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Reinforced Fills with Geosynthetics

Design and application overview

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BELGIAN GEOSYNTHETICS SOCIETY

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Reinforced Fills with Geosynthetics

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- Introduction to reinforced soil concept
- Eurocodes and design guidance
- Principles of design
  - Finishing options
  - Soil selection
  - Loading
  - Design Parameters
  - External Stability
  - Internal Stability
- Design Software
- Materials Testing
- Structural Monitoring

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Principle of soil reinforcement

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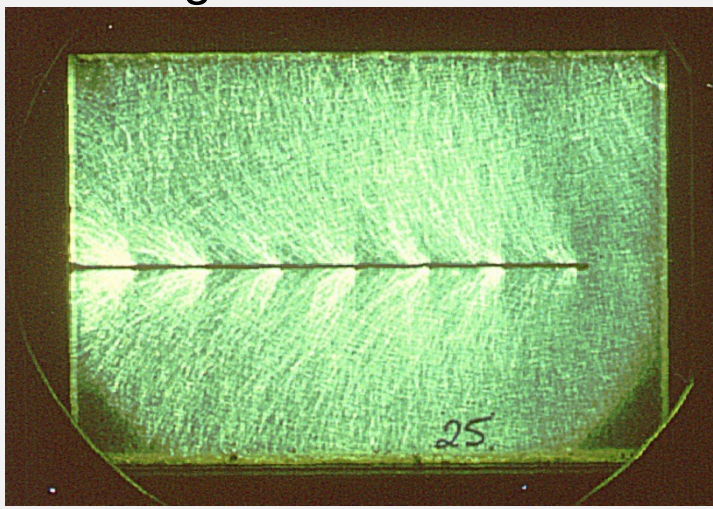
Soil is strong in compression and weak in tension so the addition of a thin **tensile layer** helps to disperse the lateral strain generated in the soil by the compressive force.



The tension within the reinforcement is mobilised by a combination of skin **friction**, granular **interlock** and potentially bearing on cross members.

For reinforcement to work **optimally** the soil needs to strain to a similar degree to the reinforcement at peak force:

Strain Compatibility

Basics - Natural slope angle of a material

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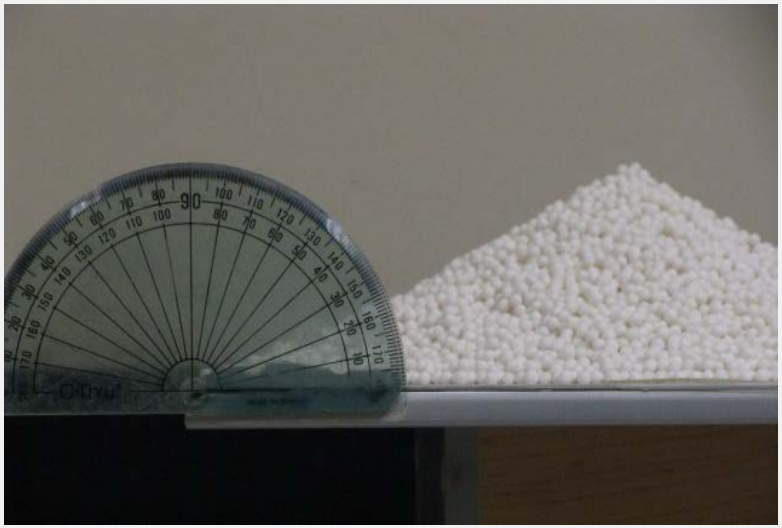
soil	Φ (phi)	Slope (V : H)
fine sand	26.5	1 : 2
coarse sand	30°	1 : 1.7
sandy gravel	34°	1 : 1.5
Clay	17.5°	1 : 3.2
Peat	15°	1 : 3.5



Scope of designed structures

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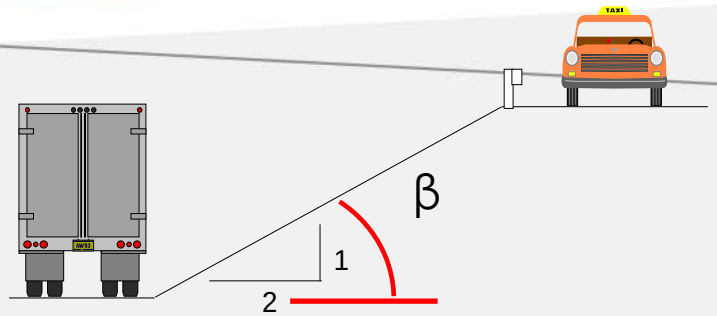
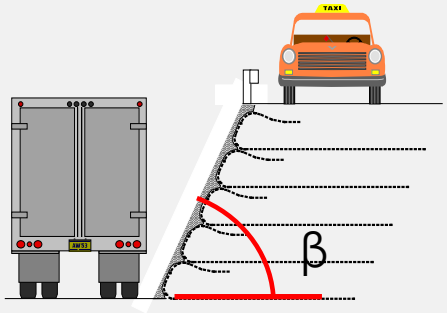
- Natural slopes : $\beta < \varphi$

  No need of soil reinforcement

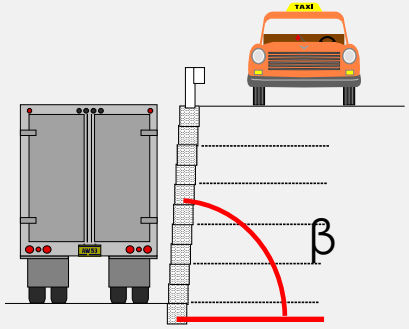


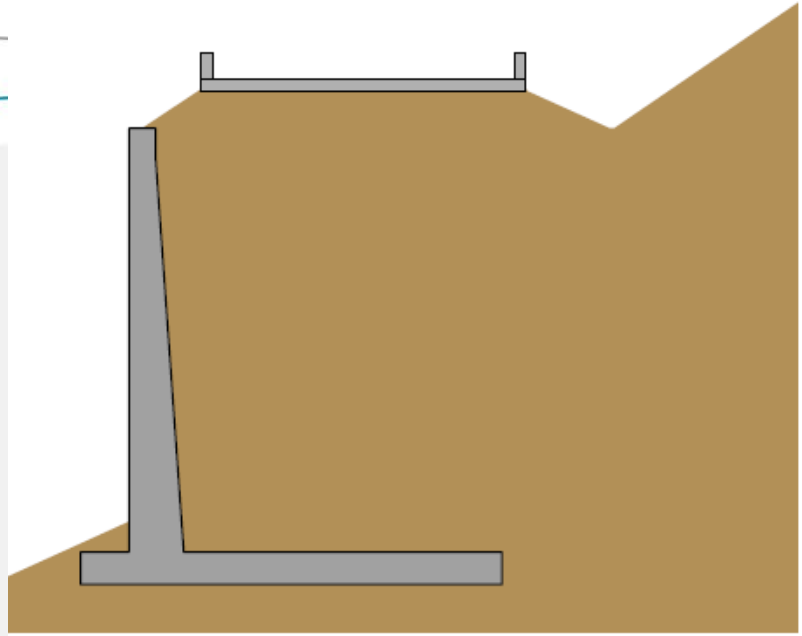
- Reinforced structures

  Steep slopes: Slope angle of $\varphi < \beta \leq 76°$

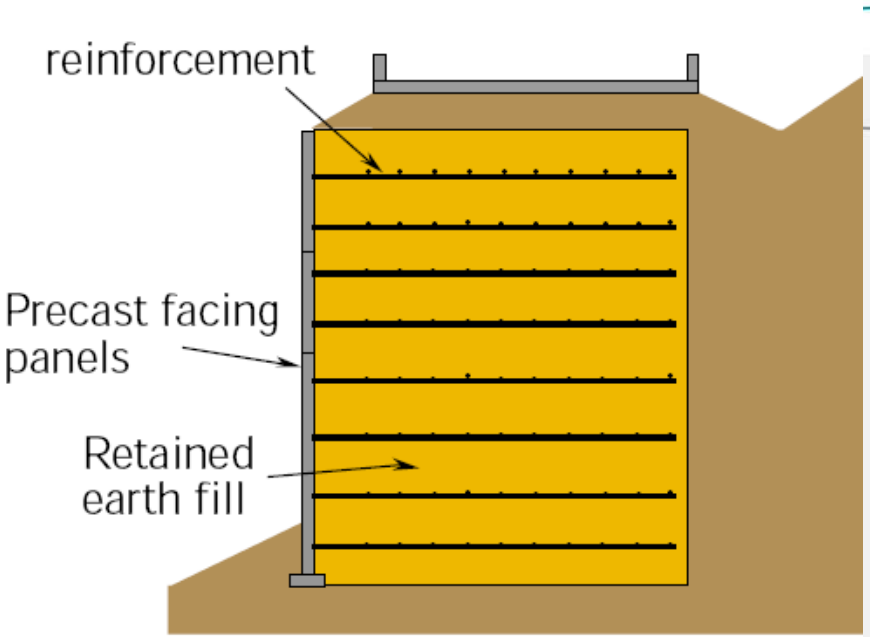


  Retaining walls: Slope angle= $76° < \beta \leq 90°$





Traditional cantilever wall



Reinforced soil wall

Conventional gravity structures are externally stabilised solutions which work against the soil's self weight. Reinforced soil solutions are internally stabilised using the soils self weight to generate the tensile forces in the reinforcement which bond the hybrid mass together.

A Simple Concept

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A Simple Concept

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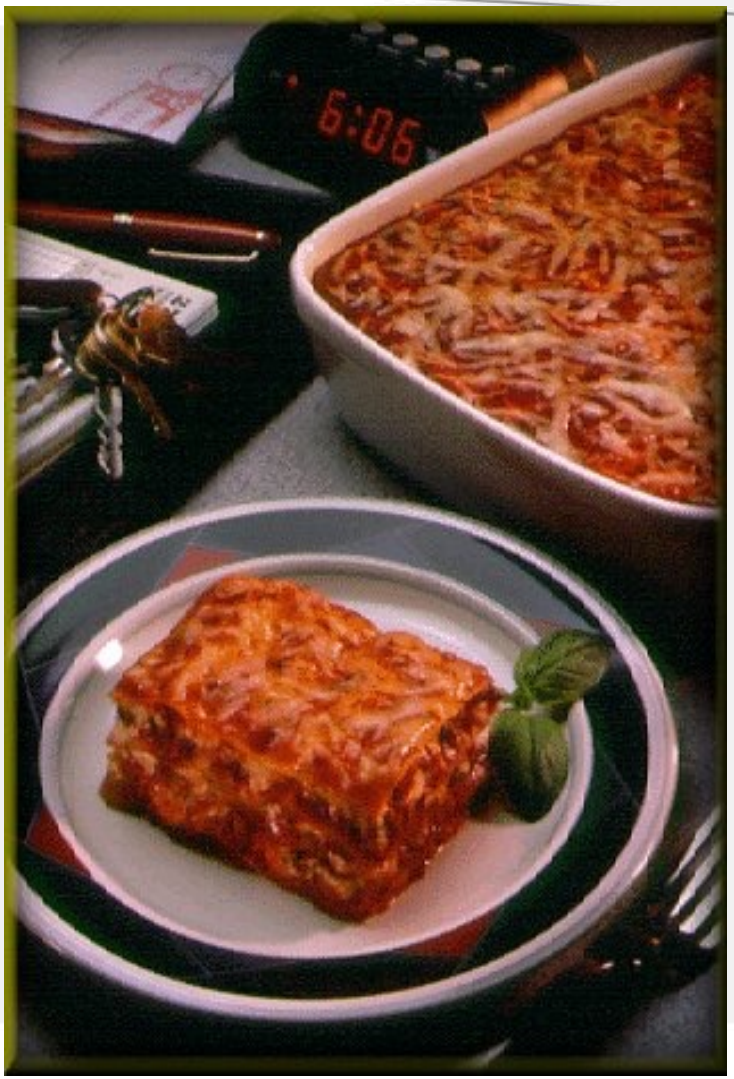

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Principle of soil reinforcement

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- Casagrande: Modern reinforced soil techniques in 1938
  - Layering strong tensile materials

- Henri Vidal: “Terre Armé” in the1960s
  - Horizontal tensile elements in frictional soil
  - Weight of material provides friction

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New Materials / Old Techniques

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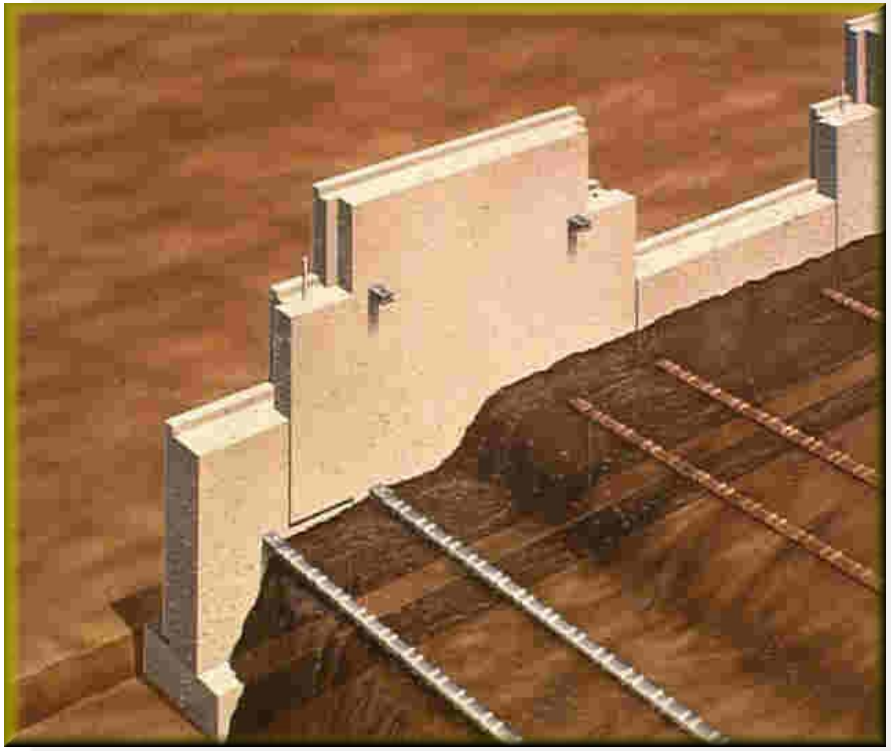
- Modern reinforced earth started in the late 60s “invented” by Henri Vidal who patented the term



New Materials / Old Techniques

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- Early construction used steel strips and meshes and reinforced concrete panels, materials familiar to all Engineers.

