XIV European Conference on Soil Mechanics and Geotechnical Engineering

Spirit of Krebs Ovesen session

A holistic view – and the origins of Design Approach 1

Brian Simpson

Arup Geotechnics

Holistic

- whole, complete, comprising or involving all parts and aspects
- tending to form or produce organised wholes which are more than the mere sum of the component units

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Consistent geotechnical and structural design
"All part of the same problem"

Benefits of "combinations" of factors

Parameters must be factored before they are combined

DA1 – good for FE

Safety is not only calculation

It should be considered that knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are usually more significant to fulfilling the fundamental requirements than is precision in the calculation models and partial factors.

(EN1997-1 2.4.1(2)).

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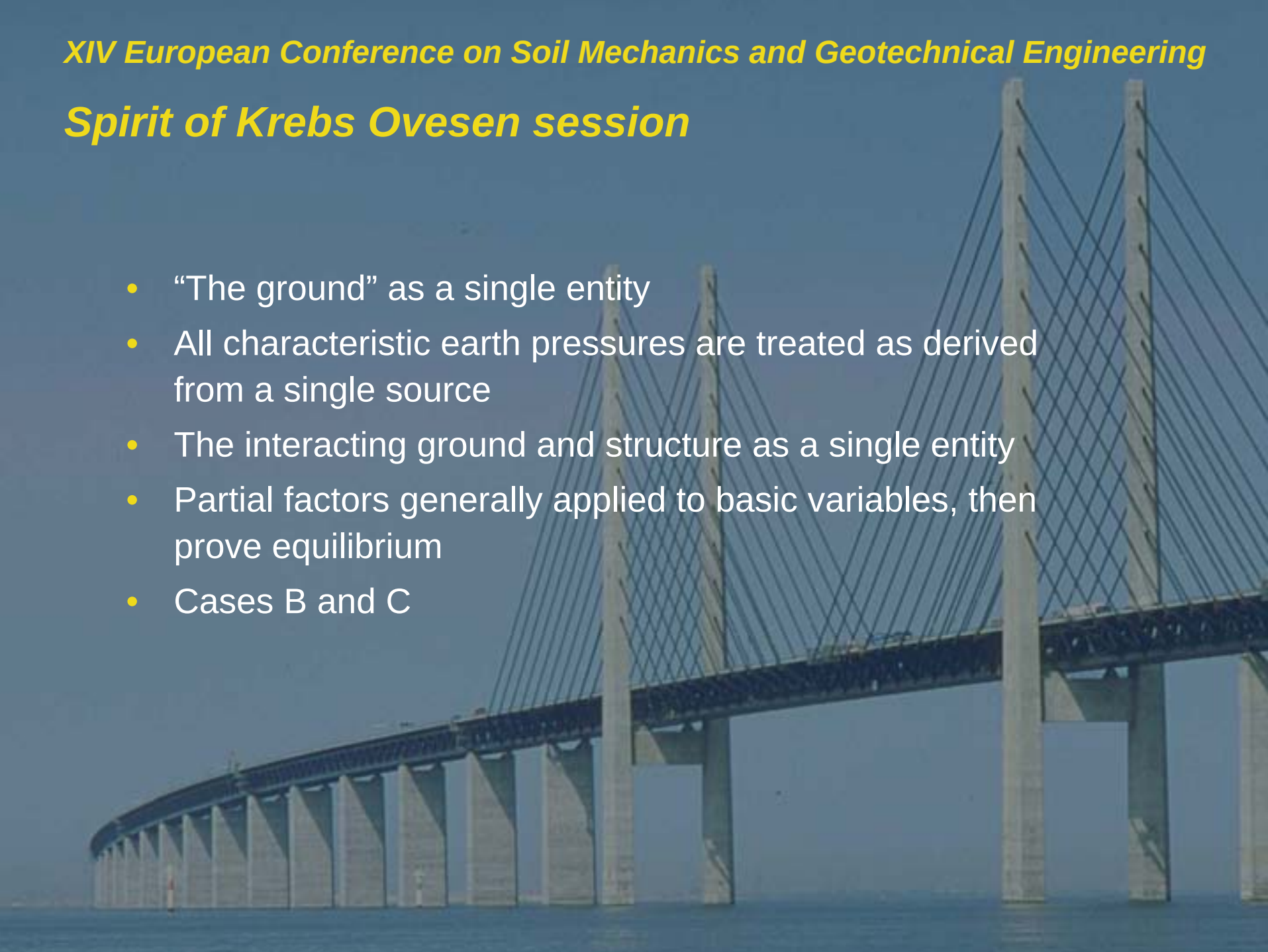

- "The ground" as a single entity
- All characteristic earth pressures are treated as derived from a single source
- The interacting ground and structure as a single entity
- Partial factors generally applied to basic variables, then prove equilibrium
- Cases B and C

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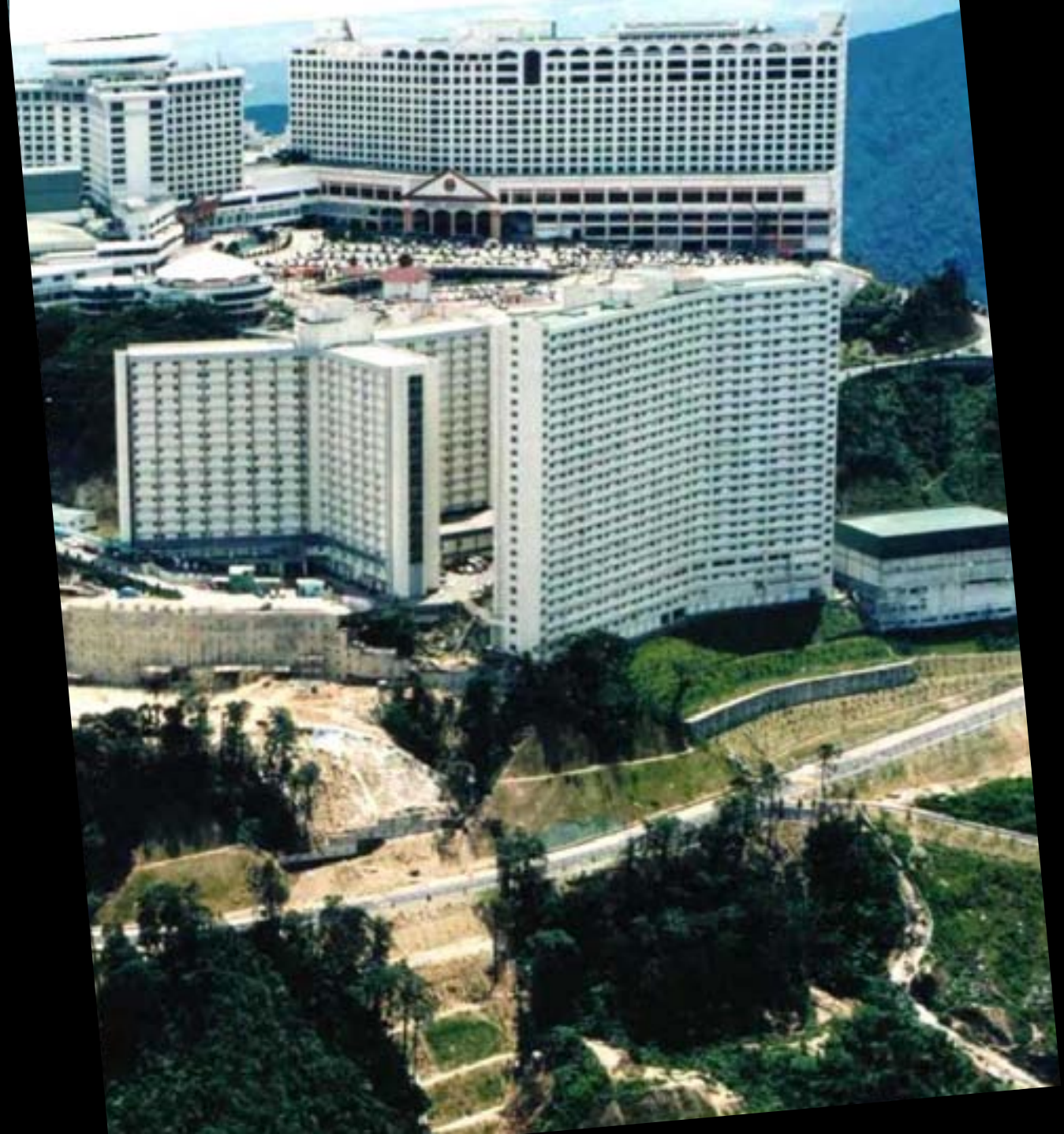
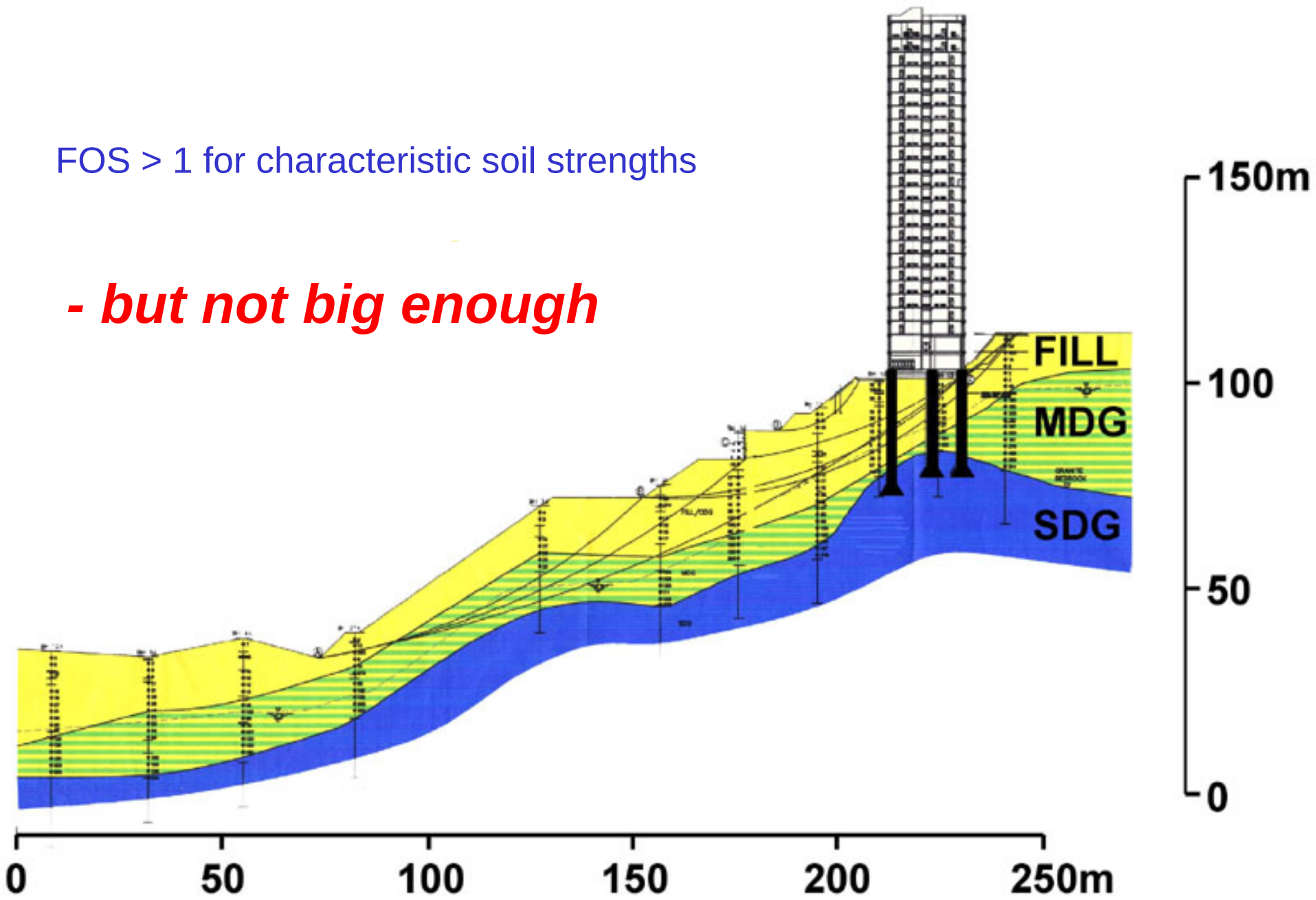


