Zentrum Geotechnik

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Implementation of Eurocode 1997-1 in Germany in Connection with a new DIN 1054

Athens, march 16th, 2009

Implementation of Eurocode 1997-1 in Germany in Connection with a new DIN 1054

Based on presentations of
B. Schuppener, N. Vogt und A. Weißenbach

Implementation of Eurocode 7 in Germany

- Introduction
- Basic principle for the implementation
  (➔ Selection of values of partial factors)
- Three design approaches of EC 7-1
- Comparative design in an example
- Conclusions of the comparative design
  (➔ German selection of approaches)
- Handbook of codes: DIN EN 1997-1 and its National Annex, which refers to a new DIN 1054

Basic principle for the implementation

The former DIN 1054 was introduced in 1976 and is mandatory in all German federal states.

➔Tradition, more than one generation

➔Validated: thousands of foundation constructions

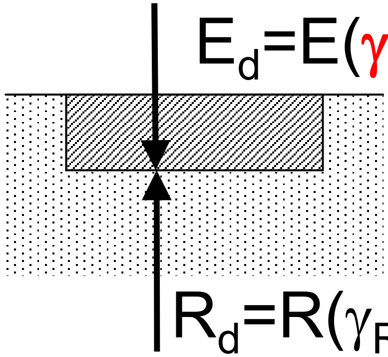
The safety level of the former global safety concept shall be maintained when adopting the concept of limit state design and partial factors of the Eurocode!

Design approaches of EC 7-1

DA-1

Combination 1

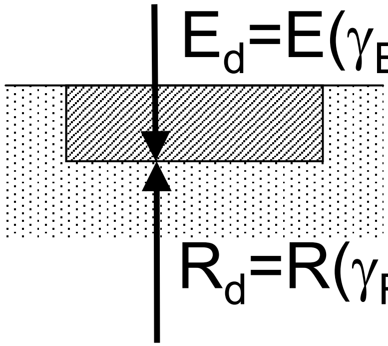
$E_d = E(\gamma_E > 1)$



$R_d = R(\gamma_R = \gamma_\varphi = 1.0)$

Combination 2

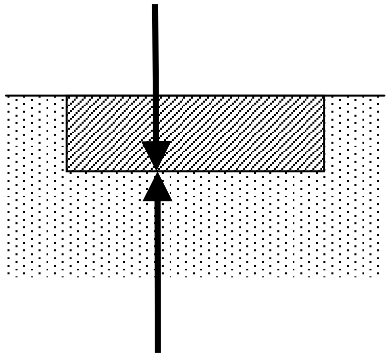
$E_d = E(\gamma_E = 1)$



$R_d = R(\gamma_R = 1;\ \gamma_\varphi > 1)$

DA-2

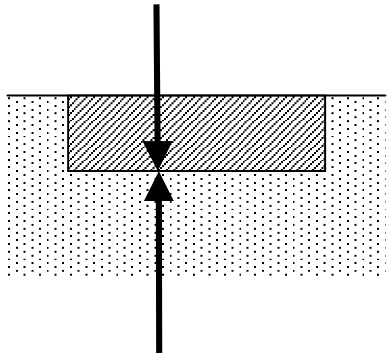
$E_d = E(\gamma_E > 1)$



$R_d = R(\gamma_R > 1,\ \gamma_\varphi = 1)$

DA-3

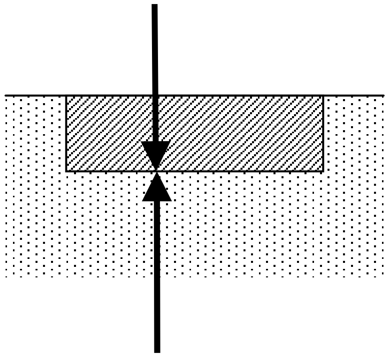
$E_d = E(\gamma_E > 1)$



$R_d = R(\gamma_R = 1,\ \gamma_\varphi > 1)$

*DA 2 and DA 2**

$E_d = E(\gamma_E > 1)$



$R_d = R(\gamma_R > 1, \gamma_\varphi = 1)$

bearing capacity is depending on
- load inclination H/V
- excentricity of loads $e = M/V$

