TC250/SC7/EG7
´Pile Design´

Results of Vienna Meetings

October 17th and 18th, 2013

A) Restructuring section ´Pile Design´

Structure of <u>existing</u> section ´Pile design´

(1/2)

Structure of existing section ´Pile design´

(2/2)

A) Restructuring section ´Pile Design´

Structure of <u>future</u> section ´Pile design´

(1/2)

1 General *[existing §7.1]*

2 Limit states *[existing §7.2]*

3 Actions and design situations *[existing §7.3]*

- **3.1 General** *[existing §7.3.1]*
- **3.2 Dynamic and cyclic loading** *[NEW]*
- **3.3 Actions due to ground displacement** *[existing §7.3.2]*
  - 3.3.1 General
  - 3.3.2 Downdrag (negative skin friction)
  - 3.3.3 Heave
  - 3.3.4 Transverse loading

4 Design methods and design considerations *[NEW, incorporating existing §7.6]*

- **4.1 Design by calculation** *[NEW]*
  - 4.1.1 General *[NEW]*
  - **4.1.2 Single standing piles**
    - 4.1.2.1 Axially loaded piles *[NEW, incorporating existing §7.6]*
    - 4.1.2.2 Transversely loaded piles *[NEW, incorporating existing §7.7]*
  - **4.1.3 Pile Groups** *[NEW]*
    - 4.1.3.1 Axially loaded piles *[NEW]*
    - 4.1.3.2 Transversely loaded piles *[NEW]*
  - **4.1.4 Piled Rafts** *[NEW]*
  - **4.1.5 Pile resistance due to cyclic, dynamic and impact loads** *[NEW]*
- **4.2 Design by testing** *[NEW, incorporating existing §7.6]*
  - 4.2.1 General *[NEW]*
  - **4.2.2 Axially loaded piles** *[NEW, incorporating existing §7.6]*
    - 4.2.2.1 Ultimate resistance from static load tests
    - 4.2.2.2 Ultimate resistance from dynamic impact tests
    - 4.2.2.3 Ultimate resistance by applying pile driving formulae
    - 4.2.2.4 Ultimate resistance from wave equation analysis
    - 4.2.2.5 Re-driving
  - **4.2.3 Transversely loaded piles** *[NEW]*
  - **4.2.4 Pile resistance due to cyclic, dynamic and impact loads** *[NEW]*

A) Restructuring section ´Pile Design´

Structure of <u>future</u> section ´Pile design´

(2/2)

Which clauses should remain / be deleted / are missing - and why?

	Comment: List is already included in section 2, there is no need for repeat.
7.3 Actions and design situations **7.3.1 General** (1) The actions listed in 2.4.2(4) should be considered when selecting the design situations. (2) Piles can be loaded axially and/or transversely. (3)P Design situations shall be derived in accordance with 2.2. (4) An analysis of the interaction between structure, pile foundation and ground can be necessary to prove that the limit state requirements are met.	**4.3 Actions and design situations** **[existing Part 1, § 7.3]** **4.3.1 General** (1) The actions listed in 2.4.2(4) should be considered when selecting the design situations. ~~(2) Piles can be loaded axially and/or transversely.~~ (3)P Design situations shall be derived in accordance with 2.2. (4) An analysis of the interaction between structure, pile foundation and ground can be necessary to prove that the limit state requirements are met. ~~*Comment: Clauses are usual engineering knowledge and not especially relevant for piles.*~~ A (1) The non-linearity of the resistance-settlement curve of axially loaded piles has to be considered in calculation of the structure. For simplification it is possible to determine a spring constant from the secant through the resistance-settlement curve for the characteristic stress range or to consider the pile by its ultimate resistance. A (2) Cyclic and dynamic stresses on piles can cause a significant reduction of long-term bearing capacity and additional displacements. ***F:*** *Taking into account cyclic effects is important but every loading is cyclic since there is always permanent and transient loads. This aspect has to more precise.* ***PL:*** *It is OK. But is it not only a 'basic knowledge'? Should not be given*

Formatiert: Nicht Durchgestrichen

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Kommentar [CM11]: Shift to seperate subsection

