Countdown to Eurocode 7: preparing for March 2010

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Outline of presentation

- General rules of Eurocode 7 for Slopes
- Implications of EC7 for slopes
  - Stability of circular slip surfaces
- Current developments in EC7 and NCCI documents
- Adapting to EC7 and use of software
- Summary of key points
General rules of Eurocode 7 for Slopes

Contents of EN 1997-1 Sections 11 and 12

Section 11 Overall stability
Section 12 Embankments

§x.1 General (2/2 paragraphs)
§x.2 Limit states (2/2)
§x.3 Actions and design situations (6/8)
§x.4 Design and construction considerations (11/13)
§x.5 Ultimate limit state design (26/7)
§x.6 Serviceability limit state design (3/4)
§11.7 Monitoring (2)/§12.7 Supervision and Monitoring (5)
Contents of EN 1997-1 Sections 11 and 12 (cont)

Scope
- Section 11 covers overall stability of the ground and movements in the ground related to foundations, retaining structures, natural slopes, embankments, and excavations
- Section 12 covers embankments for small dams and infrastructure

Supervision, monitoring, and maintenance
- Slopes must be monitored when
  - occurrence of limit states cannot be proven sufficiently unlikely by calculation or prescriptive measures
  - assumptions made in calculations are not based on reliable data
- Monitoring should provide
  - ground-water levels or pore-water pressures for effective stress analysis
  - lateral and vertical ground movements
  - depth and shape of existing slide (for remedial work)
  - rates of movement
Limits states for slopes and embankments

Limit states for slopes/embankments include:

- Loss of overall stability of the ground and associated structures
- Excessive movement
- Loss of serviceability

Limits states for slopes and embankments

Section 12 adds for embankments:

- Internal erosion
- Surface erosion or scour
- Deformations leading to
  - loss of serviceability
  - damage to adjacent structures
  - problems with transition zones
- Effects of freezing and thawing
- Degradation of base course materials
- Deformations due to hydraulic actions
- Changes in environmental conditions
**Design situations**

- Design situations must consider:
  - Construction processes
  - Previous or continuing ground movements
  - Effects of slope or embankment on existing structures or slopes
  - Vibrations
  - Climatic variations
  - Vegetation and its removal
  - Human or animal activity
  - Variations in water content or pore-water pressure
  - Wave action

**Design Approaches**

- Design Approach 1 applies partial factors to ...
  - actions in Combination 1
  - unfavourable variable actions and material properties in Combination 2

- Design Approach 2 applies partial factors to ...
  - effects of actions and to resistances
  - but not to material properties
  - different factors for favourable and unfavourable actions

- Design Approach 3 applies partial factors to ...
  - material properties and a small factor to variable actions
  - but not to other actions or resistances
  - in DA3, all actions are treated as 'geotechnical' when designing slopes and embankments
Design Approach 1 Combination 1 for slopes and embankments

Design Approach 1 Combination 2 for slopes and embankments
Design Approach 2 for slopes and embankments

Design Approach 3 for slopes and embankments
National choice of Design Approach

Partial factor groupings

<table>
<thead>
<tr>
<th>Individual partial factor or partial factor ‘grouping’</th>
<th>Design Approach</th>
</tr>
</thead>
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<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Combination 1</td>
</tr>
<tr>
<td>$\gamma_c$</td>
<td>1.35</td>
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<tr>
<td>$\gamma_{G,fav}$</td>
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</tr>
<tr>
<td>$\gamma_Q$</td>
<td>1.5</td>
</tr>
<tr>
<td>$\gamma_\phi = \gamma_c$</td>
<td>1.0</td>
</tr>
<tr>
<td>$\gamma_{Re}$</td>
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<tr>
<td>$\gamma_c \times \gamma_c \times \gamma_{Re}$</td>
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<tr>
<td>$\gamma_c \times \gamma_c / \gamma_\phi$</td>
<td>1.35</td>
</tr>
<tr>
<td>$\gamma_{G,fav} \times \gamma_c / \gamma_\phi$</td>
<td>1.0</td>
</tr>
<tr>
<td>$\gamma_G / \gamma_G$</td>
<td>1.11</td>
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</tbody>
</table>

*Factor from Set A2 on geotechnical actions
Implications of EC7 for slopes

Key features of circular slip analysis
Bishop's ‘Routine’ (aka ‘Simplified’) Method

\[
F = \sum_i \left[ \frac{(c'_i b_i) + (W_i - Q_i - u_i b_i) \tan \phi_i \sec \alpha_i}{1 + \tan \alpha_i \left( \frac{\tan \phi_i}{F} \right)} \right] 
+ \sum_i (W_i - Q_i) \sin \alpha_i
\]