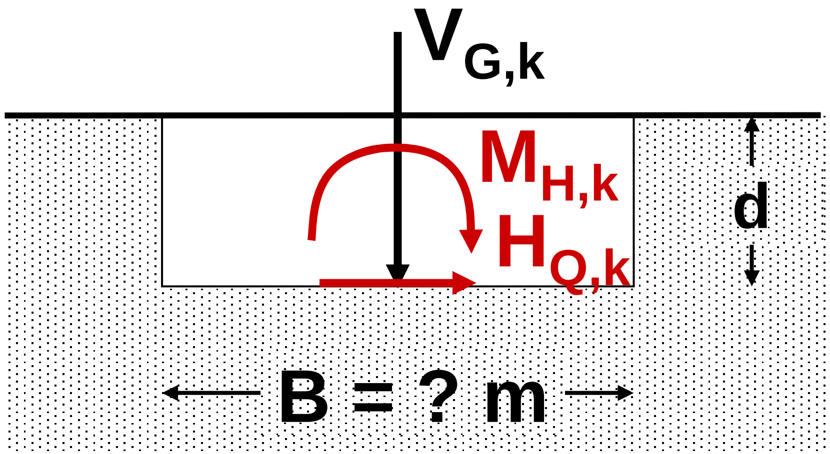
$R = R(H/V; M/V; \ldots)$

DA-2: $R_d = 1/\gamma_R \cdot R_k$ $R_k = R(H_d/V_d; M_d/V_d; \ldots)$

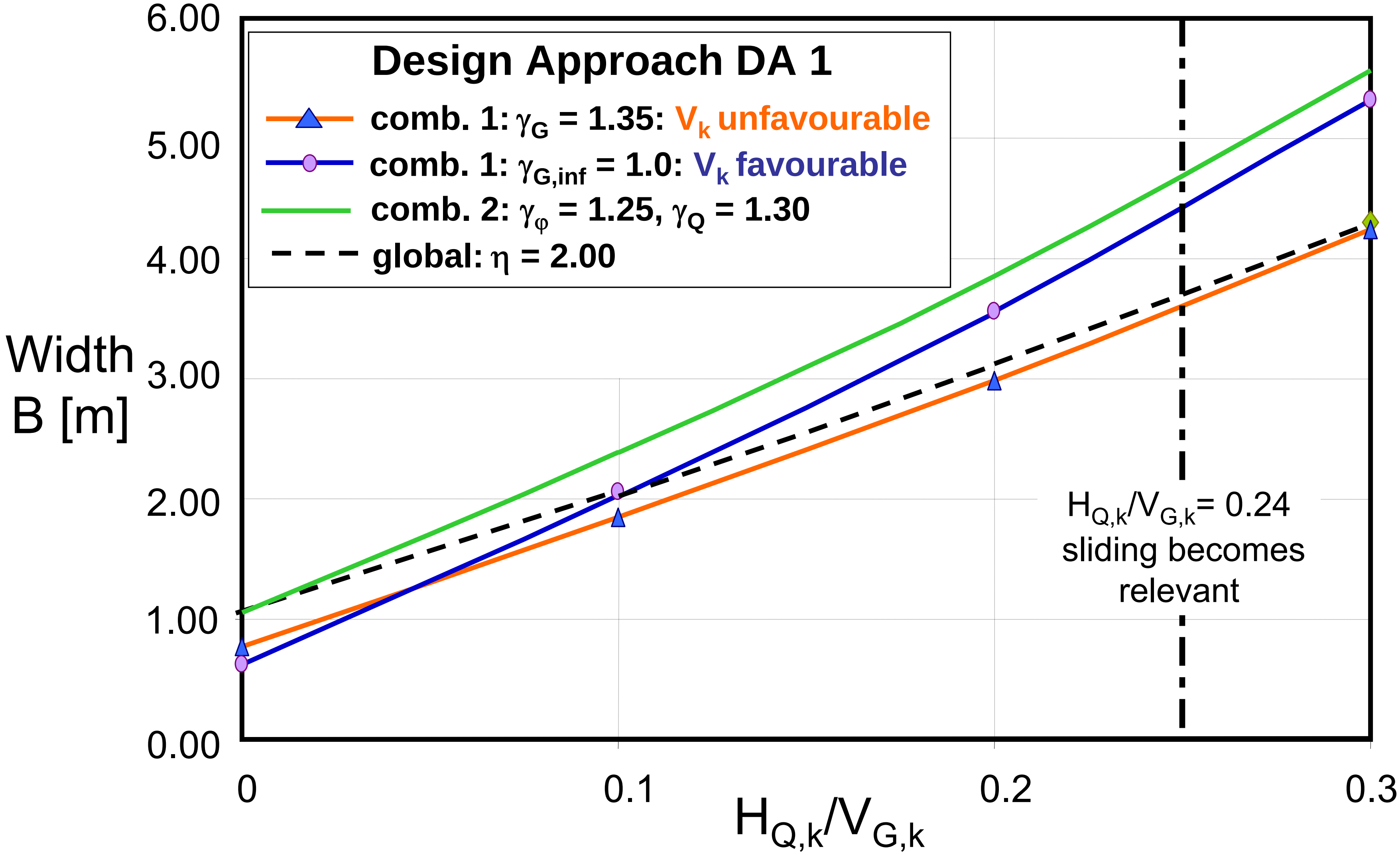
DA-2*: $R_d = 1/\gamma_R \cdot R_k$ $R_k = R(H_k/V_k; M_k/V_k; \ldots)$

With **DA 2*** all verifications are done with characteristic values of effects of action as far as possible.
Application of partial factors to effects of action is the last step of verifications

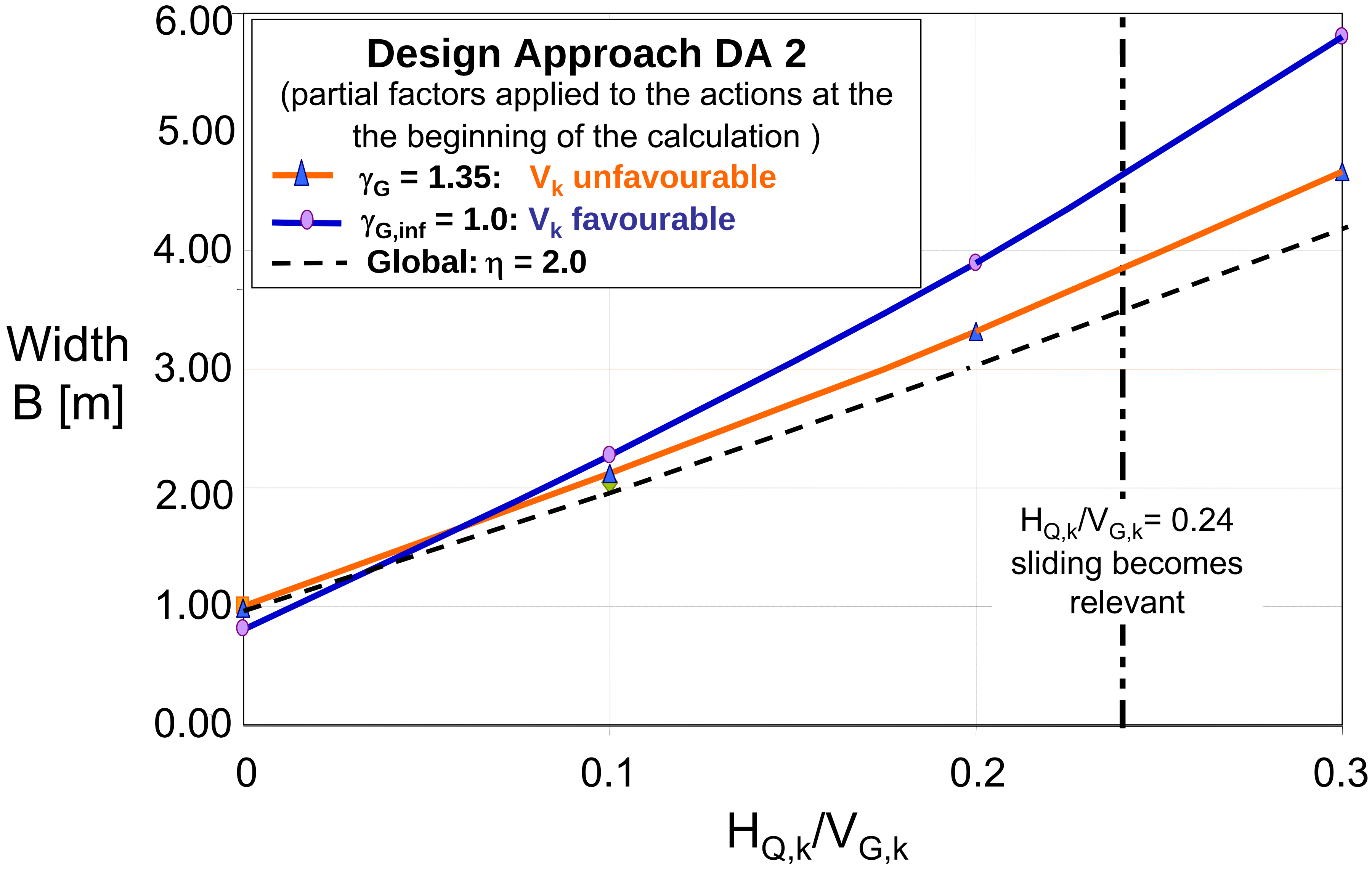
Example for a comparison of the Design Approaches of EC 7-1



