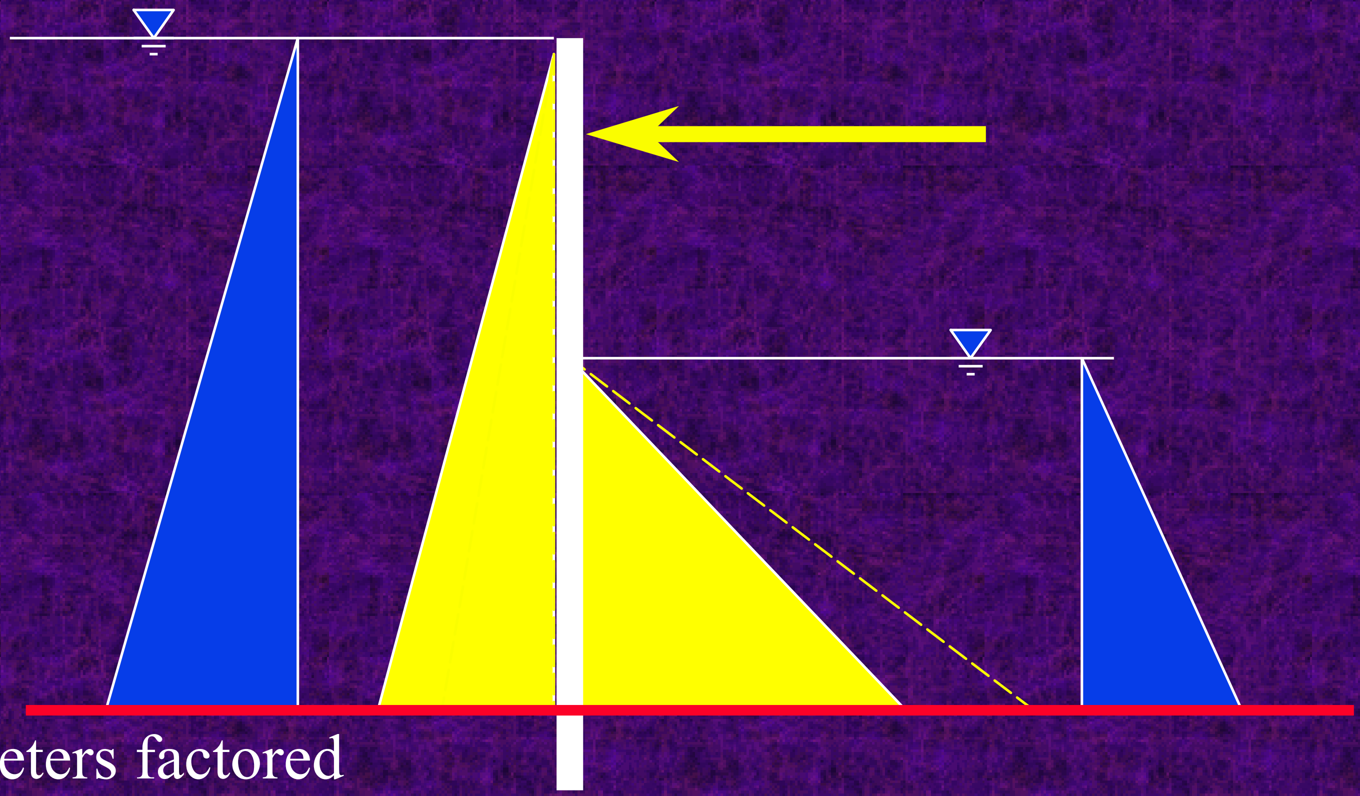
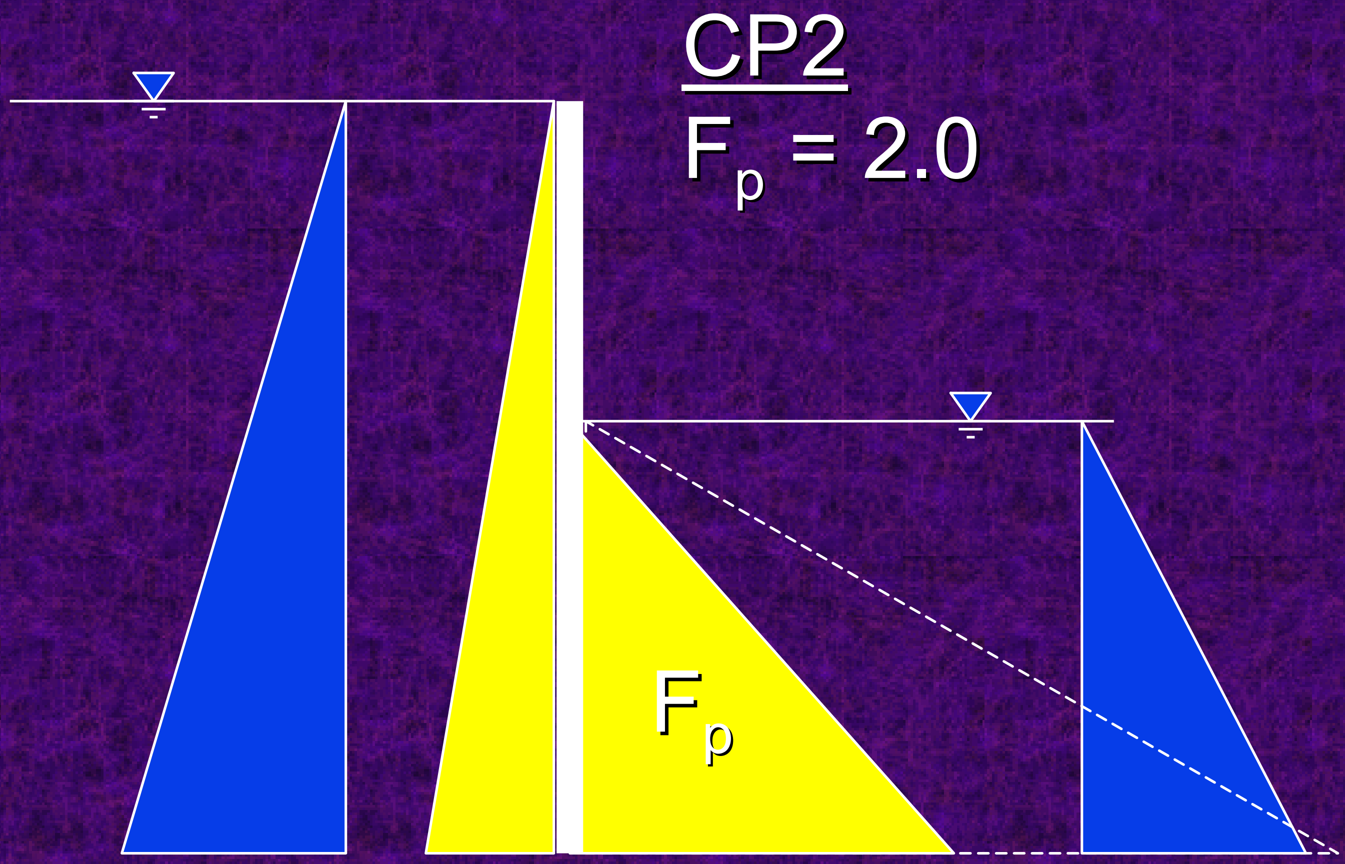
Calculation of structural forces: limit state codes