- Familiar problems too

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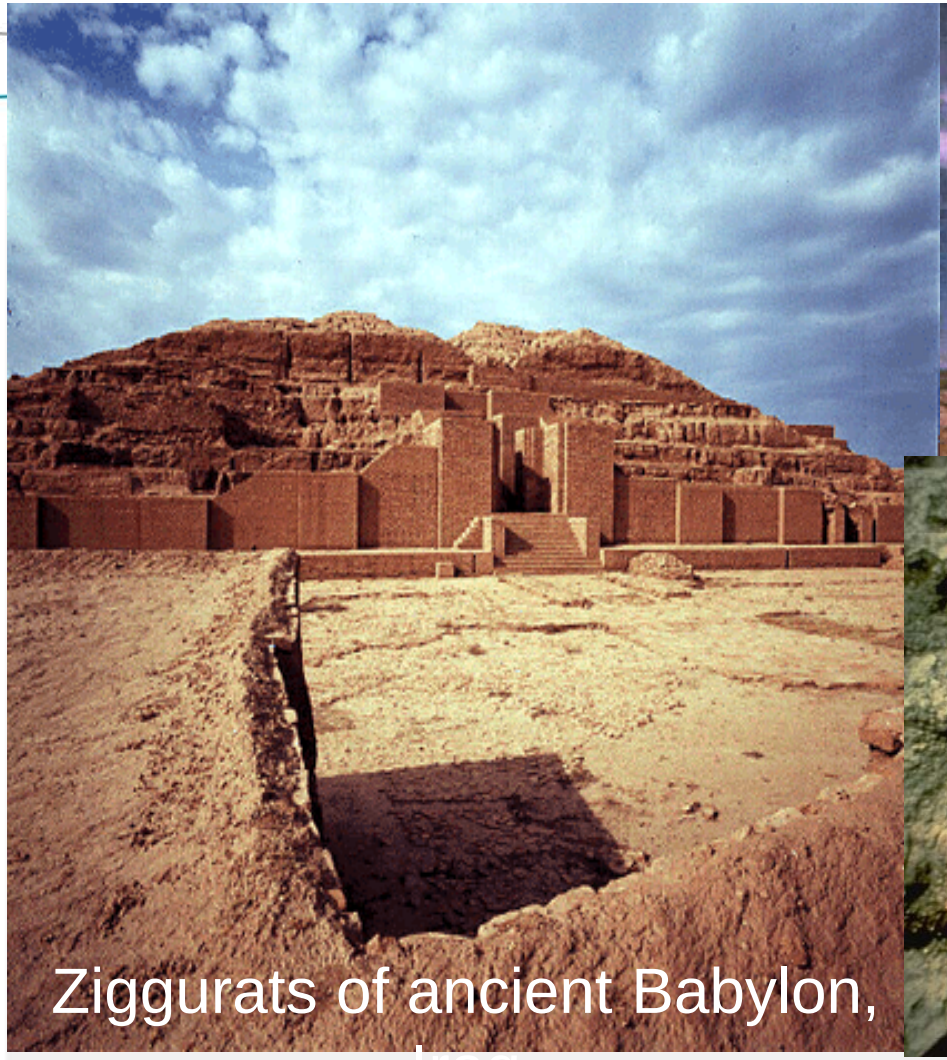
The Earliest Man made



Ziggurats of ancient Babylon, Iraq

The Earliest Man made Structures?

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Brief history of Enka-brand products in earth walls

1977 – Ht = 10 m, L = 50 m – Huesker / Akzo Nobel (Stabilenka)

Eurocodes (EC)

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Eurocodes are the basis of structural design, published as separate European standards

- Applied to all building materials: concrete (EC2), steel (EC3), wood (EC5), masonry (EC6), geotechnical design (EC7), Earthquake resistance (EC8)…
- Thanks to these common rules for European Community, it is easier for all engineering offices to compare and check the designs proposed by the contractors and their suppliers.
- Member states consider these rules as basis documents to prove the compliance of the construction works with essential requirements of the directive 89/106/EEC of the Council of European Communities, particularly the requirement n°1 – Mechanical resistance and stability.
- The Eurocodes therefore replaced the existing national building codes published by national standard bodies, although many countries had a period of co-existence until 2010.
- Some other countries like Moroccan authorities specify these European rules.

Eurocodes are based on a Limit States Design (ULS & SLS) method taking into account reduction factors as defined in the EC0 (EN 1990/A1).

Preliminary Design Decisions:

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Which Design Code?

In Europe all Geotechnical design must comply with EC7 but gives no design recommendations for Reinforced Soil. At present the choice of the design approach defers to the national application documents and is often down to the designer.

Many design guides exist:

FHWA (US), EBGEO (Germany), BS8006 (UK),
NF P 94-270 (France), CUR (Netherlands),
NORGEOSPEC (Norway), Geoguide 6 (Hong Kong)

Preliminary Design Decisions

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CEN TC 250 are attempting to rationalize all the design guidance to produce a single European design approach within EC7. EG5 aim to have their framework document on reinforced soil finalised in Q1 2016 for the Project Teams to draft sections for inclusion in EC7. Publication expected in 2019.

ISO TC221 are also drafting a guide for “Design Using Geosynthetics”.

Preliminary Design Decisions

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What do you want the structure to look like?

Face angle: Wall or Slope

A tricky issue in design guides >70° UK, >76° NL, no difference D

Face finish: Blocks, Gabions, Panels, Vegetation

Loading: Traffic loads, bridge abutments, traffic barriers, seismic loading

Temporary facings

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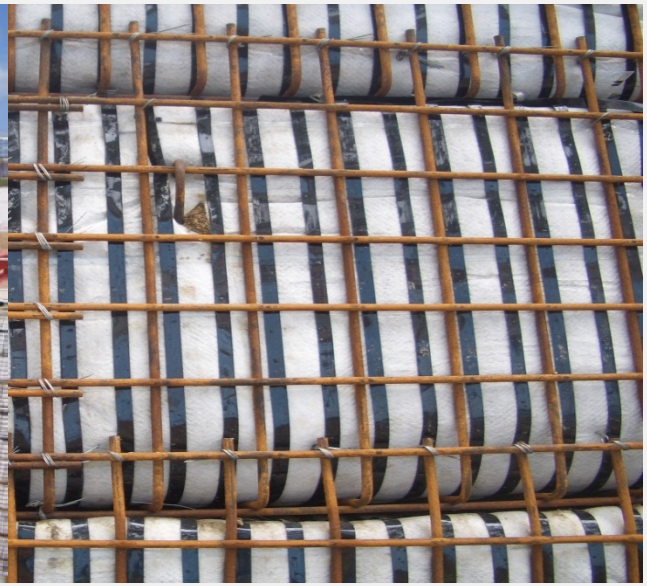
Used in situations where space constraints and existing embankment geometry require a full height retaining solution to support road / rail / bridge abutment prior to construction of a permanent solution.



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Temporary Facings

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Temporary Facings

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Permanent “Soft” Facings

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Gabions, or galvanised mesh with 200-300mm of gabion stone fill.

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Modular Blockwork

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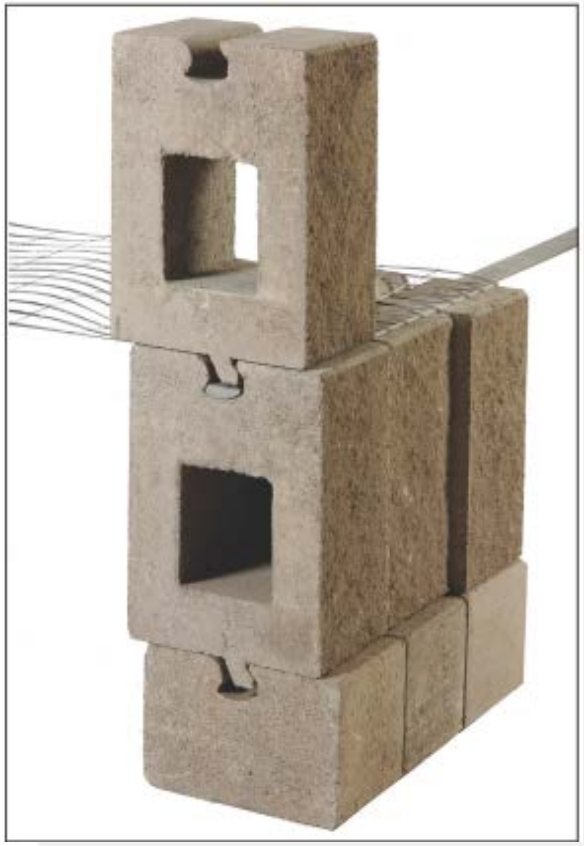

BBA BRITISH BOARD OF AGRÉMENT

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Modular Blockwork

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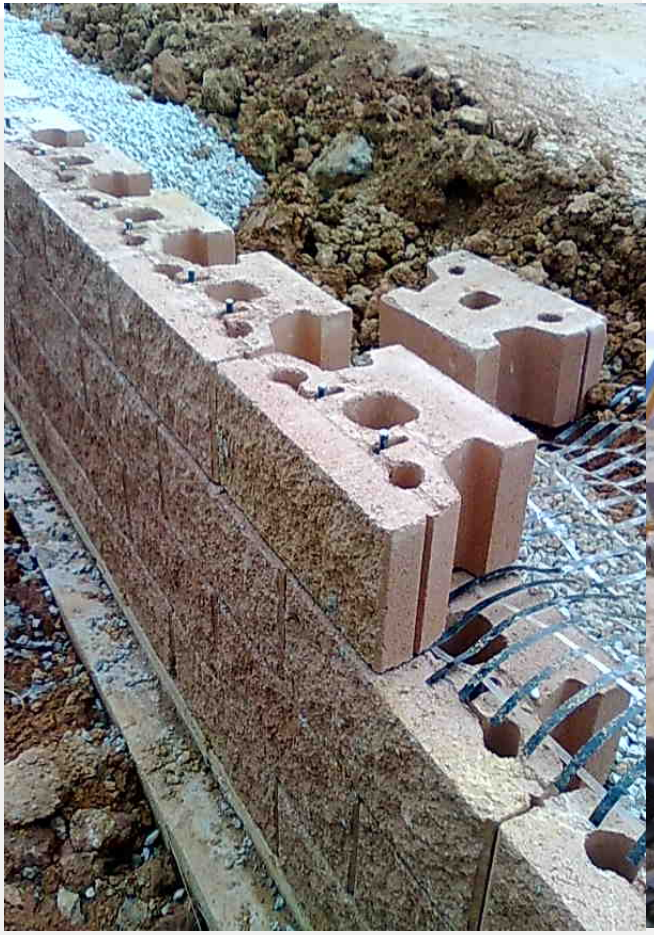

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Modular Blockwork

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- With proper design and detailing anything is possible

Discrete concrete panel facings

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Discrete concrete panels

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Full Height Concrete Panels

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- Full height props needed
- Construction can be tricky

Natural Slope Repairs

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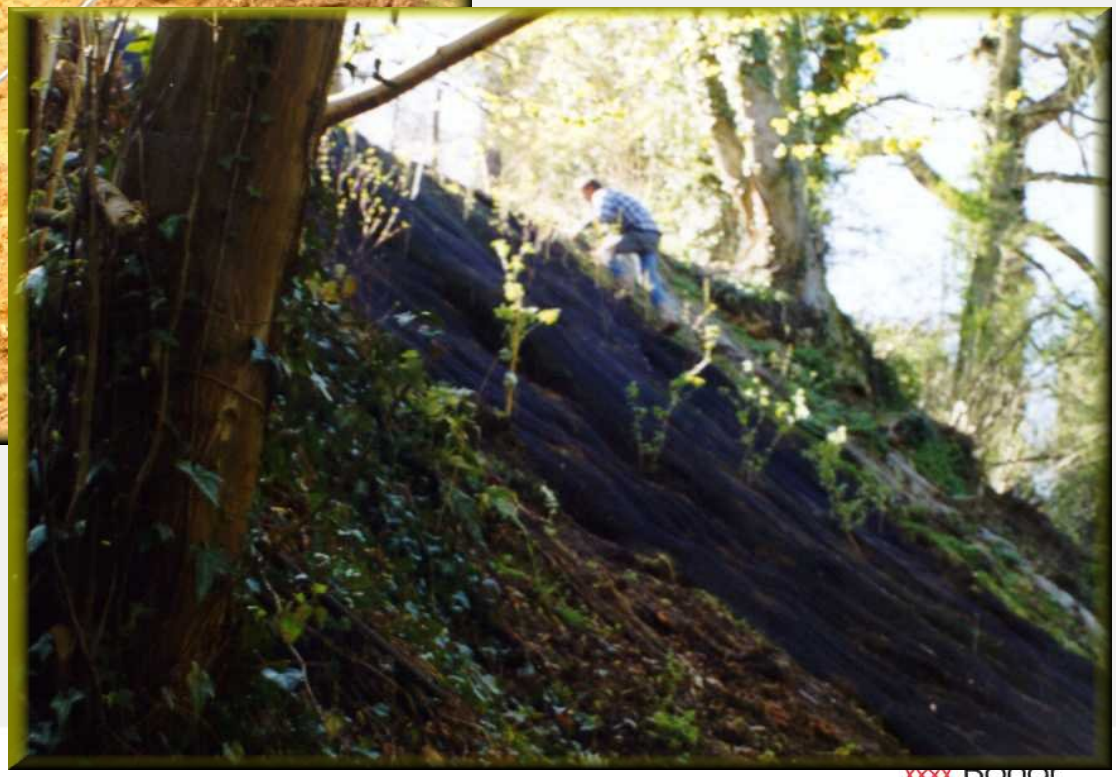

