ETC 10 – Evaluation of Eurocode 7

Eurocode 7 Design Examples 2

Background

The International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE) has established European Technical Committee 10 (ETC10) to "evaluate the ... geotechnical design process ... covered by ... Eurocode 7 by carrying out a number of design examples".

A set of Design Examples was studied in 2005, when characteristic values of soil parameters were provided. Details of the exercise are published in the Proceedings of the International Workshop organized by Dr Trevor Orr (Chairman of ETC10) and held in Dublin in March/April 2005. Proceedings can be ordered from www.tcd.ie/civileng/pdf/Eurocode 7.pdf.

'Design Examples 2'

A second set of Design Examples has now been developed, in which designers are asked:

- to select characteristic values from the available site investigation data
- to design the foundation according to Eurocode 7
- to complete the corresponding on-line questionnaire (available on the website)

These design examples involve selecting characteristic soil parameter values from the results obtained from different types of field and laboratory tests carried out at the site where the design examples are located. The designer is asked to assume that the sites involved are in his/her own country and to choose the appropriate National Annex accordingly.

A follow-up exercise will involve:

- repeating the foundation design using characteristic values selected by ETC10
- completing a follow-up questionnaire about this re-design

Instructions

Each design example comprises a specification (in PDF format) that you can download from www.eurocode7.com/etc10. The online questionnaire is also provided in PDF format so that you can prepare answers for the various questions (some of which ask for numerical values, others ask how you decided to do the design).

When you have completed the design and worked out your answers to the questions, you are asked to return to this website to submit your answers via our online questionnaire. If you encounter any difficulties with this process, please send an email to our webmaster and we will try to resolve them.

The Design Examples

1. Pad foundation with vertical central load on dense sand
2. Pad foundation with inclined load on boulder clay
3. Pile foundation in stiff clay
4. Earth and pore water pressures on basement wall
5. Embankment on soft peat
6. Pile foundation in sand

Reporting of results

The intention is for a second International Workshop to be held (in Pavia, Italy) in March or April 2010, to discuss the findings from this exercise. Details of the Workshop will follow.

Example 2.1 Pad foundation with vertical central load on dense sand

Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

The square pad foundation shown in Figure 2.1a is made from concrete with a weight density of 25 kN/m^3 and has an embedment depth of 0.8 m. The ground surface shown can reliably be assumed to be below any topsoil and disturbed ground.

The foundation is required to support the following characteristic loads:

Permanent:	Vertical	$G_{v,k}$ =	1000 kN, excluding weight of foundation
	Horizontal	$G_{h,k}$ =	0
Variable:	Vertical	$Q_{v,k}$ =	750 kN
	Horizontal	$Q_{h,k}$ =	0

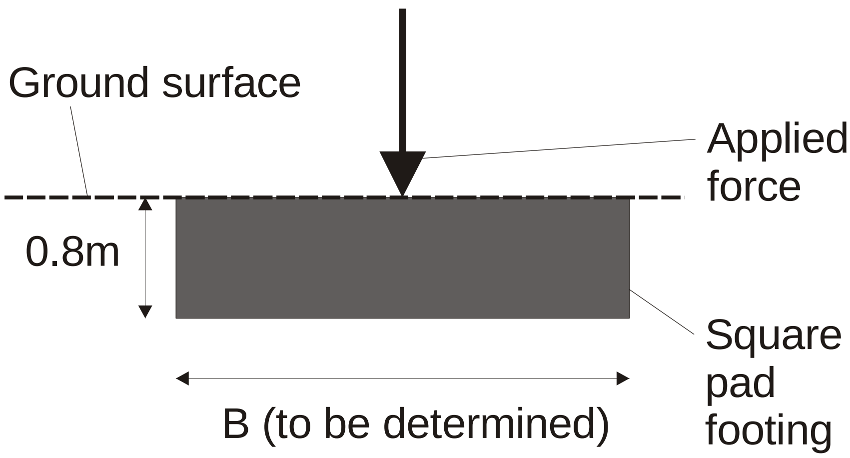


Figure 2.1a: Pad foundation (square on plan)

The soil consists of a very dense fine glacial outwash sand with a mean particle size of 0.14 mm. The soil has a bulk weight density of 20 kN/m^3 and close to 100% relative density. The ground water level is 6 m below ground level. The water content above the water table is 11% and the degree of saturation is 71%. Bedrock underlies the sand at 8m depth.

A plan of the site is given in Figure 2.1b showing the locations of four CPT tests carried out on the site with respect to the centre of the proposed foundation. The results of the four CPT tests are plotted separately in Figures 2.1c (1-4) and all the q_c values are plotted together in Figure 2.1d and listed in Table 2.1a.