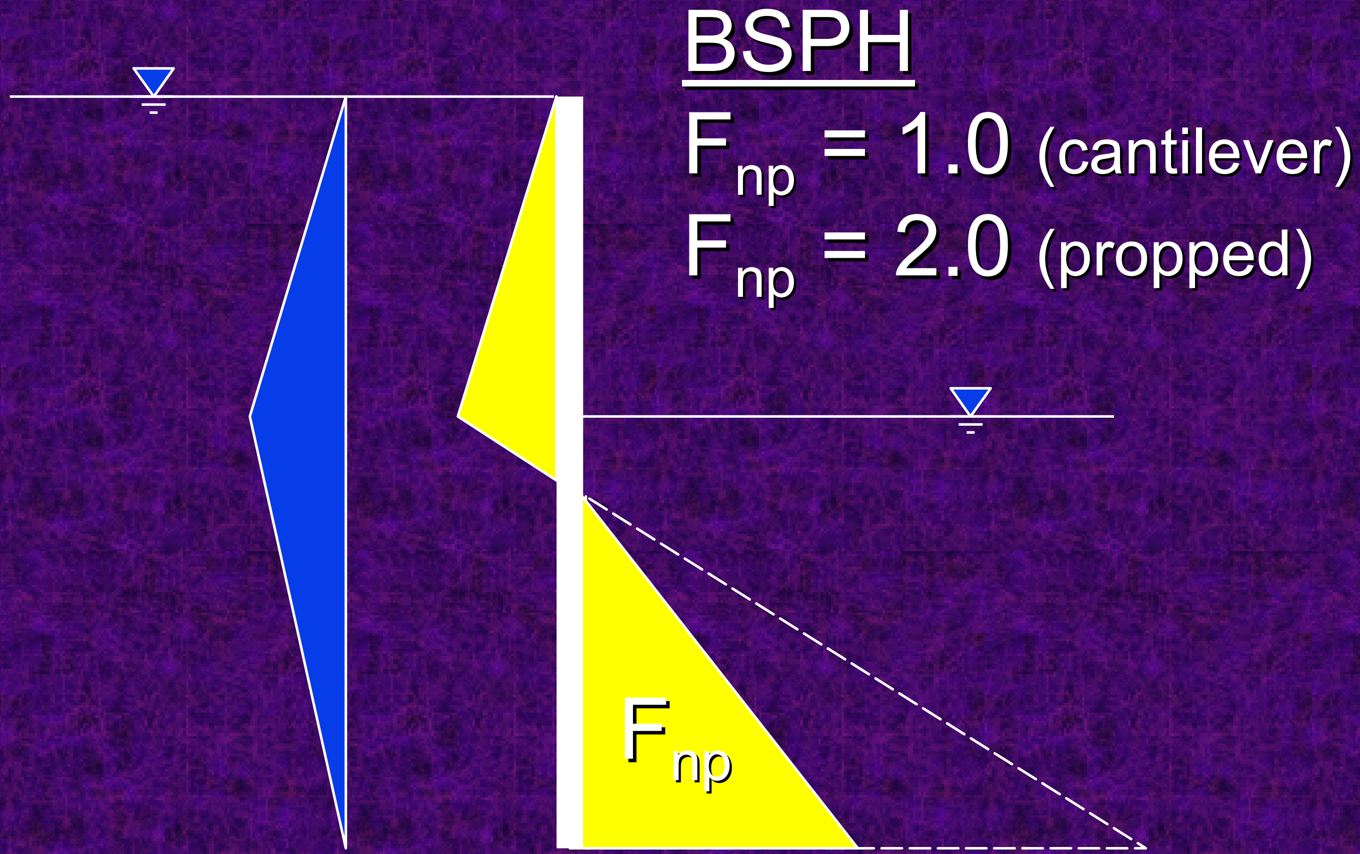


Parameters factored
Embedment reduced to achieve equilibrium

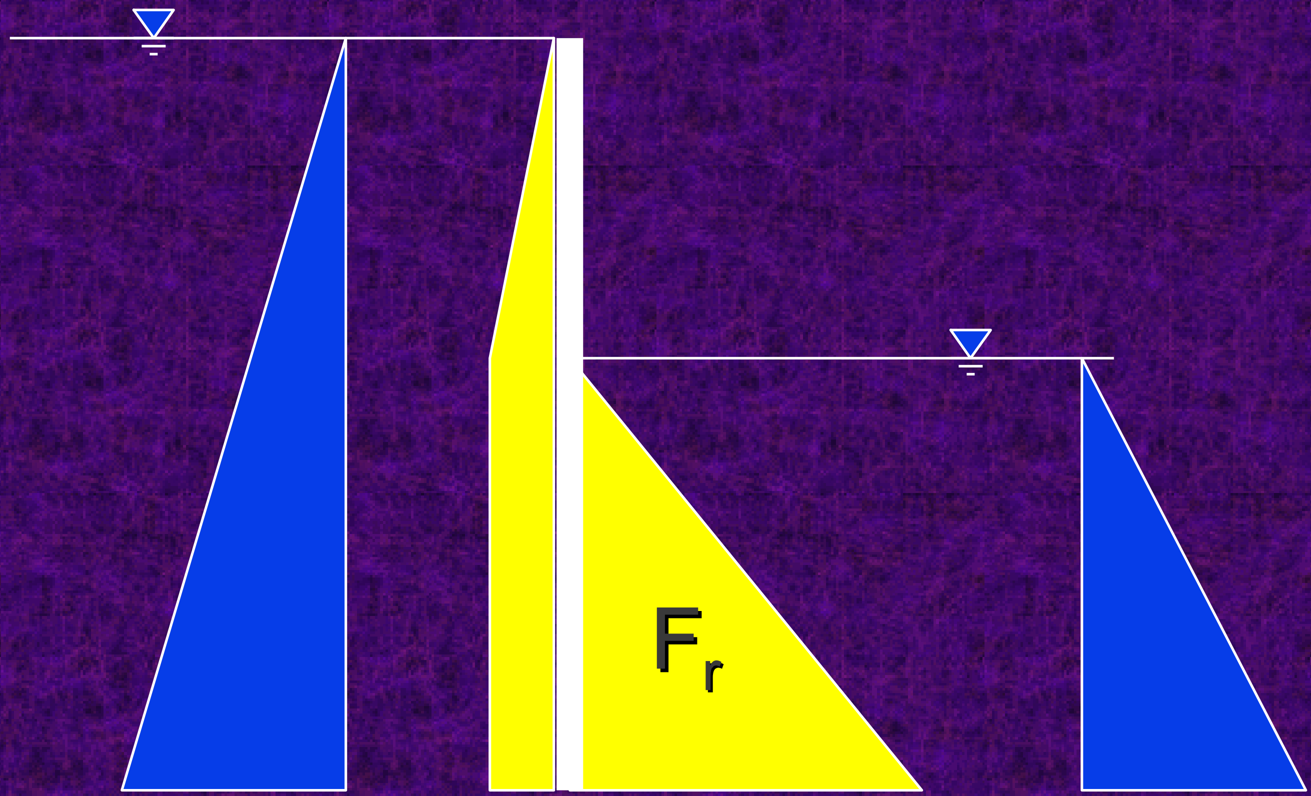