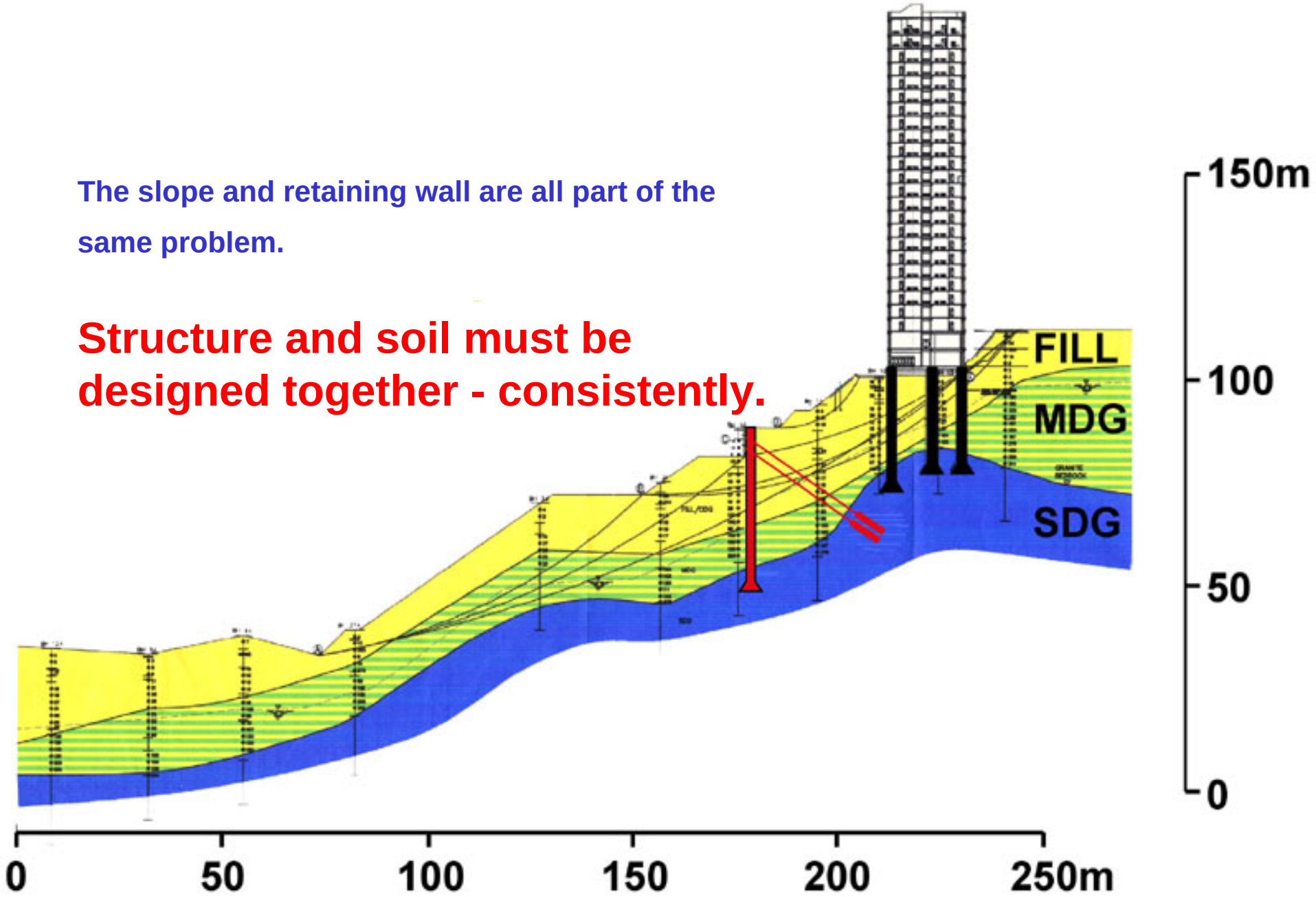
FOS > 1 for characteristic soil strengths

- but not big enough



The slope and retaining wall are all part of the same problem.

Structure and soil must be designed together - consistently.



Partial factors for DA1 - UK NA

Values of partial factors recommended in EN1997-1 Annex A

			Design approach 1								
			Combination 1			Combination 2			Combination 2 - piles & anchors		
			A1	M1	R1	A2	M2	R1	A2	M1 or … M2	R4
Actions	Permanent	unfav	1,35								
		fav									
	Variable	unfav	1,5			1,3			1,3		
Soil	tan ϕ'						1,25			1,25	
	Effective cohesion						1,25			1,25	
	Undrained strength						1,4			1,4	
	Unconfined strength						1,4			1,4	
	Weight density										
Spread footings	Bearing										
	Sliding										
Driven piles	Base										1,3
	Shaft (compression)										1,3
	Total/combined										1,3
	Shaft in tension										2,0
Bored piles	Base										1,6
	Shaft (compression)										1,3
	Total/combined										1,6
	Shaft in tension										2,0
CFA piles	Base										1,5
	Shaft (compression)										1,3
	Total/combined										1,5
	Shaft in tension										2,0
Anchors	Temporary										1,1
	Permanent										1,1
Retaining walls	Bearing capacity										
	Sliding resistance										
	Earth resistance										
Slopes	Earth resistance										

indicates partial factor = 1.0

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DA1 – good for FE

EN1990 – choice of partial factor values

BP145a.14

C7 Approach for calibration of design values

(2) Design values should be based on the values of the basic variables at the FORM design point, which can be defined as the point on the failure surface ($g = 0$) closest to the average point in the space of normalised variables (as diagrammatically indicated in Figure C2).

(3) The design values of action effects E_d and resistances R_d should be defined such that the probability of having a more unfavourable value is as follows :

$$P(E > E_d) = \Phi(+\alpha_E \beta) \quad \text{(C.6a)}$$
$$P(R \leq R_d) = \Phi(-\alpha_R \beta) \quad \text{(C.6b)}$$

Design consistently at β standard deviations from the mean

where :

β is the target reliability index (see C6).

α_E and α_R, with $|\alpha| \leq 1$, are the values of the FORM sensitivity factors. The value of α is negative for unfavourable actions and action effects, and positive for resistances.

0.7 and 0.8 or 1.0 and 0.4 ?

α_E and α_R may be taken as - 0,7 and 0,8, respectively, provided

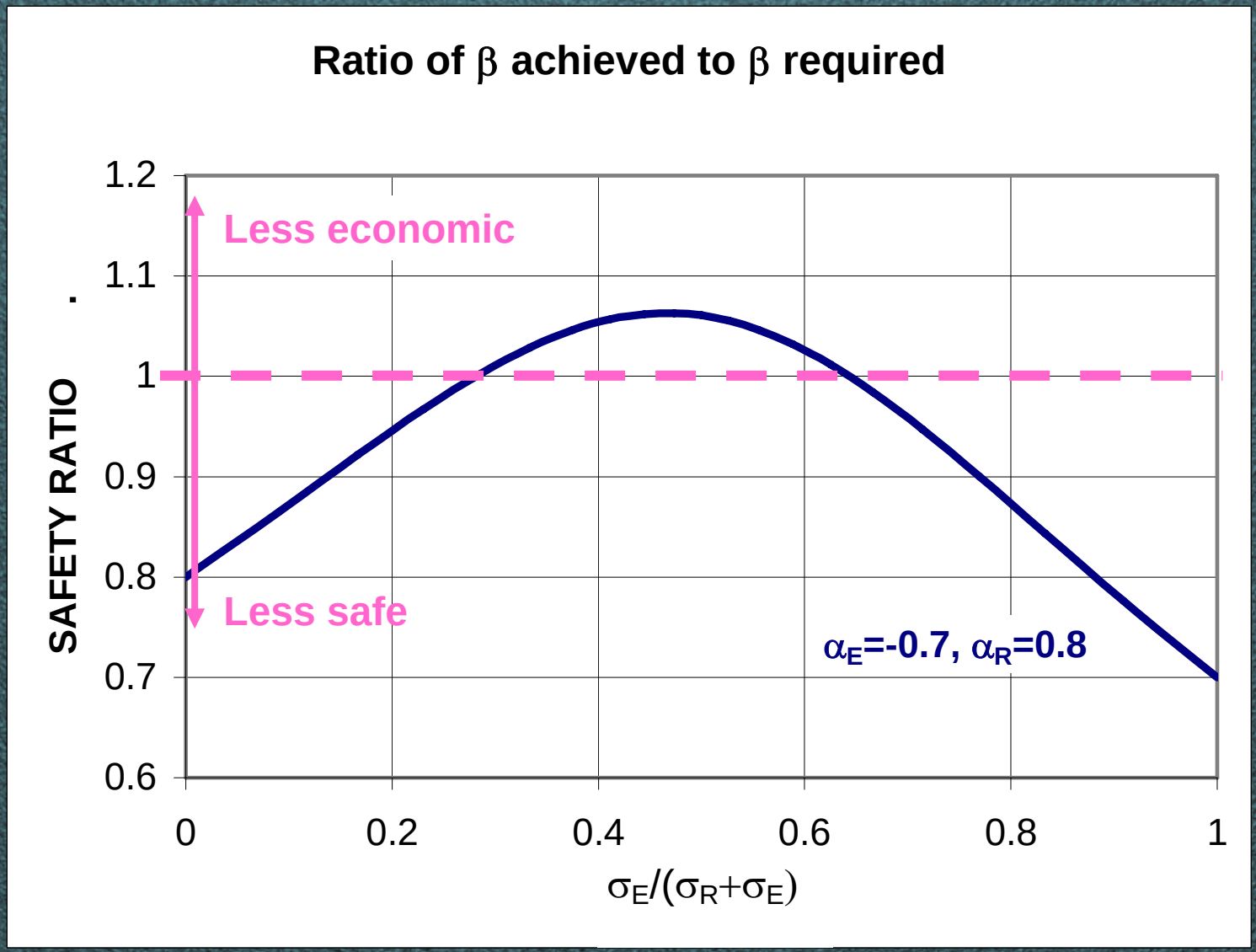
$0{,}16 < \sigma_E/\sigma_R < 7{,}6$ (C.7)

where σ_E and σ_R are the standard deviations of the action effect and resistance, respectively, in expressions (C.6a) and (C.6b). This gives :

$P(E > E_d) = \Phi(-0{,}7\beta)$ (C.8a)

$P(R \leq R_d) = \Phi(-0{,}8\beta)$ (C.8b)

(4) Where condition (C.7) is not satisfied $\alpha = \pm 1{,}0$ should be used for the variable with the larger standard deviation, and $\alpha = \pm 0{,}4$ for the variable with the smaller standard deviation.



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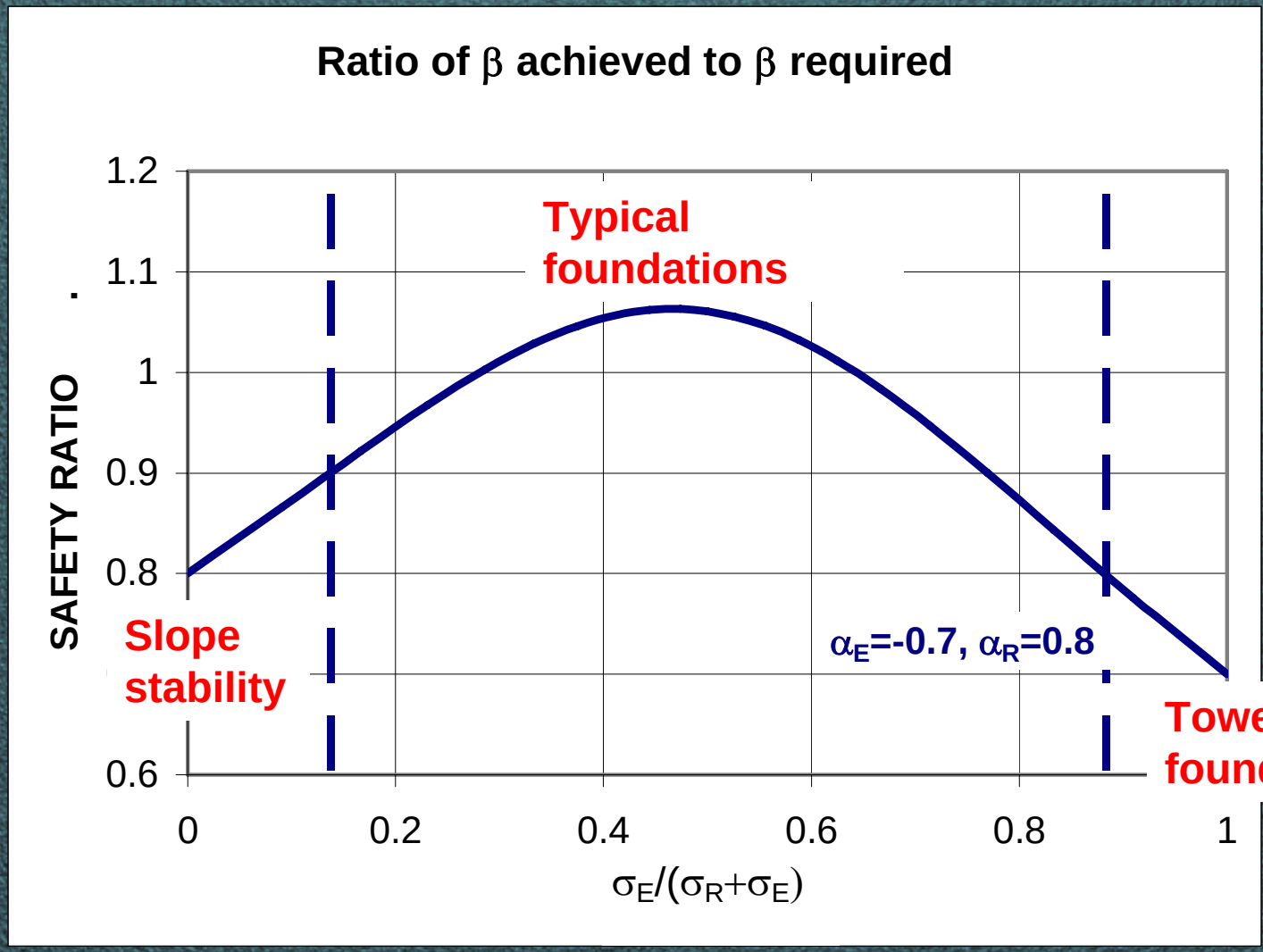

