Geosynthetics and Reinforced Soil Structures

Reinforced Soil Walls

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Outline of the Lecture

- Different Standards for Reinforced Soil Retaining walls
- Materials required
- Fundamentals of earth pressure theories
- Stability Analysis of Reinforced Soil Retaining Walls

Codes and Design Standards for the Reinforced Soil Retaining Walls

- BS 8006 Strengthened/Reinforced Soils and Other Fills, British Code of Practice (1995 & 2006)
- FHWA Mechanically Stabilised Earth Walls and Reinforced Soil Slopes: Design and Construction Guidelines, FHWA-NHI-0043 (2001)
- Segmental Retaining Walls, National Concrete Masonry Association, Herndon, Virginia, USA(2009)
- Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments, NCHRP National Cooperative Highway Research Project, Transportation Research Boads, Washington, DC USA (2008)

Comments on Design Codes

BS 8006-1995

- Limit State Based code
- Covers both polymeric and metallic reinforcements
- Reinforced walls, slopes and Anchored Earth are discussed elaborately
- Seismic Loads are not considered

FHWA NHI-00-0043

- Lumped factor of safety approach
- Covers metallic and polymeric reinforcement materials, but not anchored earth
- Slightly more tolerant of fine soils
- Seismic design

Major differences between BS 8006 and FHWA

BS 8006

- Limit state
- No check for overturning and eccentricity
- Vertical stress – simple static pressure

$$\sigma_v = \gamma z + w_s$$

FHWA

- Lumped Factor of Safety
- Checks for overturning and eccentricity
- Vertical stress – Meyerhoff pressure

$$\sigma_v = \frac{R_v}{L - 2e}$$

Soil gradation requirements

Percent passing

Particle size (mm)	BS8006-1995
125mm	100%
90mm	80-100
75mm	65-100
37.5	45-100
10mm	15-60
5mm	10-45
600 microns	0-25
63 microns	0 to 12

particle size	FHWA
102 mm	100%
0.425 mm	0-60%
0.075 mm	0-15%

Plasticity index < 6%

Electrochemical properties of soils

Property	criteria

Limits for backfills when using steel reinforcement

Resistivity	> 3000 Ohm-cm
pH	5-10
Chlorides	< 100 ppm
Sulphates	< 200 ppm

Organic content< 1%
Plasticity index of soil < 6%

Limits for backfills when using geosynthetic reinforcement

Polyester (PET) pH 3-9
Polyolefin (PP & HDPE) pH > 3
Plasticity index of soil < 6%

Suitable Type of Backfill Soils

- Soil should be granular so that it has good permeability and less corrosive effects on reinforcements.
- Good drainage is essential to minimise the hydrostatic pressures on the retaining structures.
- Soil should have low PI value so that volume changes during the service life are minimal (both expansive and contractive)
- Soil should not have very large size particles as they are difficult to compact and installation damage of geosynthetics could be high.

Shear Strength Properties

- Direct shear strength values are used
- Peak friction angle is used for all steep slopes and retaining walls
- Large strain friction angle (constant volume friction angle) is used for shallow slopes and soil structures supported on soft soils
- Cohesion is usually neglected as it gives an additional factor of safety

Sacrificial thickness on each surface due to corrosion

Design service life, years	Reinforce material	Sacrificial thickness, mm	
		Land based structure (out of water)	Fresh water structure
60	B	1.35	1.68
	G	0.38	0.63
	S	0.05	0.09
70	G	0.45	0.7
	S	0.05	0.1
120	G	0.75	1.0
	S	0.1	0.2

NOTE 1. B black steel (un galvanized); G galvanized steel; S stainless steel. Black steel should not be used as a reinforcement material for a design service life greater than 60 years.
NOTE 2. Linear interpolation may be used for intermediate service lives.
NOTE 3. These values apply to steels embedded in fills of class 6I, 6J, 7C, 7D in the Specification for Highway Works [1].
NOTE 4. Sites of special aggressiveness are to be assessed by specific study.