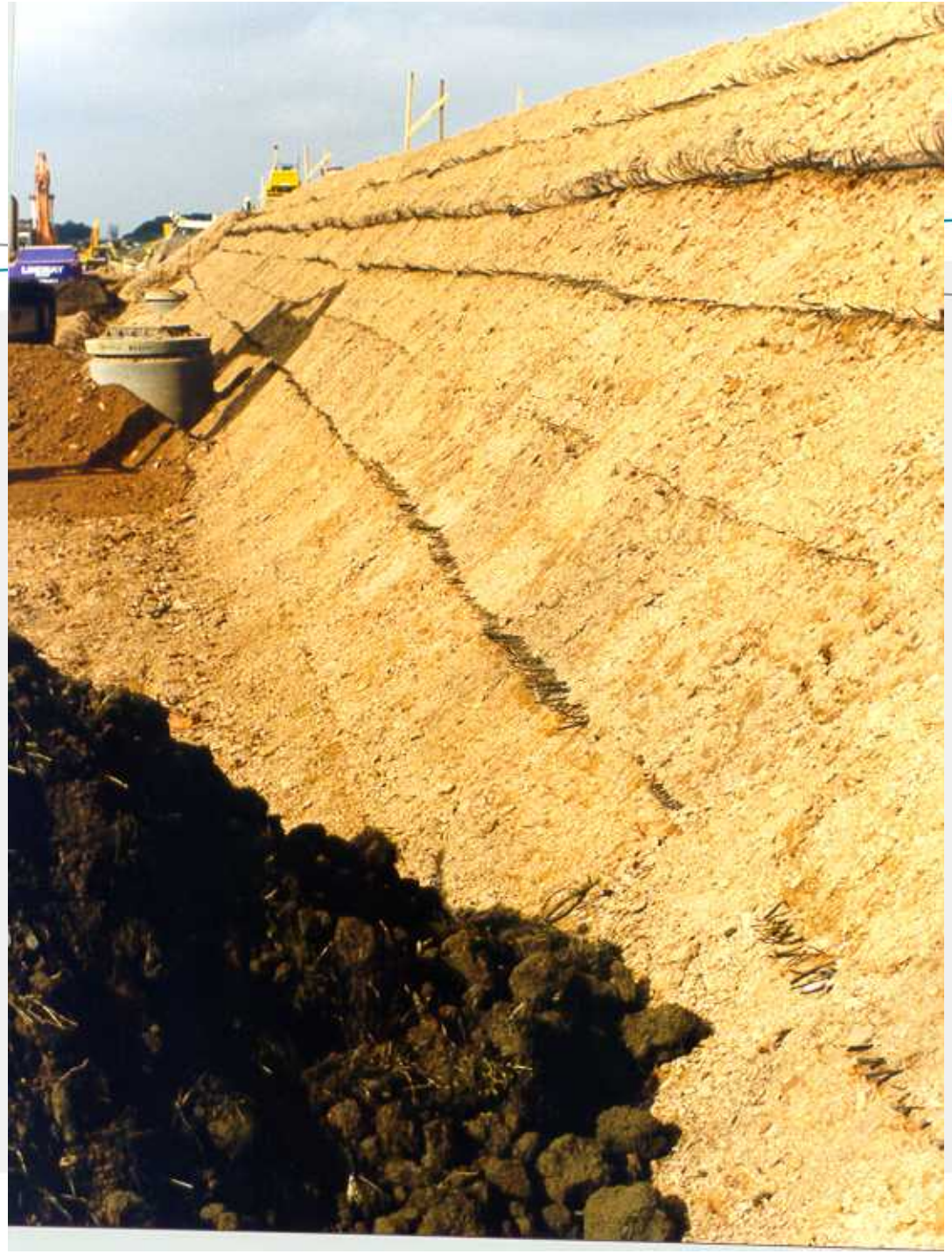

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Shallow Reinforced Slopes

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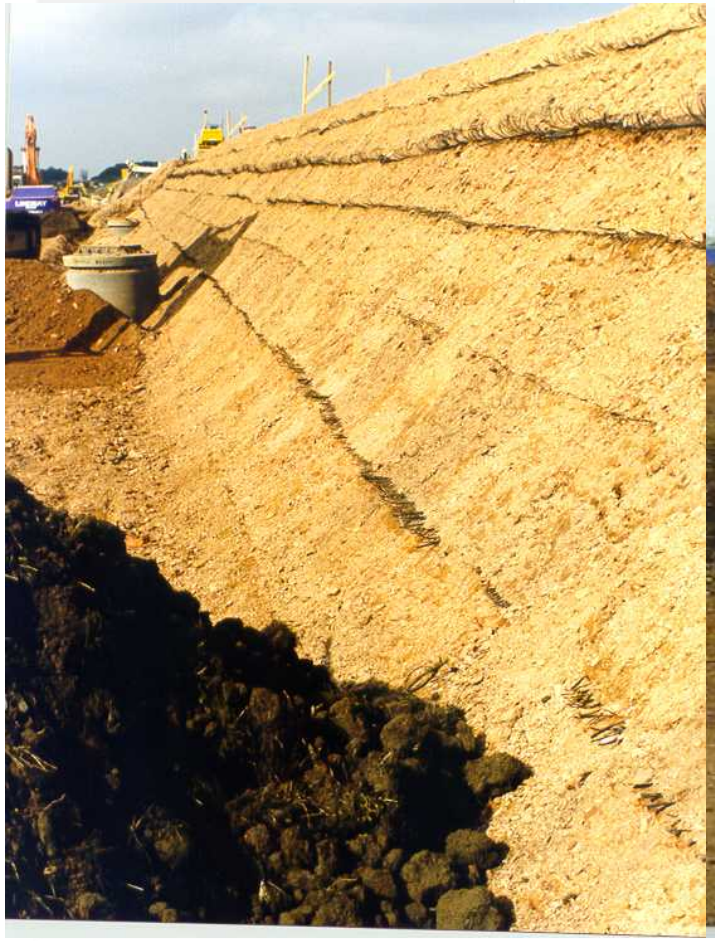

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Steep Reinforced Slopes

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Steep Reinforced Slopes

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Steep Reinforced Slopes

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Preliminary Design Decisions:

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What Soil?

Fill Material Requirements to BS8006

	Walls and abutments	*Steep slopes (≤ 70, > 45°)*	*Shallow slopes (≤ 45°)*	*Foundations*
Fill materials				
Class or type	*Selected granular fills (Classes 6I/J), Selected cohesive fills (Classes 7B/C/D) and Chalk (see Note 3)*	*Selected granular fills (Classes 6I/J), Selected cohesive fills (Classes 7B/C/D), General granular fill (Class 1), General cohesive fill (Class 2)(see Note 4) and Chalk (see Note 3)*	*Selected granular fills (Classes 6I/J), Selected cohesive fills (Classes 7B/C/D), General granular fill (Class 1), General cohesive fill (Class 2), and Chalk (see Note 3)*	*Classes 6F2 and 6F3*

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Soil Design parameters

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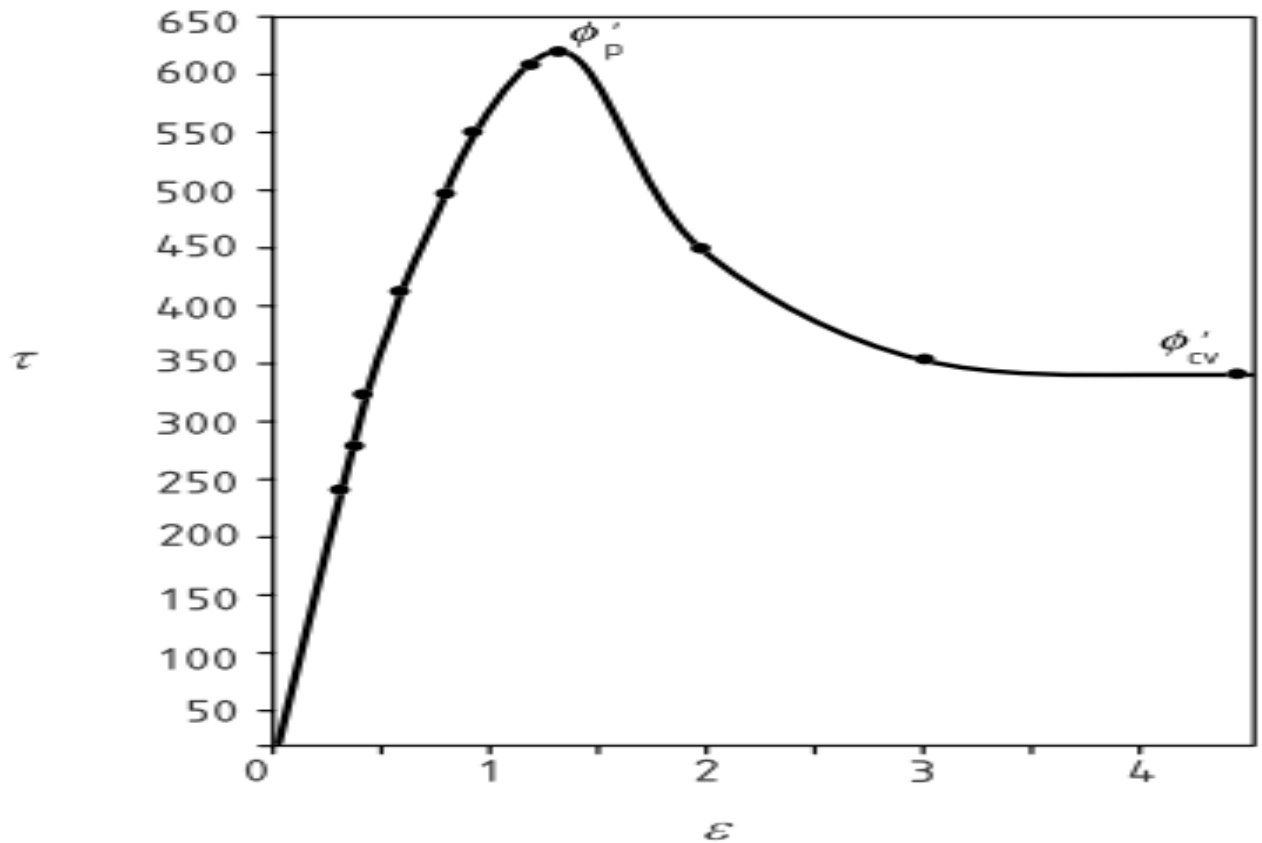

Φ'_P is used in walls where strain is <1%, Φ'_{cv} is used in slopes and cohesive materials where higher strains are expected

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Preliminary Design Decisions

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Loading: Bridge Bank Seats and Traffic Barriers

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Design reinforced soil

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- EC7: Ultimate Limit State & Serviceability limit state
  - ULS: Possible and probable failures are considered
  - SLS: relevant working conditions are identified

- Method of partial factors:
  - Load factor
  - Material factor
  - Soil/reinforcement interaction factors

BS8006 Partial Factors

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Table 11 **Summary of partial factors to be used in Section 6**

Partial factors		Ultimate limit state	Serviceability limit state
Load factors	Soil unit weight density e.g. wall fill	The appropriate value of f_{fs} to be chosen according to Table 12 and Table 13 for the particular load combinations	
	External dead loads e.g. line or point loads	The appropriate value of f_f to be chosen according to Table 12 and Table 13 for the particular load combinations	
	External live loads e.g. traffic loading	According to Table 12 and Table 13 for the particular load combinations	
Soil material factors:	to be applied tan ϕ'_p	$f_{ms} = 1.0$	$f_{ms} = 1.0$
	to be applied to c'	$f_{ms} = 1.6$	$f_{ms} = 1.0$
	to be applied to c_u	$f_{ms} = 1.0$	$f_{ms} = 1.0$
Reinforcement material factor:	to be applied to the reinforcement base strength	The value of f_m should be consistent with the type of reinforcement to be used and the design life over which the reinforcement is required (see **5.3.3** and Annex A)	
Soil/reinforcement interaction factors	Sliding across surface of reinforcement	$f_s = 1.3$	$f_s = 1.0$
	Pull-out resistance of reinforcement	$f_p = 1.3$	$f_p = 1.0$
Partial factors of safety	Foundation bearing capacity: to be applied to q_{ult}	$f_{ms} = 1.35$	NA
	Sliding along base of structure or any horizontal surface where there is soil-to-soil contact	$f_s = 1.2$	NA

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BS8006 Load Combinations

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Table 13 **Partial load factors for load combinations associated with abutments**

Effects		Combinations		
		A	B	C
Dead load of the structure		$f_{fs} = 1.5$	$f_{fs} = 1.0$	$f_{fs} = 1.0$
Dead load of the fill on top of the structure		$f_{fs} = 1.5$	$f_{fss} = 1.0$	$f_s = 1.0$
Dead load of bridge and bank seat		$f_f = 1.2$	$f_f = 1.0$	$f_f = 1.0$
Backfill pressure behind the bank seat		$f_{fs} = 1.5$	$f_{fs} = 1.5$	$f_{fs} = 1.0$
Backfill pressure behind the structure		$f_{fs} = 1.5$	$f_{fs} = 1.5$	$f_{fs} = 1.0$
Horizontal loads due to creep and shrinkage		$f_f = 1.2$	$f_f = 1.2$	$f_f = 1.0$
Traffic loading		Over the entire structure, $f_q = 1.5$	Behind the reinforced zone, $f_q = 1.5$	
Bridge vertical live load	HA	$f_q = 1.5$	$f_q = 1.5$	
	HA and HB	$f_q = 1.3$	$f_q = 1.3$	
Braking dynamic load	HA	$f_q = 1.25$	$f_q = 1.25$	
	HA and HB	$f_q = 1.1$	$f_q = 1.1$	
Temperature effects		$f_q = 1.3$	$f_q = 1.3$	

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BS8006 Load Combinations

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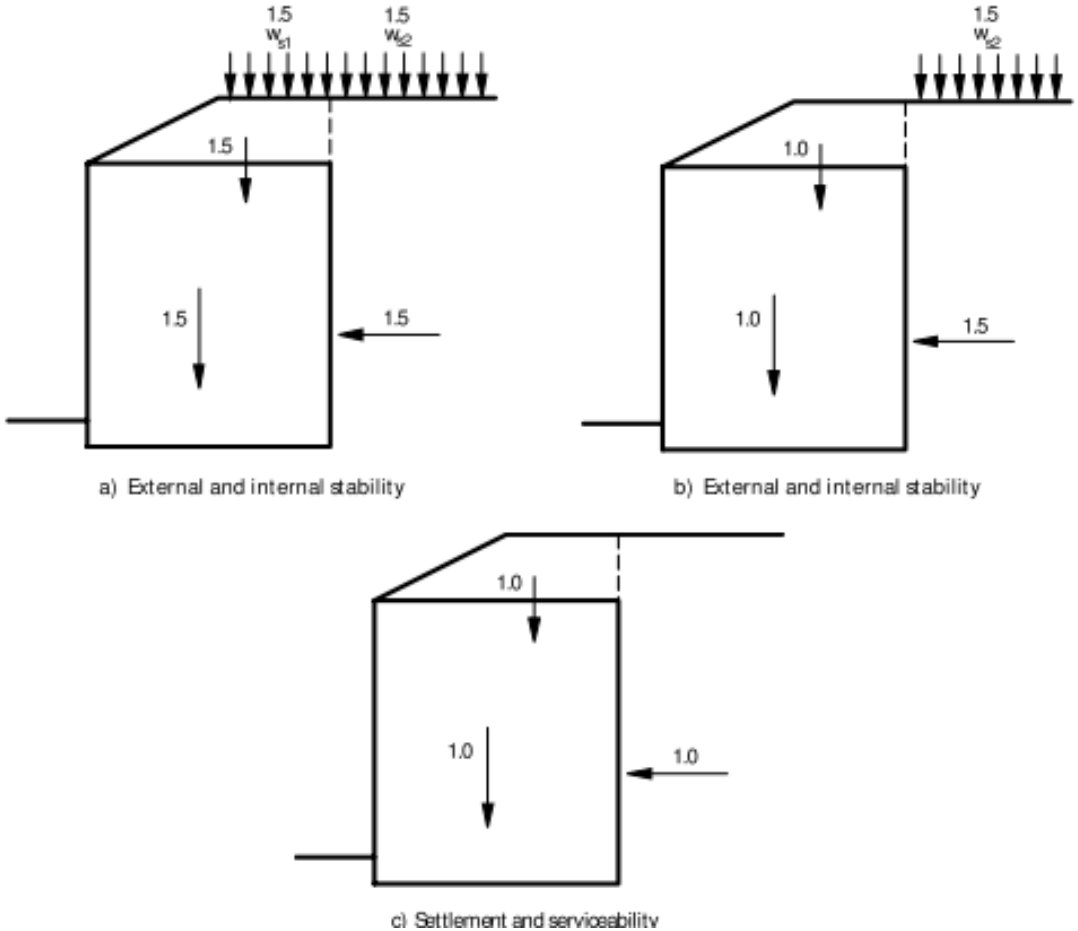
Figure 17 Load combinations showing partial load factors (see Table 12)



Design Life

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Design working life category (BS EN 1990:2002+A1)	Category	Typical service life years	Example
1	Temporary works	1 to 5	Contractors site structures Piling platforms
1	Short term	5 to 10	Contractors site structures Basal reinforced platforms for settlement control or in association with ground improvement
3/4	Industrial	10 to 50	Structures at mines
4/5	Long term	60	Marine structures in accordance with BS 6349 Highway embankments Railway embankments (NR/SP/CIV071 [17]) Basal reinforcement in association with Piles or other supports under embankments
5	Long term	120	Highway and railway retaining walls and highway structures and bridge abutments Basal reinforcement in association with piles or other supports under retaining walls and structures

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Consequence of Failure

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Table 9 **Category of structure depending upon ramification of failure**

Category	Partial factor f_n	Examples of structures
1 (low) [A)]	1.0 if analysis is undertaken	Retaining walls and slopes less than 1.5 m in retained height above finished ground level in front where failure would result in minimal damage and loss of access
2 (medium)	1.0	Embankments and structures where failure would result in moderate damage and loss of services
3 (high)	1.1	Abutments, structures directly supporting motorway, trunk and principal roads or railways or inhabited buildings, dams, sea walls and slopes, river training walls and slopes

NOTE See Figures 10 to 14 for examples of structures in categories 1, 2 and 3.