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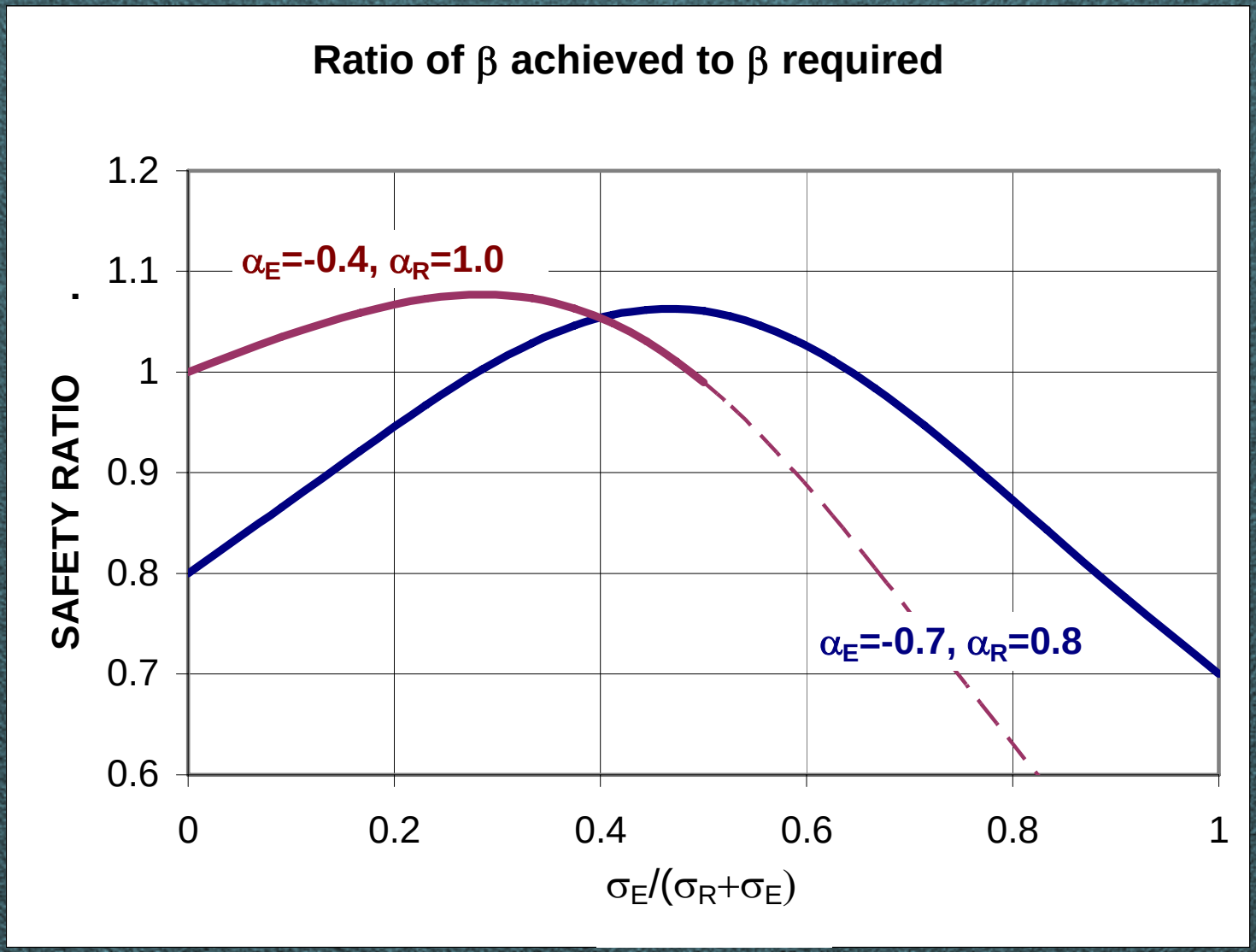

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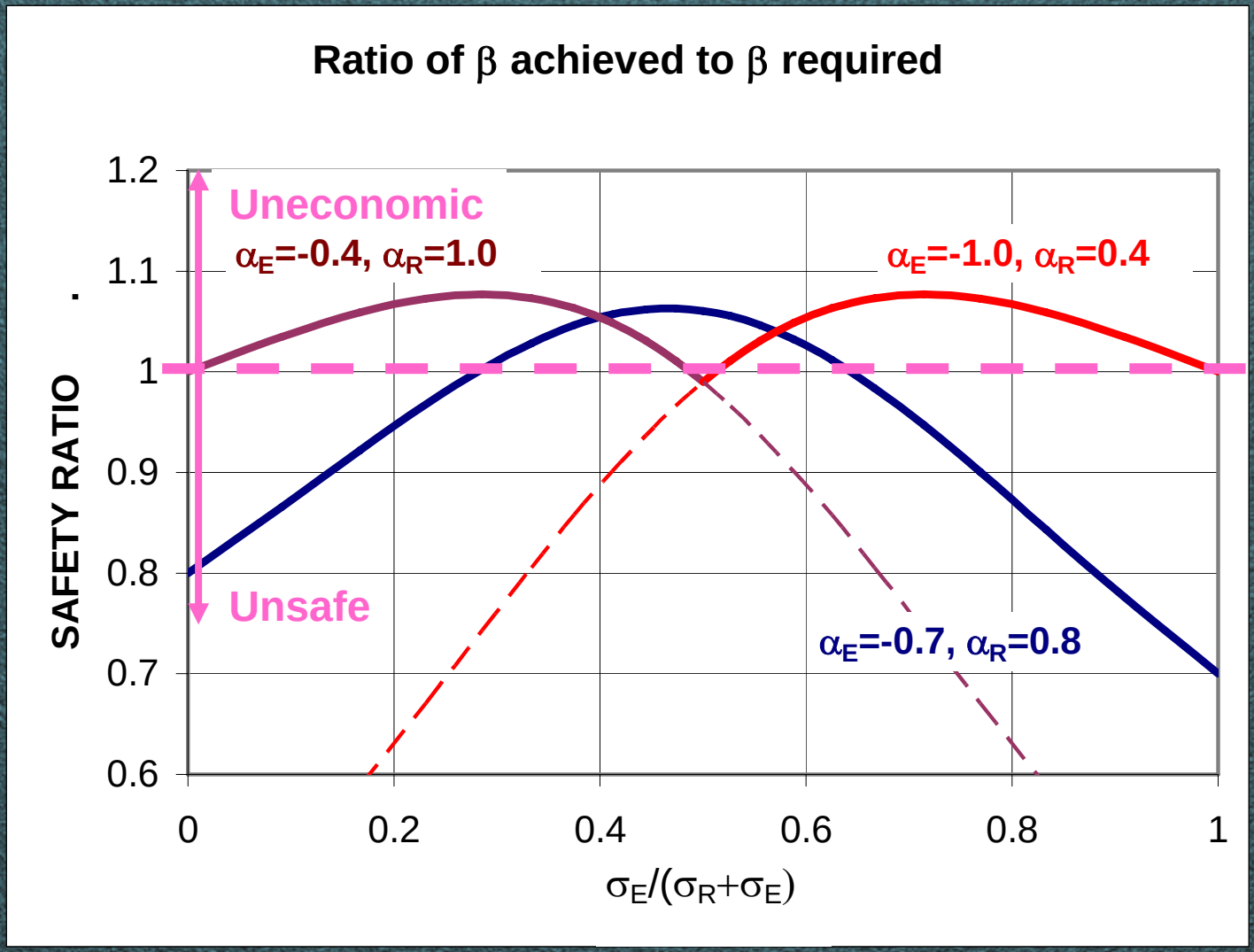

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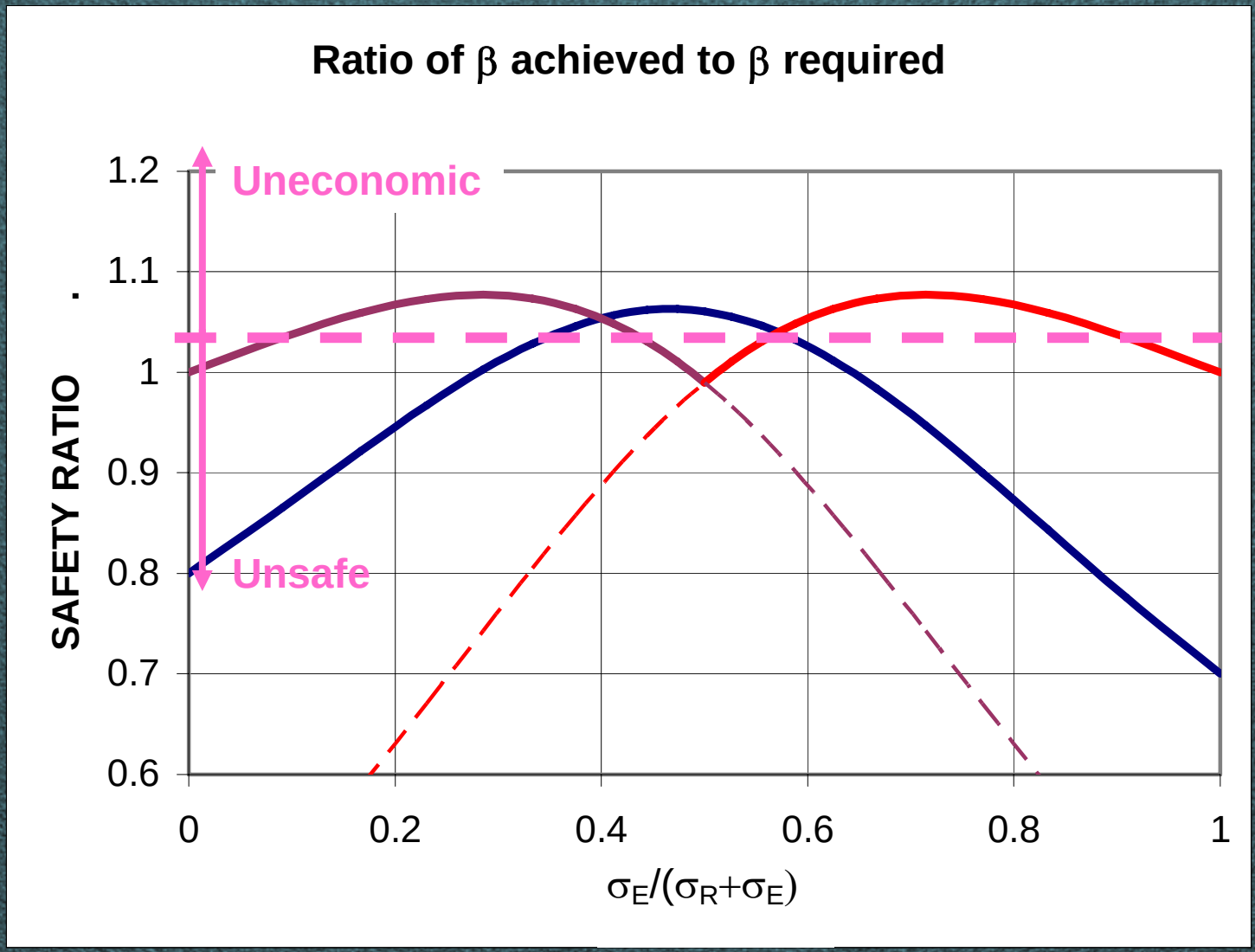

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Combinations 1 and 2 in EC7 - DA1

- Just like load combinations
- All designs must comply with both combinations in all respects, both geotechnical and structural
- Turkstra's principle for load combinations - extended

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DA1 – good for FE

EN1990 – variables with disproportionate effects

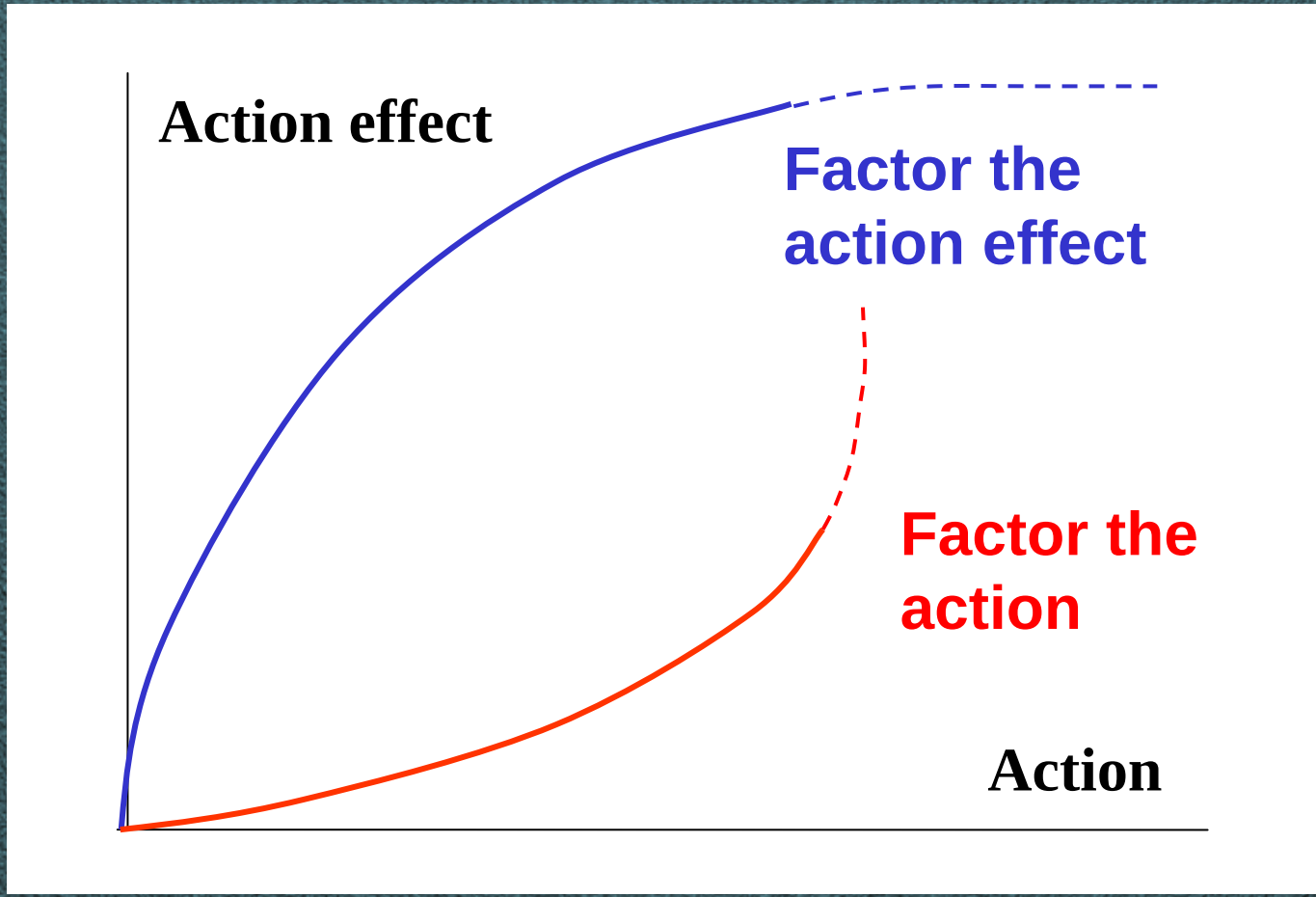
6.3.2 Design values of the effects of actions

(4) For non-linear analysis (i.e. when the relationship between actions and their effects is not linear), the following simplified rules may be considered in the case of a single predominant action :

a) When the action effect increases more than the action, the partial factor γ_F should be applied to the representative value of the action.

b) When the action effect increases less than the action, the partial factor γ_F should be applied to the action effect of the representative value of the action.