(Extracted from BS 8006-1995)

Lateral Earth Pressures

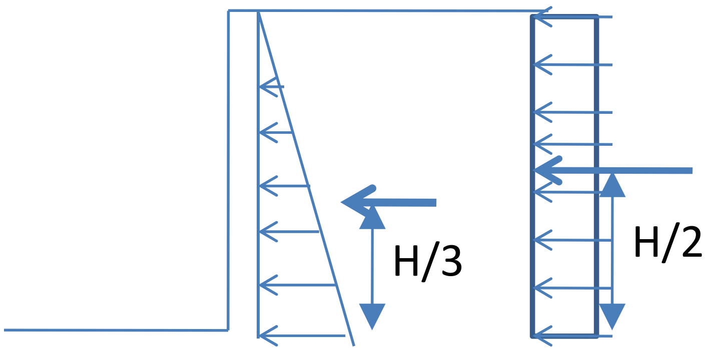
- Active earth pressures are used as they are developed even at small strains
- The lateral stresses at shallow depths in very tall structures may be influenced more by compaction – these may be near to K_o rather than to K_a.
- The above happens due to the incremental nature of construction of soil structures – top of the wall may not deform much as compared to the bottom

Rankine Lateral Earth Pressures

Horizontal ground surface and smooth vertical wall

$$K_a = \frac{1-\sin\phi}{1+\sin\phi}$$

$$\sigma_x = K_a \gamma z - 2c\sqrt{K_a} + K_a q$$



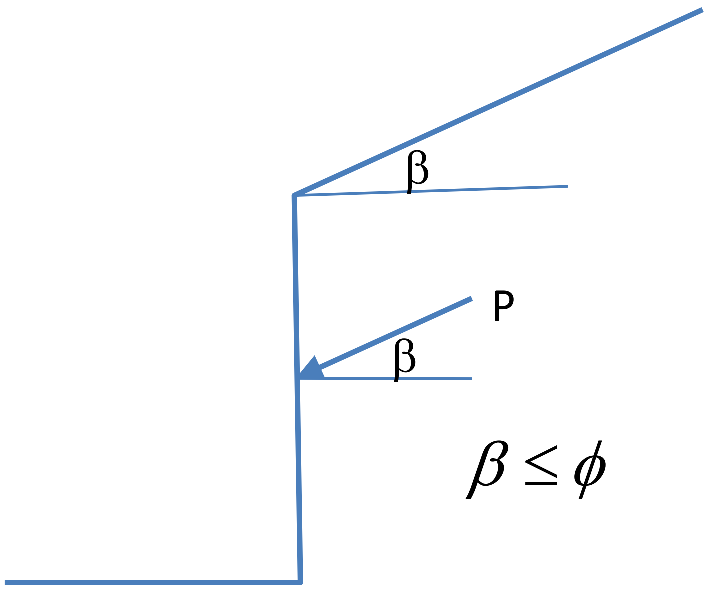
Cohesion, c is usually neglected

$$P = \frac{1}{2} K_a \gamma H^2 + K_a q H$$

$$M = \frac{1}{2} K_a \gamma H^2 \times \frac{H}{3} + K_a q H \frac{H}{2} = \frac{1}{6} K_a \gamma H^3 + \frac{1}{2} K_a q H^2$$