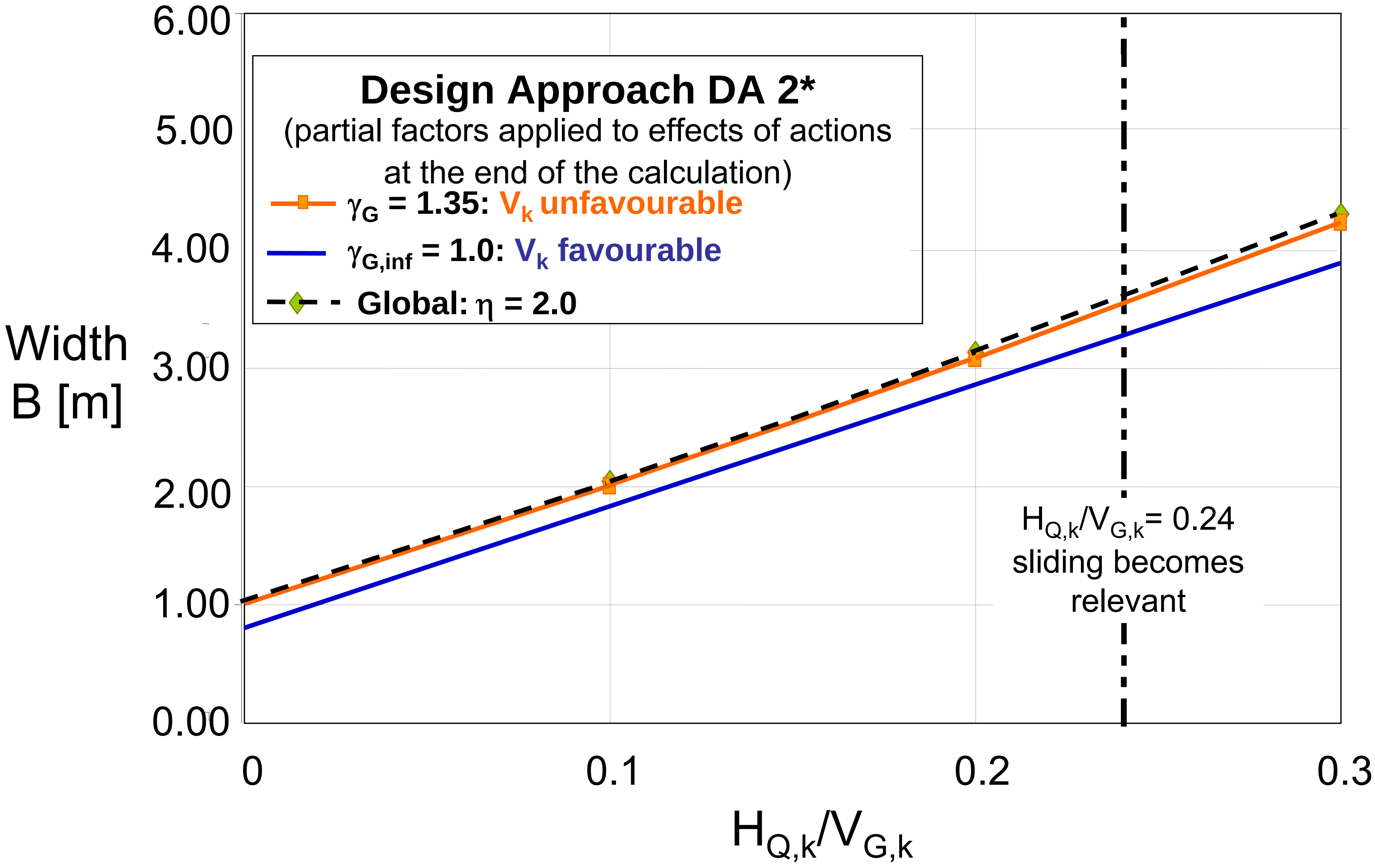
Depth of the strip footing:	d = 1,0 m
Permanent vertical effect of action:	$\mathbf{V_{G,k} = 400\ kN/m}$
Variable horizontal action:	$\mathbf{H_{Q,k}}$ **gradually increased**
Variable moment:	$\mathbf{M_{H,k} = 4.0 \cdot H_k}$
Weight density of the soil:	$\gamma_1 = \gamma_2 = 19\ kN/m^3$
Angle of shearing resistance:	$\varphi'_k = 32.5°$
partial factor for permanent/variable actions	$\gamma_{G/Q} = 1.35/1.50$
partial factor for bearing resistance	$\gamma_{R;v} = 1.40$
partial factor for sliding	$\gamma_{R;h} = 1.10$