Factors on materials and actions, or resistances and action effects?



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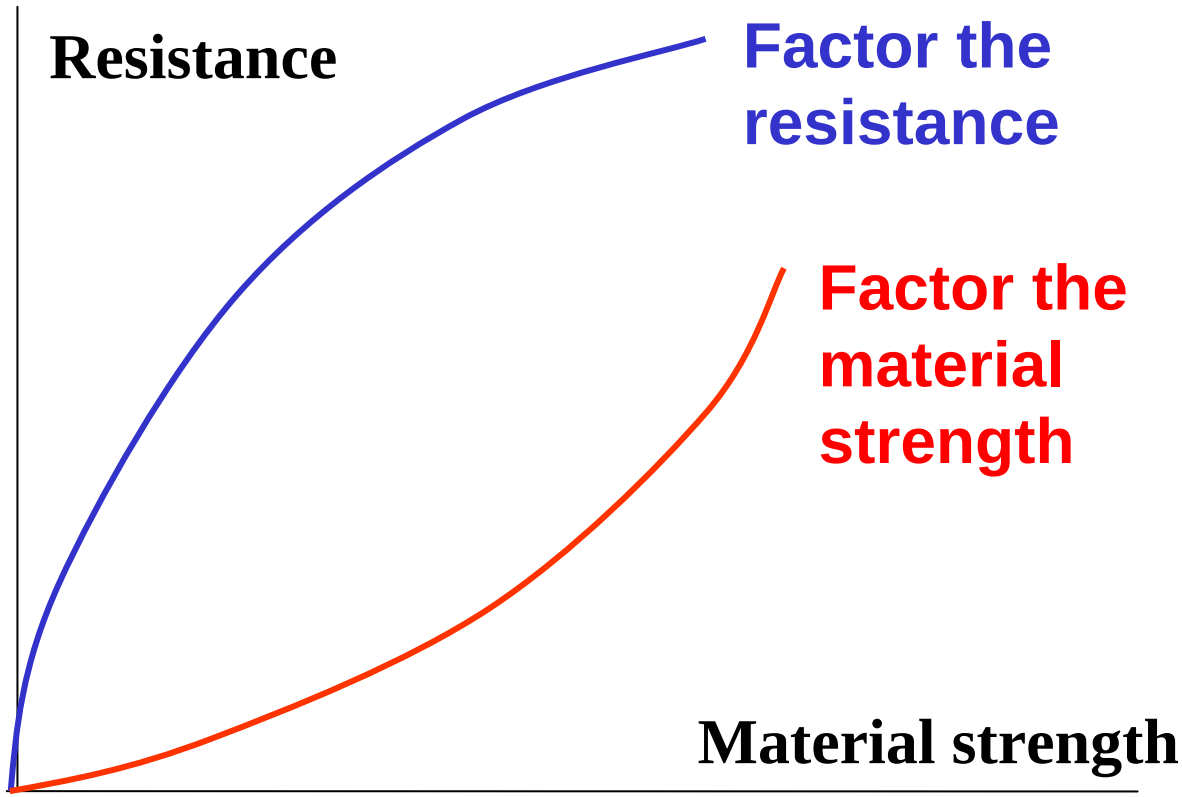


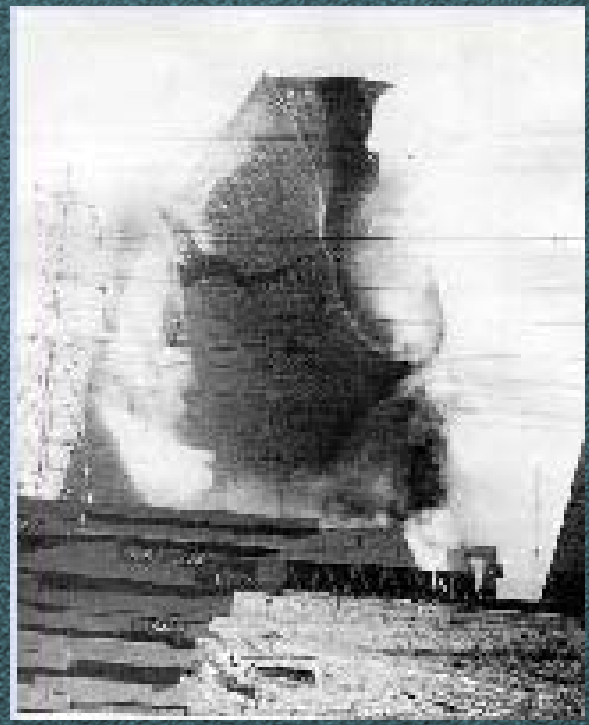
Ferrybridge power station – actions which tend to cancel each other

A cooling tower comes crashing to the ground during high winds at Ferrybridge 'C' Power Station in 1965.

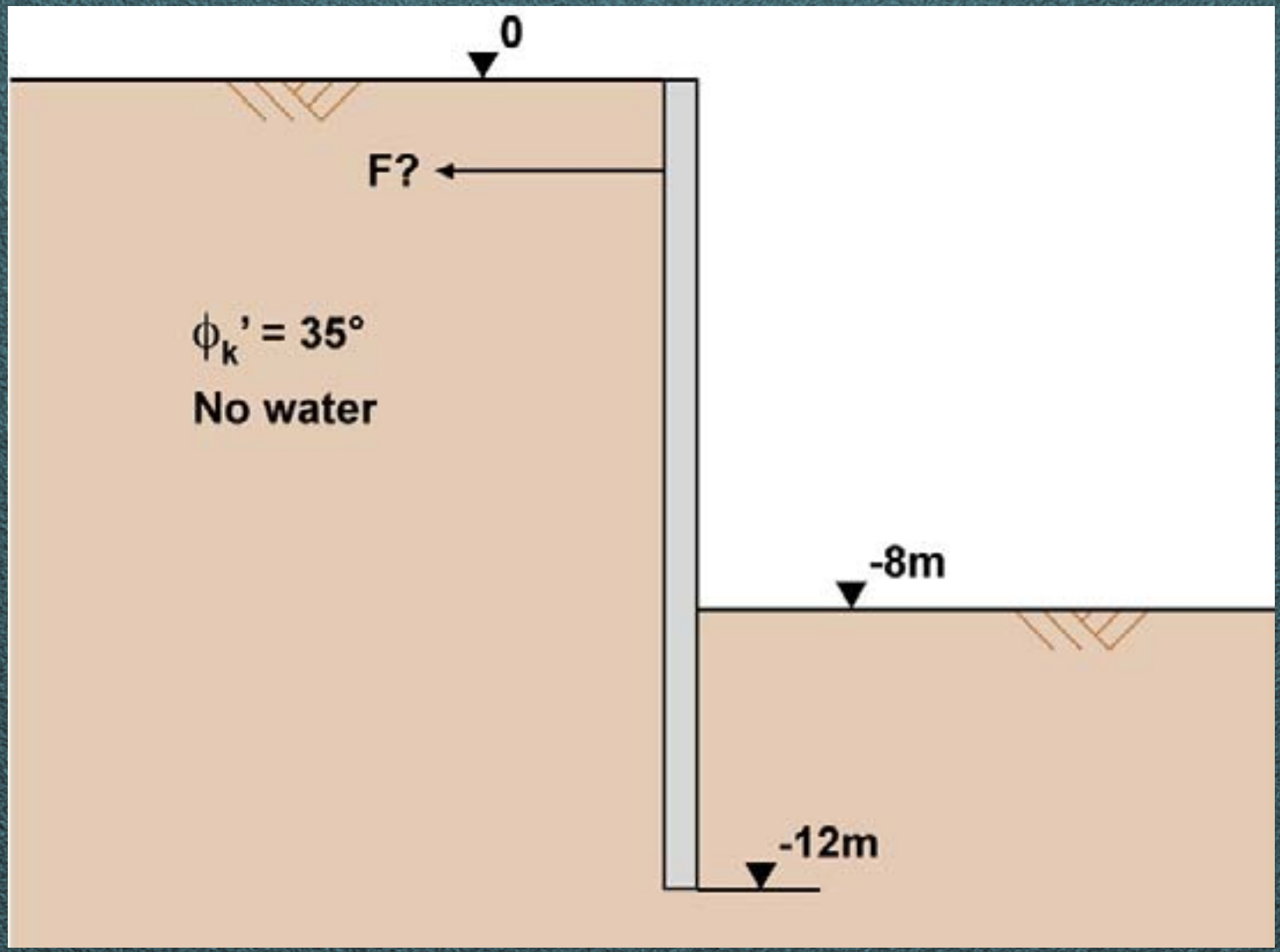
The aftermath of the incident. Three of the eight cooling towers were completely destroyed.

Must factor independent actions before they are combined

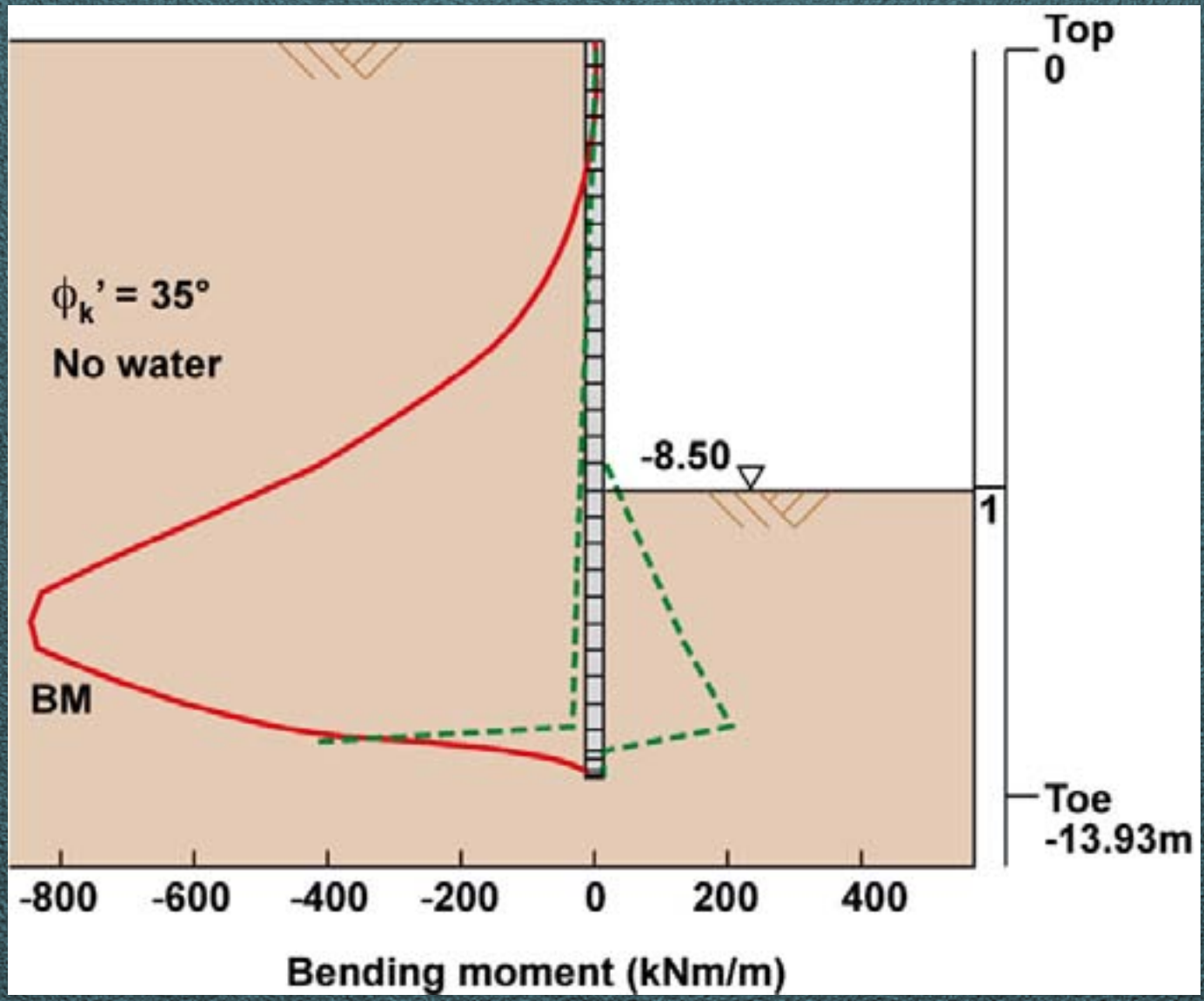
- Subject to permanent action (weight) plus variable action (wind)
- Unfactored, their “characteristic” action effects almost cancelled
- So little strength was provided
- But the wind blew slightly harder …