The foundation is to be designed to Eurocode 7 to determine the foundation width when the maximum allowable settlement is 25 mm. There is no need to consider any effects due to frost or vegetation. The foundation's design working life is 50 years.

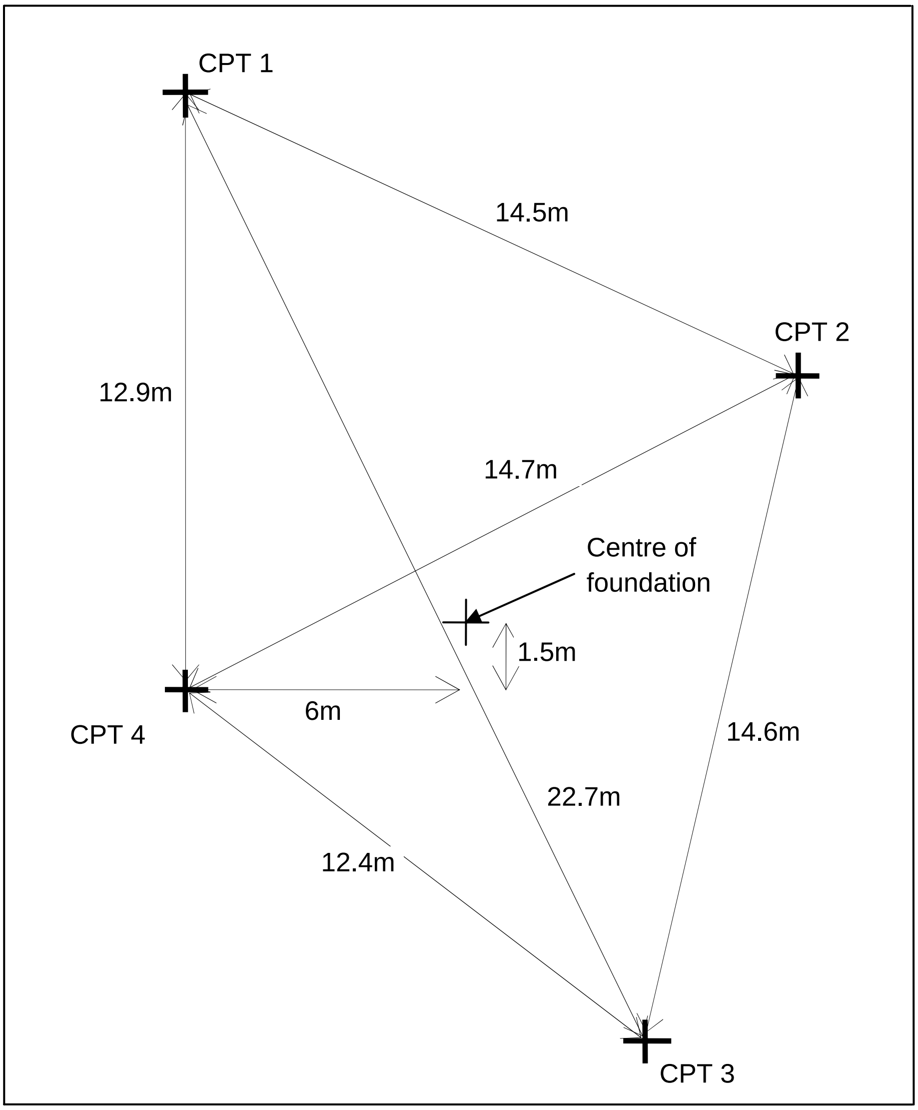


Figure 2.1b: Example 2.1 Site plan and location of CPT tests

Note: vertical axis on following diagram should read 'Depth below ground level (m)'