A) Structures in category 1 should be restricted to small and relatively simple structures, with negligible risk, which may be designed by experience without analysis as described in BS EN 1997-1:2004.

Initial Sizing of Structures

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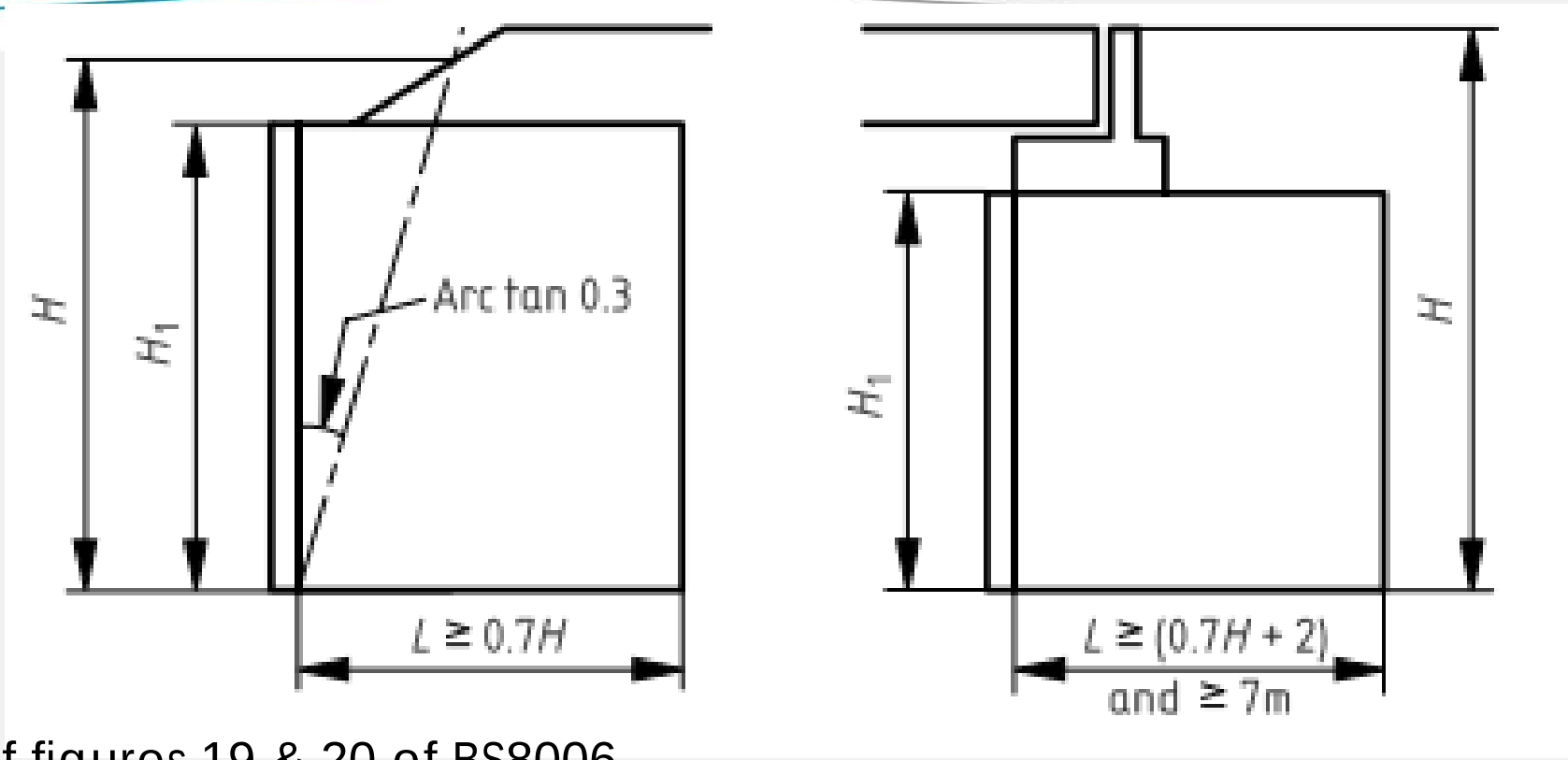

Ref figures 19 & 20 of BS8006

Initial Sizing of Structures

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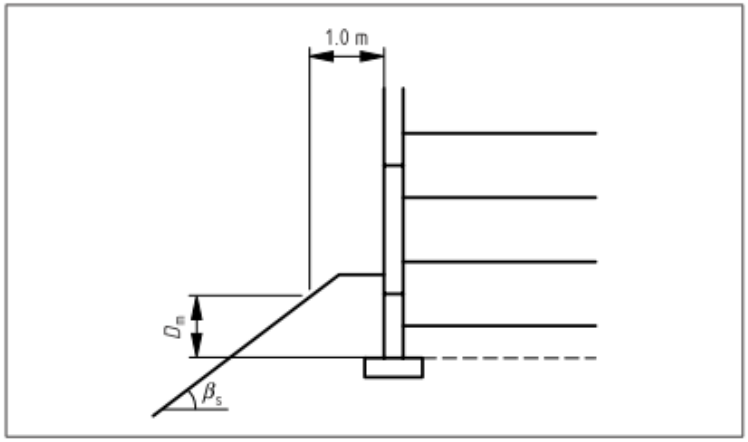
Table 15 **Determination of the minimum embedment as a function of the mechanical height H in metres and the factored bearing pressure q_r in kN/m²**

Slope of the ground at toe β_s		Minimum embedment D_m m	Minimum embedment factor D_m/q_r m^3/kN
$\beta_s = 0$	Walls	$H/20$	1.35×10^{-3}
$\beta_s = 0$	Abutments	$H/10$	1.35×10^{-3}
$\beta_s = 18°$ ($\cot \beta_s = 3/1$)	Walls	$H/10$	2.7×10^{-3}
$\beta_s = 27°$ ($\cot \beta_s = 2/1$)	Walls	$H/7$	4.0×10^{-3}
$\beta_s = 34°$ ($\cot \beta_s = 3/2$)	Walls	$H/5$	5.9×10^{-3}

NOTE 1 For definition of notation see Figure 21.

NOTE 2 $D_m \geq 0.45$ m.



Reinforced Soil Wall Design

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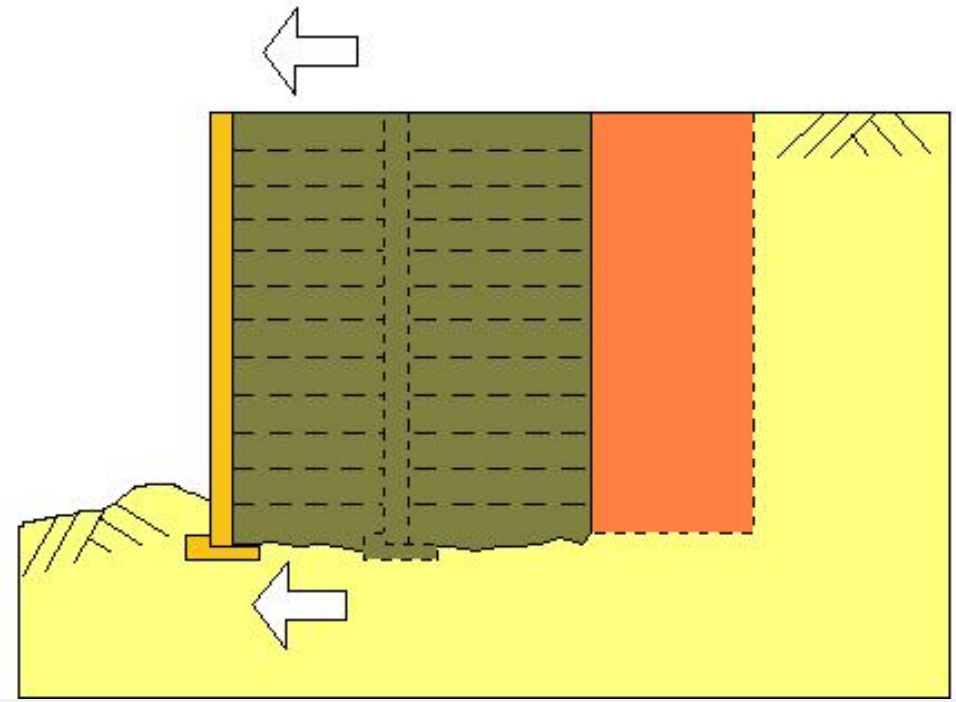
Design Criteria

External Stability

1. Sliding along base of reinforced soil block



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Reinforced Soil Wall Design

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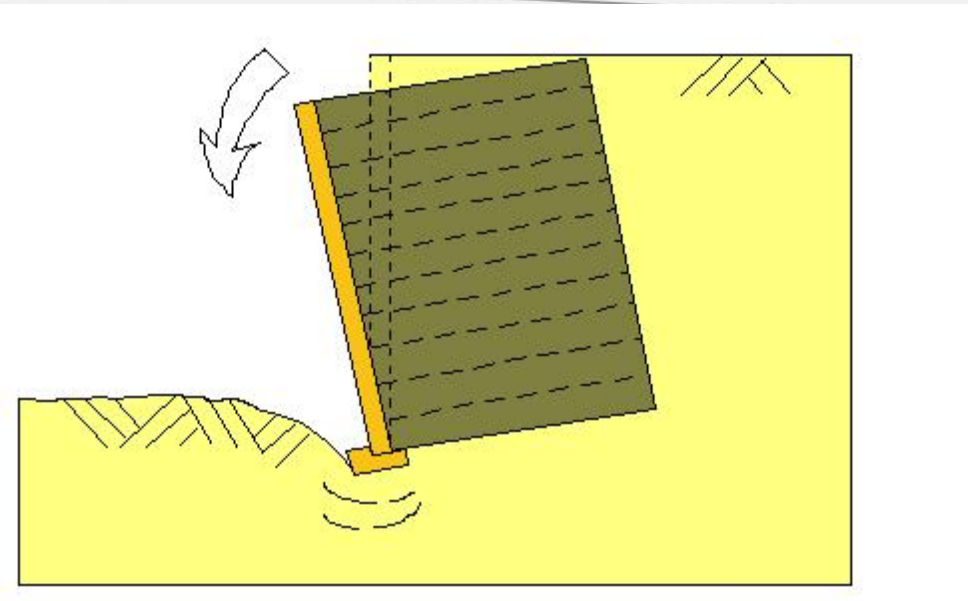
Design Criteria

External Stability

1. Sliding along base of reinforced soil block

2. Bearing capacity



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Reinforced Soil Wall Design

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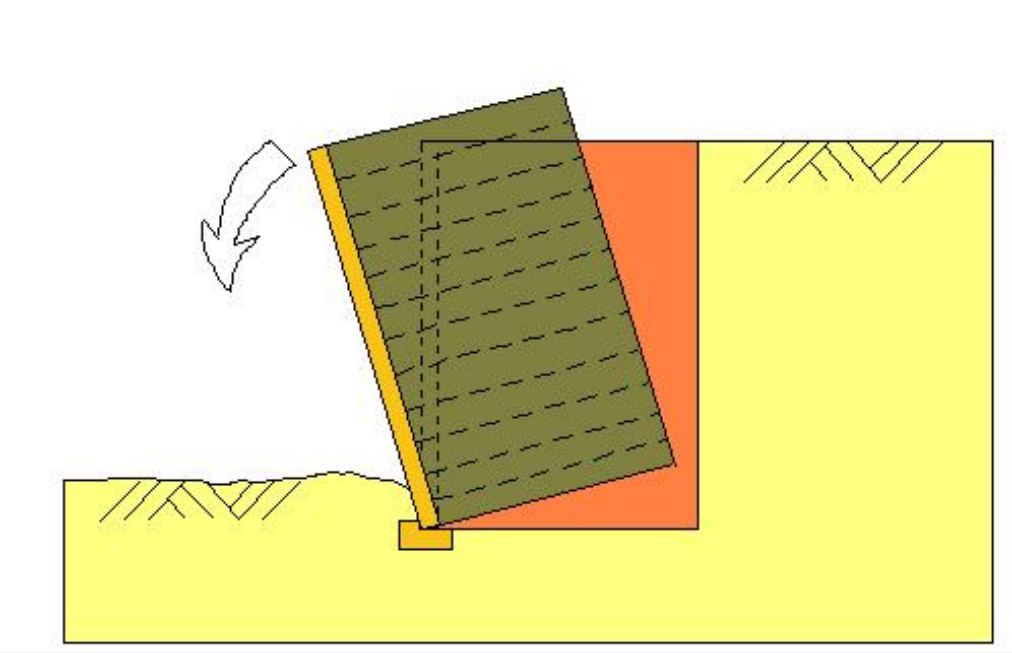
Design Criteria