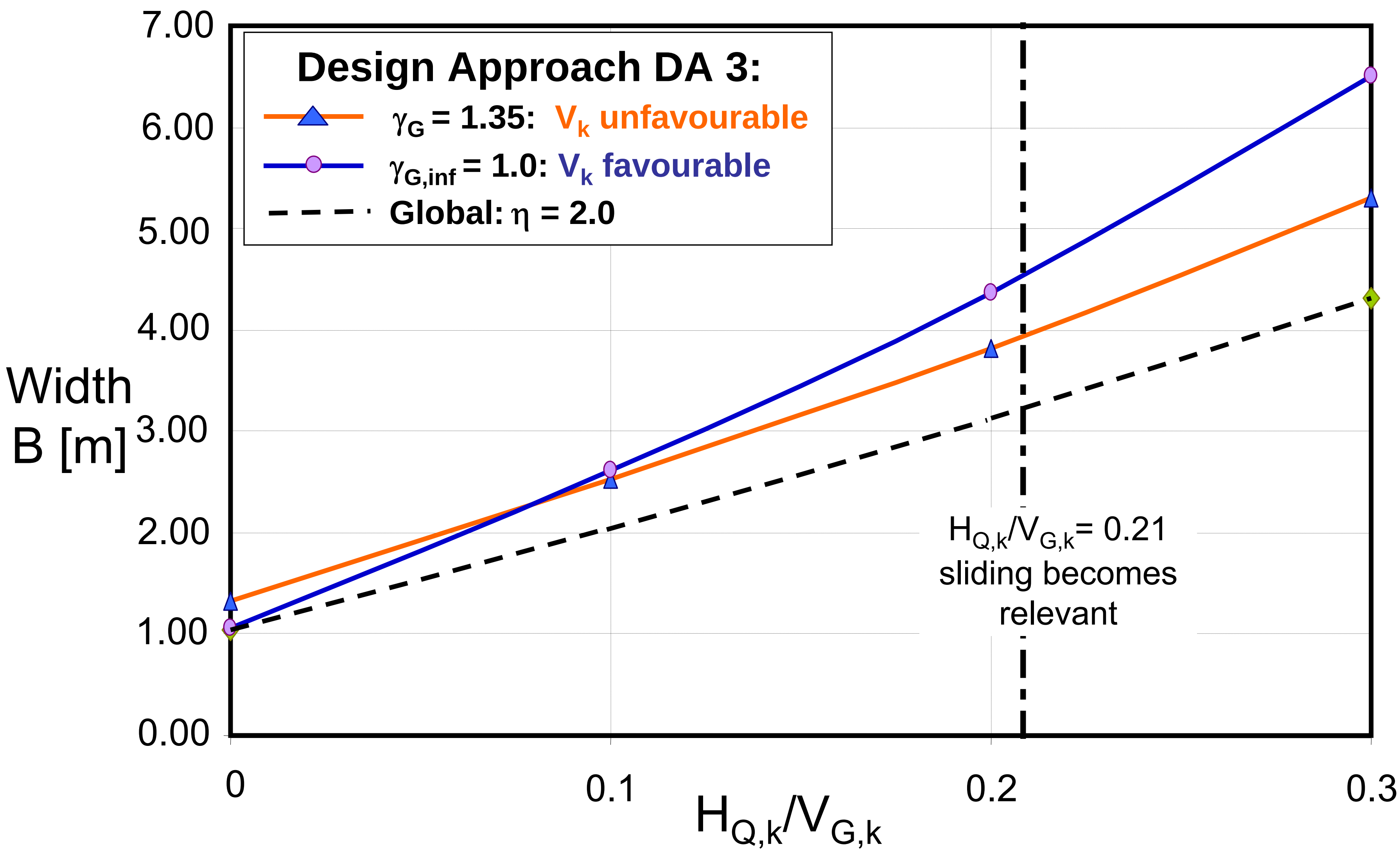


Design Approach DA 1
comb. 1: γ_G = 1.35: V_k unfavourable
comb. 1: $\gamma_{G,inf}$ = 1.0: V_k favourable
comb. 2: γ_φ = 1.25, γ_Q = 1.30
global: η = 2.00
Width B [m]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
$H_{Q,k}/V_{G,k}$
$H_{Q,k}/V_{G,k}$= 0.24
sliding becomes relevant



Design Approach DA 2
(partial factors applied to the actions at the
the beginning of the calculation)
γG = 1.35: Vk unfavourable
γG,inf = 1.0: Vk favourable
Global: η = 2.0
Width
B [m]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
HQ,k/VG,k
HQ,k/VG,k= 0.24
sliding becomes
relevant


Design Approach DA 2*
(partial factors applied to effects of actions
at the end of the calculation)
γG = 1.35: Vk unfavourable
γG,inf = 1.0: Vk favourable
Global: η = 2.0
Width
B [m]
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
HQ,k/VG,k
HQ,k/VG,k= 0.24
sliding becomes
relevant



Design Approach DA 3:
γG = 1.35: Vk unfavourable
γG,inf = 1.0: Vk favourable
Global: η = 2.0
HQ,k/VG,k= 0.21
sliding becomes
relevant
Width
B [m]
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
HQ,k/VG,k

Summary

- Maintaining the safety level of the former global safety concept is the basic principle in selecting the partial factors and the design approach in Germany.
- The comparative design calculation for a strip footing showed that the safety level of the former global safety concept can only be maintained using design approach DA 2*.
- Moreover, the comparative calculation showed that design approach DA 2***** gave the most economic design.

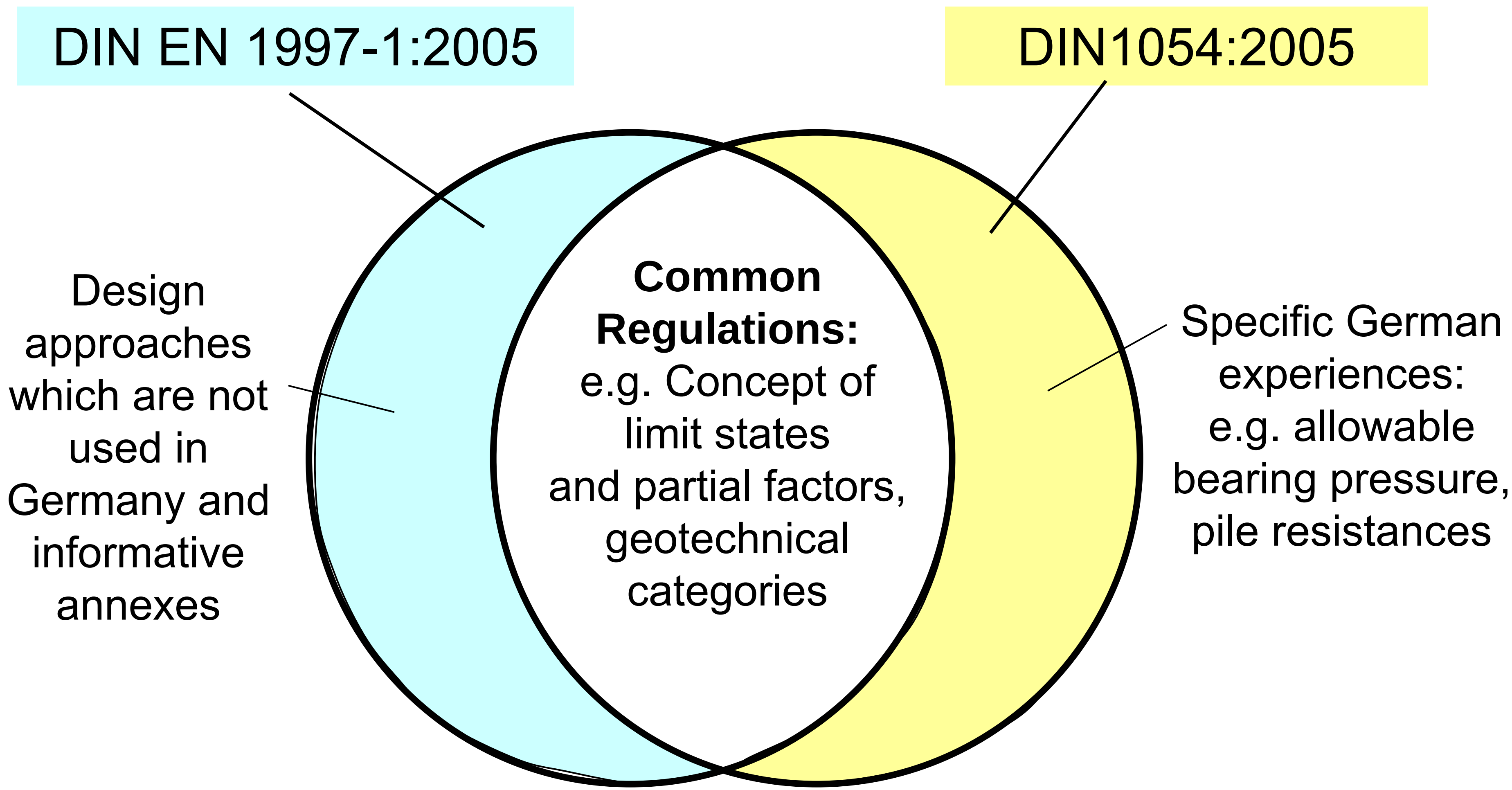
Selection of values of partial factors

EN 1990 gives the partial factors γ_F to be applied on actions and effects of action.