Rankine's theory – Sloped Fill

$$K_a = \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}\cos\beta$$

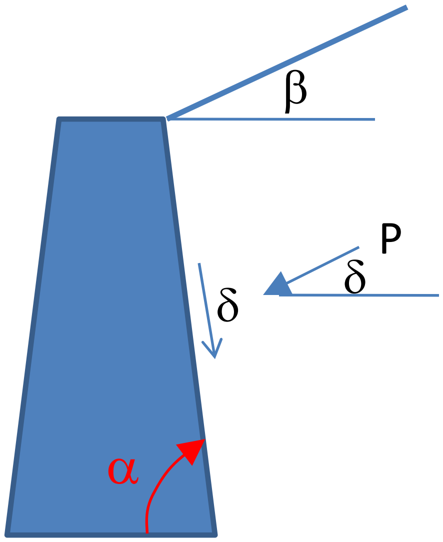


$$\beta \le \phi$$

$$P_a = \frac{1}{2}\gamma H^2 \cos\beta$$

Coulomb's equation

$$K_a = \frac{\sin^2(\alpha + \phi)}{\sin^2\alpha \sin(\alpha - \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \beta)}{\sin(\alpha - \delta)}}\right]^2}$$



β = back slope angle

α = angle at back face of retaining wall

φ= friction angle of the soil

δ= interface friction angle between wall and backfill soil

Effect of wall friction is to reduce the active lateral earth pressures

Design Loads

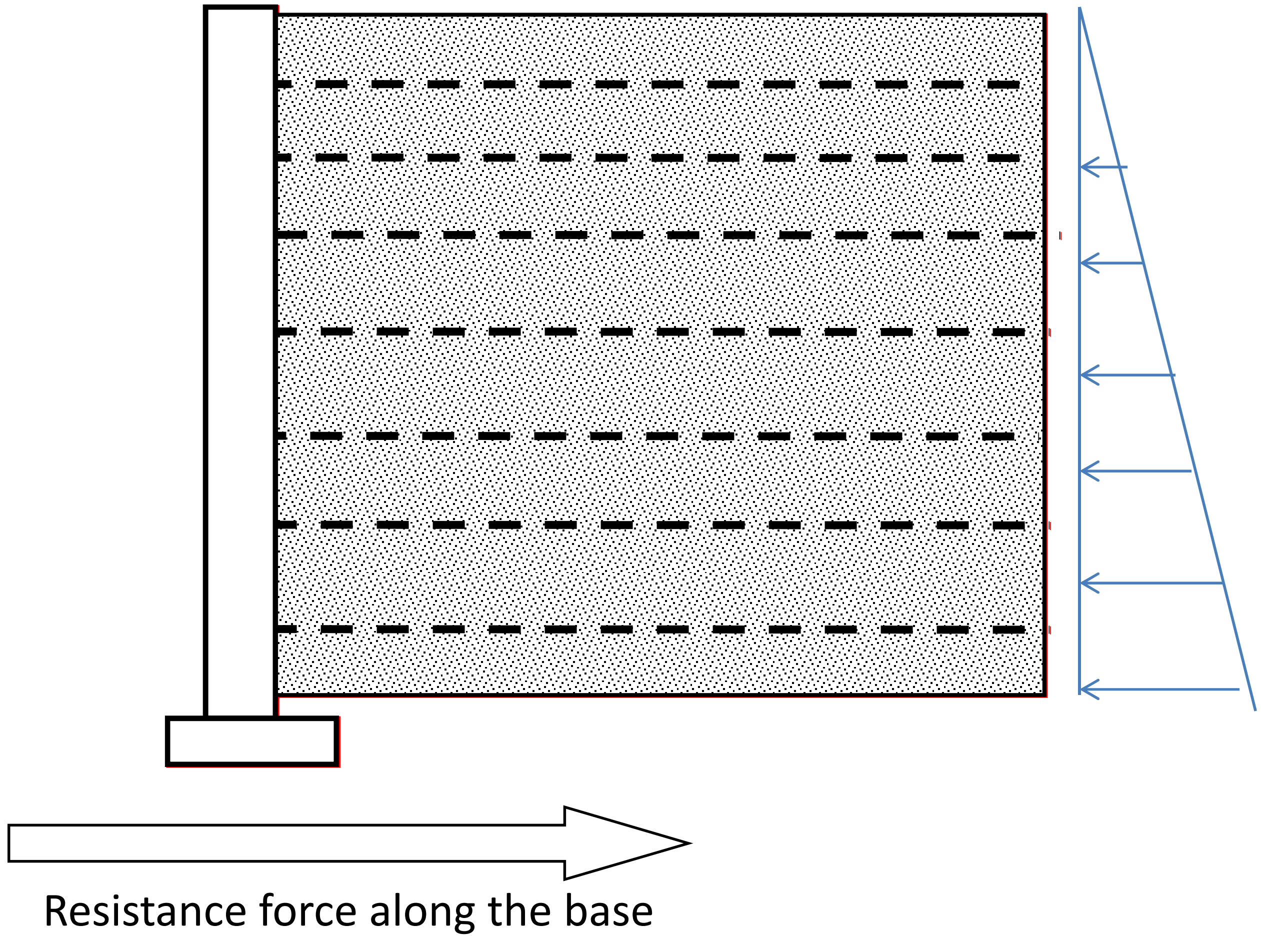
- Self weight loads
- Live loads due to point loads or uniform surcharge
- Horizontal Loads from the crash barrier
- Horizontal loads due to breaking forces on bridge abutments
- Vertical loads from Bridge abutments
- Seismic loads

