DGF meeting, 13.09.2012 at Rambøll, Ørestaden
EC7-1, Intro of new Ch. 8 Anchors

Agenda

- Standards for design, execution and test of anchors

- Why we need an amendment for Ch. 8 Anchors in EC7-1

- Evolution Groups

EC7-1, Intro of new Ch. 8 Anchors
Standards for design, execution and test

Design of anchorages → anchors: TC 250 – EN 1997-1, Ch. 8
- ULS limits: safety factors on resistance … and load
- SLS limits: creep rates, load loss
- Lock-off load, limits, influence on ULS and/or SLS

- Execution methods
- Tolerances
- Corrosion protection (durability)
- Limits of apparent free length
- Purpose and scope of tests (what to test), test methods

- Load steps or circles, observation periods (how to test)
EC7-1, Intro of new Ch. 8 Anchors
Why we need an amendment of Ch. 8 Anchors

The current Ch.8 of EN 1997-1:2004
  • is inconsistent regarding test or not test
  • has no guidance on test loads or SLS limits

In the revised execution standard (EN 1537:2012):
  • all about design is removed ... should enter EN 1997-1, Ch. 8
  • all about testing is removed ... should enter EN-ISO 22477-5

Another problem:
When EN 1537:2012 is published, and EN 1537:1999 is withdrawn
there is no guidance of how to test anchors until EN-ISO 22477-5 is available
In the meantime a provisional solution should be found for each individual country:
Denmark will probably use the German DIN SPEC 18537:2012-02
From the current Ch.8 of EN 1997-1:2004

8.5.1 Design of the anchorage

(1) P The design value, \( R_{a;d} \), of the pull-out resistance, \( R_a \) of an anchor shall fulfil the limit condition:

\[
P_d \leq R_{a;d}
\]  

(8.1)

(2) Design values of the pull-out resistance may be determined from the results of tests on anchorages, or by calculation.
From the current Ch.8 of EN 1997-1:2004

8.5.2 Design values of pull-out resistance determined from the results of tests

(3) The characteristic value should be related to the suitability test results by applying a correlation factor $\xi_a$.

NOTE 8.5.2(3) refers to those types of anchorage that are not individually checked by acceptance tests. If a correlation factor $\xi_a$ is used, it must be based on experience or provided for in the National annex.
EC7-1, Intro of new Ch. 8 Anchors  
Why we need an amendment of Ch. 8 Anchors

From the current Ch.8 of EN 1997-1:2004

8.8 Acceptance test

(1)P It shall be specified in the design that all grouted anchorages shall be subjected to acceptance tests prior to lock-off and before they become operational.

This (clause (1)P) has been modified according to a corrigendum effective on 18 February 2009, EN 1997-1:2004/AC to:

(1)P All grouted anchorages shall be subjected to acceptance tests prior to lock-off and before they become operational.
9.7 Acceptance test

Each working anchor shall be subjected to an acceptance test.
What are the Eurocode 7 Evolution Groups?

At the 26th meeting of TC250/SC7 (the Eurocode 7 committee), a decision was made to establish a number of 'Evolution Groups' (EGs) to look at the technical issues that require improved coverage in a future revision of Eurocode 7. A total of 12 EGs were established initially (with a further one under consideration)

Link: http://www.eurocode7.com/sc7/evolutiongroups.html
EG1: Anchors

Eric Farrell (Ireland, AGL Consulting), convenor
Bernd Schuppener (Germany, BAW)
Klaus Dietz (Germany, Dietz Geotechnic Consult)
Brian Simpson (UK, Arup and BSI)
Caesar Merrifield (UK, Coffey Geotechnics and convenor of TC 288-WG14)
Pierre Schmitt (France, Soletanche-Bachy)
Yves Legendre (France, Soletanche-Bachy)
Arne Schram Simonsen (Norway, Multiconsult)
Ole Møller (Denmark, Aarsleff)
EC7-1, Intro of new Ch. 8 Anchors
Evolution Groups (EGs)

EG0: Management and oversight
Andrew Bond (UK, Chairman SC7)
Giuseppe Scarpelli (Italy, Vice Chairman SC7)
Bernd Schuppener (Germany, Past Chairman SC7)
Roger Frank (France, Past Chairman SC7)
Mark Lurvink (Netherlands, Secretary SC7)
EC7-1, Intro of new Ch. 8 Anchors
New / different : 8.1.1 Scope