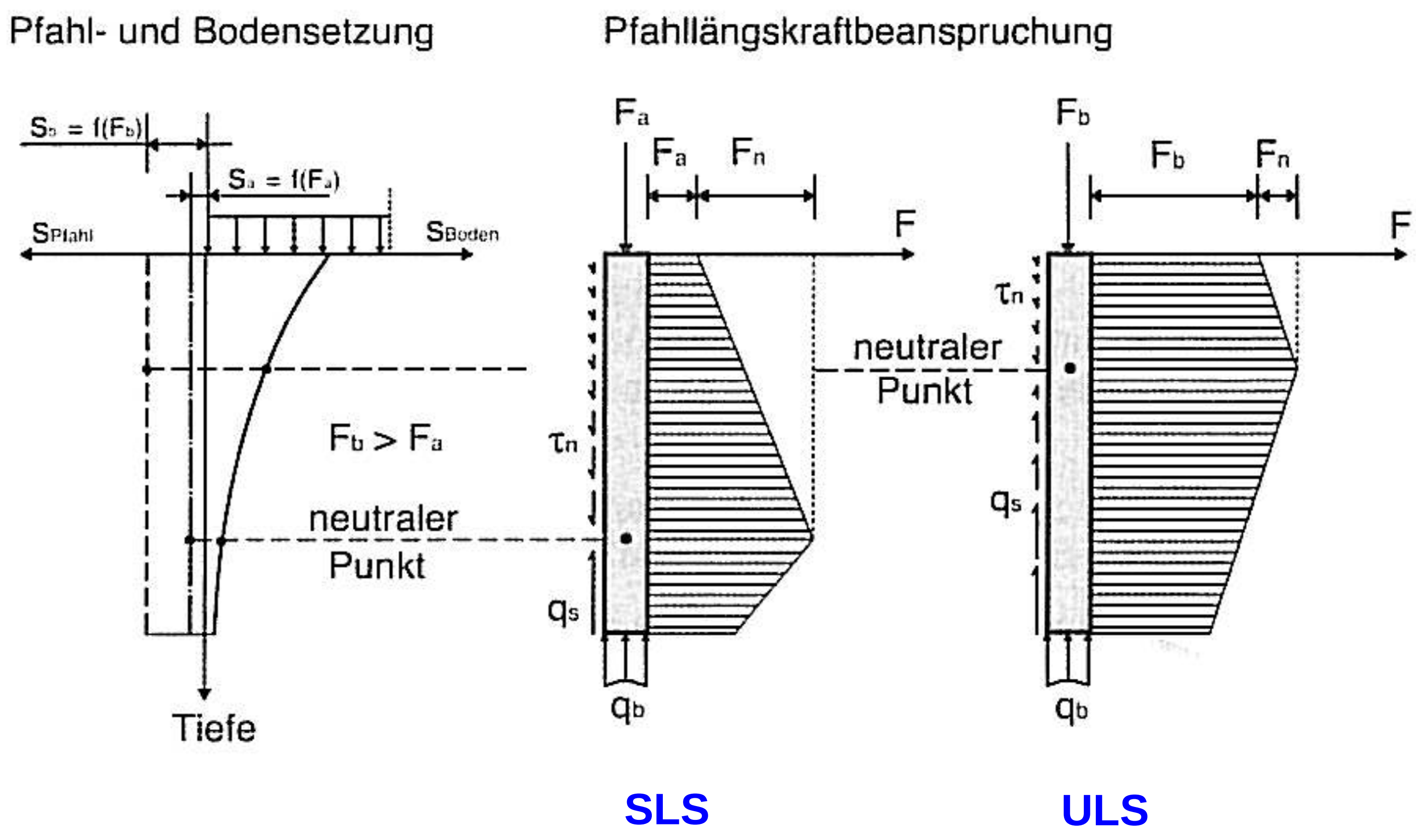
General: What is a pile – and what not?

(2)P A pile is a slender (l/D ≥ 5) monolithic structural element used for transferring loads into ground without need for confining support by the soil. Other systems like stone columns, jet grouting columns, deep soil mixing columns etc. may be designed according to this section

(3)P The construction of pile foundations is based on European Execution Standards EN 1536 (Bored Piles), EN 12699 (Displacement Piles) and EN 14199 (Micropiles).