External Stability

1. Sliding along base of reinforced soil block
2. Bearing capacity
3. Overturning



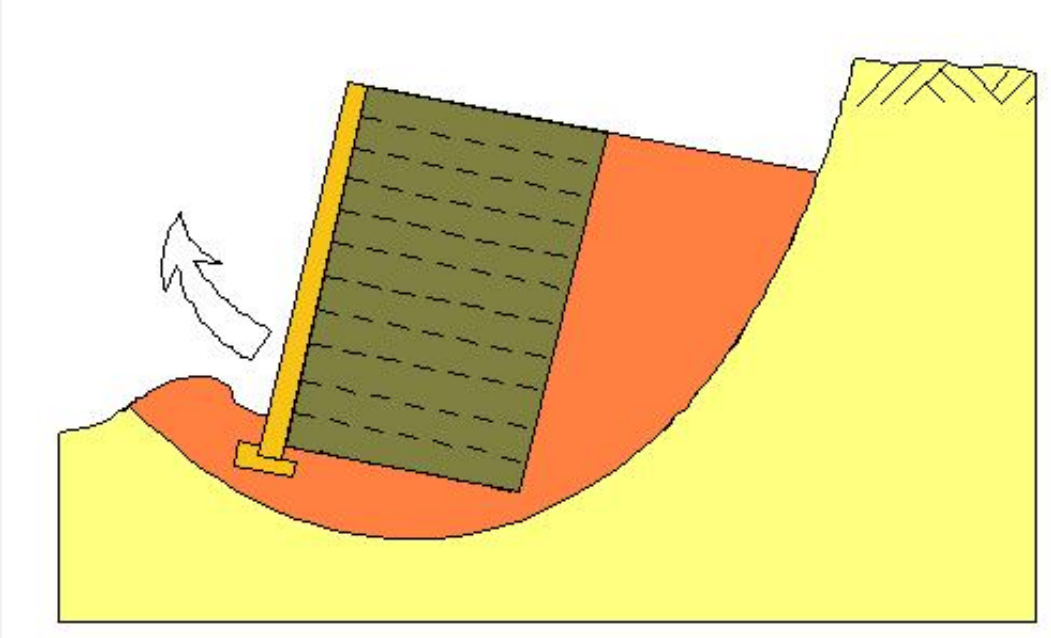
Reinforced Soil Wall Design

Enka solutions

Design Criteria

External Stability

1. Sliding along base of reinforced soil block
2. Bearing capacity
3. Overturning
4. Overall stability



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Reinforced Soil Wall Design

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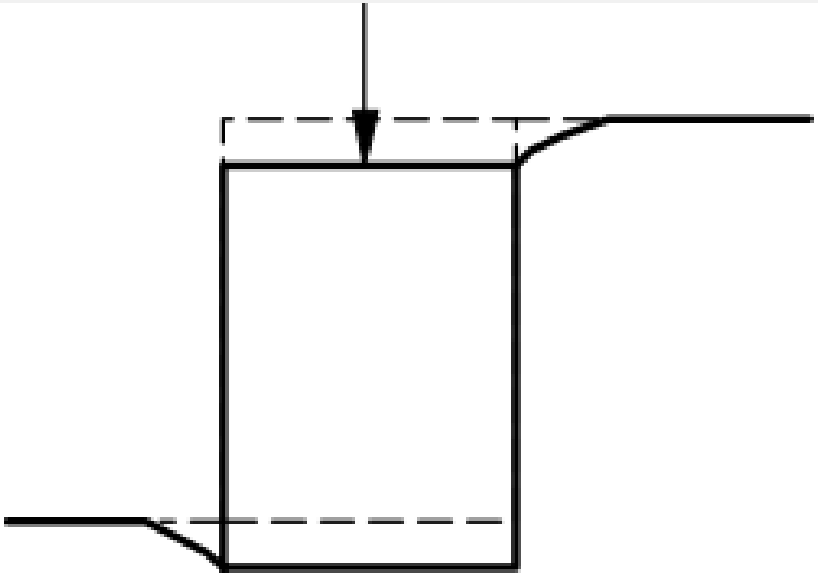
Design Criteria

External Stability

1. Sliding along base of reinforced soil block
2. Bearing capacity
3. Overturning
4. Overall stability
5. Settlement



a) Settlement

Flexibility of the systems make them better over poor ground

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BS8006 suggests the following limitations to differential settlement

Table 17 **Guide to the effects of settlement**

Maximum differential settlement	Comment
1 in 1000	Not normally significant
1 in 200	Full height panels may be affected by joints closing or opening. Normal safe limit for segmental blockwalls.
1 in 100	Normal safe limit, without special measures, for discrete concrete panel facings
1 in 50	Normal safe limit for semi-elliptical steel face elements. Discrete concrete panels may suffer closed joints if special measures not included
1 in < 50	Soft facings might suffer distortion affecting their retaining ability

NOTE There is no intended firm limit between categories. This is a preliminary guide only.

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Flexibility of the systems make them better over poor ground

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Reinforced Soil Wall Design

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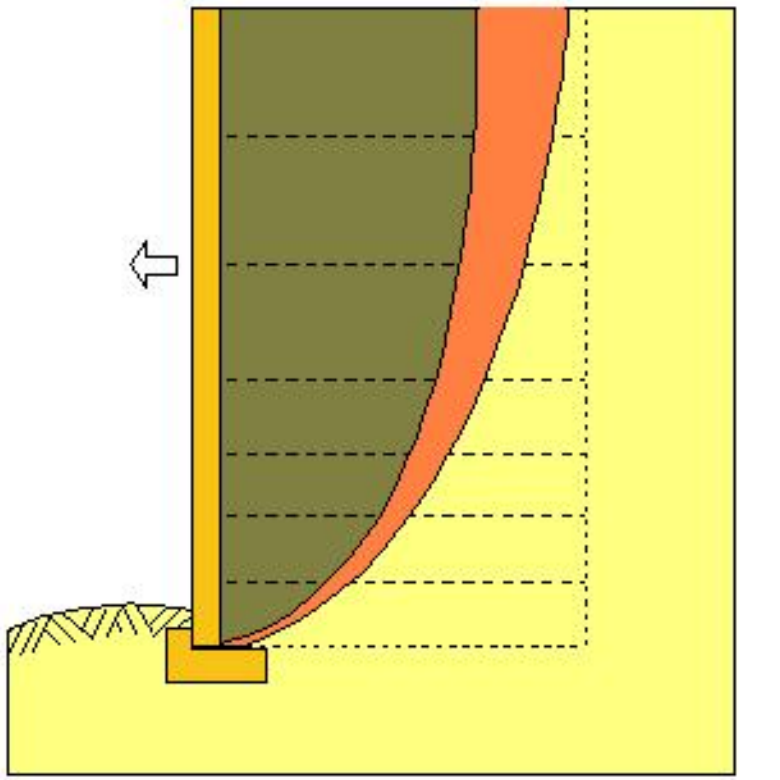
Design Criteria

Internal Stability

1. Tensile failure of reinforcement



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Reinforced Soil Wall Design

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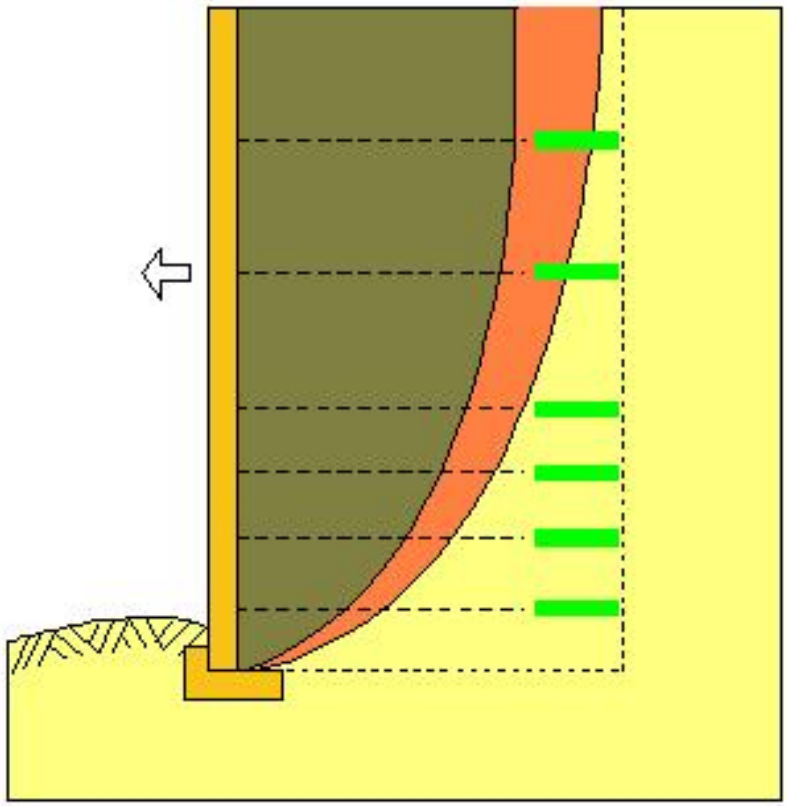
Design Criteria

Internal Stability

1. Tensile failure of reinforcement

2. Reinforcement pullout



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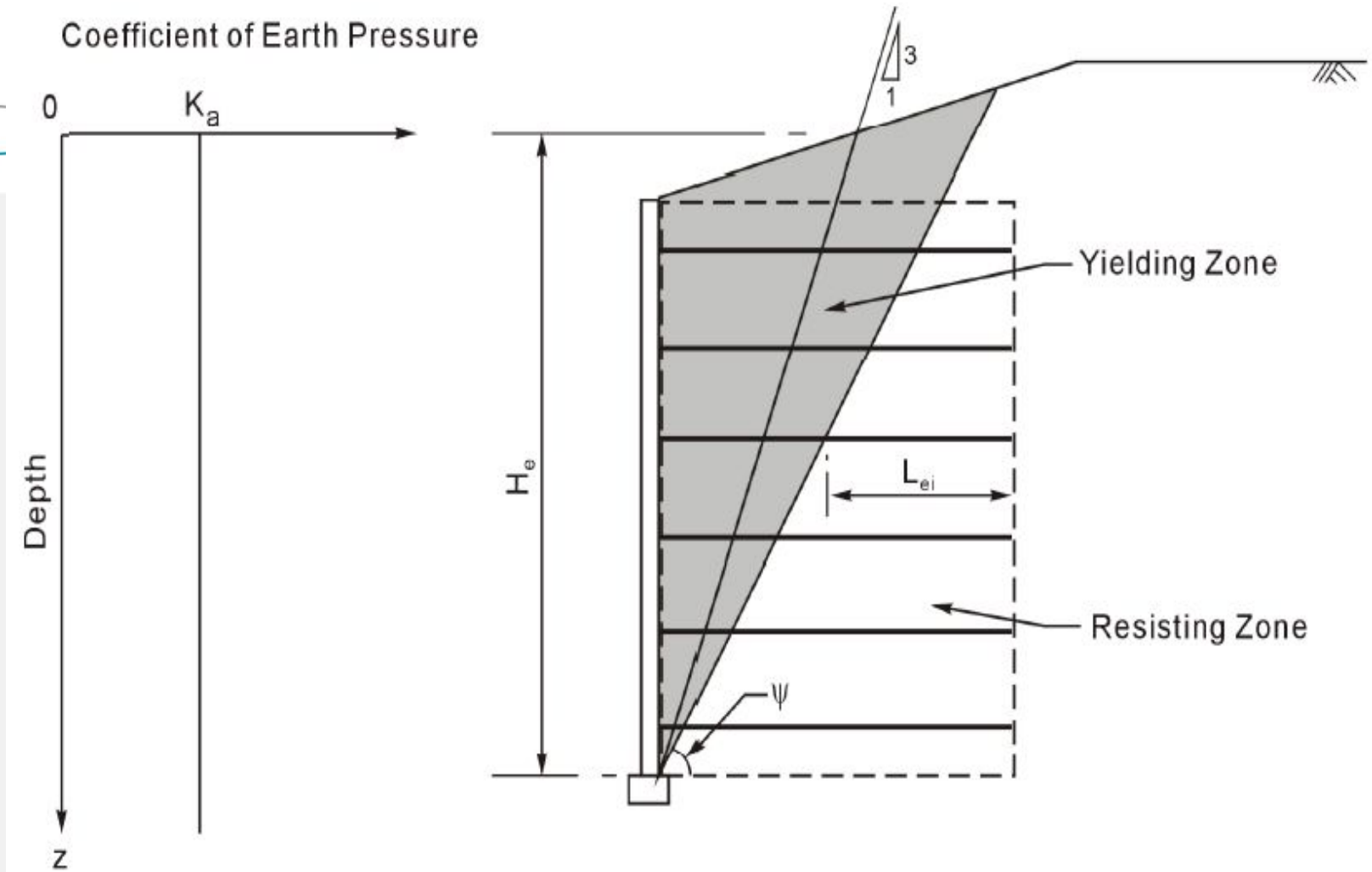
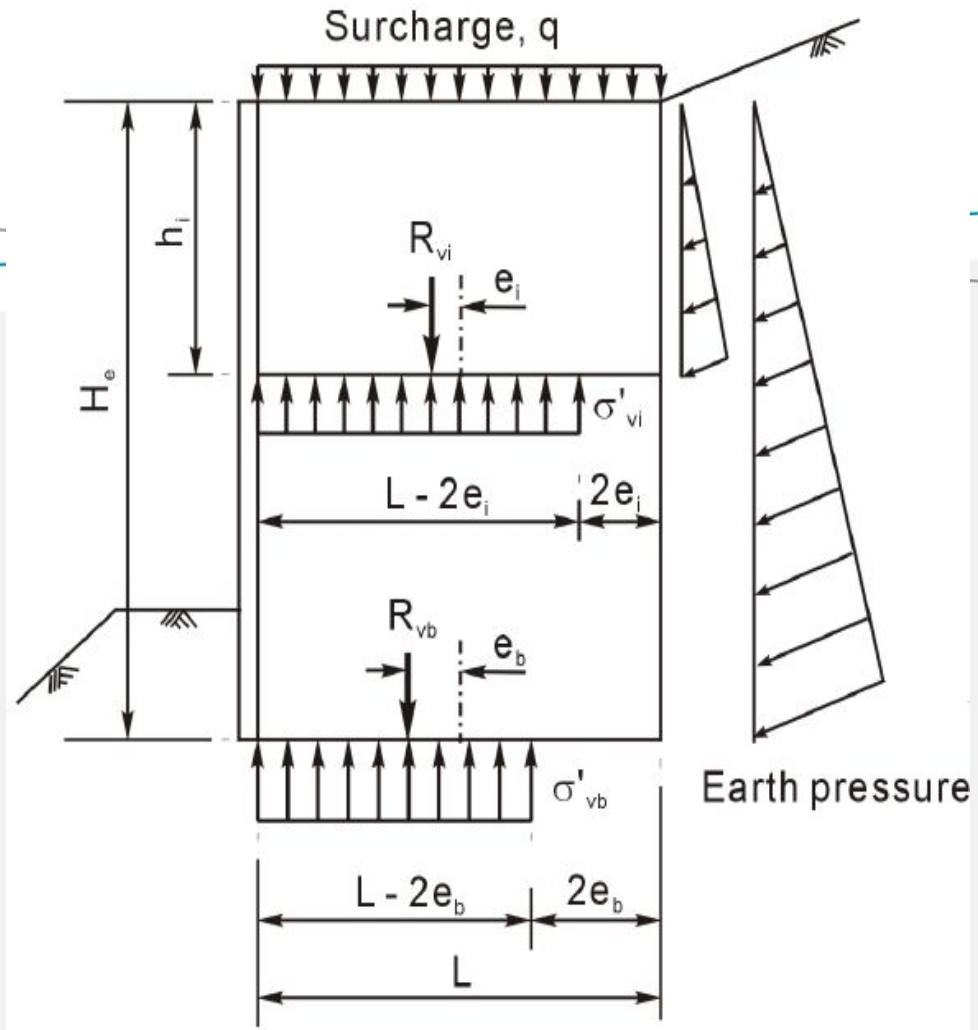
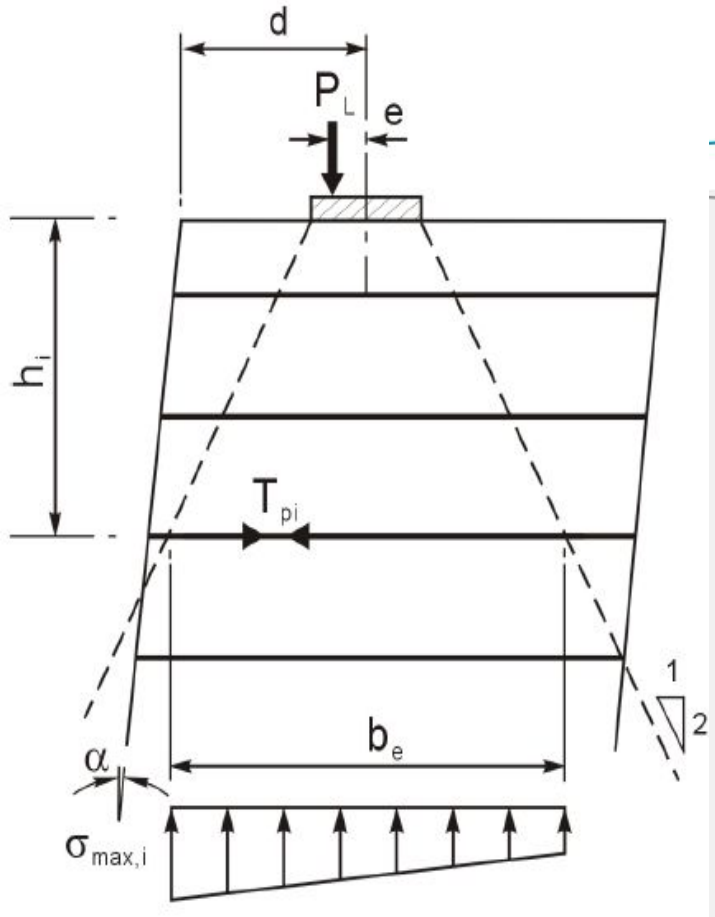