Applying partial factors to Bishop’s Method

- Applying partial factors is complicated by the iterative nature of circular slip analysis (or non-circular).
- It is unclear what parts of the equation are favourable or unfavourable at any point in the analysis. For example, when \( \alpha \) is negative, the self-weight of the slip reduces the overturning moment.
- There is therefore no fully logical way of applying \( \gamma_G \) and \( \gamma_{G,fav} \).
- Applying different partial factors to different materials may result in a different mechanism.
Current developments in EC7 and NCCI documents

TC250 SC7 is the CEN committee responsible for EC7. The maintenance sub-committee considers:
- all matters associated with the development of the code
- Collecting errors and ambiguities in the current text
- Re-writing some sections where different EN documents contradict each other, e.g. Anchorages
- Producing corrigendum and eventually further versions of the code

ETC10 is responsible for the evaluation of EC7
- Assessing current best practice and interpretation of the code
- Has produced a set of standard design examples for comparative purposes

No major changes currently proposed for Sections 11 and 12 of EN 1997-1
ETC10 examples

ETC10 has produced a set of examples for engineers to apply EC7 principles, please visit [www.eurcode7.com/etc10](http://www.eurcode7.com/etc10) and attempt problems, closing date end of December 2009

NCCI documents

Documents containing Non-conflicting complementary information (NCCIs) are being produced based on current British Standards and other recognised guidance documents e.g. CIRIA C580, Specification for Highways Works

Of particular relevance to slope engineering are BS 6031 - Earthworks and BS 8006 – Strengthened reinforced soils and other fills + BS5930, BS1377 etc
A draft of BS 6031 has been produced but is now closed for public comment.

It suggests that Design Approach 1 Combination 2 should be used for slopes.

- The overall stability of slopes should be checked against DA1 Combination 2. For completeness, DA1 Combination 1 should also be checked if the designer considers that the loading applied to the slope (other than the mass of the ground in the slope) might control the failure mechanism rather than the ground strength parameters (DPC BS 6031 §7.3.3).
- A minimum surcharge load of 10 kN/m² should be applied to the surface at the top of embankments and cuttings where the external action might adversely affect the stability of the slope. (DPC BS 6031 §7.2.3).

Combination 1 should only be used where there are large external forces acting on the slope. A three-stage method has been suggested by Frank et al, but this results in an equivalent factor of safety of at least 1.35 for the effective stress case.

The partial factors given in the NA annex to BS EN1997 should be used in routine work coupled with the other recommendations of EC7 for selection of design parameters.

BS 6031 points out that the partial factors may not be adequate where the risk of any slope failure is very high and may be too high for situations where residual strength is adopted – in this case it recommends $\gamma_f = 1.1$. 
DPC BS 8006 – Strengthened reinforced soils

- DPC BS 8006 states
  - BS EN 1997-1:2004 does not cover the design and execution of reinforced soil structures; the values of partial factors and load factors given in BS EN 1997-1:2004 have not been calibrated for reinforced soil structures. BS EN 1997-1:2004 should not be used in the design and execution of reinforced soil. In the UK, the design and execution of reinforced fill structures should be carried out in accordance with BS 8006-1 and BS EN 14475:2006. The partial factors set out in BS 8006-1 should not be replaced by similar factors in BS EN 1997-1:2004. (DPC BS 8006 §5.1)

Adapting to EC7 and use of software
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- Essentially if Design Approach 1 Combination 2 is used very little change is required except for:
  - Multiplying unfavourable variable actions by 1.3
  - Ensuring that the characteristic parameters and the design situation are appropriately conservative
- Software does not need to be modified - apply the partial factors to obtain design material properties and variable actions. As long as the resultant factor of safety quoted by the program is $\geq 1.0$ then the design complies with EC7
- The above only checks the ULS limit state, where necessary the SLS limit state must also be verified

Summary of key points
Summary of key points

- BS EN 1997 is already a current standard to which projects may be designed
- By March 2010 all conflicting standards will be withdrawn
- For slopes Design Approach 1 Combination 2 is recommended
- Combination 1 may be ignored for slope design except where external loading is high
- Care should be exercised in using the BS EN partial factors for all design situations and risk levels
- Current related BSs are being updated to remove conflicts or withdrawn

To be kept up-to-date on the developments of Eurocode 7
- www.eurocode7.com
- For discussion on the application of Eurocode 7 see
  - Bond & Harris (2008), Decoding Eurocode 7, Taylor and Francis