External Stability Calculations

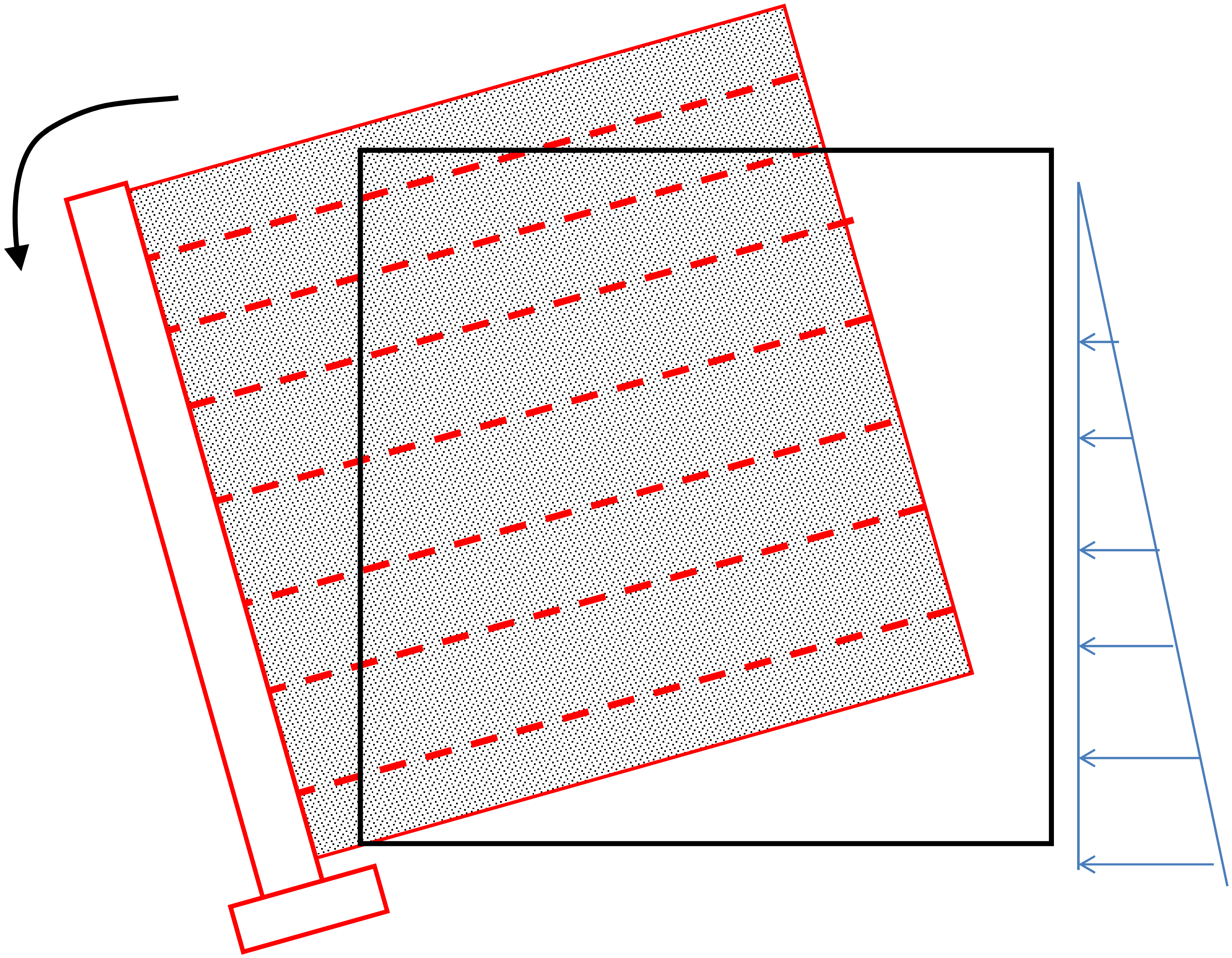
- Stability Against Lateral Sliding
- Stability against Overturning
- Stability Against bearing capacity failure
- Slip circle or overall failure mechanism