Tie Back Wedge analysis for use with polymeric reinforcement



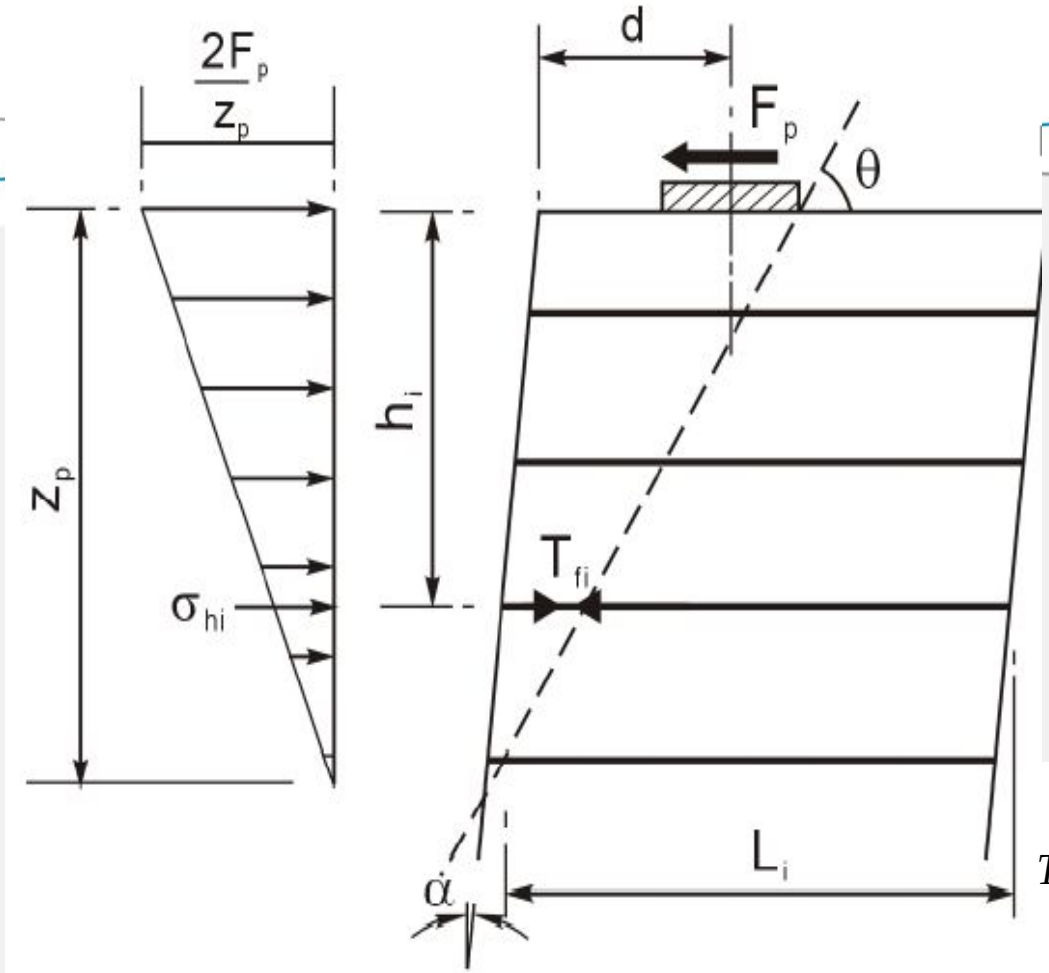
$$T_{sj} = K\sigma_{vj}$$

Tension Generated by surcharge, self weight and backfill pressure in each layer of reinforcement



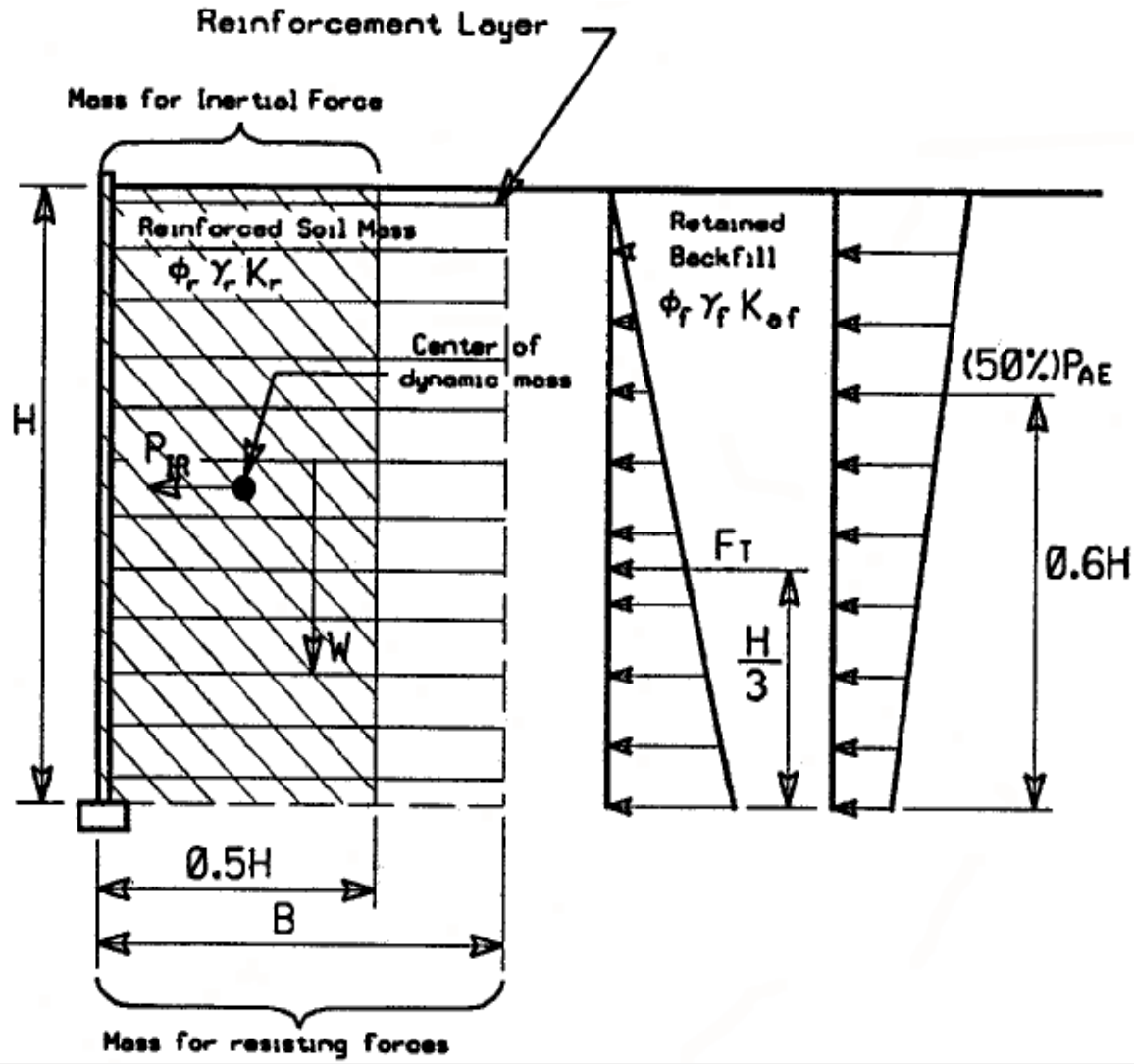
$$T_{pj} = KP_L/b_e$$

Tension Generated by vertical pressure from strip load



$$T_{fj} = \frac{2F_p \tan\left(45^o - \varphi/2\right)}{c_f + b_f}\left(1 - \frac{h_j \tan\left(45^o - \varphi/2\right)}{c_f + b_f - 2e'_{parapet}}\right)$$

Tension generated by horizontal loading to strip



Seismic loading designed to Mononobe-Okabe pseudo static method

$$T_{md} = \frac{P_I \; L_{ej}}{\Sigma L_{ej}}$$

Additional force checked against tensile capacity of reinforcement based on 75% of the static FoS

Additional tension generated by seismic loading

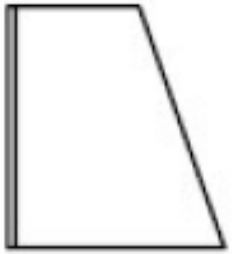
Reinforced Soil Wall Design

Enka solutions

Connection Loads

Checked for both ULS & SLS

Table 20 **Connection loads for the ultimate and serviceability limit states**

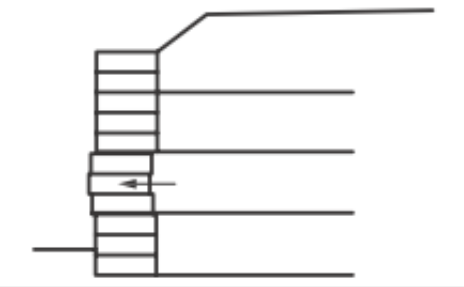
Tie back wedge method		
All facings with movement capacity or movement capacity at connections	 Toe	$T_{conn} = 75\% T_j$ $T_{conn} = 100\% T_j$
Stiff face, e.g. segmental block walls and full height panels with no movement capacity at connections	 Toe	$T_{conn} = 100\% T_j$

Reinforced Soil Wall Design

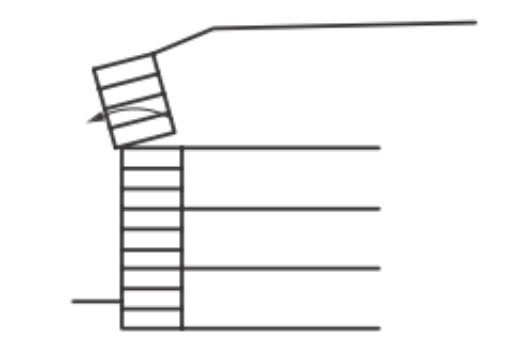
Enka solutions

System Dependent checks

1. Bulging or overturning of facing



2. Failure of connection



Simple Excel Spreadsheet Checks

Enka·solutions

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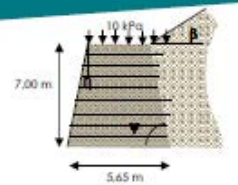
Enkagrid PRO en remblai renforcé

25/01/2014



Données et hypothèses

Hauteur du mur : **7,00 m** Inclinaison (tan η) : **0,25** (14,0°)

Remblai technique : γ_{soil} = **20 kN/m3** Frottement interne ϕ'_{soil} : **35°** Coef. ρ = 0,74

Coefficient de poussée du remblai $k_{a,soil}$ = 0,271 Flexibilité du parement (EN 14 475) a_0 = 0,75

Talus de surcharge arrière : β = **0°** surcharge routière q = **10 kPa**

Choc de véhicule sur dispositif solidaire d'une dalle de frottement en tête de massif : **non**

Terrain arrière : γ_{soil2} = **20 kN/m3** Frottement interne ϕ'_{soil2} : **35°**

Inclinaison écran fictif ψ = **75°** Frottement écran fictif δ = 23° $0 \le \delta \le 2/3\phi'_{soil2}$

Coefficient de poussée du terrain $k_{a,soil2}$ = 0,300

Renforcements Enkagrid® PRO : Espacement des lits s_v = **0,50 m** Long. max = **5,65 m**

Coef. d'interaction Cip_1 = 0,80 Coef. de glissement Cip_2 = 0,87

Coef. partiels : ρ_{end} = 0,91 ρ_{tu} = 0,68* ρ_{deg} = 0,89* * 100 ans

γ_w = 1,00 γ_{ret} = 1,25 γ_{ret} = 1,35

Paramètres sismiques (cf. EN 1998-1)

Accélération maximale de référence pour la zone de l'ouvrage a_{gR} : **2,0 m/s²**

Coefficient d'importance γ_I : 1,0 Spectre type 1 $m = a_{vg}/a_g$ = 0,90

Accélération de calcul horizontale $a_g = \gamma_I . a_{gR}$: a_g = 2,0 m/s² a_g/g = 0,20

Accélération de calcul verticale a_{vg} : $m.a_g$ a_{vg} = 1,8 m/s²

Paramètre du sol dépendant du profil stratigraphique (*) S = 1 pour spectre de type 1

* Classe du sol (selon $v_{s,30}$) : **A** (vitesse de propagation des ondes supérieure à 800 m/s)

Coefficient sismique horizontal k_h : k_h = 0,102 pour r = 2,0

Coefficient sismique vertical k_v : k_v = 0,051

θ_A = 0,097 rad K_A = 0,74 θ_B = 0,107 rad K_B = 0,75

sollicitation dyn. descendante $(1+k_v)K_A$ = 0,78 soll. dyn. ascendante $(1-k_v)K_B$ = 0,71

Stabilité au glissement en conditions drainées (cf. NF P 94-270)

Soit V'_k la composante verticale de la charge transmise au sol par le mur

Soit R_d la valeur de calcul de la résistance ultime au glissement du mur

Soit H_d la composante horizontale de la résultante des actions appliquées au mur

Combinaisons	V'_k	γ_{Ek}	R_d	H_d	$H_d \le R_d$?
Statique	728 kN/m	1,10	403 kN/m	192 kN/m	OK
Séisme desc.	858 kN/m	1,00	523 kN/m	388 kN/m	OK
Séisme asc.	779 kN/m	1,00	475 kN/m	363 kN/m	OK

Quantités

Retour géogrille:	**oui**
42,8 m²/ml	**PRO 40**
40,9 m²/ml	**PRO 60**
0,0 m²/ml	**PRO 90**
0,0 m²/ml	**PRO 120**
0,0 m²/ml	**PRO 180**
14,0 m²/ml	**7010/1**