To maintain the same global safety factors η as in advance, suited design approaches have to be chosen and partial factors γ_R to be applied on resistances to obtain:

$$\eta = \gamma_F \cdot \gamma_R$$

DIN EN 1997-1:2005 and DIN 1054:2005



Relation between EN 1997-1 and national codes

- Text passages of EC 7-1 may not be changed, i.e. nothing can be deleted and amendments are not allowed
- Only at few distinguished points national choices can be made using the national annex
- National codes will be allowed in the future

  but:

- National Codes may not be contradictory to European Codes and may not be competing

National Annex to EN 1997-1

The national Annex contains:

- Choices about design approaches to be applied
- Regulations about the values of partial factors
- Determinations about the use of informative annexes

and

- Links to non-contradictory additional informations, which may help the user in applying the Eurocodes – especially links to a new DIN 1054

DEUTSCHE NORM Oktober 2005

DIN EN 1997-1

ICS 91.010.30; 93.020

Ersatz für
DIN V ENV 1997-1:1996-04

Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik - Teil 1: Allgemeine Regeln: Deutsche Fassung EN 1997-1:2005

DIN 1054

ICS 93.020

Ersatz für
DIN 1054:2003-01 und
DIN 1054 Berichtigung 1:2003-10

Baugrund –
Ergänzende Regelungen zu DIN EN 1997-1:2005-10,
Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik - Teil 1: Allgemeine Regeln

Additional Regulations

DIN EN 1997-1/I

ICS 91.010.30; 93.020

Nationaler Anhang zu
Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik - Teil 1: Allgemeine Regeln;
Deutsche Fassung EN 1997-1:2005

National Annex

Normenhandbuch zu

DIN EN 1997-1: 2005-10
Geotechnische Bemessung - Allgemeine Regeln

und

DIN 1054: 2009-xx
Ergänzende Regelungen zu DIN EN 1997-1

Handbook of Codes

(DIN) EN 1997-1

German Annex to
(DIN) EN 1997-1

DIN 1054: 2009
Additional regulations in connection of DIN EN 1997-1

ANMERKUNG Die Art und Weise, in der diesen Mindestanforderungen entsprochen wird, darf im Nationalen Anhang angegeben werden.

NA zu (8)P In Deutschland sind Geotechnische Kategorien zur Festlegung der Mindestanforderungen an Umfang und [...] der Bauüberwachung anhand der Sch[...] [...]rgänzende Regeln zur Anwendung der Geotechnischen Kategorien sind in DIN 1054:2008 angegeben.

Green text at left: National Annex

(9) Bei Bauwerken und Erdarbeiten von geringem geotechnischem Schwierigkeitsgrad und geringem Risiko, wie obe[...] [...]t werden.

(10) Zur Festl[...] [...]technische Kategorien 1, 2 und 3 eingeführt werden.

Black text in the middle: EC 7

A ANMERKUNG zu (10) In DIN 1054 werden die Bezeichnungen GK 1, GK 2 und GK 3 benutzt.

(11) Eine vorläufige Einstufung eines Bauwerks in eine der Geotechnischen Kategorien sollte im Allgemeinen vor der Baugrunduntersuchung erfolgen. Wenn notwendig, sollte diese Einstufung in jeder Phase der Planung und der Bauausführung überprüft und geändert werden.

A(11) Die Einstufung in die Geotechnischen Kategorien GK 1, GK 2 oder GK 3 ist vor Beginn der geotechnischen Erkundung unter Beachtung der nachfolgenden Anwendungsregeln und der DIN 402[...] [...]erium, das die höchste [...] [...]enden Anforderungen sind im Zuge der Projektbearbeitung aufgrund der Ergebnisse geotechnischer Untersuchungen, Berechnungen und der Bauausführung zu überprüfen und gegebenenfalls anzupassen.

Red text at right: Additional Regulations

(12) Die aufwändigeren Verfahren für Bauwerke der höheren Kategorien können durch wirtschaftlichere Entwürfe gerechtfertigt sein oder vom Aufsteller als sachgemäß angesehen werden.

Geotechnical Categories (GK)

The Geotechnical Categories serve to determine minimal requirements with respect to

- Soil Investigation,
- Calculations and analyses
- Control and measurements during construction time

Definitions and examples are meanwhile harmonized in DIN 1054 und DIN 4020 (and other codes)

The identical annex: „Examples of characteristics to classify into Geotechnical Categories“ will be used with DIN 1054 (design) and DIN 4020 (Soil investigation).

Design Situations

- **BS-P:** Persistent Design Situation :
  this situation is in accordance with prevailing requirements to use a structure (previously it was loading case LF 1)
- **BS-T:** Transient Design Situation :
  in accordance with temporal conditions and conditions which occur seldom or expectedly never (previously it was loading case LF 2, used for most construction situations)
- **BS-A:** Accidential Design Situation :
  related to exceptional conditions for a structure (previously it was loading case LF 3)
- **BS-E:** Earthquake Design Situation :
  (previously it was loading case LF 3)

Determination and Combination of Design Values of Effects of Action

$$E_d = \sum_{j\geq 1} \gamma_{G,j} \cdot E(G_{k,j}) + \gamma_{Q,1} \cdot E(Q_{k,1}) + \sum_{i>1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot E(Q_{k,i})$$

E_d	Design value of effect of action
$\gamma_{G,j}$	Partial factor for permanent effects of action
E(..)	Effect of action resulting from (..)
$G_{k,j}$	Characteristic value of a permanent action
$\gamma_{Q,i}$	Partial factor for variable effects of actions
$Q_{k,1}$	Characteristic value of the leading variable action
ψ	Combination factor
$Q_{k,j}$	Characteristic values of accompanying variable actions

Determination and Combination of Design Values of Effects of Action where superposition is not possible

$$E_d = E\left(\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j} \text{"+"} \gamma_{Q,1} \cdot Q_{k,1} \text{"+"} \sum_{i>1} \gamma_{Q,1} \psi_{0,i} \cdot Q_{k,i}\right)$$

„+“ „is to be combined “, Σ: „joint effect of “

E_d Design value of effect of action

E(..) Effect of Action resulting from (..)

