British standard code of practice. BS8006

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ABSTRACT:

The British Standard Code of Practice B S8006 was the first design Code of Practice to cover the full range of reinforced soil applications of vertical walls, steep slopes and embankment foundations. It was written in a limit state format and calibrated against the existing design methods that were being used at the time. The document is in the process of being revised to take advantage of any developments that have taken place since it was published in 1995.

1 CONCEPTS AND FUNDAMENTAL PRINCIPLES

In order to satisfy the requirements of a limit state code partial load factors are applied to the actions and material factors are applied to the material properties. Once the factors have been applied the requirement for stability is that the design restoring forces and moments should be greater than the design disturbing forces and moments. In a particular application the load factors applied to dead loads and live loads can vary depending on the load combination under consideration; in some circumstances the partial load factors for live loads may be set at zero to produce a worst case combination for the design load.

The loads, both dead and live, are calculated in their unfactored form as characteristic values which then have the appropriate partial factor applied to give the design load.

The resisting forces in any application are generated from the available shear strength of the soil and the tensile strength of the reinforcing elements. The shear strength of the soil, allowing for any pore pressure, should be a characteristic value determined as a cautious estimate of the value recognizing the limit state under consideration. For walls and slopes the peak friction angle is used. In all applications the consideration of external, internal and compound stability is required. For internal and compound stability the resistance provided by the soil is supplemented by the strength of the reinforcement.

The reinforcement strength is derived following a procedure described in an Annex of the document. Reinforcement is defined as being extensible if the design strength is sustained at a total axial strain value > 1%, and inextensible if the design strength is sustained at a total axial strain < 1%. This definition can determine the actual design method adopted for a particular application.

The Code of Practice is applicable to all types of geosynthetic and steel soil reinforcement.

2 VERTICAL WALLS AND BRIDGE ABUTMENTS

The principles described in the previous section apply to both reinforced soil walls and bridge abutments which are designed as vertical structures. Other structures with facing angles within 20^0 of the vertical can also be designed as vertical structures to the Code. Table 17 (Table 1) of the Code gives the partial load factors for load combinations associated with walls and Table 18 (Table 2) gives the same information relating to bridge abutments. Soil material factors can be extracted from Table 16 (Table 3) with a number of partial factors of safety relating to soil/reinforcement interaction, foundation bearing capacity and sliding along the base of the structure.

The most adverse loads likely to occur should be considered.

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		$f_q = 1.3$	$f_q = 1.3$	

Table 1. Partial Load Factors for Walls

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		$f_q = 1.3$	$f_q = 1.3$	

Table 2.Partial Load Factors for Abutments

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	$f_{ms} = 1.0$	$f_{ms} = 1.0$

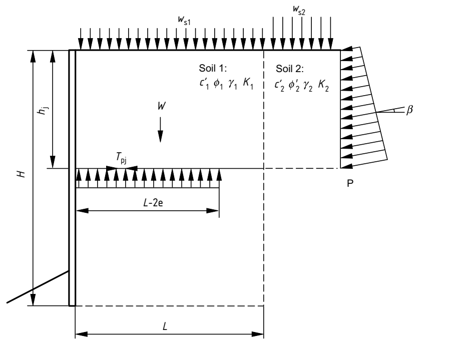
Soil/reinforcement interaction factors	Sliding across surface of reinforcement	$f_s = 1.3$	$f_s = 1.0$
	Pull-out resistance of reinforcement	$f_p = 1.3$	$f_p = 1.0$
Partial factors of safety	Foundation bearing capacity: to be applied to q_{ult}	$f_{ms} = 1.35$	NA
	Sliding along base of structure or any horizontal surface where there is soil-to-soil contact	$f_s = 1.2$	NA

Table 3. Partial Material Factors for Soils and partial safety factors

3 DESIGN METHODS FOR WALLS

The design approach to wall design is based on the classification of the reinforcement materials, whether the reinforcement is extensible or inextensible. Extensible reinforcement is designed using the Tie-Back Wedge method where the stress condition within the reinforced soil block is taken to be an active stress state and wall friction on the back of the block is zero. Figure 1.

When inextensible reinforcement is used the Coherent Gravity the design method is used with a stress condition within the reinforced soil block that varies between the “at-rest” condition in the upper zone reducing to active conditions deeper in the structure with wall friction calculated. Figure 2.