Old (current)
(2)P This Section is applicable to;
— pre-stressed anchorages consisting of an anchor head, a tendon free length and a
tendon bond length bonded to the ground by grout;
— non pre-stressed anchorages consisting of an anchor head, a tendon free length
and a restraint such as a fixed anchor length bonded to the ground by grout, a
deadman anchorage, a screw anchor or a rock bolt.
(3) This Section does not apply to soil nails.
(4)P Section 7 shall apply to the design of anchorages comprising tension piles.

New
(2)P Tension members without a free length (such as tension piles) shall be designed
using the principles given in Section 7 ‘Pile foundations’.
(3)P Anchor walls used as dead-man anchors shall be designed using the principles
given in Section 9, ‘Retaining structures’.
(4) This section does not cover the design of soil nails or rock bolts.
8.1.2.1
anchor
installation capable of transmitting an applied tensile load through a free length to a load bearing stratum

8.1.2.2
grouted anchor
anchor that uses a bonded length formed of cement grout, resin or similar material to transmit the tensile force to the ground

NOTE  A ‘grouted anchor’ in EN 1997-1 is termed a ‘ground anchor’ in EN 1537.
EC7-1, Intro of new Ch. 8 Anchors

New / different : Terms (not mentioned)

prestressed = active anchor

non prestressed = passive anchor

is a micro pile a passive anchor? No, it has no free length.

difference between a tension pile and an anchor? the free length

purpose of a free length: to document stability

purpose / need for prestress: to limit deformation

purpose / need for test: to document free length and geotechnical resistance
NOM question:

What is the purpose of a free length if you do not test the anchor?

Consider the simple case, where you as a design engineer (client or contractor) decides not to do acceptance test. Will you then intentionally provide your ground anchor with a free length or not? And if you do, then why?

Answer from the other EG1-members:
If it was decided in advance not to do a load test and not to preload the “anchor”, then a free length would not be necessary.

(NOM) Conclusion: the need for test comes with the definition – the presence of a free length
EC7-1, Intro of new Ch. 8 Anchors
New / different : Symbols (Terms mentioned)

\[ E_{ULS,d} \]  ULS design force to be resisted by the anchor

\[ F_{ULS,d} \]  design value of the ultimate limit state force required to prevent any ultimate limit state in the supported structure.

\[ F_{Serv,k} \]  characteristic value of the maximum anchor force, including effect of lock off load, and sufficient to prevent a serviceability limit state in the supported structure

\[ F_{Serv,d} \]  design value of the maximum anchor force, including effect of lock off load, and sufficient to prevent a serviceability limit state in the supported structure
(3) For a group of anchors, the most critical failure surface should be considered. Depending on spacing and the profile of ground strength, this may involve displacement of part or all of the block contained by the anchors, often combined with pull-out of the distal ends of the anchors.
EC7-1, Intro of new Ch. 8 Anchors
New: 8.3 Design situations and actions

(3)P The design value of the anchor load shall be derived from the design of the retained structure, taking into consideration ultimate and serviceability limit states of the retained structure.

which is actually not new.

According to the current Ch. 8:

8.5.5 Design value of the anchorage load
(1)P The design value of the anchorage load, Pd, shall be derived from the design of the retained structure as the maximum value of
— the ultimate limit state force applied by the retained structure, and if relevant
— the serviceability limit state force applied by the retained structure.
8.5.1 General

(1)P The design value of the geotechnical ultimate limit state resistance of an anchor, $R_{ULS;d}$, shall satisfy the following inequality:

$$E_{ULS,d} \leq R_{ULS;d}$$  \hspace{1cm} (8.1)

where $E_{ULS,d} = \text{Max}(F_{ULS,d}; F_{Serv,d})$  \hspace{1cm} (8.2)

and where $F_{Serv,d} = \gamma_{Serv} F_{Serv,k}$  \hspace{1cm} (8.3)

Note: The value of partial factor $\gamma_{Serv}$ may be set by the National Annex. The recommended value for persistent and transient situations is given in Table A.18.
8.5.1 General, cont.