$\gamma_{G,j}$ Partial factor for permanent actions

$G_{k,j}$ Characteristic value of a permanent action

γ_Q Partial factor for variable actions

$Q_{k,1}$ Characteristic value of the leading variable action

ψ Combination factor

$Q_{k,i}$ Characteristic values of accompanying variable actions

Limit States according to DIN 1054:2005

Three limit states with different use of partial factors

LS 1A: Partial factors only to be used on actions (to be used with overturning, uplift and buoying upwards)

LS 1B: Partial factors to be applied on effects of action and resistances; (to be used with verifications of constructions and parts of construction)

LS 1C: Partial factors to be applied on actions and on shear resistance (to be used with verifications of slope stability and overall stability)

Limit States according to EN 1997-1

DIN EN 1997-1	DIN 1054	Limit State
EQU	LS 1A	Loss of equilibrium of the structure or the ground, in which the strengths are insignificant in providing resistance.
UPL	LS 1A	Loss of equilibrium of the structure or the ground due to uplift by water pressure (buoyancy) or other vertical actions.
HYD	LS 1A	Hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients
STR	LS 1B	Internal failure of the structure or ist parts, in which the strength of structural materials is significant in providing resistance.
GEO-2		Failure or excessive deformation of the ground, in which the strength of the ground is significant in providing resistance.
GEO-3	LS 1C	

Partial Factors for Actions in Germany

Action and Effects of Action	1054 old new	(LF 1) BS-P	(LF 2) BS-T	(LF 3) BS-A
Hydraulic Failure and Uplift (buoyancy) (HYD and UPL)				
Destabilising Permanent Actions	$\gamma_{G,dst}$	1,00 1,05	1,00 1,05	1,00 1,00
Stabilising Permanent Actions	$\gamma_{G,stb}$	0,90 0,95	0,90 0,95	0,95 0,95
Destabilising Variable Actions	$\gamma_{Q,dst}$	1,00 1,50	1,00 1,30	1,00 1,00
Failure of Stuctures and Ground (STR und GEO-2)				
Effects of Action due to Permanent Actions	γ_G	1,35	1,20	1,00 1,10
Effects of Action due to Variable Actions	γ_Q	1,50	1,30	1,00 1,10

Partial Factors for Soil Resistances

		Design Situation		
		BS-P	BS-T	BS-A
GEO-3: Limit State by loss of overall stability				
tan φ' of drained soil; tan φ_u of undrained soil	γ_φ, $\gamma_{\varphi u}$	1,25	1,15	1,10
cohäsion c' of drained soil and shear strength c_u of undrained soil	γ_c, γ_{cu}	1,25	1,15	1,10

Partial Factors for Resistances

Resistance		Design Situation		
		BS-P	BS-T	BS-A
STR und GEO-2: Limit state of failure of constructions, parts of construction and ground				
Ground Resistance				
earth pressure resistance and bearing resistance	$\gamma_{R,e}$, $\gamma_{R;v}$	1,40	1,30	1,20
Resistance against sliding	$\gamma_{R,h}$	1,10	1,10	1,10
Pile Resistance based on static and dynamic pile loading tests				
Base Resistance	γ_b	1,10	1,10	1,10
Shaft Resistance (Compression)	γ_s	1,10	1,10	1,10
Total Resistance (Compression)	γ_t	1,10	1,10	1,10
Shaft Resistance (Tension)	$\gamma_{s,t}$	1,15	1,15	1,15
Pile Resistance based on Experience				
Compression Piles	γ_b; γ_s; γ_t	1,40	1,40	1,40
Tensile Piles (only in exceptional cases)	$\gamma_{s,t}$	1,50	1,50	1,50
Pull-Out-Resistance				
Soil-Nails and Rock-Nails	γ_a	1,40	1,30	1,20
Bodies of grouted anchors	γ_a	1,10	1,10	1,10
Flexible reinforcement elements	γ_a	1,40	1,30	1,20

Partial Factors for Pile Resistance

Resistance	1054 old new	(LF 1) BS-P	(LF 2) BS-T	(LF 3) BS-A
Pile Resistance based on static Pile Loading Tests				
Base Resistance	γ_b	1,20 1,10	1,20 1,10	1,20 1,10
Shaft Resistance (Compression)	γ_s	1,20 1,10	1,20 1,10	1,20 1,10
Total Resistance (Compression)	γ_t	1,20 1,10	1,20 1,10	1,20 1,10
Shaft Resistance (Tension)	$\gamma_{s,t}$	1,30 1,15	1,30 1,15	1,30 1,15
Pile Resistance based on Experience				
Compresion Piles Tensile Piles (only in exceptional cases)	γ_b, γ_s, γ_t $\gamma_{s,t}$	1,40 1,40 1,50	1,40 1,40 1,50	1,40 1,40 1,50

Recommendations concerning Piles

Links to these recommendations are given in DIN 1054:2009

Links to further recommendations: EAB concerning excavation pits

Will also be available in English

Simplified Verification for Shallow Footings

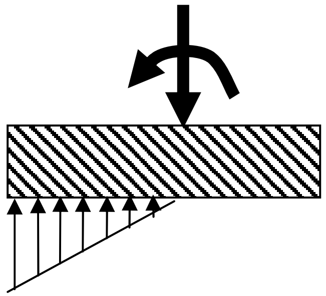
Table A 6.7: Design Value of Bearing Resistance $\sigma_{R,d}$ for Strip Foundations on Clay and Silt (UM, TL, TM)

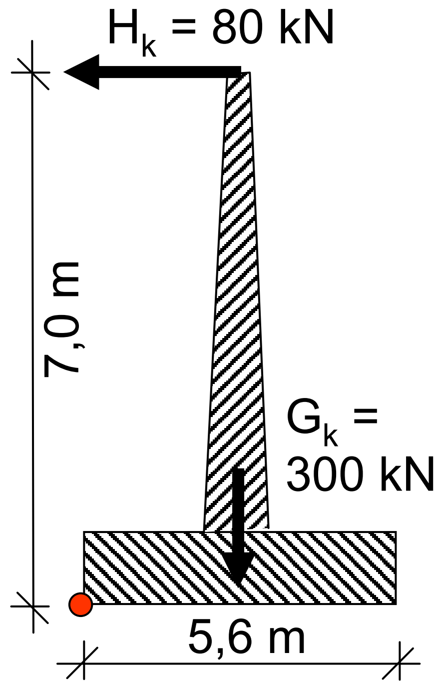
Embedment depth of the footing	Design Value of Bearing Resistance $\sigma_{R,d}$ kN/m²		
	Consistency		
m	$I_c > 0.75$	$I_c > 1.0$	$I_c > 1.25$
0,50	170	240	390
1,00	200	290	450
1,50	220	350	500
2,00	250	390	560
Uniaxial Compression strength $q_{u,k}$ in kN/m²	120 bis 300	300 bis 700	> 700

Attention: the values are not allowable bearing pressures!

Limit State 1A / EQU, UPL, HYD (Problem of Equilibrium)
1B / STR (Strength of the Construction)
or 1C / GEO (Failure of the Ground) ?