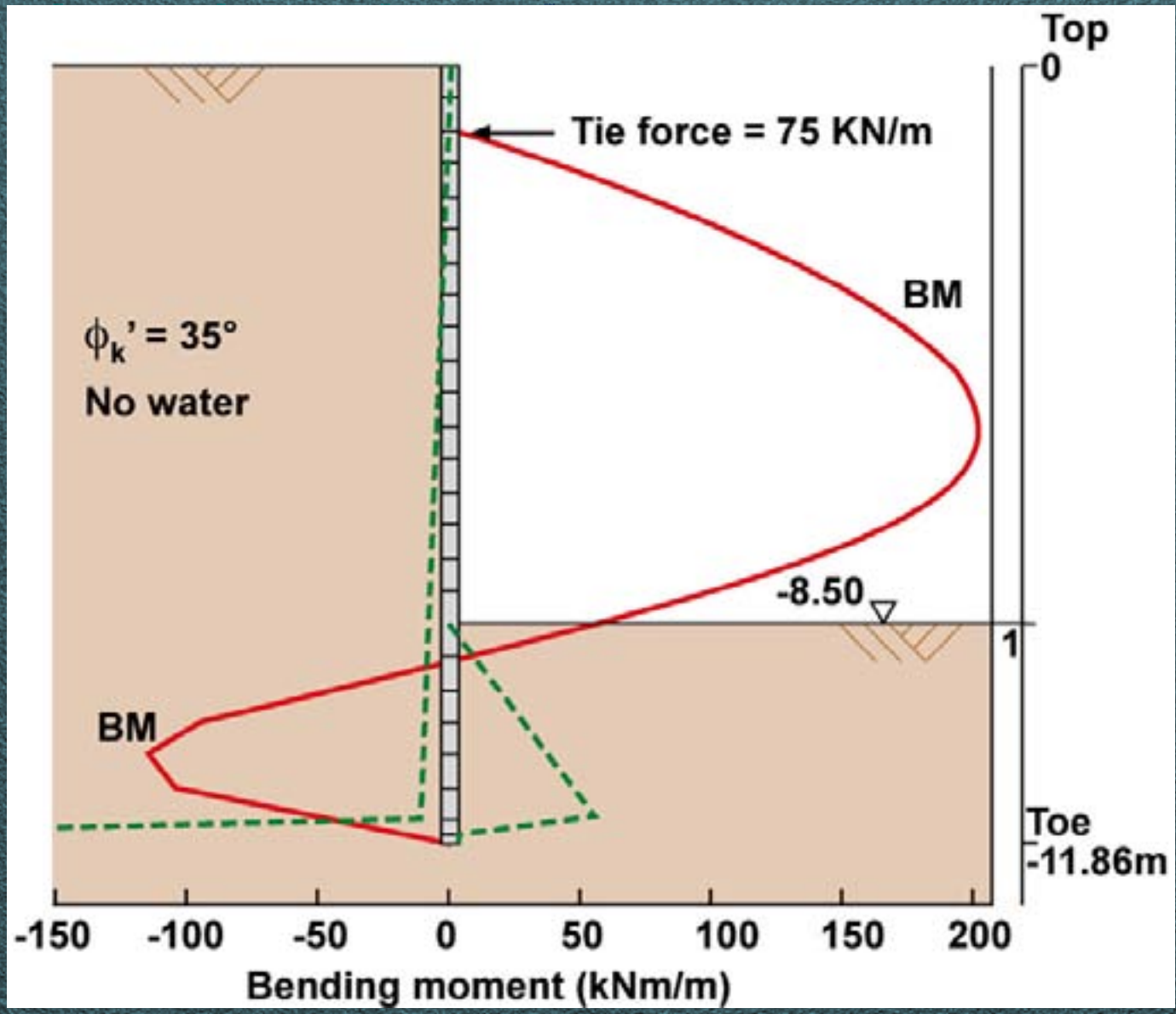
The wall must be 12m long. What tie force is required?



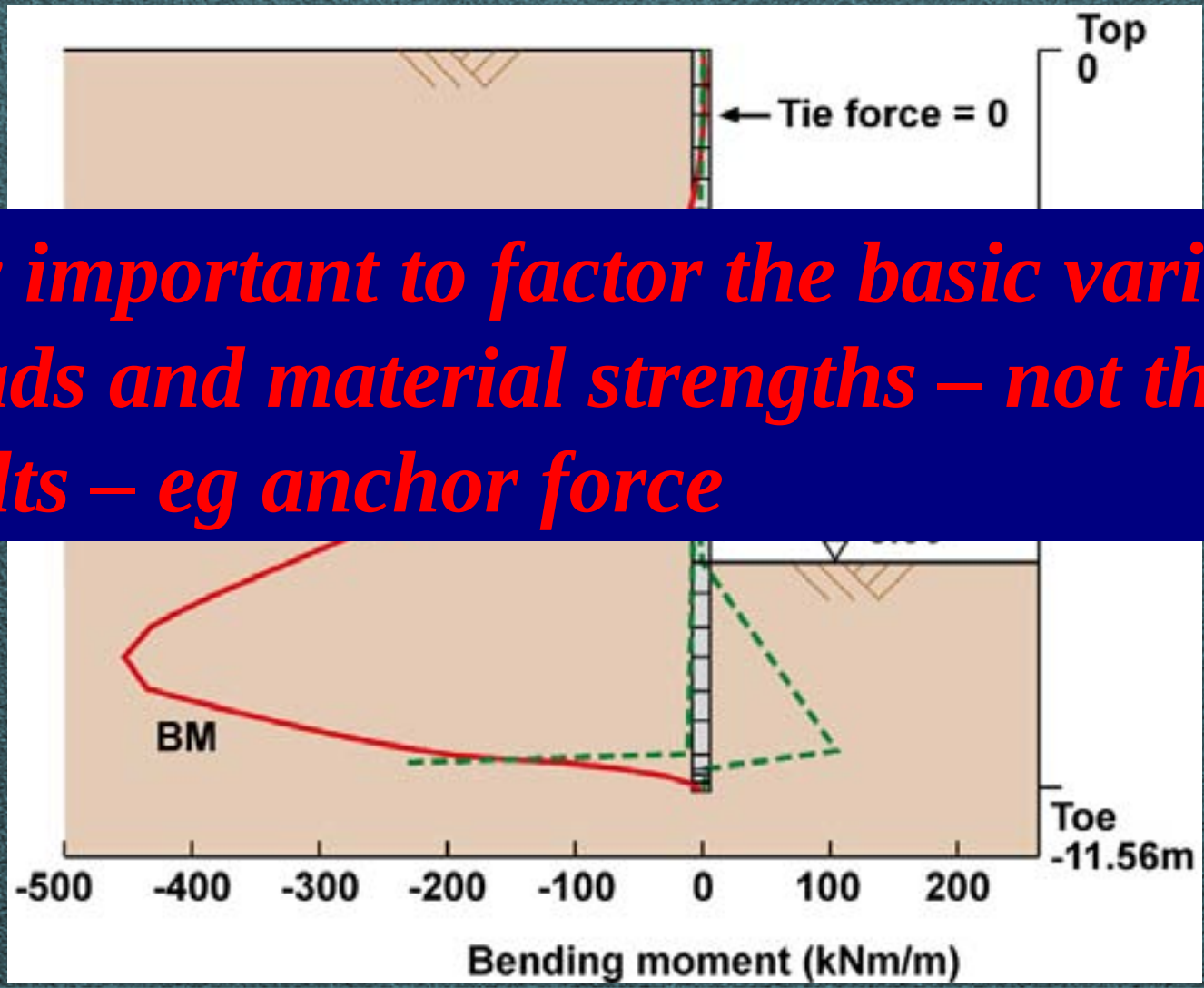
As a cantilever, length would be about 14m.



DA1 Comb 2 gives a design tie force of 75kN/m



But characteristic calculation gives zero tie force, for 12m length. 0 x 1.35 = 0



Very important to factor the basic variables – loads and material strengths – not the results – eg anchor force

Example from Schuppener et al

$V_{G,k}$ = 400 kN/m

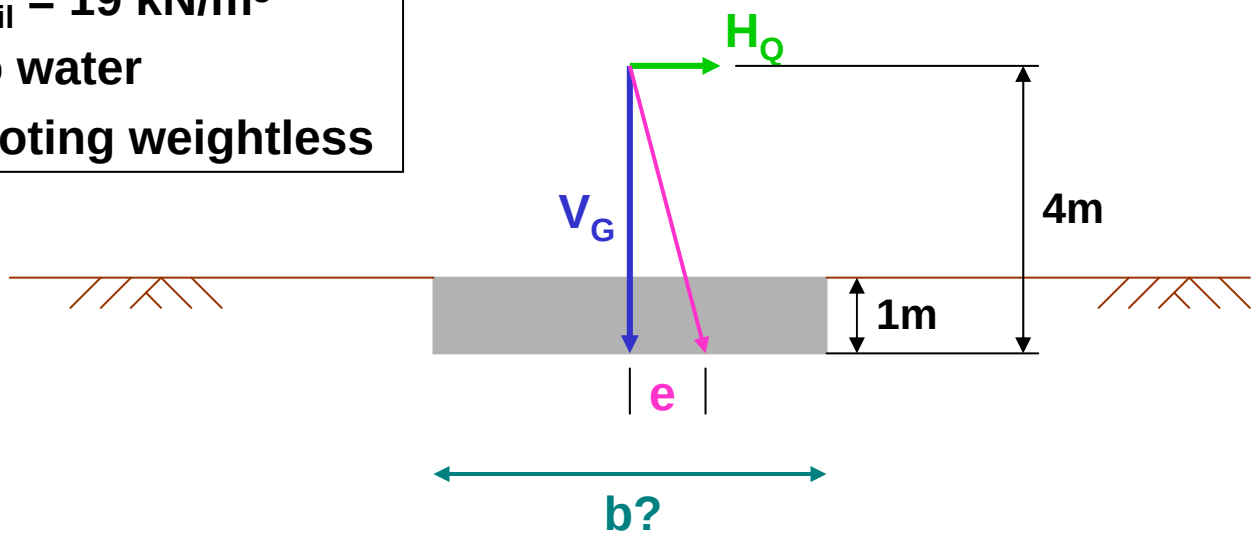
$H_{Q,k}$ varied

ϕ'_k=32.5°

γ_{soil} = 19 kN/m³

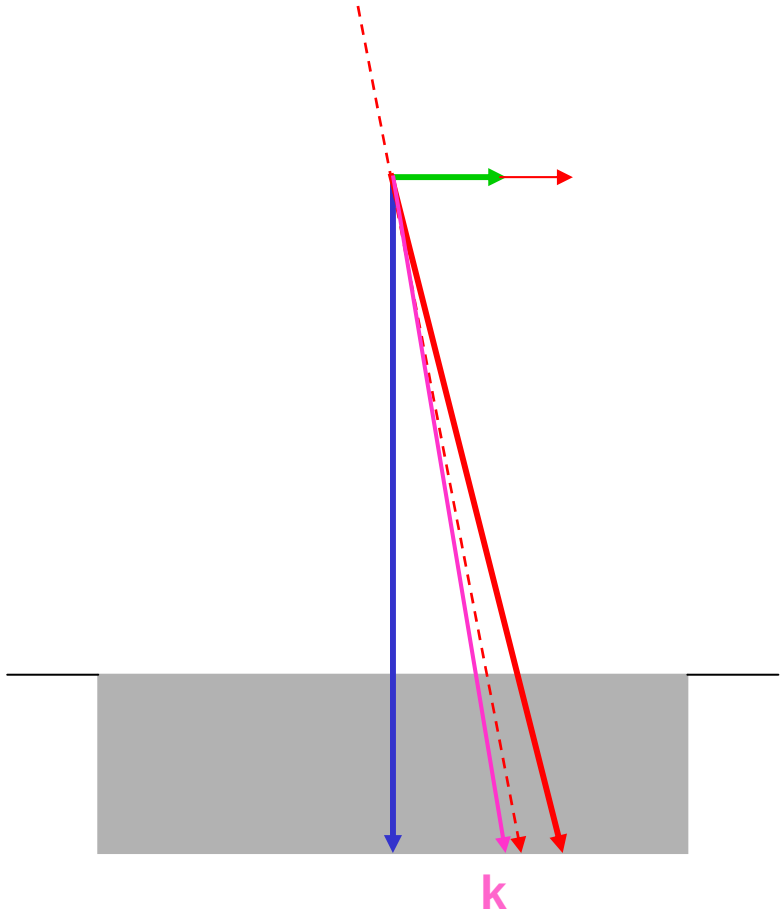
No water

Footing weightless



DA1 combination 1

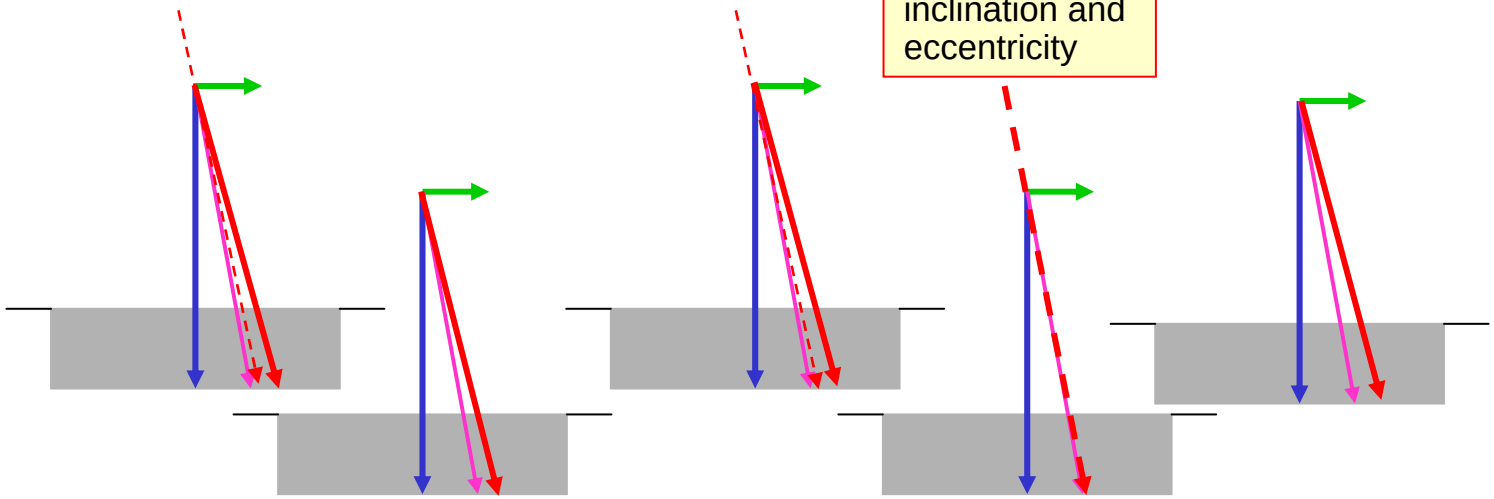
	DA 1	
	Comb 1	
V_G	1.35 or 1.0	
H_Q	1.5	
tan ϕ’	1.0	
R(bearing)		
R(sliding)		