(2)P When a separately evaluation of the serviceability limit state of the anchor is required, the evaluation shall be carried out using formula (8.4).

\[ \gamma_{F,SLS} \cdot F_{\text{Serv},k} \leq R_{\text{SLS},d} \]  

(8.4)

NOTE 1 The National Annex may set whether a separate evaluation of the serviceability limit state of the anchor is required.

NOTE 2 The National Annex may set whether the verifications for ultimate limit state and serviceability limit state are to be carried out separately or in a combined procedure.

NOTE 3 The value of partial factor \( \gamma_{F,SLS} \) may be set by the National Annex. The recommended value is given in Table A.18.
EC7-1, Intro of new Ch. 8 Anchors
New: 8.5 Limit state design of anchors

8.5.1 General, cont.

Table A.18 — Partial factors on actions and action effects for persistent and transient design situations at the ultimate limit state and for serviceability limit states

<table>
<thead>
<tr>
<th>Limit state</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate</td>
<td>$\gamma_{Serv}$</td>
<td>1.35</td>
</tr>
<tr>
<td>Serviceability</td>
<td>$\gamma_{F,SLS}$</td>
<td>1.0</td>
</tr>
<tr>
<td>Serviceability</td>
<td>$\gamma_{F,SLS}$</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note: the recommended value of $\gamma_{Serv}$ applies to all Design Approaches

* Eq. 8.4 only relevant when stated in the National Annex.
New: 8.5.2 Geotechnical ULS resistance

(2)P The measured geotechnical ultimate limit state resistance of an anchor \( R_{ULS;m} \) shall be determined as the lesser of the proof load or the load causing a limiting condition \( (R_m) \). The limiting condition depends on the test method and may be:

- the asymptote to the creep rate vs load curve or

- the load corresponding to a limit value of the creep rate \( (\alpha_{ULS}) \) or

- the load corresponding to a limit value of load loss \( (k_{i,ULS}) \).

Thus:

\[
R_{ULS;m} = \text{Min} \{ \ R_m \ (\alpha_{ULS} \text{ or } k_{i,ULS}) \text{ and } P_P \}\]  

(8.5)

NOTE The limit value of the creep rate \( (\alpha_{ULS}) \) or load loss \( (k_{i,ULS}) \) may be set by the National Annex, which may specify the use of an asymptote to the creep rate vs load curve in place of a specified value for \( a_{ULS} \). Provisional values for persistent and transient situations are given in Table A.21.
Plot of creep rate (1) versus applied load (2) ... for Test Method 3 (EN 1537:1999)
EC7-1, Intro of new Ch. 8 Anchors
New: Geotechnical ULS and SLS resistance

$R_{ULS,m}$ ... by Test Method 3 (from pr EN ISO 22477-5)
Critical creep load, $P_c$ ... by Test Method 3 (from pr EN ISO 22477-5)
EC7-1, Intro of new Ch. 8 Anchors
New: Geotechnical ULS and SLS resistance

The concept of the “SLS” resistance comes from French practice:

\[ T_s \text{ (Traction de service)} \leq \min \{2/3 \, R_u ; 0,8 \, P_c \} \text{ for permanent anchors} \]
\[ T_s \text{ (Traction de service)} \leq \min \{2/3 \, R_u ; 0,9 \, P_c \} \text{ for temporary anchors} \]

Translation to Eurocode language:

\[ T_s = F_{\text{Serv},k} \]
\[ R_u = R_{\text{ULS},k} \]
\[ 1/0,8 = 1,25 = \gamma_{a,\text{acc},\text{SLS}} \]
\[ 1/(2/3) = 1,5 \sim 1,35 \cdot 1,1 = \gamma_{\text{Serv}} \cdot \gamma_{a,\text{ULS}} \text{ (}\gamma_{\text{Serv}} \text{ is a load factor similar to } \gamma_F \text{ or } \gamma_E \text{)} \]

**SLS:** \[ T_s \leq 0,8 \, P_c \text{ (consider permanent anchors)} \]  \[ F_{\text{Serv},k} \leq 0,8 \, P_c = P_c / 1,25 = P_c / \gamma_{a,\text{acc},\text{SLS}} = R_{\text{SLS},d} \]