Traditional gross pressure method



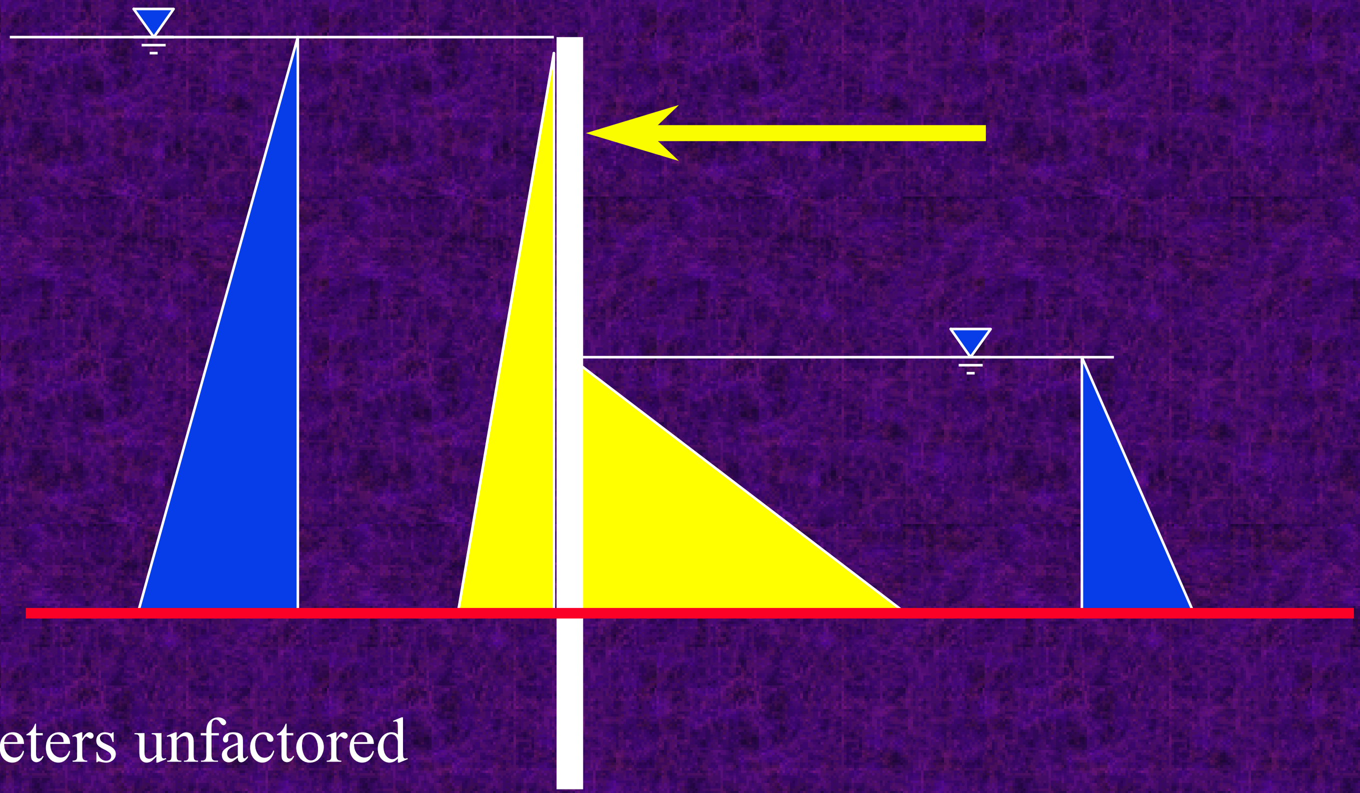
Traditional nett pressure method