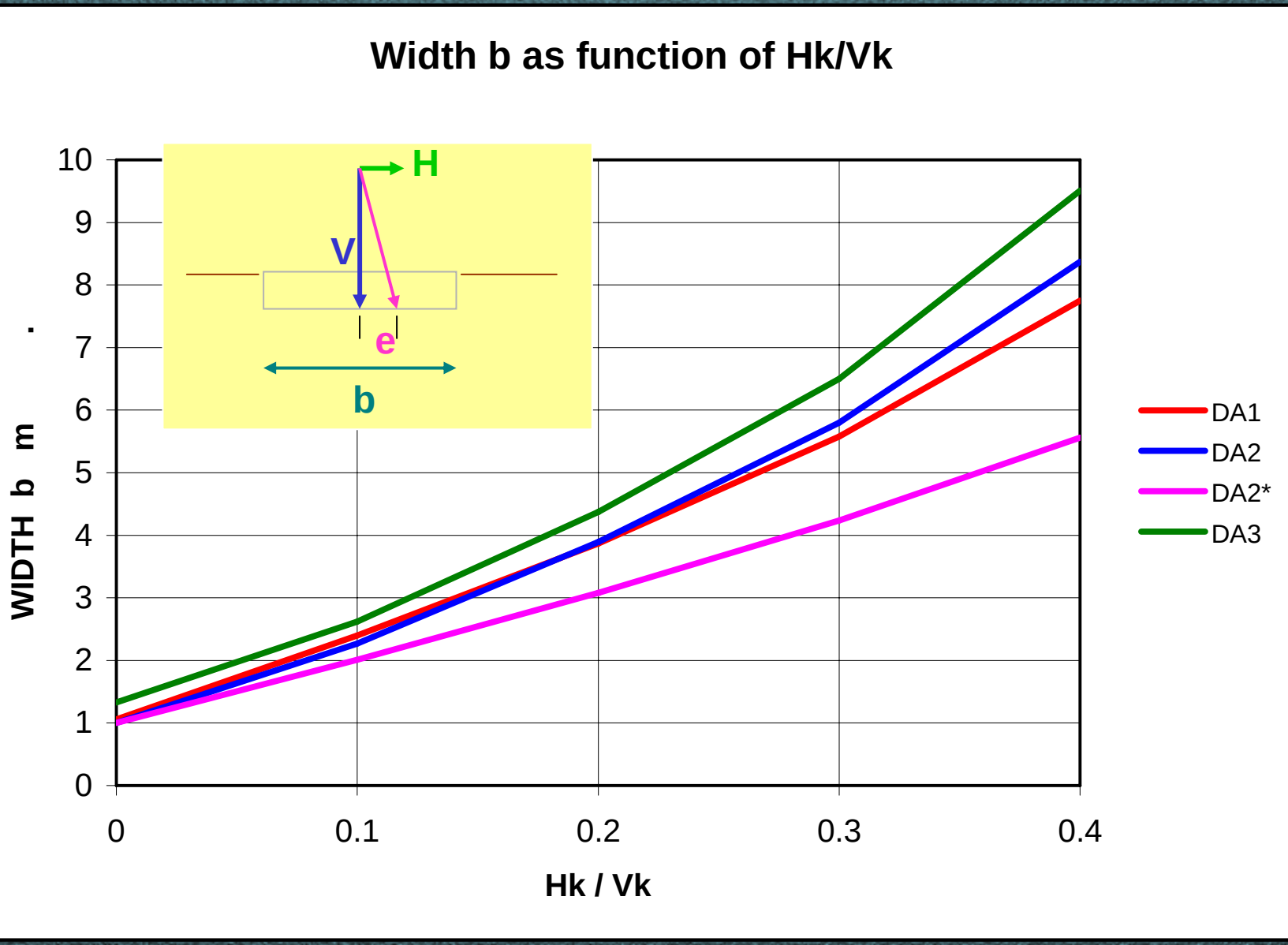
DA1, DA2 and DA2*

	DA 1		DA2	DA2*	DA2*
	Comb 1	Comb 2		bearing	sliding
V_G	1.35 or 1.0	1.0	1.35 or 1.0	1.35	1.0
H_Q	1.5	1.3	1.5	1.35 (1.5??)	1.5
tan ϕ'	1.0	1.25			
R(bearing)			1.4	1.4	
R(sliding)			1.1		1.1

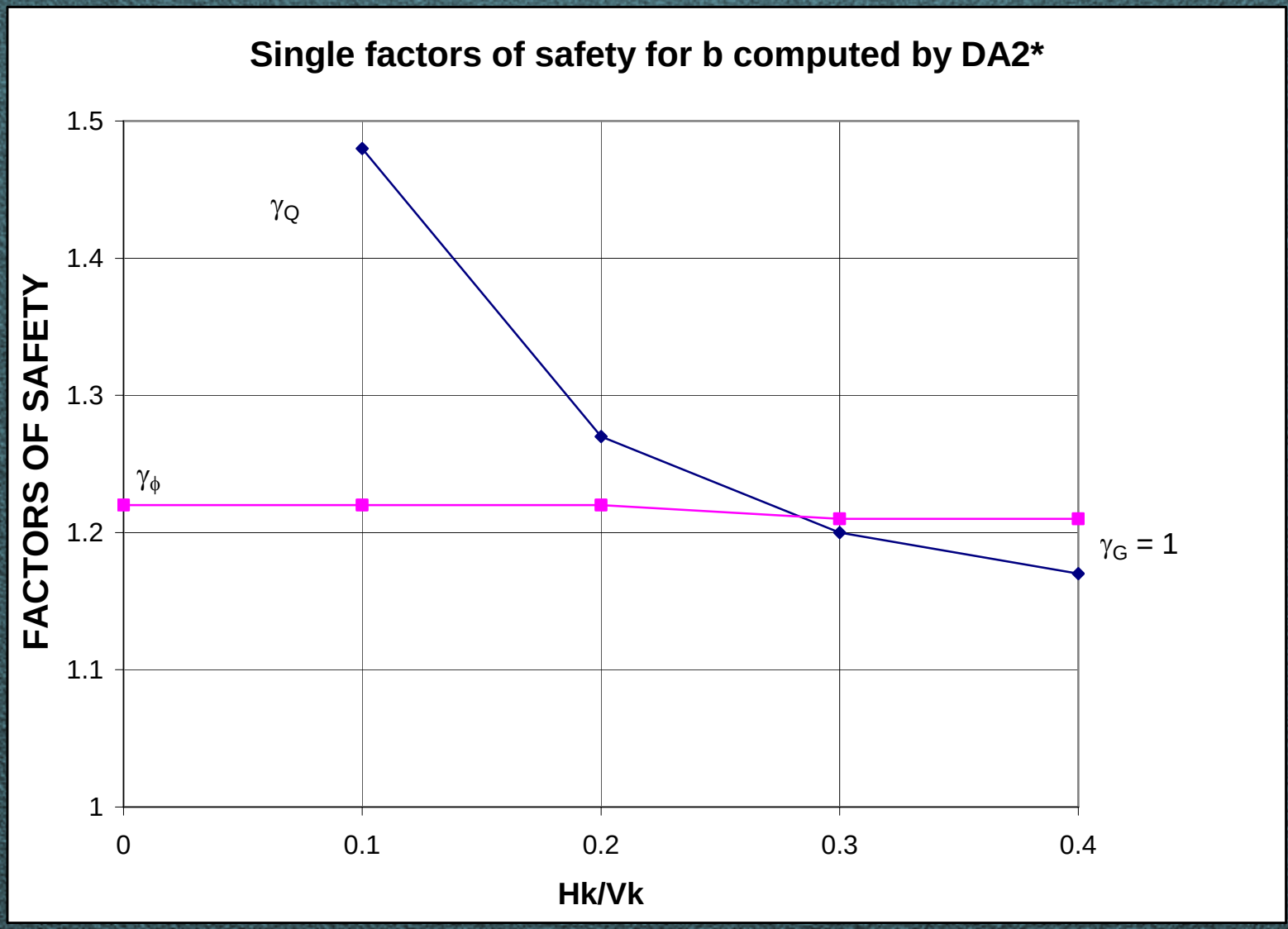
Retains characteristic inclination and eccentricity