The length of the reinforced soil block is determined from these calculations.

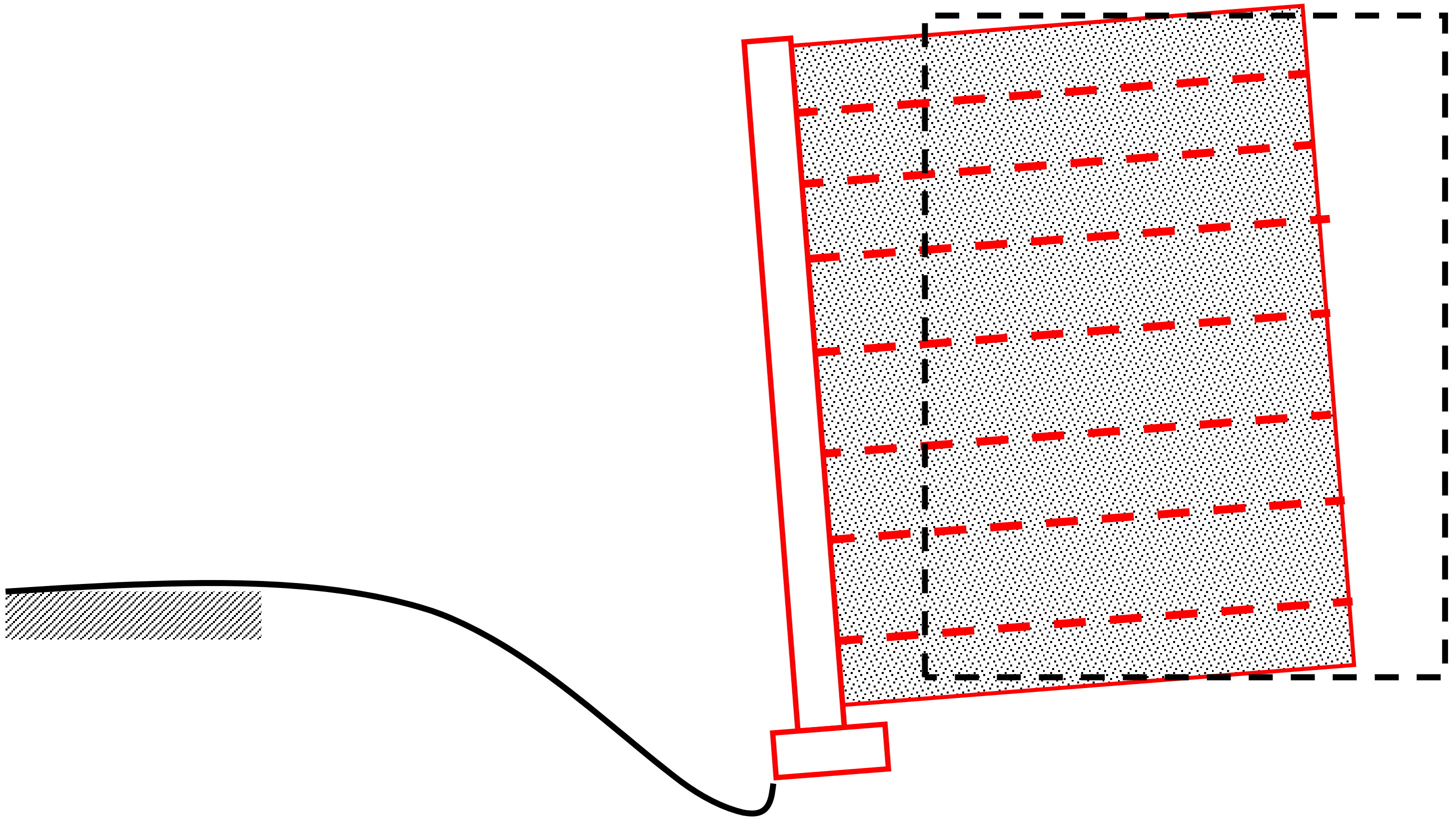
For the purpose of external stability calculations, the reinforced block is treated as a rigid block.