Revised (Burland-Potts) method



Calculation of structural forces: CIRIA 104



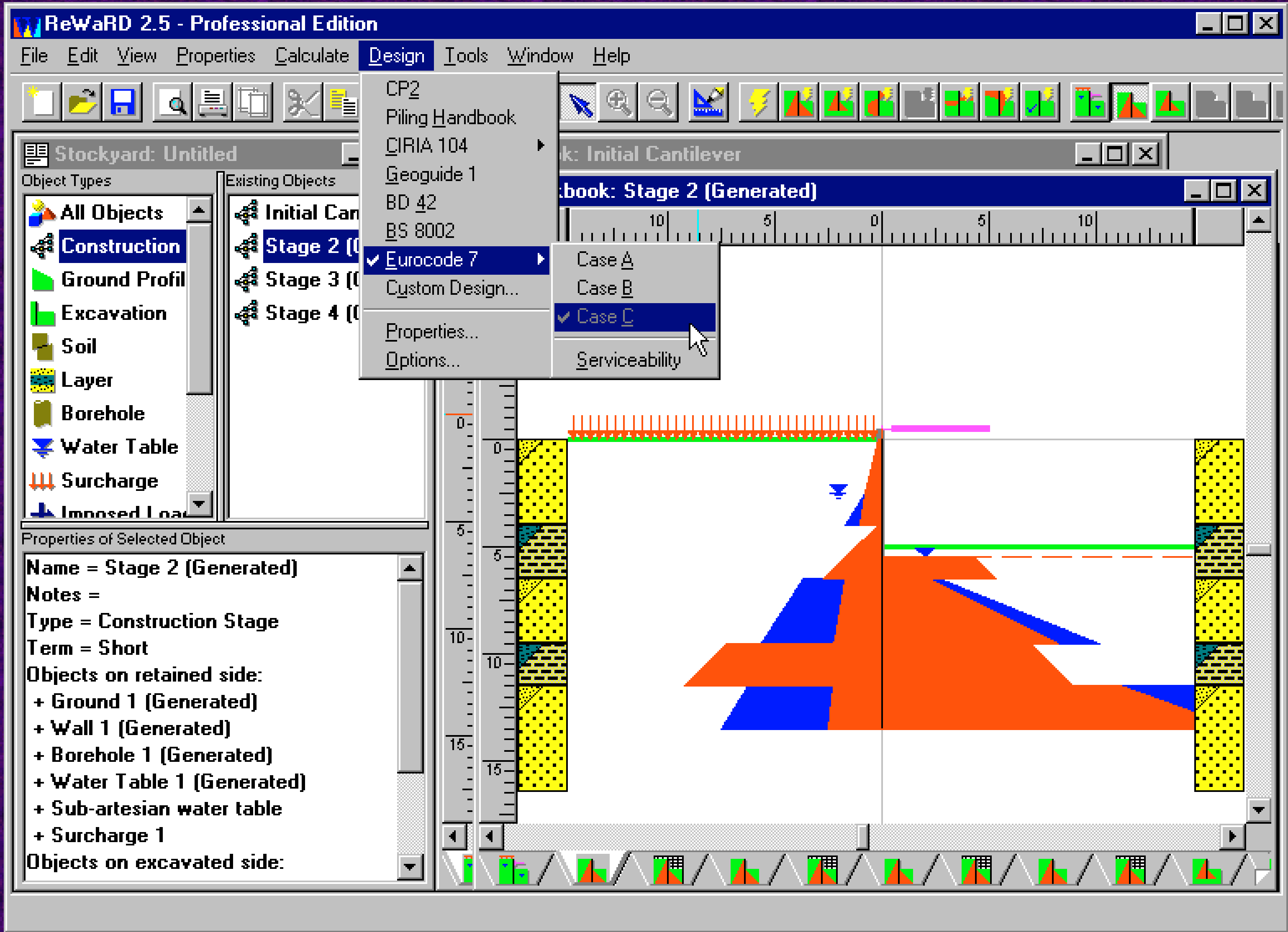
Parameters unfactored
Embedment reduced to achieve equilibrium
Calculated moment multiplied by 1.4-1.6 (typically 1.5)