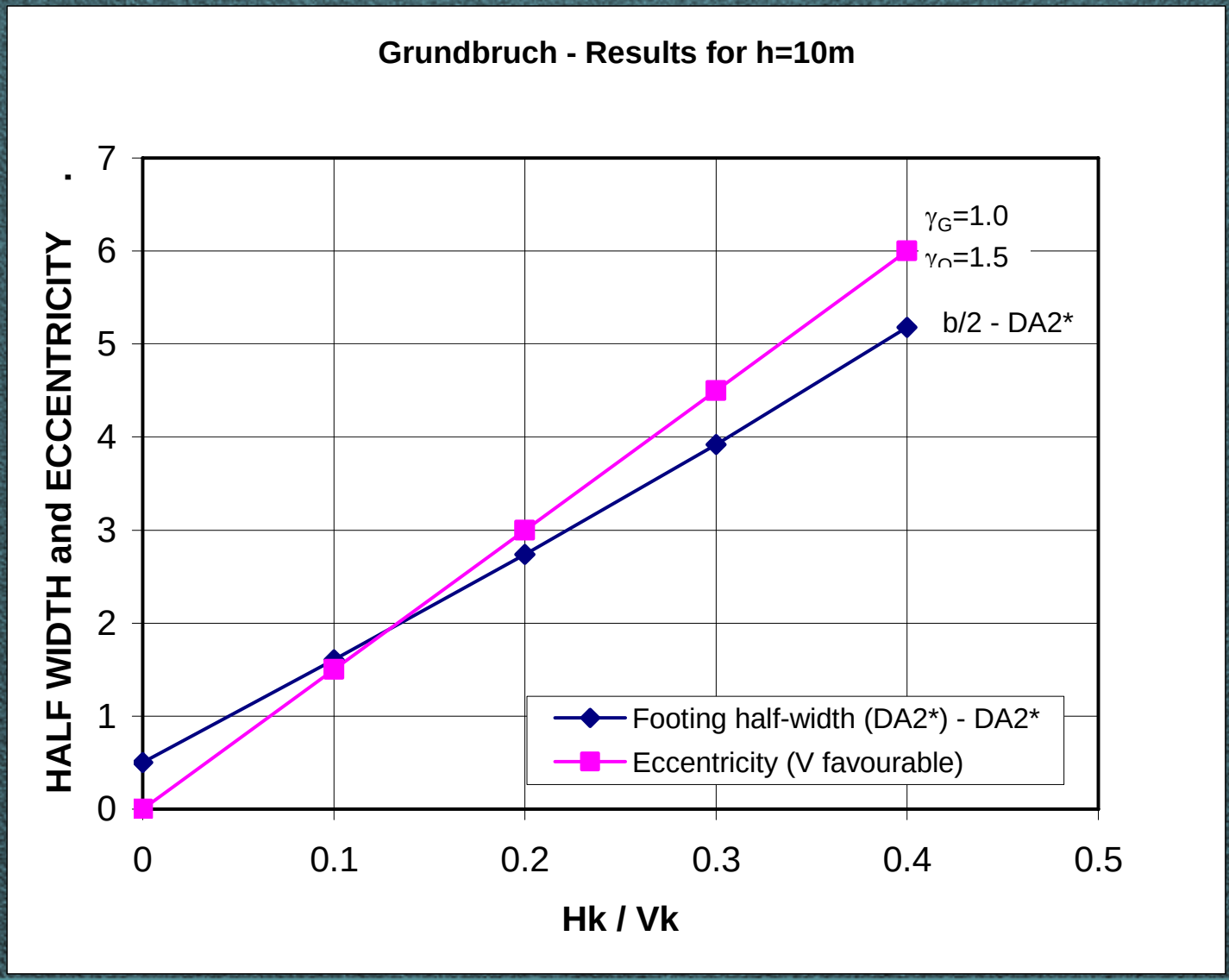
Results for h=4m



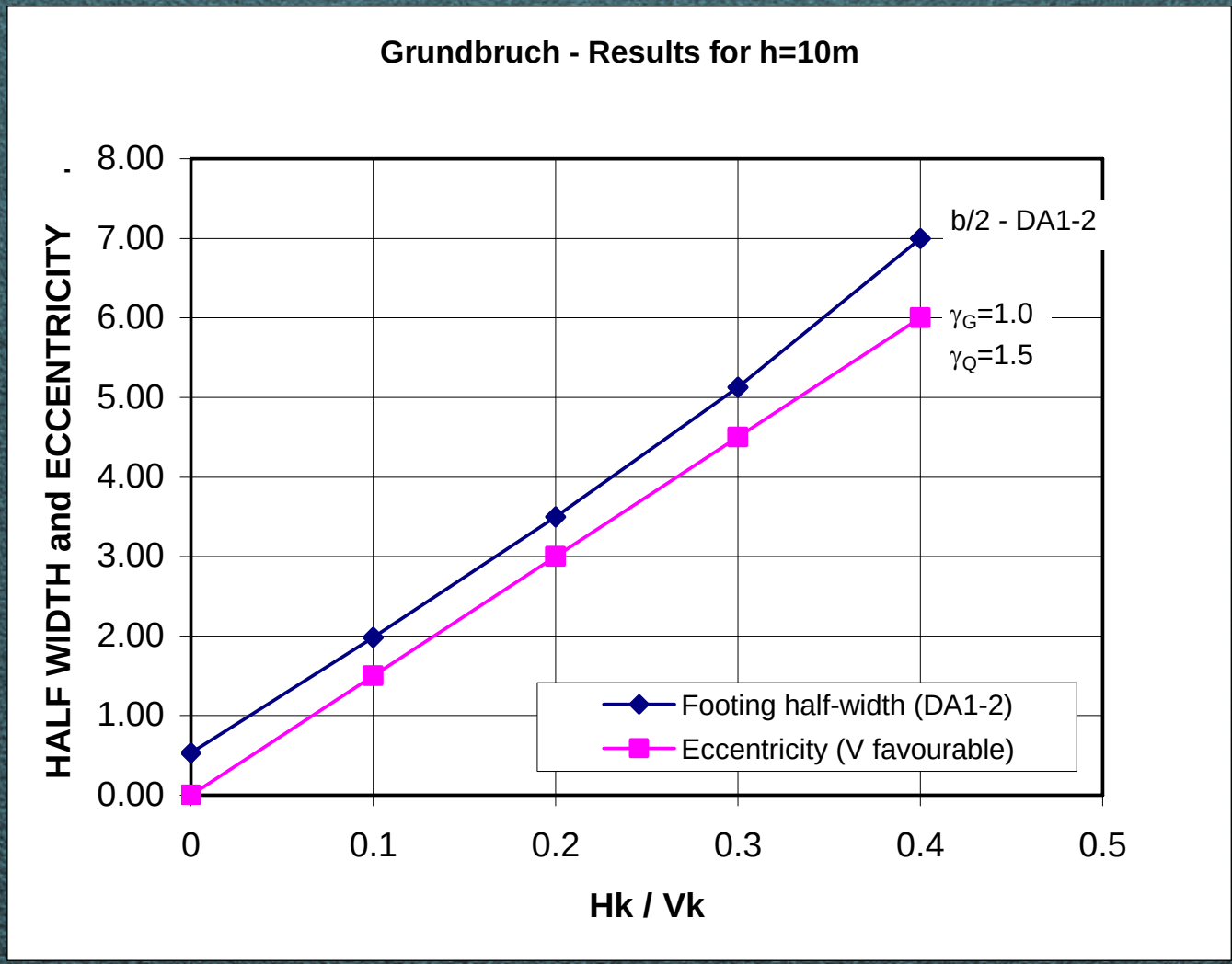
Single factors of safety for b computed by DA2*



For h=10m, structural design resultant lies outside base of DA2* design



For h=10m, structural design resultant lies inside base for DA1



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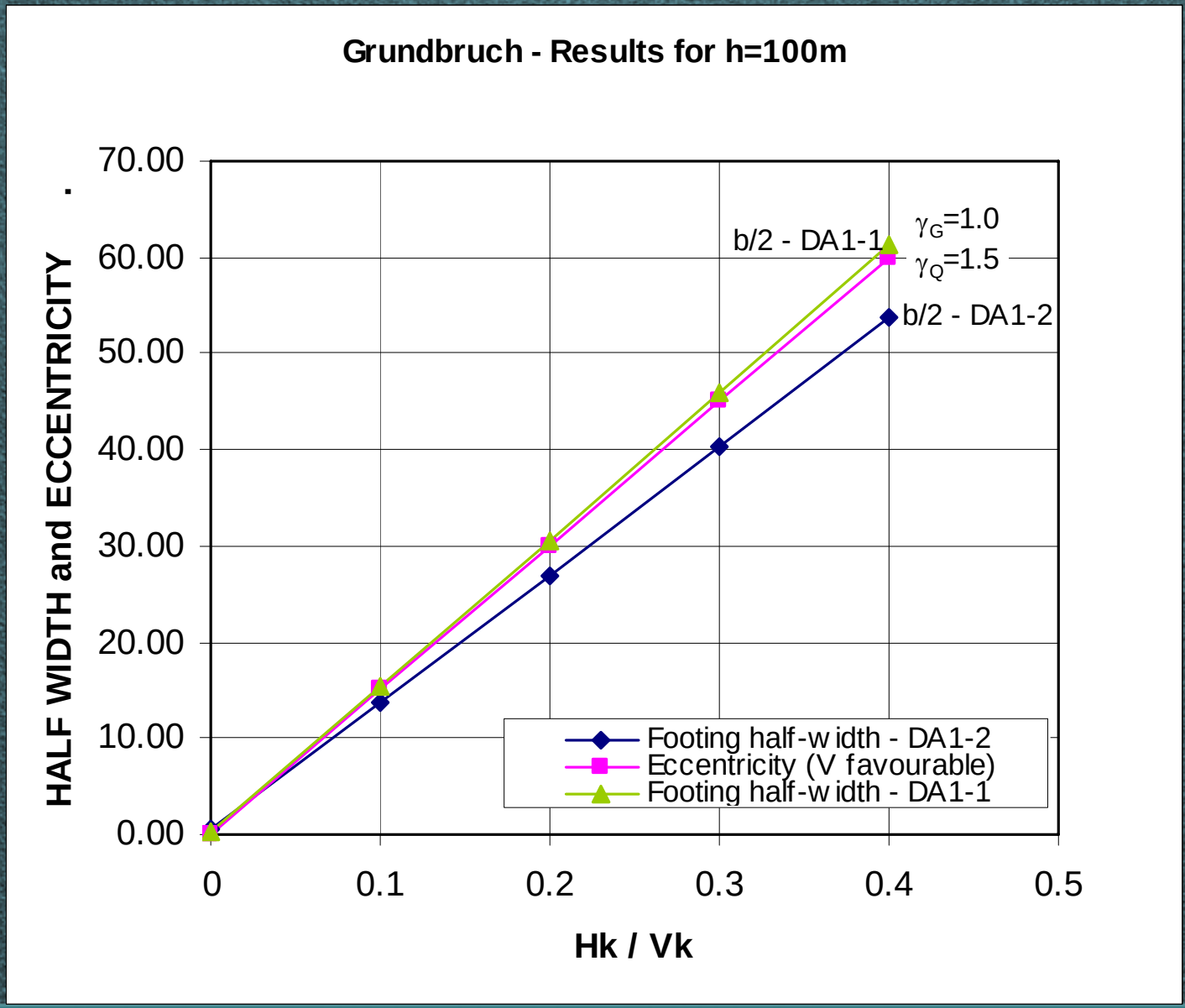
DA1 tested to extremes – h=100m



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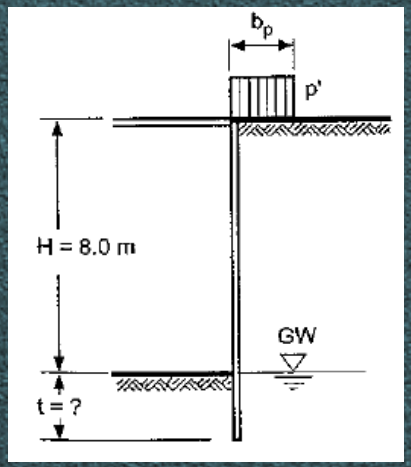
DA1 – good for FE

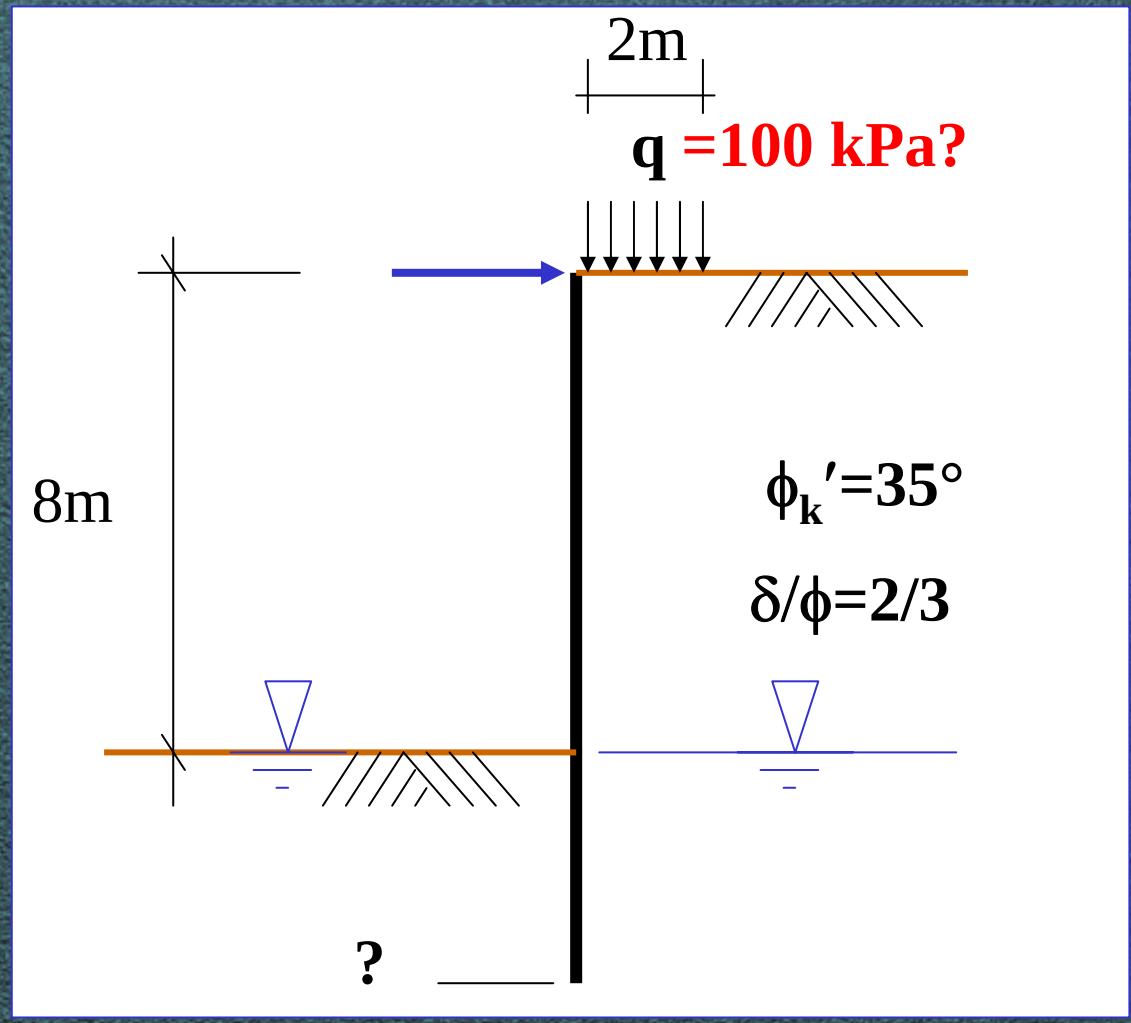
Finite element analysis of retaining walls

- **Easy to factor:**
  - soil strength (DA1-2)
  - applied loads (DA1-1,2)
  - results (DA1-1)
    - bending moment, prop force
- **Difficult to factor:**
  - active earth pressure
  - passive resistance
  - intermediate quantities in the calculation

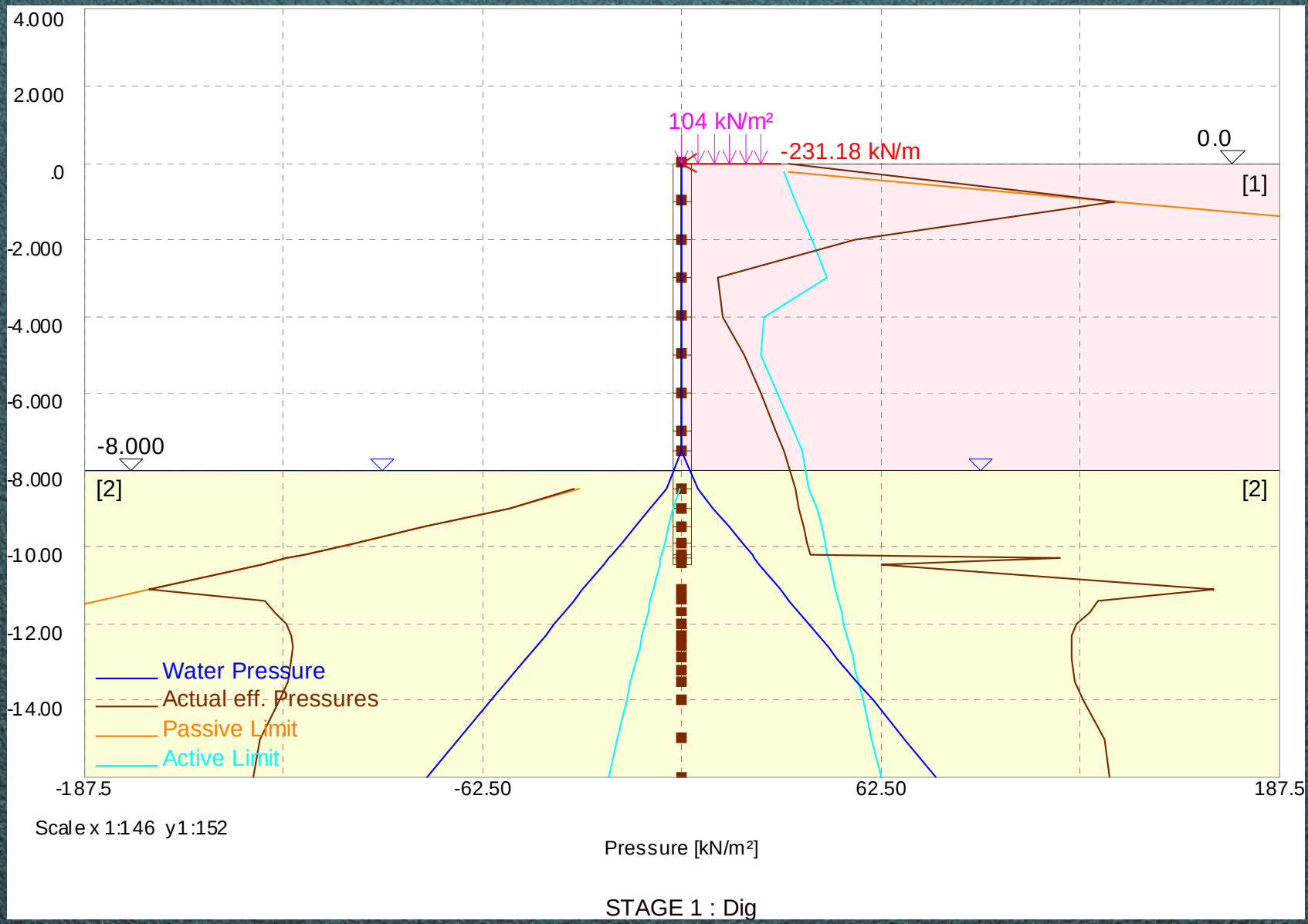
Grundbautaschenbuch – Geotechnical Engineering Handbook

