Outline of talk

- Overview of Eurocode 7
- New principles for geotechnical design
- Impact on retaining wall design
- Impact on pile design
- Benefits of Eurocode 7

This presentation is available from:
www.geocentrix.co.uk/eurocode7
Foundation design to Eurocode 7
Overview of Eurocode 7

Structural Eurocodes suite

- Main resistance Eurocodes:
  - Same Principles, different Rules
- Eurocode 7:
  - Same Rules, different Principles

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Eurocode 7 timetable

- Prospective standards for provisional application (ENVs)
  - ENV 1997-1: 1994 General rules
  - ENV 1997-2: 1999 Field testing
  - ENV 1997-3: 1999 Lab. testing
- Full European standards (ENs)
  - EN 1997-1 published December 2004
  - prEN 1997-2 available 2005
  - EN 1997-2 to be published late 2006?

Contents of EN1997-1 General rules

- §1 General
- §2 Basis of geotechnical design
- §3 Geotechnical data
- §4 Supervision
- §5 Fill, dewatering, etc
- §6 Spread foundations
- §7 Pile foundations
- §8 Anchorages
- §9 Retaining structures
- §10 Hydraulic failure
- §11 Overall stability
- §12 Embankments
- Annexes
Contents of prEN 1997-2
Design assisted by field and laboratory testing

Foundation design to Eurocode 7
New principles for geotechnical design
§2.1 Design requirements

- (1)P For each geotechnical design situation it shall be verified that no relevant limit state ... is exceeded
- (4) Limit states should be verified by
  - Use of calculations
  - Adoption of prescriptive measures
  - Experimental models and load tests
  - An observational method

Geotechnical categories

<table>
<thead>
<tr>
<th>GC</th>
<th>Includes...</th>
<th>Design requirements</th>
<th>Design procedure</th>
</tr>
</thead>
</table>
| 1  | Small and relatively simple structures... **with negligible risk** | Negligible risk of instability or ground movements
Ground conditions known
No excavation below water table | Routine design & construction methods |
| 2  | Conventional types of structure & foundation **with no exceptional risk** or difficult soil or loading conditions | Quantitative geotechnical data & analysis to ensure fundamental requirements are satisfied | Routine field & lab testing
Routine design & execution |
| 3  | Structures or parts of structures not covered above | Use alternative provisions and rules to those in Eurocode 7 |
## Example geotechnical categories

<table>
<thead>
<tr>
<th>GC</th>
<th>Includes...</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small and relatively simple structures... with negligible risk</td>
<td>None given in Eurocode 7</td>
</tr>
<tr>
<td>2</td>
<td>Conventional types of structure &amp; foundation with no exceptional risk or difficult soil or loading conditions</td>
<td>§2.1(19) Spread; raft; &amp; pile foundations; walls &amp; other structures retaining or supporting soil or water; excavations; bridge piers &amp; abutments; embankments &amp; earthworks; ground anchors &amp; other tie-back systems; and tunnels in hard, non-fractured rock and not subjected to special water tightness or other requirements.</td>
</tr>
<tr>
<td>3</td>
<td>Structures or parts of structures not covered above</td>
<td>§2.1(21) Very large or unusual structures; structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions; structures in highly seismic areas; and structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures</td>
</tr>
</tbody>
</table>

### Ultimate limit states for stability

**EQU**  
Loss of static equilibrium

**UPL**  
Uplift by water pressure

**HYD**  
Hydraulic heave/erosion

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Ultimate limit states for strength

Limit states GEO and STR

- **Definition of limit state GEO**
  - Failure or excessive deformation of the ground, in which the strength of soil or rock is **significant** in providing resistance
  - Often critical to sizing structural elements in foundations or retaining structures

- **Definition of limit state STR**
  - Internal failure or excessive deformation of the structure or structural elements ... in which the **strength of structural materials is significant** in providing resistance
  - Includes (for example) footings, piles, and basement walls
Structural verification of strength (STR)

Verification of limit state STR

- Actions and effects
  - Representative actions \( F_{re} \)
  - Design actions \( F_d \)
- Material properties and resistances
  - Characteristic material properties \( X_c \)
  - Design material properties \( X_d \)
- Structural analysis
- Design effect of actions \( E_d \)
- Design resistance \( R_d \)
- Verify \( E_d \leq R_d \)

Allowable stress design procedure

Checking geotechnical load capacity

- Loads \( P \) and \( W \)
- Material properties
  - Material properties \( p \) and \( c \)
- Geotechnical analysis
- Ultimate load capacity \( Q_u \)
- Allowable load capacity \( Q_a \)
- Safety factor \( F \)
- Check \( P + W \leq Q_a \)
§2.4.7.3.4 Design Approaches

- (1)P The manner in which [GEO and STR are applied] shall be determined using one of three Design Approaches
  - Design Approaches are ONLY relevant to limit states STR and GEO
  - NOTE 1 Particular Design Approach to be used may be given in the National Annex
    - UK/Denmark prefer DA1
    - Germany/France prefer DA2
    - Some countries will allow a choice
# Design approaches for STR/GEO