Bonar partners in performance

Bonar - Tour Pleyel, 153 bd. A. France, 93 521 St Denis Cedex
Tél. 01.49.46.24.30, fax. 01.49.46.24.35

Page No: 1 of 13
Made by:
Date :

MPLE RE WALL DESIGN
E Wall - Polymeric system

φ'	c'	γ	K_a
30deg	0	20.0 kN/m3	0.333
30deg	0	20.0 kN/m3	0.333
30deg	0	20.0 kN/m3	

Soil Reinforcement

Polymer strip Grades	Tensile Strength (Mpa)
G30	30
G50	50
G70	70
G100	100

ial (kN/m³)
aterial
Years

N/m²) = 24kN/m2 Horizontal load on parapet (kN/m) = 10 kN/m

rs
Reinforcement : -

or	=	1.55
ctor	=	1.05
duction factor	=	1.05
or	=	1.709
on(C_i)	=	0.800
ding(C_{ds})	=	0.900
for polymeric reinforcement, f_m	=	1.709
of failure of the structure, f_s	=	1.1

		ULS	SLS
To be applied to tan ϕ'_p	f_{ms}	1.0	1.0
To be applied to c'	f_{ms}	1.6	1.0
To be applied to c_u	f_{ms}	1.0	1.0

l reinf interaction : -

Sliding across surface of reinf	f_s	1.3	1.0
Pull - out resistance to reinf	f_p	1.3	1.0

ety

apacity to be applied to q_{ult}	f_{ms}	1.35	1.0
structure or any horizontal surface where there is soil to soil contact			
	f_s	1.2	1.0

Road level)

h	11.600 m
D_m	1.000 m
H_T	12.600 m
H	11.960 m
L	8.800 m
T_P	0.160 m
T_m	0.640 m

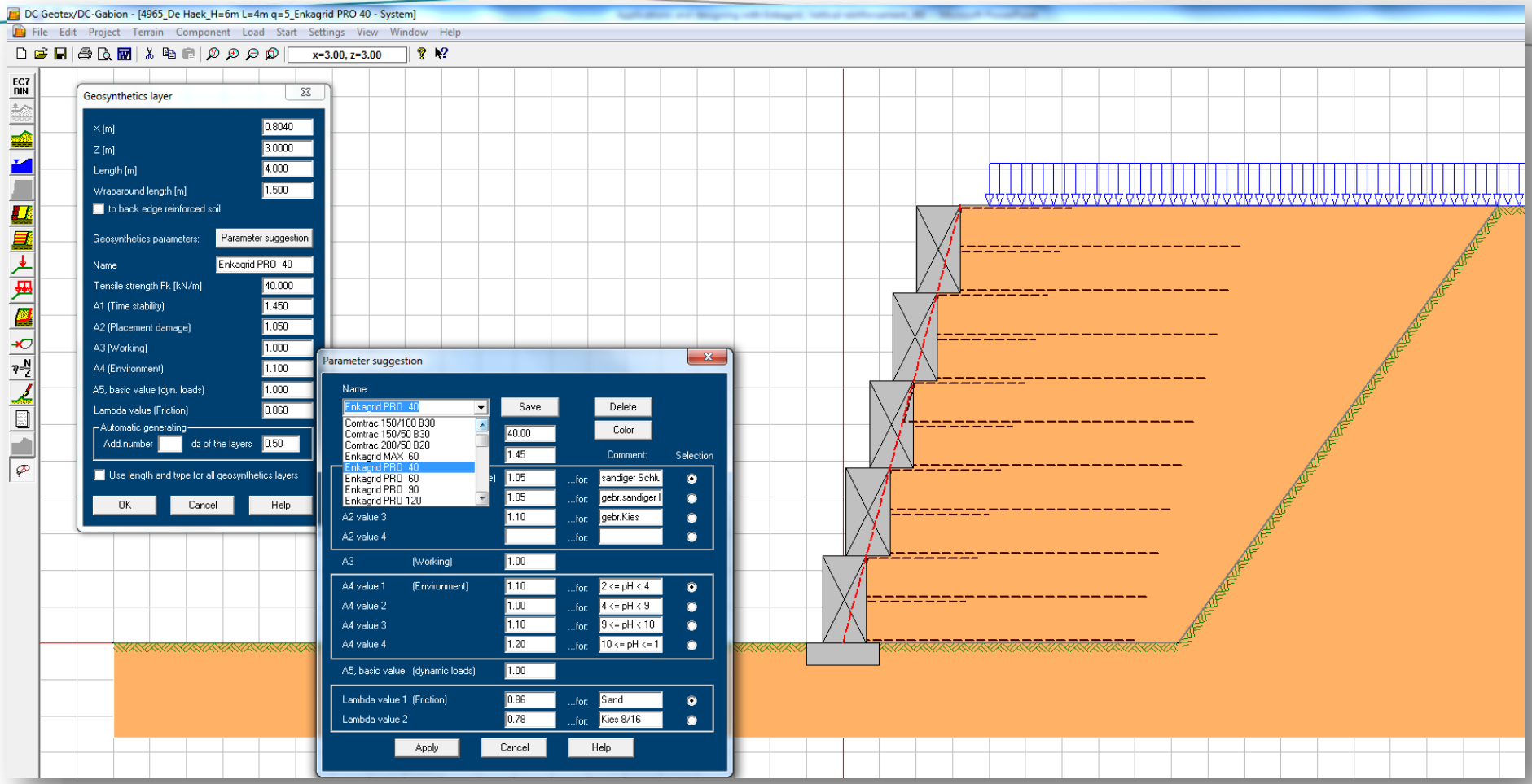
wall
oil block
Panel
aterial

BILITY CHECK

	Rupture	FS_{PO}	Bond	FS_{TEN}	Rupture	FS_{PO}	Bond	FS_{TEN}	Rupture	FS_{PO}	Bond
27	✓	1.55	✓	10.49	✓	1.48	✓	5.21	✓	1.16	✓
40	✓	1.41	✓	7.10	✓	1.42	✓	3.94	✓	1.14	✓
48	✓	1.25	✓	3.81	✓	1.31	✓	2.46	✓	1.09	✓
21	✓	1.49	✓	2.73	✓	1.54	✓	1.91	✓	1.29	✓
10	✓	1.86	✓	2.25	✓	1.87	✓	1.65	✓	1.58	✓
01	✓	2.23	✓	1.89	✓	2.17	✓	1.45	✓	1.86	✓
10	✓	3.12	✓	1.98	✓	2.99	✓	1.58	✓	2.61	✓
30	✓	2.72	✓	2.25	✓	2.59	✓	1.84	✓	2.29	✓
15	✓	2.93	✓	1.94	✓	2.76	✓	1.64	✓	2.49	✓
03	✓	3.13	✓	1.68	✓	2.91	✓	1.46	✓	2.67	✓
16	✓	4.14	✓	1.84	✓	3.79	✓	1.65	✓	3.56	✓
05	✓	4.34	✓	1.62	✓	3.91	✓	1.49	✓	3.75	✓
07	✓	3.62	✓	1.59	✓	3.19	✓	1.51	✓	3.15	✓
21	✓	4.69	✓	1.76	✓	4.04	✓	1.72	✓	4.10	✓
10	✓	4.82	✓	1.55	✓	4.05	✓	1.57	✓	4.24	✓
01	✓	4.92	✓	1.36	✓	4.01	✓	1.44	✓	4.36	✓
06	✓	4.05	✓	1.37	✓	3.19	✓	1.52	✓	3.61	✓

DC-Geotex software

Enka solutions



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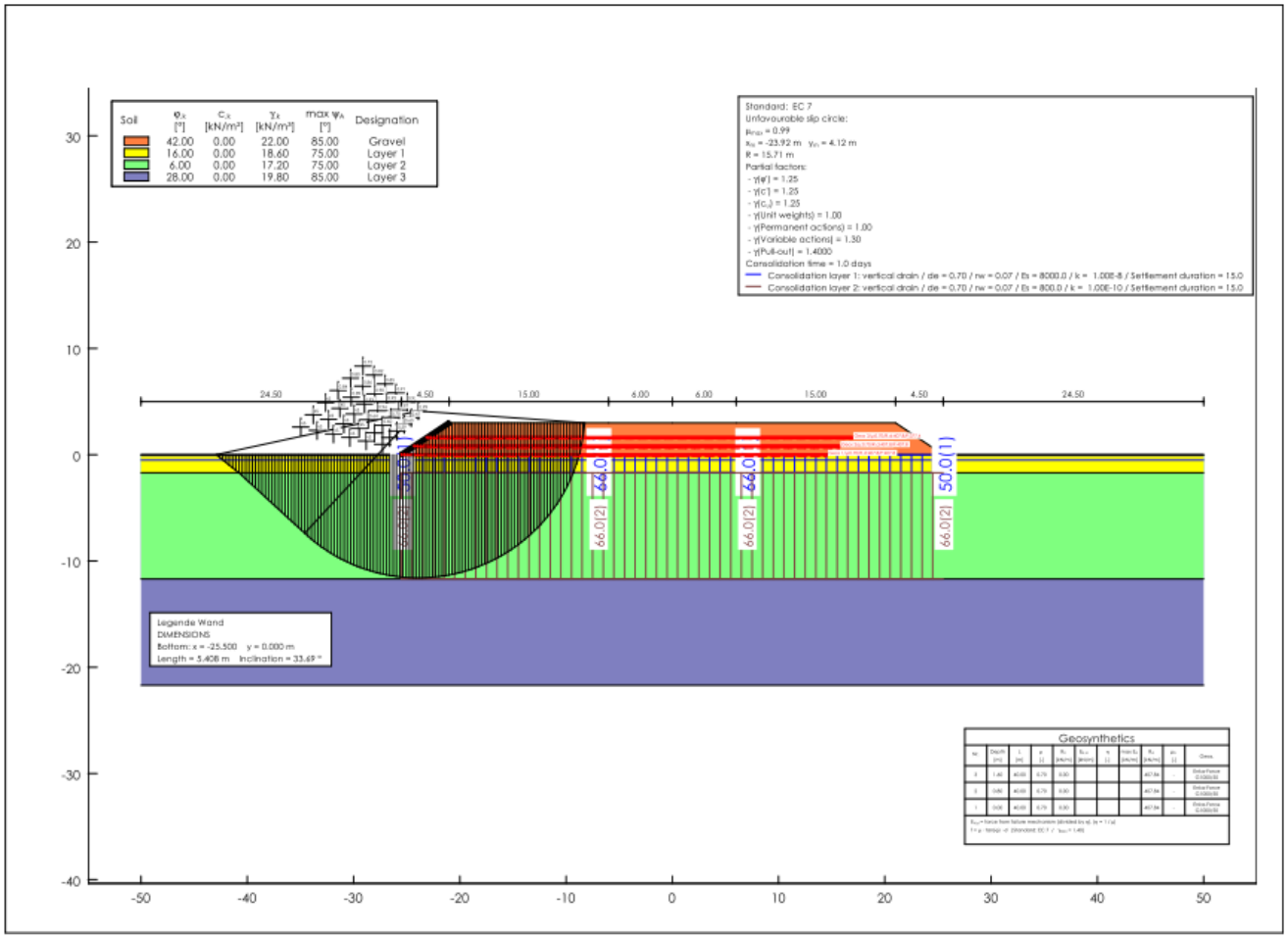
GGU software

Enka solutions



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For complex loadings or geometries compound design checks are required

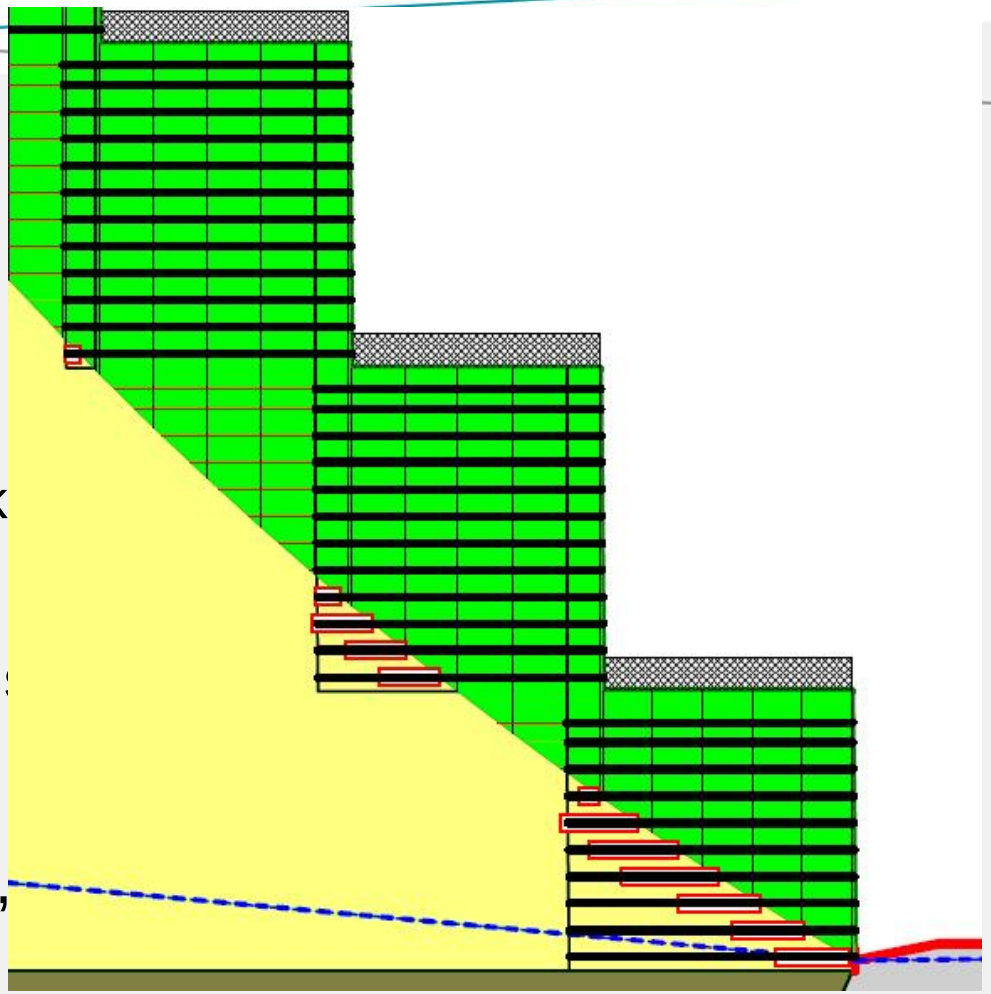
Enka solutions

Design Criteria
Compound Stability

1. Combination of global and internal stability checking circular or planar failure surfaces passing partially through the reinforced block

