Calculation Models for Ultimate Limit States

Andrew Smith
Coffey Geotechnics Ltd.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Objectives

- What is new about EC7 Ultimate Limit State Design?
- How does EC7 ULS design appear?
  - From the point of view of a user
- How can we best use EC7 ULS methods?

Contents

- What is new in EC7
- Attributes of a new design code
- Some perceptions of EC7
- ULS in EC7 and before
- Use of EC7

What has changed?

- Much of EC7 is little different from previous practice, e.g.:
  - SLS calculations with partial factors unity
  - SI practice
- The main change is in ULS design:
  - Formalises definition of ULS
  - Terminology:
    action, effect, resistance
  - Use of partial factors

Attributes of a New Design Code

- Comprehensiveness
- Ease of Use
- Consistency
  - Internal
  - With previous codes
  - With physical reality
- Leads to reliable and economic design

Some Perceptions

From Bond & Harris:

- Negative
  - "a cross between '*the European Scream'* and the reaction of the ostrich"
  - Codification for codification's sake
  - Too high a cost
- Positive
  - Opinions improved once people had had experience of EC7

Some Identified Problems

- Is passive pressure a resistance
  or a favourable action? (Bond & Harris)
- What strength should one use at ULS?
  - Peak? Critical State? (Tony O'Brien, John Atkinson)
- Should water pressures be factored? (Brian Simpson)
- The single source principle – what does it mean? (CIRIA)
- Bond and Harris:
  - "The book deliberately presents ......
    a completely different running order from the Eurocodes
    so they can be explained more clearly" (My italics)

Example of Obscurity

- John Atkinson gave training sessions for Coffey
- He missed out the Model Factor ($\gamma_{R:d}$)
  for Pile Design by calculation
- After I drew his attention to it,
  it took him 20 minutes to find the reference in EC7,
  Even though he knew it must be there

Consistency with Physical Reality

Statics
Newton's Laws

1. If a body is at rest,
   the sum of the forces acting on it must be zero

2. (Dynamics)

3. To every Action there is always opposed
   an equal Reaction

ULS Design

- For Limit State EQU:

  $E_{dst;d} \leq E_{stb;d}$

- For Limit State GEO

  $E_d \leq R_d$

- How does the inequality affect
  consistency with Newton's Laws?

ULS Design

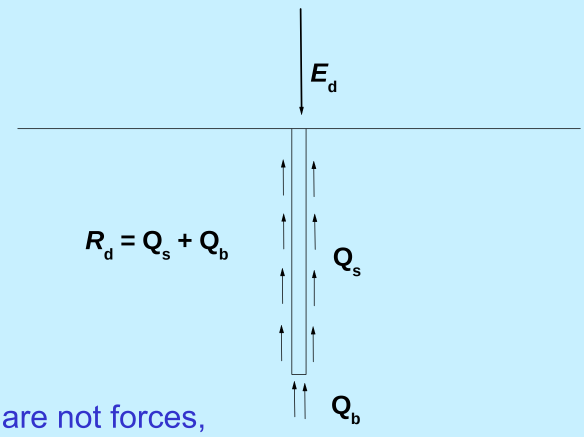
- For Limit State EQU:

  $E_{dst;d} \leq E_{stb;d}$

- How does the inequality affect consistency with Newton's Laws?

ULS in Practice

- Pile Design



- The resistances are not forces, they are *capacities* (maximum possible forces)

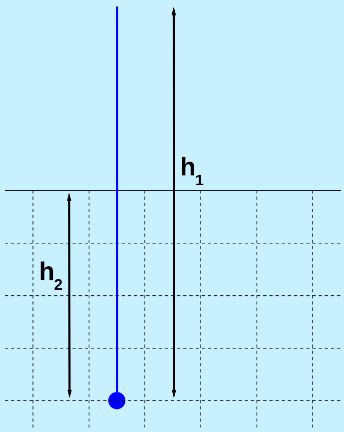
ULS in Practice

- Piping with upward water flow
- What is the safety factor?
- It depends on how you define it

- Total Stresses:
  - FS = $\gamma_b h_2 / \gamma_w h_1$

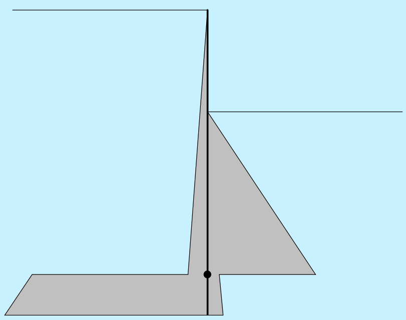
- Effective Stresses:
  - FS = $(\gamma_b h_2 - \gamma_w h_2) / (\gamma_w h_1 - \gamma_w h_2)$