Partial material factors from various codes

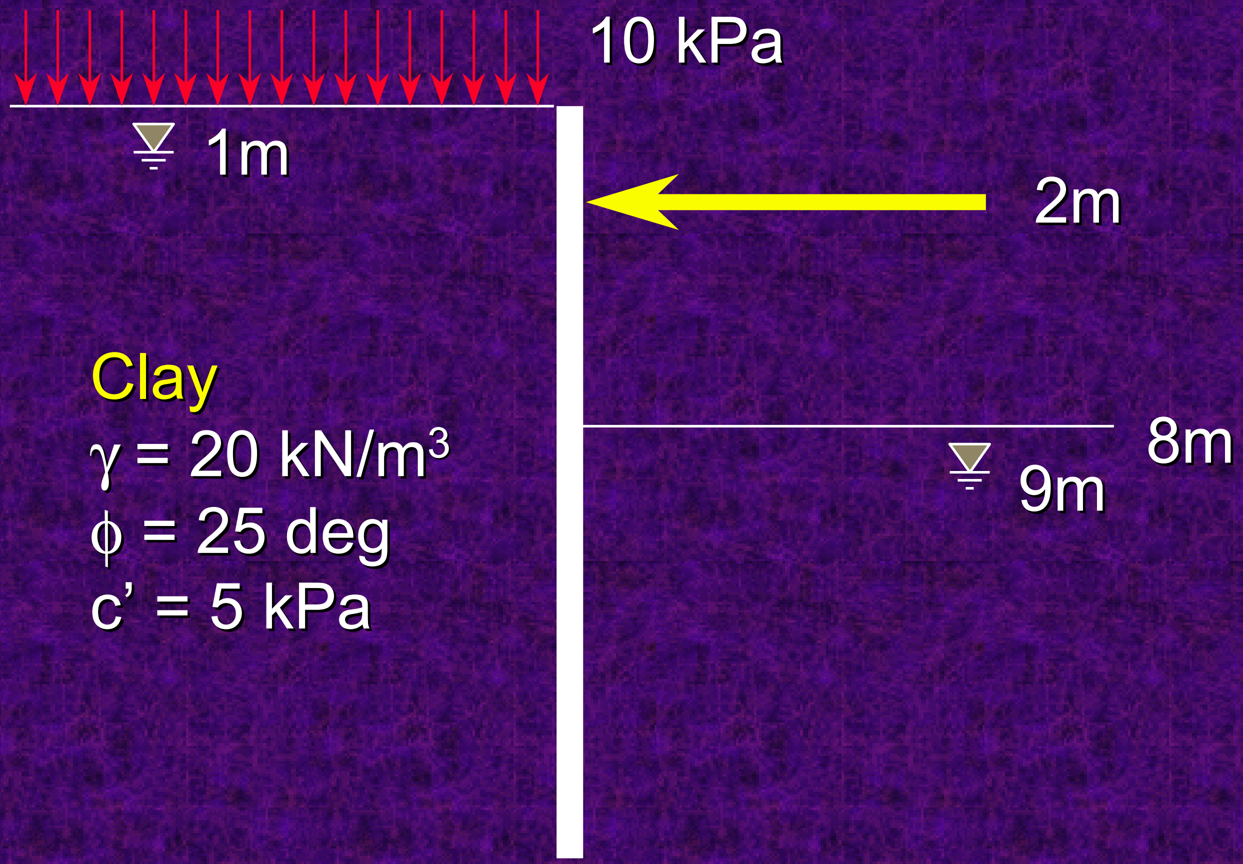
Code			tan ϕ	c'	C_u
EN1997	Set M2		1.25	1.25	1.4
ENV1997	Case C		1.25	1.6	1.4
BS 8002			1.2	1.2	1.5
Geoguide 1			1.2	1.2	2.0
CIRIA 104	Mod. Con.	Temporary	1.2	1.2	1.5
		Permanent	1.5	1.5	*
	Worst Cred.	Temporary	1.0	1.0	*
		Permanent	1.2	1.2	*

*Not applicable

Dedicated software makes this easy



Example C3 from CIRIA 104



Results of parametric study: Example C3

Design standard		Embedment (m)	Bending (kNm/m)	Shear (kN/m)
CP2	F_p	19.8	823	285
BSPH	F_{np}	14.6	727	263
CIRIA 104	F_r	16.5	695*	253*
CIRIA 104	F_s	17.8	695*	253*
Geoguide 1		14.9	839	269
BS 8002		16.2	1116	312
Eurocode 7	A	(15.2)	(934)	(281)
	B	(13.8)	(921)	(294)
	C	16.9	1276	352

Results compared to CIRIA 104

- Embedment
  - BSPH & Geoguide 1 = 15% lower
- Bending moments/shear forces
  - CP2 & Geoguide 1 = 20% higher
  - BS 8002 = 60% higher
  - Eurocode 7 = 80% higher

Conclusions

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Pros and cons of Eurocode 7

- Cons
  - Code is unnecessarily complicated in places
  - Unhappy compromise between countries
  - New terminology is difficult for some to learn
  - Appears to abandon traditional methods
  - Proposed safety system has not been tested!
- Pros
  - Logical framework for the design of geotechnical structures
  - Prospect of a universal design approach based on sound engineering principles

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