⇒ **interaction with EG 14 ´Ground improvement´ necessary**

Actions due to ground displacements - downdrag (negative skin friction)



Use of correlation factors ξ to derive pile load resistance

… from static load tests,

Table A.9 - Correlation factors ξ to derive characteristic values from static pile load tests (n - number of tested piles)

ξ for n =	1	2	3	4	≥ 5
ξ_1	1,40	1,30	1,20	1,10	1,00
ξ_2	1,40	1,20	1,05	1,00	1,00

… from ground test results,

Table A.10 - Correlation factors ξ to derive characteristic values from ground test results (n - the number of profiles of tests)

ξ for n =	1	2	3	4	5	7	10
ξ_3	1,40	1,35	1,33	1,31	1,29	1,27	1,25
ξ_4	1,40	1,27	1,23	1,20	1,15	1,12	1,08

… dynamic impact tests

Table A.11 - Correlation factors ξ to derive characteristic values from dynamic impact tests[a, b, c, d, e] (n - number of tested piles)

ξ for n =	≥ 2	≥ 5	≥ 10	≥ 15	≥ 20
ξ_5	1,60	1,50	1,45	1,42	1,40
ξ_6	1,50	1,35	1,30	1,25	1,25

[a] The ξ-values in the table are valid for dynamic impact tests.

[b] The ξ-values may be multiplied with a model factor of 0,85 when using dynamic impact tests with signal matching.

[c] The ξ- values should be multiplied with a model factor of 1,10 when using a pile driving formula with measurement of the quasi-elastic pile head displacement during the impact.

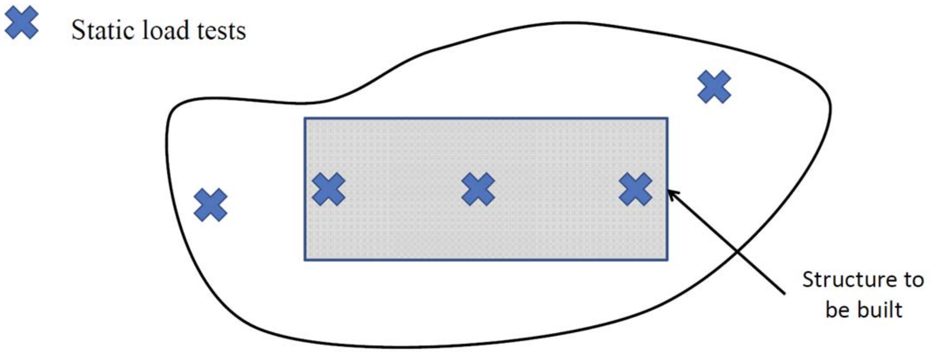
[d] The ξ-values shall be multiplied with a model factor of 1,20 when using a pile driving formula without measurement of the quasi-elastic pile head displacement during the impact.

[e] If different piles exist in the foundation, groups of similar piles should be considered separately when selecting the number n of test piles.

Use of correlation factors ξ

French standard

Use of correlation factors ξ_{1-2}



N	1	2	3	4	5
ξ_1	1.4	1.3	1.2	1.1	1.0
ξ_2	1.4	1.2	1.05	1.0	1.0

→ the correlation factors ξ_{1-2} do not vary with the surface of the project.

In the recent French standard for piles (NF P 94-262), the values for the correlation factors provided by the Annex A of the Eurocode 7-1 are only valid for a surface S_{ref} equal to 2500 m².

The following equation is used to calculate the correlation factors in relation with any surface S:

$$\xi_{1-2}(N,S) = 1 + (\xi'_{1-2}(N) - 1).(S/S_{ref})^{0.5}$$

ξ'_{1-2} is the value indicated by the annex A of the Eurocode 7

$625\ m^2 < S < S_{ref}$

$S = L \times l$ with $L/l < 2$

S is the surface of the project

Use of correlation factors ξ

⇒ need to be improved:

- **ξ as a %-value related to total number of fondation piles (e.g. 1% / 3% / 10% / 50% / 100% of all piles tested) or/and related to size (area) of pile foundation**
- **more significant steps for ξ = f(n) (instead of n = 1, 2, 3, ... , 5 piles)**
- **clearify which effects are considered by ξ - and to which extent:**
  - soil variability,
  - variation of installation effects,
  - uncertainity in execution of pile test (static ↔ dynamic) (?)
  - uncertainity in analysis and evaluation of (dynamic) test signals (?)
- **problem: R_{min}**

$$R_{t;k} = \mathrm{Min}\left\{ \frac{(R_{t;m})_{mean}}{\xi_1} ; \frac{(R_{t;m})_{min}}{\xi_2} \right\}$$

- **provide benefit to design by using ground test results, in case that verification by pile load tests during exexution is part of design concept**