Overturning and Gap in Base Joint





Verification of Gap in Base Joint; :

$M_k = 80 \cdot 7{,}0 = 560$ kNm

$V_k = 300$ kN/m

Excentricity: $e = 560 / 300 = 1{,}87$ m

Maximum of Gap: Centre of footing: $e < b/3$

$b/3 = 5{,}6 / 3 = 1{,}87$ m

Verification is ok

Overturning related to ●

destabilising: $M_{dst,Q,k} = 80 \cdot 7{,}0 = 560$ kNm

stabilising: $M_{stb,G,k} = 300 \cdot 2{,}8 = 840$ kNm

➔

$M_{d,Q,dst} = 1{,}50 \cdot 560 = 840$ kNm

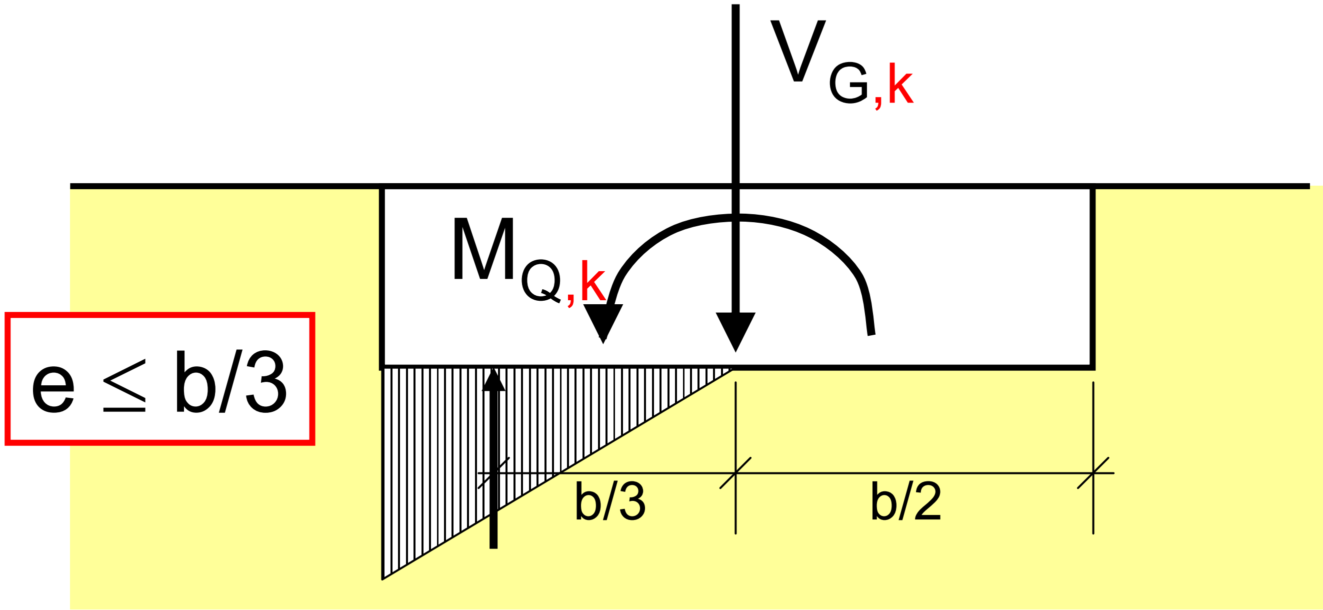
$M_{d,G,stb} = 0{,}90 \cdot 840 = 756$ kNm ($< M_{d,Q,dst}$)

$\gamma_{Q,dst} = 1{,}50$

$\gamma_{G,stb} = 0{,}90$

Verification is not ok. Footing must be enlarged.
As the geometry of a footing can be determined by this verification, DIN 1054:2009 requires this verification, although overturning over an edge is physically not possible: ground failure will occur before overturning

Verification of foundations with intensive excentric loading



Global Safety against Overturning: η **= 1,50 =** $\dfrac{V \cdot b/2}{V \cdot b/3}$

Limit State of Static Equilibrium EQU

with $\gamma_{Q,dst}$ = 1,50 and $\gamma_{G,stb}$ = 0,90 ➔ $\eta = \gamma_{Q,dst} / \gamma_{G,stb}$ = **1,67**

➔ **Both verifications are necessary with DIN 1054:2009**

Overturning and Verification of reinforced concrete structure of a footing

enlarged footing, B = 6,4 m

Verification of overturning related to ●

destabilising: $M_{dst,Q,k} = 80 \cdot 7{,}0 = 560$ kNm

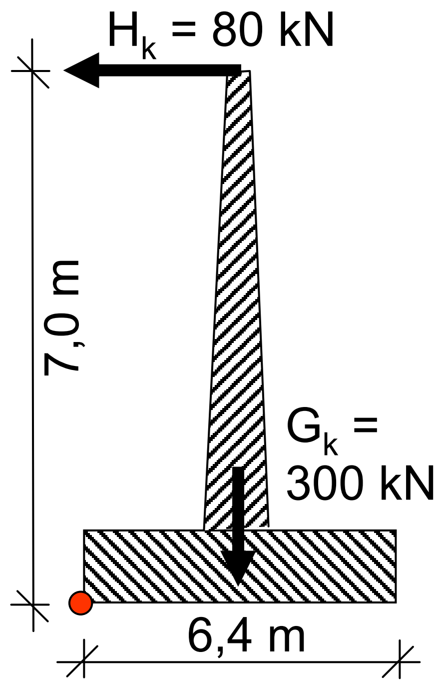
stabilising: $M_{stb,G,k} = 300 \cdot 3{,}2 = 960$ kNm

➔

$M_{d,Q,dst} = 1{,}50 \cdot 560 = 840$ kNm

$M_{d,G,stb} = 0{,}90 \cdot 960 = 864$ kNm $(> M_{d,Q,dst})$

Verification is ok.



With this enlarged footing verification of reinforced concrete structure of the footing can be done with a (fictive) ground pressure distribution within the area of the footing