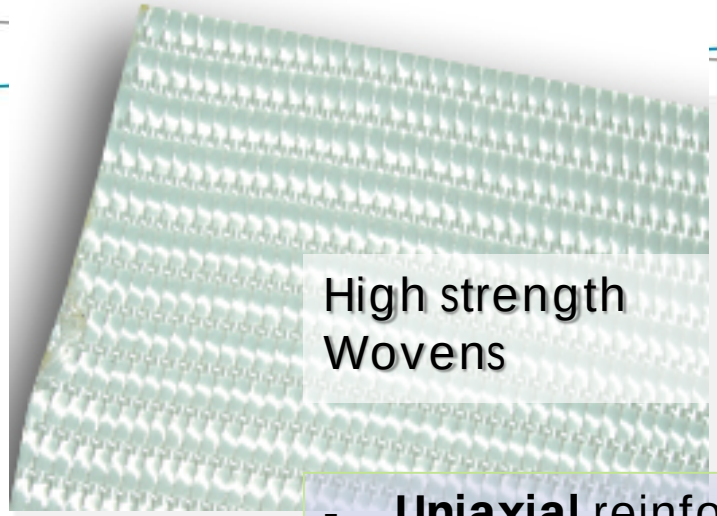
2. Essential check for complex wall geometries and loadings

Commercial packages include:
Geo5 MSEW & Slope, SlopeW, TALREN, DC Geotex, etc

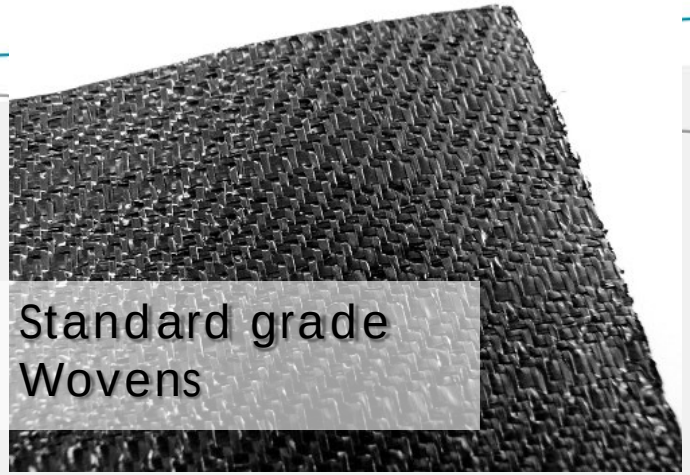


Types of reinforcement material

Enka solutions



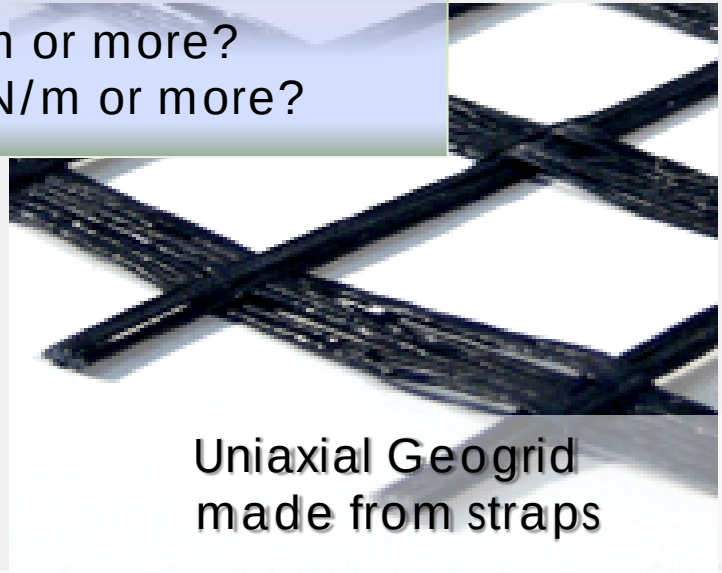
High strength Wovens



Standard grade Wovens

- **Uniaxial** reinforcement
- **Geogrids** up to 350 kN/m or more?
- **HS Wovens** up to 1250 kN/m or more?

Uniaxial Geogrid made from straps



Uniaxial Geogrid made from straps

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Product related specifications

Enka solutions

$$LTDS = \frac{UTS}{RF_{CR} \cdot RF_{ID} \cdot RF_{CN} \cdot RF_{DU} \cdot SF}$$

- A1: reduction factor for creep
- A2: reduction factor for installation damage
- A3: reduction factor for connection
- A4: reduction factor for durability

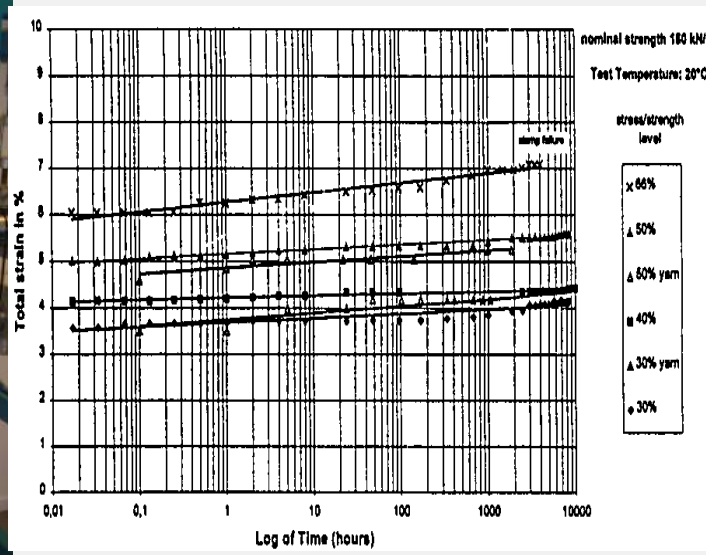
Product related specifications

Enka solutions

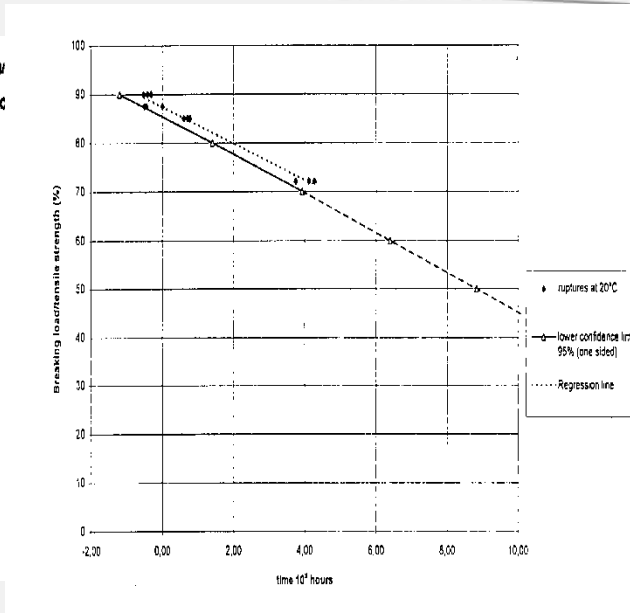
Determination of the tensile strength in accordance with EN ISO 10319:

Product related specifications

Enka solutions



Creep Curves



Creep Rupture

Creep data tested on continuous samples for over 25 years.

Results are plotted for creep as linear deformation vs log time

For creep rupture linear or log load vs log time.

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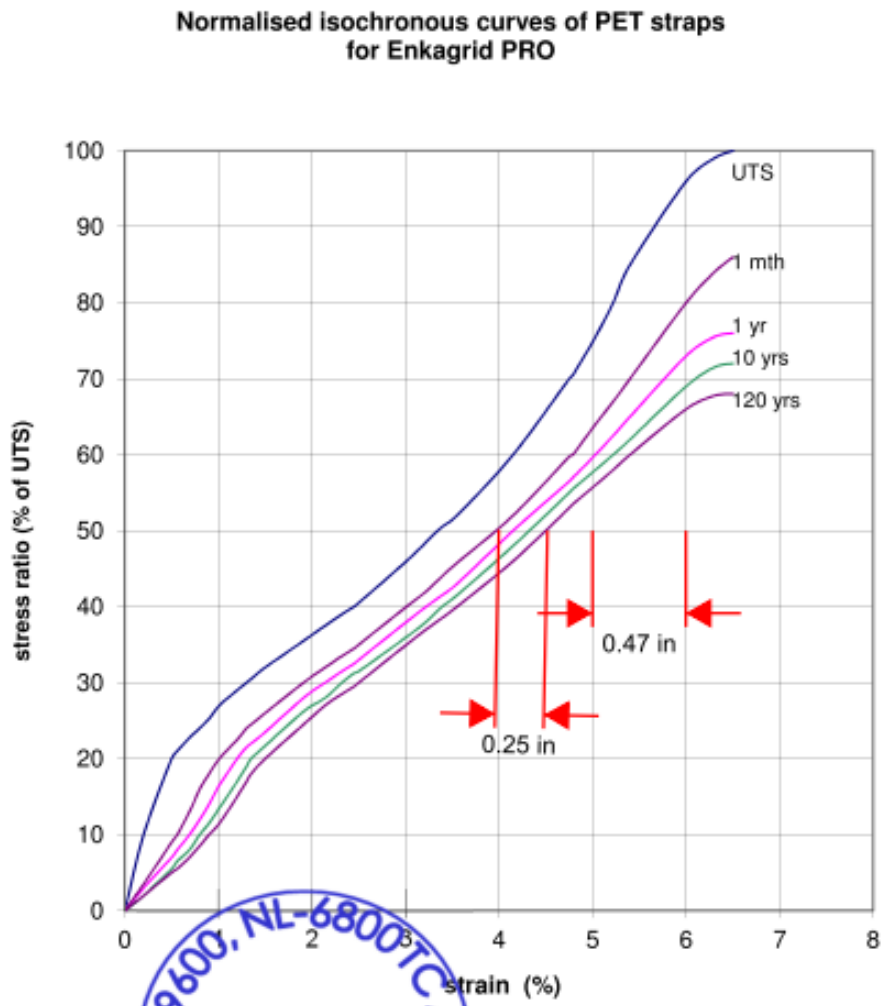
Product related specifications

Enka solutions



From creep curves at different stress grades isochronous stress strain curves may be derived and extrapolated for prediction of structural deformation at a given time.

Bonar BV, Arnhem (NL)
Product Management

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Installation damage reduction factor (A2)

Field test at La Grave

Product related specifications

Enka solutions

Direct physical testing of connection strength.

Product related specifications

Enka®solutions

Durability Testing:

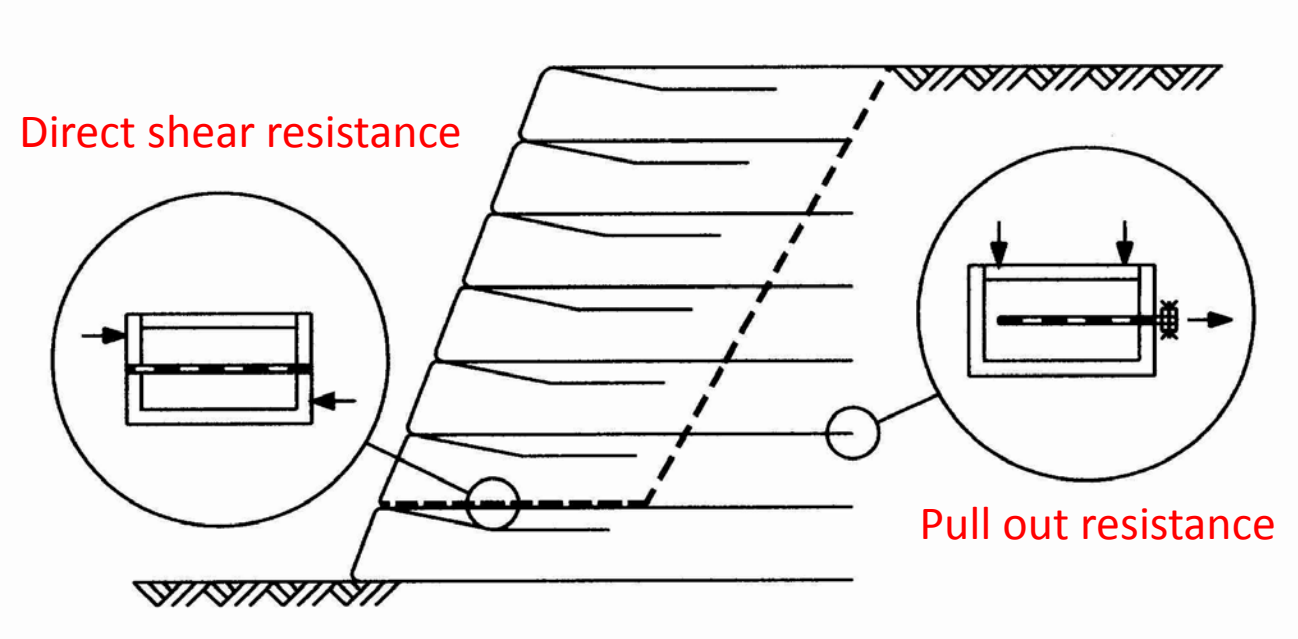
- Hydrolysis
- Oxidation
- UV Degredation
- Weathering

Used to determine design reduction factors and application specific exposure limits (pH values of soil, storage & installation procedures, exposure limitation and protection)

Product related specifications

Enka solutions

- Interaction:



Product related specifications

Enka®solutions

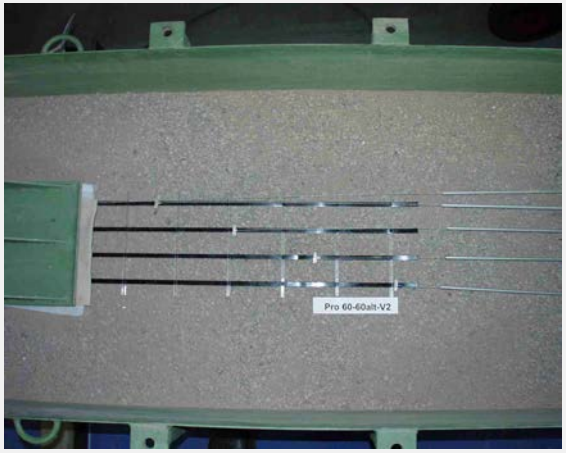
- Pull out resistance:
  - Summarizes the friction behaviour of both the top and the bottom surface and the soil or fill material.
  - Geogrid as anchorage layer
  - Anchorage force depends on interaction behaviour
  - Mobilize tensile forces from the active part => stable part

Product related specifications

Enka®solutions

- Pull out resistance test EN 13738:

  Apply a horizontal force to a specimen embedded between two layers of soil under different normal stresses. The pullout force is recorded.



soil	type	c_i	Test reports
Sand	PRO	0.86	GeoSyntec GLI0856
gravel	PRO	0.78	tBU 2003
sandy gravel	MAX	1.00	GeoSyntec GLI0856

Product related specifications

Enka solutions

- Direct shear resistance:
  - The angle of friction
  - shear resistance is critical for the direct sliding resistance
  - The test velocity is 1 mm/min. The tests should be carried out with 3 normal stresses

Monitoring

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Monitoring

Enka solutions

Extensometers and strain gauges on reinforcement & pressuremeters within the fill.

- A more academic approach to structures which is seldom performed but which has proven the approximations of peak load positions, working strains and pressure distribution used within the designs

Survey points on wall profile, inclinometer with pore pressure measurement behind/within structure, sacrificial reinforcement samples for durability verification over time.

- Practical approach to monitor structural movement, particularly after concerns are raised and guarantee confidence.

Section Tétouan/Jebha – Morocco / Pk4+ 370-750
273 000 sqm of Enkagrid PRO – Ht = 31 m

Thank you for your attention
Any Questions?

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