<table>
<thead>
<tr>
<th>Structure</th>
<th>Design Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Combination 1</strong></td>
</tr>
<tr>
<td>Axially loaded piles and anchors</td>
<td>Actions</td>
</tr>
<tr>
<td>Other structures</td>
<td></td>
</tr>
<tr>
<td>Slopes</td>
<td></td>
</tr>
</tbody>
</table>

**Foundation design to Eurocode 7**

**Impact on retaining wall design**
Contents of Section 9

§9.1 General
§9.2 Limit states
§9.3 Actions, geometrical data and design situations
§9.4 Design and construction considerations
§9.5 Determination of earth pressures
§9.6 Water pressures
§9.7 Ultimate limit state design
§9.8 Serviceability limit state design

Design Approach 1-1 for retaining structures
Design Approach 1-2 for retaining structures

Supervision, monitoring, and testing

- There are no clauses in EN1997 that specifically cover supervision, monitoring, and maintenance of retaining structures
- However, separate European execution standards give valuable information
  - EN 1536: 2000 (bored piles)
  - EN 12063: 1999 (sheet pile walls)
  - EN 12699: 2001 (displacement piles)
  - BS EN 1537: 2000 (ground anchors)
  - BS EN 1538: 2000 (diaphragm walls)
Foundation design to Eurocode 7
Impact on pile design

Contents of Section 7

§7.1 General
§7.2 Limit states
§7.3 Actions and design situations
§7.4 Design methods and design considerations
§7.5 Pile load tests
§7.6 Axially loaded piles
§7.7 Transversely loaded piles
§7.8 Structural design of piles
§7.9 Supervision of construction

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Design methods for pile foundations

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>Use empirical or analytical calculation methods or results of dynamic load tests</td>
<td>Validity must be demonstrated by static load tests in comparable situations</td>
</tr>
<tr>
<td>Testing</td>
<td>Use results of static load tests, provided consistent with relevant experience</td>
<td>Validity must be demonstrated by calculation or other means</td>
</tr>
<tr>
<td>Observation</td>
<td>Use observed performance of comparable pile foundation</td>
<td>Must be supported by results of site investigation and ground testing</td>
</tr>
</tbody>
</table>

Design Approach 1-1 for pile foundations

Verification of limit state GEO (DA 1-1)

- Actions and effects
  - Representative actions $P_{eq}$
- Design actions $P_d$
- Design effect of actions $E_d$
- Pile capacity analysis
- Verify $E_d \leq R_d$
- Design resistance $R_d$
- Characteristic material properties $X_0$
- Design material properties $X_d$
- Typical procedures for pile and anchor
- Test results
- Load tests
- Static load tests
- Consistent with relevant experience
- Empirical or analytical calculation methods or results of dynamic load tests
- Must be supported by results of site investigation and ground testing

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Design Approach 1-2 for pile foundations

Correlation factors for pile foundations

<table>
<thead>
<tr>
<th>Static load tests</th>
<th>Ground tests</th>
<th>Dynamic impact tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Mean</td>
<td>Min.</td>
</tr>
<tr>
<td>ξ₁</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>1.2</td>
<td>1.05</td>
</tr>
<tr>
<td>4</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>≥5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>1.27</td>
<td>1.12</td>
</tr>
<tr>
<td>10</td>
<td>1.25</td>
<td>1.08</td>
</tr>
</tbody>
</table>

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Supervision, monitoring, and testing

- ...installation of all piles [shall be] monitored and records ... made as the piles are installed
- The records for each pile should include aspects of construction covered in the relevant execution standards
  - EN 1536: 2000 (bored piles)
  - EN 12063: 1999 (sheet pile walls)
  - EN 12699: 2001 (displacement piles)
  - prEN 14199: 2001 (micro-piles)
    - now published as EN 14199: 2005

Foundation design to Eurocode 7

Benefits of Eurocode 7
More pile load tests?

“...the scourge of the UK construction industry will soon be upon us with ... the Eurocodes and specifically EC7

“...factors of safety [to] derive safe pile load capacity are ... inversely proportional to the number of soil profiles available

“As a result there will be a direct design benefit from carrying out a comprehensive site investigation. Put crudely, more boreholes will mean lower factors of safety”

• Reference: David Puller, chief engineer at Bachy Soletanche, Ground Engineering Talking Point (October 2004)

Unified principles for geotechnical design

“[Eurocode 7 Part 1] introduces ... important changes in ... design practices ...:

• for the first time, a unified set of Principles for all geotechnical design
• bridges the philosophical divide between geotechnical design and superstructure design
• clear distinction between ... ultimate limit state [and] serviceability limit state
• requires more systematic thought about ... uncertainty in ... geotechnical material parameters ...
• introduces a degree of compulsion by indicating that certain (Principle) activities ‘shall’ be undertaken”

• Reference: forthcoming CIRIA Report RP701
Impact of Eurocode 7

“...within the UK, the extent to which geotechnical design has been codified [is] much less than in other sectors

“... the introduction of EN 1997 (Geotechnical design) will represent a marked change in UK practice

“... the needs of geotechnical designers ... to adapt ... will be significant”