NOTE $\beta = 0$ for tie back wedge method, $\beta = (1.2 - L/H)\phi'_2$ for coherent gravity method.

Figure 1. Stresses imposed by the soils and surcharges

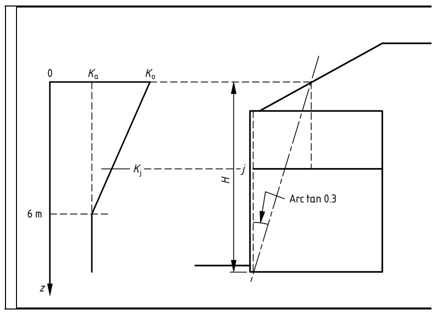


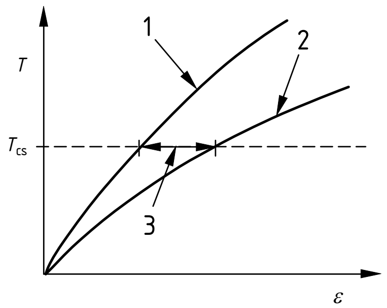
Figure 2. Coherent Gravity Stress state

3.1 *Ultimate Limit State*

The appropriate partial factors are applied to the loads and materials depending on the Load Case under consideration. Load Case A with maximum factors applied throughout is normally the critical condition for reinforcement capacity and foundation bearing pressure and sometimes governs reinforcement anchorage. Load case B, with minimum mass of the structure but maximum overturning forces is normally critical for sliding along the base of the reinforced soil block and reinforcement anchorage.

3.2 *Serviceability Limit State*

Load Case C with dead loads only and partial factors of unity is used to determine the serviceability limit states of foundation settlement and reinforcement tension for internal strains. The limit value of reinforcement tension in the serviceability check is defined by a theoretical post-construction strain value. For a wall the limit is 1% and therefore the SLS allowable load carrying capacity is the value at which the reinforcement would strain 1% between the end of construction and the end of the design life. Figure 3.



Key

1. Isochrone for end of construction
2. Isonchrone for end of design life
3 Prescribed post-construction strain limit

Figure 3. Assessment of post construction strain

For an abutment the limiting post construction strain is 0.5%.

4 REINFORCED SLOPES

The design methods for reinforced slopes, generally defined as those slopes with face angles greater than 20^0 to the vertical, are all derived from limit equilibrium methods, originally derived for unreinforced slopes. The code does not limit the methods that can be used for design provided that they can be adapted to a limit state format. However it does describe the most common methods in some detail.

The partial factors are defined in Table 4. with only two load cases, ULS and SLS. The friction angle of the fill should be defined as the peak value and, as with the wall design, there are partial factors of safety applied to soil/reinforcement interaction and sliding along the base.

In order to achieve a measure of safety which is equivalent to the acceptable values for unreinforced slopes in circular slip and log spiral analyses it is necessary to apply a moment correction factor χ to the resisting moment. This should be done for both internal and external analyses.

For reinforced slopes where the face angle is 45^0 or less the need for a formal facing may not be required. In those situations the reinforcement capacity close to the front face may be limited because of bond although higher shear strengths may be mobilised because of the low confining stress. A check of superficial stability can be carried out to assess the stability of a free face in resistance to sliding on a plane that is very close, and parallel, to the slope surface.

	Partial factors	Ultimate limit state	Serviceability limit state
Load factors	Soil unit mass, e.g. slope fill,	$f_{fs} = 1.5$	$f_s = 1.0$
	External dead loads, e.g. line or point loads	$f_f = 1.2$	$f_f = 1.0$
	External live loads, e.g. traffic loading	$f_q = 1.3$	$f_q = 1.0$
Soil material factors	To be applied tan ϕ'_p	$f_{ms} = 1.0$	$f_{ms} = 1.0$
	To be applied to c'	$f_{ms} = 1.6$	$f_{ms} = 1.0$
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** 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	Sliding along base of structure where there is soil-to-soil contact	$f_s = 1.2$	NA

Figure 4. Partial factors for reinforced slopes

It is noted in the code that compound stability considerations where a slip surface passes partially through the reinforced fill and partially through the unreinforced fill may well be the critical situation.