Ed. U Smoltczyk (2003) Ernst & Sohn

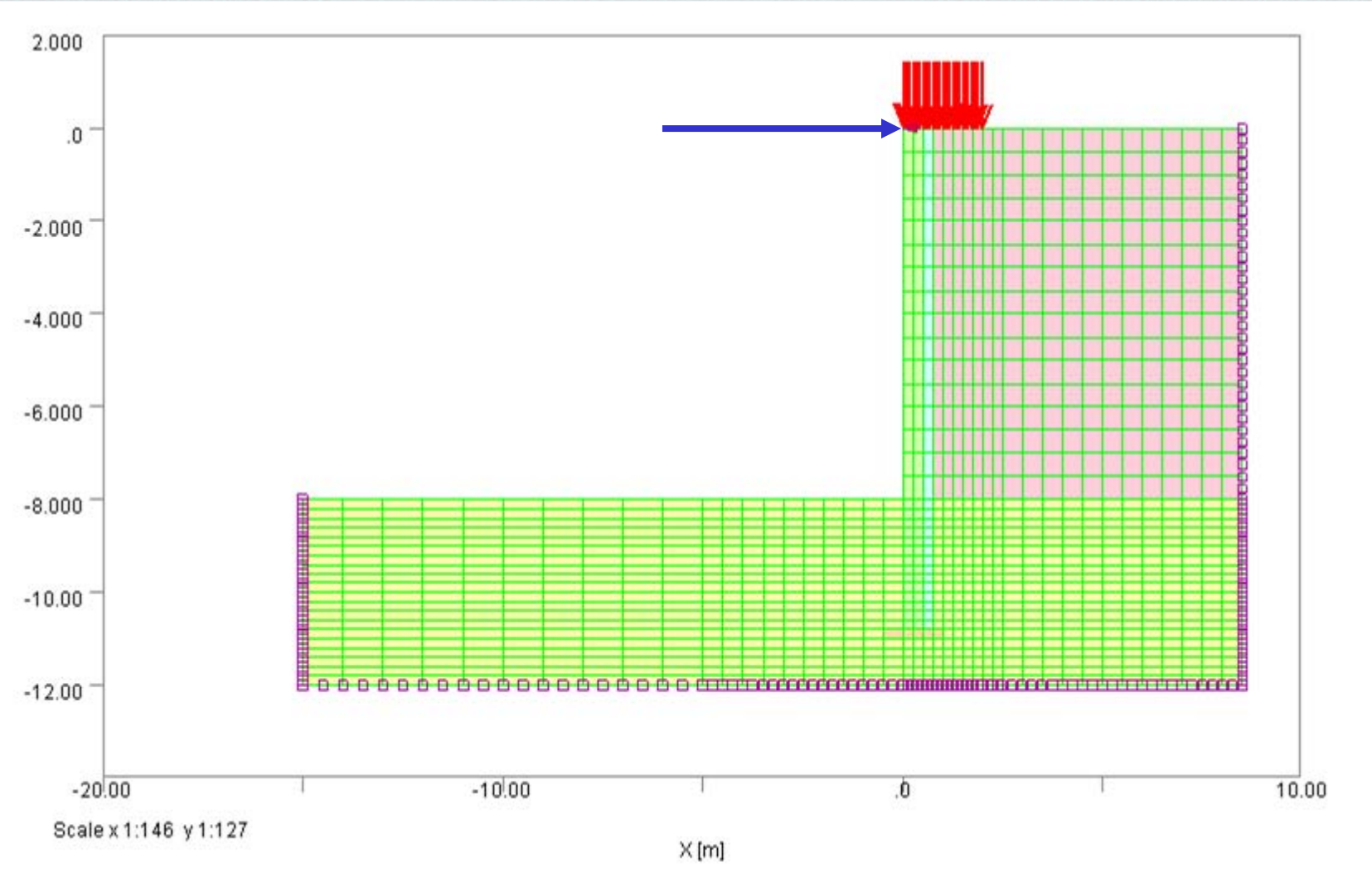




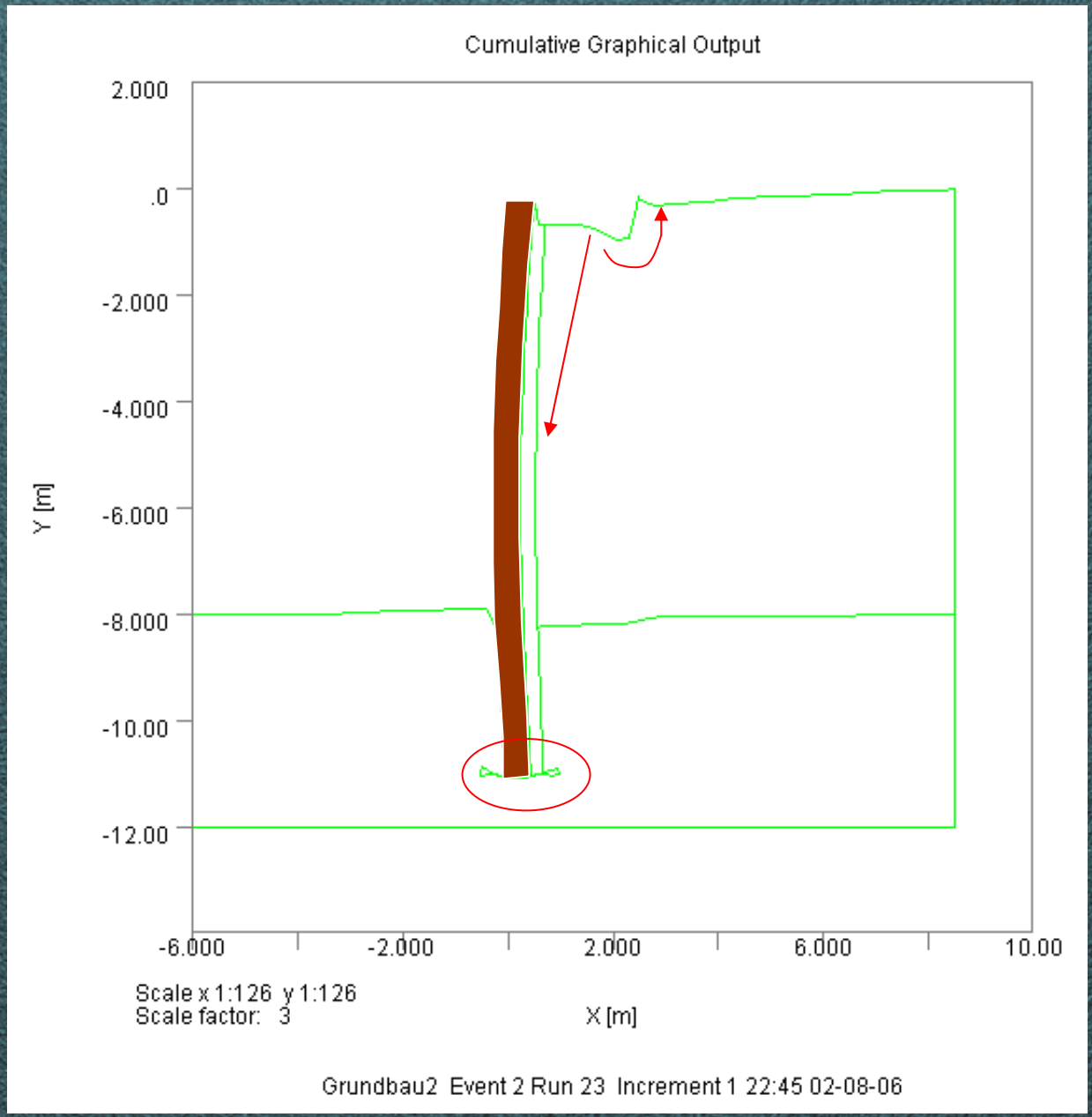
DA1 combination 2 – FREW (80x1.3=104)



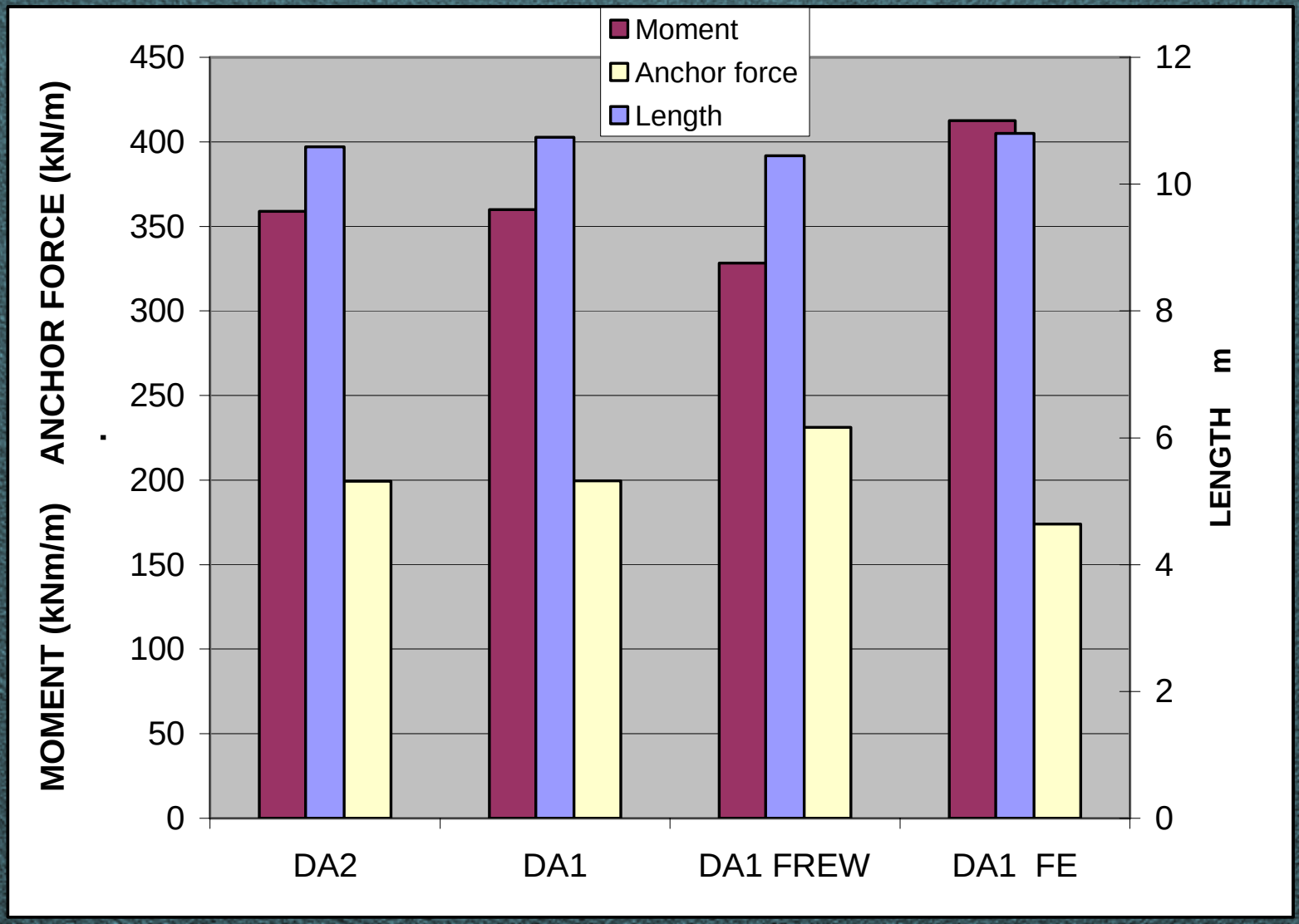
Simple finite element mesh



Typical deformed mesh (DA1-2)



Comparison of results



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DA1 - Some basic points about design

Type of situation	Safety and intelligibility of method	Economy of method	Usable with various calculation methods (simple, FE etc)
Common	✓	✓	✓
Unusual	✓	?	✓
Extreme	✓ *	?	✓ *

*** Perfection is impossible!**

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