Define:

\[ R_{\text{SLS},m} = P_c \text{ and } R_{\text{SLS},k} = R_{\text{SLS},m,\text{min}} / \xi_{\text{SLS}} = P_{c,\text{min}} / \xi_{\text{SLS}} \ldots (\xi_{\text{SLS}} = 1,00000) \]
\[ \gamma_{F,\text{SLS}} (= 1,0000) \text{ and } \gamma_{F,\text{SLS}} \cdot F_{\text{Serv},k} \text{ (not to be taken as } F_{\text{Serv},d} \text{ nor } F_{\text{SLS},d} \text{)} \]
\[ \gamma_{F,\text{SLS}} \cdot F_{\text{Serv},k} \leq R_{\text{SLS},d} \text{ (8.4)} \ldots (\gamma_{F,\text{SLS}} = \xi_{\text{SLS}} = 1,0000) \text{ Voila!} \]
EC7-1, Intro of new Ch. 8 Anchors
New: Geotechnical ULS and SLS resistance

The concept of the “SLS” resistance comes from French practice:

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\[ R_u = R_{\text{ULS},k} \]
\[ 1/0,8 = 1,25 = \gamma_{a,\text{acc},\text{SLS}} \]
\[ 1/(2/3) = 1,5 \sim 1,35 \cdot 1,1 = \gamma_{\text{Serv}} \cdot \gamma_{a,\text{ULS}} \text{ (} \gamma_{\text{Serv}} \text{ is a load factor similar to } \gamma_F \text{ or } \gamma_E \text{) } \]

**ULS:**

\[ T_s \leq 2/3 \ R_u = R_u / 1,5 \]
\[ F_{\text{Serv},k} \leq R_{\text{ULS},k}/1,5 = R_{\text{ULS},k}/(1,35 \cdot 1,1) \]
\[ 1,35 \cdot F_{\text{Serv},k} \leq R_{\text{ULS};k} / 1,1 \]
\[ \gamma_{\text{Serv}} \cdot F_{\text{Serv},k} \leq R_{\text{ULS};m,\text{min}} / (\xi_{\text{ULS}} \cdot \gamma_{a,\text{ULS}}) \]
\[ F_{\text{Serv},d} \leq R_{\text{ULS};d} \text{ (8.1), (8.2) and (8.3) ..... (} \xi_{\text{ULS}} = 1,0 \text{) } \]
\[ E_{\text{ULS};d} = \max \{F_{\text{ULS},d} ; F_{\text{Serv},d}\} \leq R_{\text{ULS};d} \]

Voila!
8.6.2 Acceptance tests

(1) Acceptance tests shall be carried out on all grouted anchors in accordance with EN ISO 22477-5 prior to their lock off and before they become operational.

(2) The proof load, $P_p$, to be applied to the anchor in an acceptance test shall be derived from the ULS design force $E_{ULS;d}$ or from $F_{Serv,k}$ using the following inequalities:

$$P_p \geq \xi_{a,acc,ULS} \gamma_{a,acc,ULS} E_{ULS;d} \quad (8.13)$$

or

$$P_p \geq \xi_{a,acc,SLS} \gamma_{a,acc,SLS} \gamma_{F,SLS} F_{Serv,k} \quad (8.14)$$
8.6.2 Acceptance tests

NOTE 1: ...

NOTE 2: The National Annex may state whether the proof load in an acceptance test is to be related to the ULS design force (8.13) or to $F_{\text{Serv},k}$ (8.14).

NOTE 3: ...