$\gamma_{Q,dst} = 1{,}50$

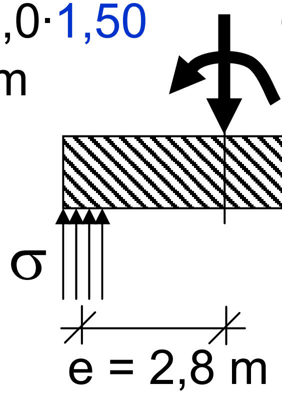
$\gamma_{G,stb} = 0{,}90$

$\gamma_{G,inf} = 1{,}00$

$(\gamma_{G,sup} = 1{,}35)$

$M_d = 80 \cdot 7{,}0 \cdot 1{,}50$
$= 840$ kNm

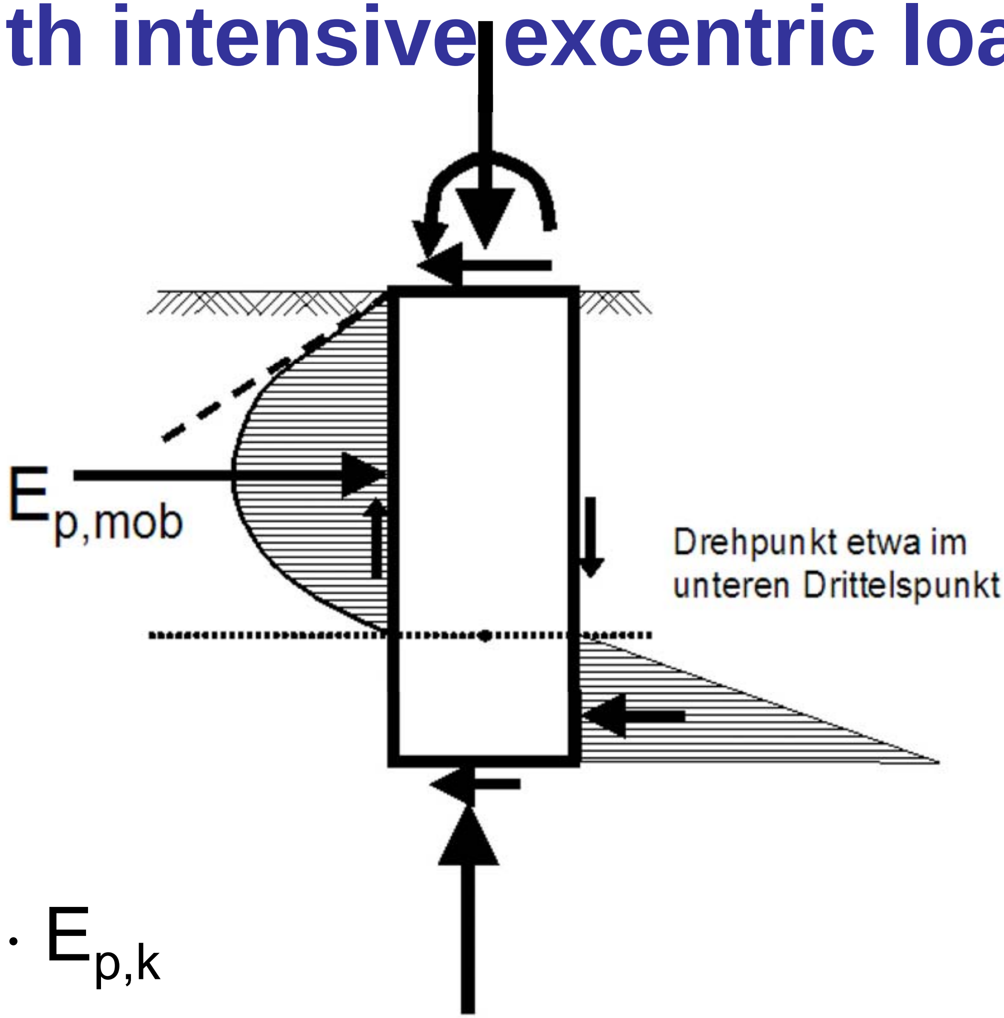
$G_d = \gamma_{G,inf} \cdot G_k$
$1{,}00 \cdot 300$ kN



$e = 840 / 300 = 2{,}8$ m

$\sigma = 300 / ((3{,}2-2{,}8) \cdot 2) = 375$ kN/m²

Verifications of block foundations with intensive excentric loading



$$E_{p,mob} \leq 0,25 \cdot E_{p,k}$$

$E_{p,mob}$ Mobilised Part of the Characteristic Passive Earth Pressure

$E_{p,k}$ Characteristic Passive Earth Pressure

Anchorages

- There are some national additional rules for all kinds of anchors within DIN 1054

- Forces to be applied within suitability tests and acceptance tests :

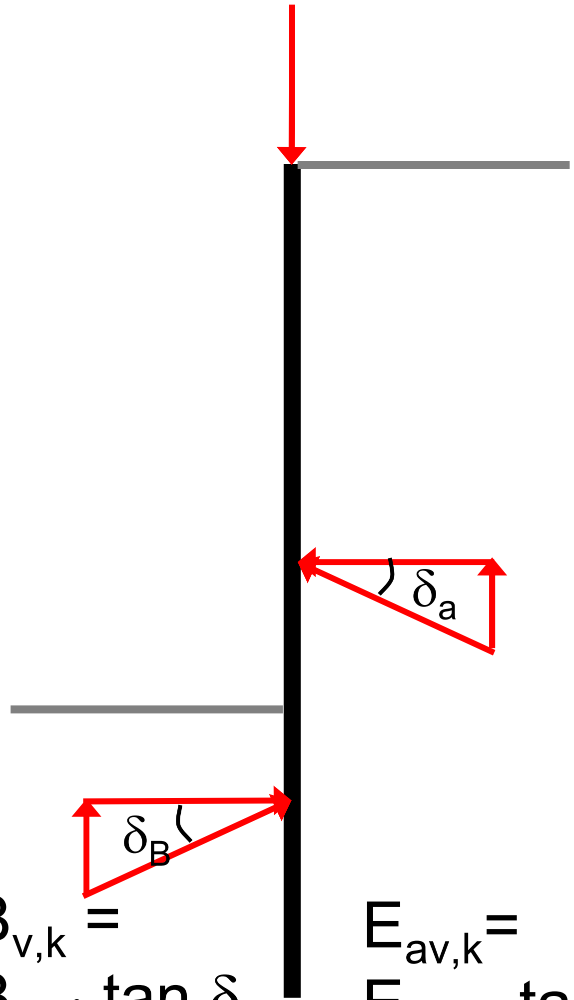
  $P_p = 1{,}1 \cdot P_d$

  P_p Maximum Force within the tests

  P_d design value of the effect of actions of anchors

- Details concerning testing of anchors are given in DIN EN 1537 and a national additional code

Failure of walls embedded in soil due to vertical movement



$B_{v,k} = B_{h,k} \cdot \tan \delta_B$

$E_{av,k} = E_{ah,k} \cdot \tan \delta_a$

Roughness of the wall	$E_{av,k}$	$B_{v,k}$
Interlocked wall	$\lvert \delta_a \rvert \leq \frac{2}{3} \cdot \phi'_k$	$\lvert \delta_B \rvert \leq \phi'_k$
Rough wall	$\lvert \delta_a \rvert \leq \frac{2}{3} \cdot \phi'_k$	$\lvert \delta_B \rvert \leq \phi'_k - 2{,}5°$ and $\lvert \delta_B \rvert \leq 27{,}5°$
Not so rough wall	$\lvert \delta_a \rvert \leq \frac{1}{2} \cdot \phi'_k$	$\lvert \delta_B \rvert \leq \frac{1}{2} \cdot \phi'_k$
Plain wall	$\lvert \delta_a \rvert = 0$	$\lvert \delta_B \rvert = 0$

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