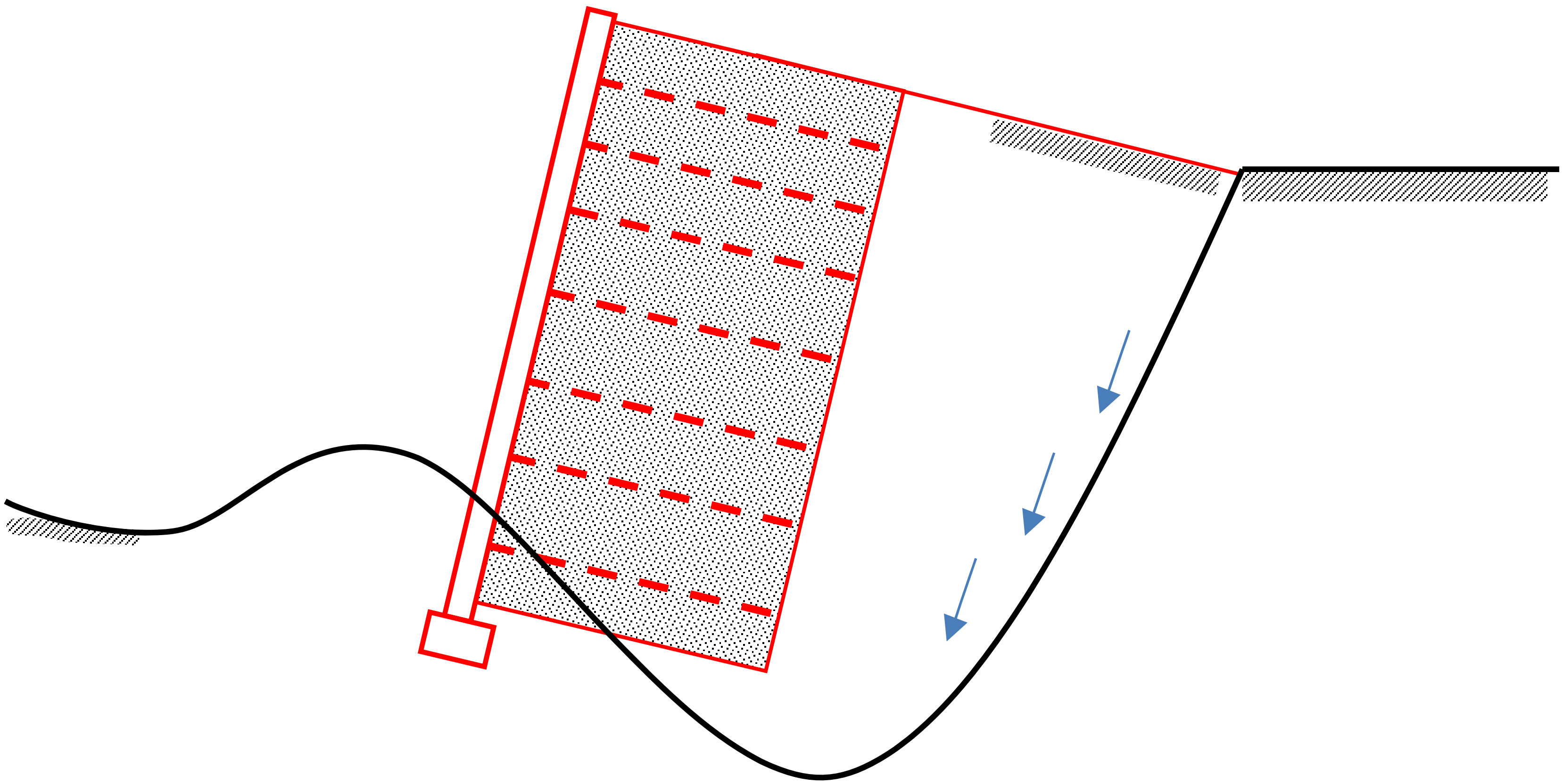
Lateral Sliding Failure Mechanism



Overturning mechanism of failure – resistance due to self weight of the reinforced soil block



Bearing capacity of settlement failure mechanism



Slip circle failure or Global failure mechanism – length of reinforcement layers should be large enough so that most critical slip circle will have adequate factor of safety – this is especially critical for structures built on soft foundation soil or structures built on high slopes

Load combinations in BS 8006

Partial load factors for load combinations associated with walls			
Effects	Combinations		
	A	B	C
Mass of the reinforced soil body	1.5	1	1
Mass of the backfill on top of the reinforced soil wall	1.5	1	1
Earth pressure behind the structure	1.5	1.5	1
Traffic load on reinforced soil block and behind reinforced soil block	F_q=1.5 F_q=1.5	F_q=0.0 F_q=1.5	F_q=0 F_q=0

Partial load factors for load combinations for bridge abutment walls				
Effects		Combinations		
		A	B	C
Dead load of the structure		1.5	1	1
Dead load of the fill on top of the structure		1.5	1	1
Dead load of bridge and bank seat		1.2	1.0	1
Backfill pressure behind the bank seat		1.5	1.5	1
Backfill pressure behind the structure		1.5	1.5	1
Horizontal loads due to creep and shrinkage		1.2	1.2	1
Traffic Loading		Over the entire structure F_q=1.5	Behind reinforced zone F_q=1.5	
Bridge vertical live load	**HA** **HA & HB**	**Fq=1.5** Fq=1.3	Fq=1.5 Fq=1.3	
Breaking dynamic load	HA HA & HB	Fq=1.25 Fq=1.1	Fq=1.25 Fq=1.1	
Temperature effects		1.3	1.3	

Combination-A: Considers the maximum values of all loads and therefore normally generates the maximum reinforcement tension and foundation bearing pressure. It may also determine the reinforcement requirement to satisfy pull-out resistance although it is usually governed by combination-B.

Combination-B: Causes maximum overturning loads together with minimum self mass of the structure and superimposed traffic loads. Dictates the reinforcement requirement for pull-out resistance and sliding along the base.

Combination-C: Dead loads only without partial load factors. Used for foundation settlement calculations and for generating reinforcement tensions for checking the serviceability limit state.

What is the height of the wall, H to consider for design purposes ?

Recap

- This lecture has described the different design standards for the reinforced soil retaining walls and some design issues
- Discussed the external stability calculations for these walls

Questions ????

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