Values appear from Table A.20
### 8.6.2 Acceptance tests

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Test method</th>
<th>TM1</th>
<th>TM2</th>
<th>TM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi_{ULS}$</td>
<td>(eq. 8.6)</td>
<td>1,0</td>
<td>1,0/1,8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,0</td>
</tr>
<tr>
<td>$\xi_{SLS}$</td>
<td>(eq. 8.9)</td>
<td>NA</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>$\gamma_{a,SLS}$</td>
<td>(eq. 8.10)</td>
<td>NA</td>
<td>1,0</td>
<td>1,2</td>
</tr>
<tr>
<td>$n$</td>
<td></td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>$\xi_{acc,ULS}$</td>
<td>(eq. 8.13)</td>
<td>1,0</td>
<td>1,0</td>
<td>NA</td>
</tr>
<tr>
<td>$\gamma_{a,acc,ULS}$</td>
<td>(eq. 8.13)</td>
<td>1,1</td>
<td>1,1</td>
<td>NA</td>
</tr>
<tr>
<td>$\xi_{acc,SLS}$</td>
<td>(eq. 8.14)</td>
<td>NA</td>
<td>1,0</td>
<td>1,0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>$\gamma_{a,acc,SLS}$</td>
<td>(eq. 8.14)</td>
<td>NA</td>
<td>1,0</td>
<td>1,25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**NOTE**  
NA = Not Applicable

<sup>a</sup> If acceptance test on every anchor (proof load to equation 8.13) gives assurance that $E_{ULS,d} \leq R_{ULS,d}$ then $\xi_{ULS} = 1,0$, otherwise $\xi_{ULS} = 1,8$.

<sup>b</sup> For permanent anchors.
8.6.2 Acceptance tests

(3)P For each test, the creep rate/load loss that occurs under the proof load and under other specified loads shall be less than limiting values.

NOTE 1: The limiting values for creep rate/load loss at Proof Load may be set by the National Annex. Recommended values for persistent and transient situations are given in Table A.21.

NOTE 2: The requirement to check creep rate/load loss at other specified loads, less than the proof load, is optional and may be set by the National Annex. No provisional values are provided in this Eurocode.
Investigation, suitability and acceptance tests

Table A.21 — Limiting criteria for investigation, suitability and acceptance tests for persistent and transient design situations at the ultimate limit state and for serviceability limit states

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Investigation and suitability tests</th>
<th>Acceptance tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ULS</strong> (Eq. 8.5)</td>
<td><strong>SLS</strong> (Eq. 8.8)</td>
</tr>
<tr>
<td>1</td>
<td>$\alpha_1 = 2,\text{mm}$</td>
<td>NA</td>
</tr>
<tr>
<td>2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>$k_l = 2,%,\text{per log cycle of time}$</td>
<td>$k_l = 2,%,\text{per log cycle of time}$</td>
</tr>
<tr>
<td>3</td>
<td>$\alpha_3 = 5,\text{mm}$</td>
<td>$P_c$</td>
</tr>
</tbody>
</table>

**NOTES**

- NA = Not Applicable
- Times of observation for load loss in accordance with Table H.1, Annex H, EN ISO 22477-5
- For permanent anchors $\alpha_3 = 1,5\,\text{mm}$, for temporary anchors $\alpha_3 = 1,8\,\text{mm}$. 
EC7-1, Intro of new Ch. 8 Anchors
New: Lock-off load

Lock off load – the pre-stress load $P_0$

What came first? The hen or the egg? Speaking of anchor loads, the lock off load (the pre-stress) comes before the service load.

Thus you cannot relate or limit the lock off load to the service load. This will imply a “circular reference”.

You can only relate the lock off load to a load, determined WITHOUT effect of prestress.
8.7 Lock-off load for prestressed anchors

(1)P The lock-off load should be sufficient to ensure serviceability of the structure and supporting structures.

(2)P The lock-off load shall not give rise to a limit state in the ground, in the structure or in supporting structures.

(3) Where tendon bond lengths of a group of anchors cross at spacings less than 1,5 m (centre to centre), the pre-stress should be checked on selected anchors after completion of the lock-off process.
8.2 Limits states
(3) For a group of anchors, the most critical failure surface should be considered. Depending on spacing and the profile of ground strength, this may involve displacement of part or all of the block contained by the anchors, often combined with pull-out of the distal ends of the anchors.

8.6.1 Investigation of suitability tests
(2) Grouted anchors with tendon bond lengths spaced at less than 1.5 m should be tested in groups unless comparable experience has shown that the interaction has quantifiable effects which can be taken into account.

8.7 Lock-off load for pre-stressed anchors
(3) Where tendon bond lengths of a group of anchors cross at spacings less than 1.5 m (centre to centre), the pre-stress should be checked on selected anchors after completion of the lock-off process.
Test of negative adverse interaction
Group effect or negative adverse interaction?

Test of group effect