- e.g. For h_1 = 3 m, h_2 = 2 m
- FS_T = 40/30 = 1.3 FS_E = 20/10 = 2



ULS in Practice

- Cantilever Wall Design



- Problem of definition of safety factor was addressed during development of CIRIA 104
- We are used to using partial factors for strength
- The resistances depend on the actions

  and the actions depend upon the resistances

Problems with ULS Calculations

- Resistances are sometimes treated as forces, when in fact they are *capacities*
  - i.e resistances and actions interact
- This applies to any ULS calculation, (e.g. Global safety factors) not just EC7 (with partial factors)
  - We are used to this with global safety factors (e.g. Hydraulic uplift, cantilever walls, slopes)
  - Partial factors can make the problem more complex, but not intrinsically different
- A safety factor is still what you define it to be

Comparison of Global and Partial Safety Factor Methods

- Global safety factors are simpler, and therefore easier to get a feel for
  - For any particular problem and depending on how they are defined
- Partial factors allow better assessment of uncertainty (variation?) of real physical factors (e.g. Variable loadings, material strengths)
  - But how do the code factors relate to real variation? Have they just been chosen to fit previous codes?
- Thinking about partial factors has enabled better identification of inconsistencies in previous practice

Can we Simplify ULS in EC7?

- Reduce to two sheets of A4:

- All except piles & anchors:
  - DA1:C1   A1 + M1 + R1
  - DA1:C2   A2 + M2 + R1

- Piles and anchors:
  - DA1:C1   A1 + M1 + R1
  - DA1: C2   A2 + M1 or M2 + R2
  - + Model Factor

- And write down what you have done!

Appendix E: EC7 Part 1: Annex A. Table of Partial Factors

Catergory	F.M.R	Detail	Action		Partial Factors			
EQU	γ_F	G.dst	Perm	Destab	1.1			
		G.stb	Perm	Stab	0.9			
		Q.dst	Var	Destab	1.5			
		Q.stb	Var	Stab	0			
	γ_M	ϕ'			1.25			
		c'			1.25			
		cu			1.4			
		qu			1.4			
		γ			1.0			
UPL	γ_F	G.dst	Perm	Destab	1.0			
		G.stb	Perm	Stab	0.9			
		Q.dst	Var	Destab	1.5			
HYD	γ_F	G.dst			1.35			
		G.stb			0.9			
		Q.dst			1.5			
					A1	A2		
STR + GEO	γ_F, γ_E	G	Perm	Unf	1.35	1.0		
		G	Perm	Fav	1.0	1.0		
		G	Var	Unf	1.5	1.3		
		G	Var	Fav	0	0		
					M1	M2		
	γ_M	ϕ'			1.0	1.25		
		c'			1.0	1.25		
		cu			1.0	1.4		
		qu			1.0	1.4		
		γ			1.0	1.0		
					R1	R2	R3	R4
Shallow	γ_R	R.v	Bearing		1.0	1.4	1.0	
		R.h	Sliding		1.0	1.1	1.0	
Driven	γ_R	b	Base		1.0	1.1	1.0	1.3
		s	Shaft		1.0	1.1	1.0	1.3
		t	Total		1.0	1.1	1.0	1.3
		s.t	Shaft tension		1.25	1.15	1.1	1.6
Bored	γ_R	b	Base		1.25	1.1	1.0	1.6
		s	Shaft		1.0	1.1	1.0	1.3
		t	Total		1.15	1.1	1.0	1.5
		s.t	Shaft tension		1.25	1.15	1.1	1.6
CFA	γ_R	b	Base		1.1	1.1	1.0	1.45
		s	Shaft		1.0	1.1	1.0	1.3
		t	Total		1.1	1.1	1.0	1.4
		s.t	Shaft tension		1.25	1.15	1.1	1.6
Anchors	γ_R				1.1	1.1	1.0	1.1
Retaining wall	γ_R	R.v	Bearing		1.0	1.4	1.0	
		R.h	Sliding		1.0	1.1	1.0	
		R.e	Earth press		1.0	1.4	1.0	
Slopes	γ_R	R.e			1.0	1.1	1.0	

Conclusions

- Partial Factors constitute the main new feature of EC7 ULS calculations
- ULS calculations have intrinsic difficulties
- We are used to them in global factor methods, but not yet in partial factor methods
- EC7 calculations can be made more straightforward

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