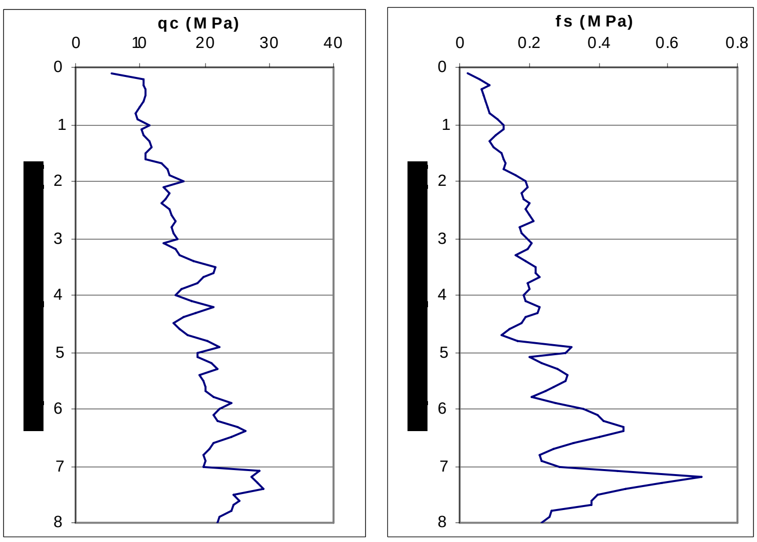


Figure 2.1c(1): CPT 1 test results - $q_{c \text{ and }} f_s$

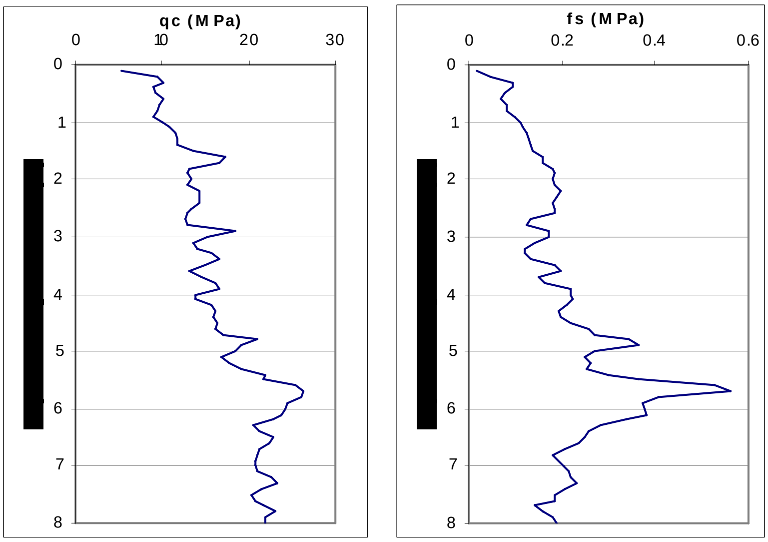


Figure 2.1c(2): CPT 2 test results - q_c and f_s

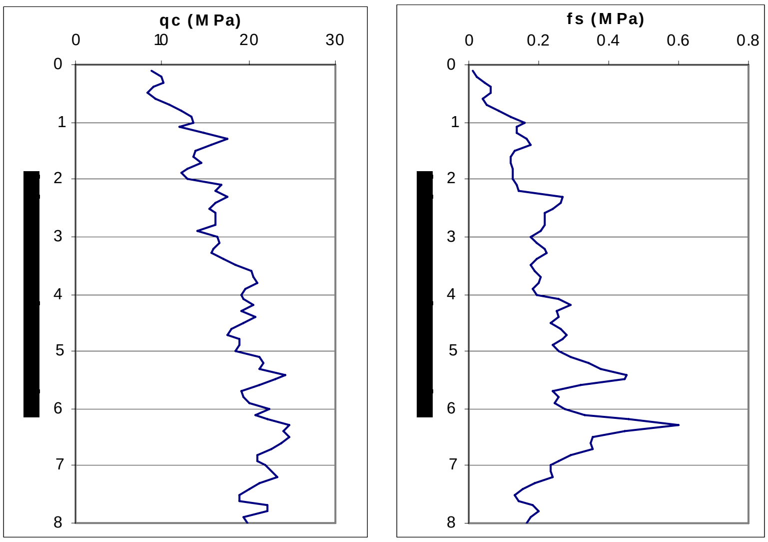


Figure 2.1c(3): CPT 3 test results - q_c and f_s

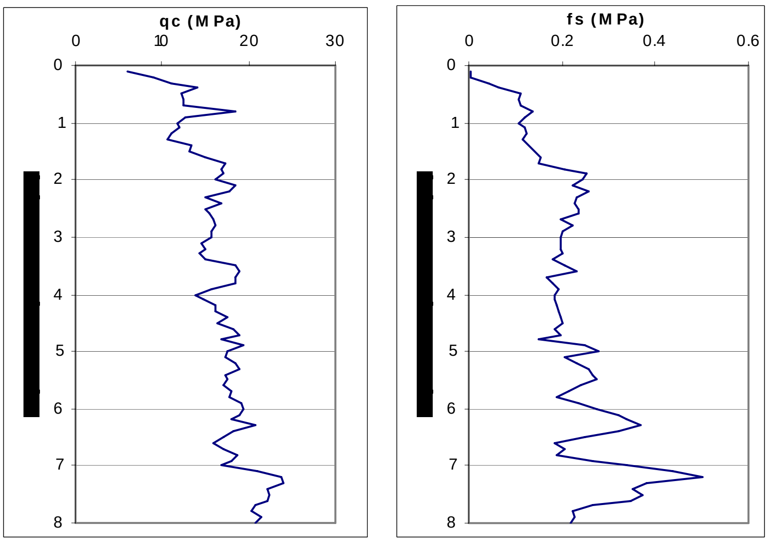


Figure 2.1c(4): CPT 4 test results - q_c and f_s

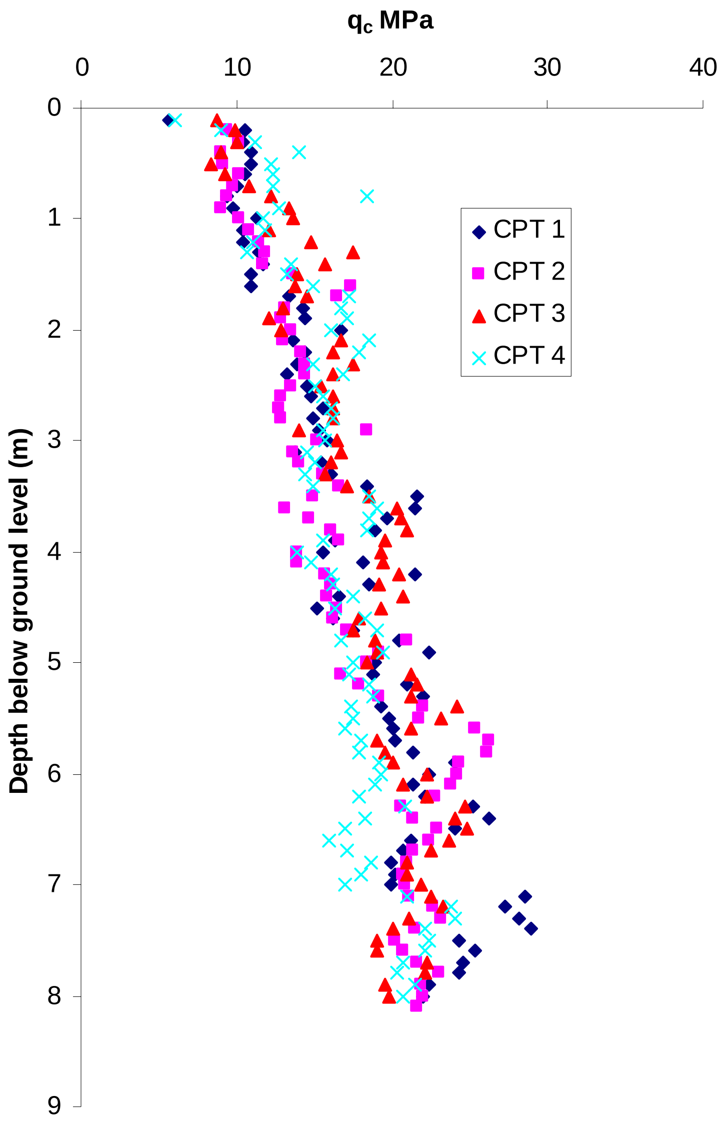


Figure 2.1d: Combined plot of CPT test results

ETC10 Design Example 2.1 (version 07/06/2009)

Table 2.1a: CPT test results
(data available in separate Excel spreadsheet)

	CPT 1		CPT 2		CPT 3		CPT 4	
Depth (m)	qc (MPa)	fs (MPa)	qc (MPa)	fs (MPa)	qc (MPa)	fs (MPa)	qc (MPa)	fs (MPa)
0.1	5.62	0.0236	5.41	0.018	8.78	0.0091	5.99	0.0057
0.2	10.56	0.0565	9.37	0.0456	9.89	0.0256	9	0.0061
0.3	10.4	0.0835	10.1	0.0928	10.05	0.0453	11.14	0.044
0.4	10.95	0.0619	8.94	0.0959	8.96	0.0616	14.01	0.0648
0.5	10.92	0.068	9.14	0.0751	8.38	0.0633	12.23	0.1107
0.6	10.6	0.0763	10.1	0.0679	9.27	0.038	12.36	0.1064
0.7	10.01	0.0805	9.78	0.0829	10.78	0.0533	12.36	0.1117
0.8	9.34	0.087	9.38	0.0811	12.17	0.0883	18.37	0.1392
0.9	9.72	0.1071	8.95	0.1003	13.42	0.1222	12.79	0.1211
1	11.35	0.127	10.18	0.1098	13.63	0.1603	11.72	0.1056
1.1	10.36	0.1287	10.82	0.1156	12.03	0.1362	11.89	0.1198
1.2	10.4	0.1024	11.48	0.1239	14.79	0.1366	11.06	0.1228
1.3	11.46	0.0858	11.81	0.1266	17.5	0.167	10.71	0.1152
1.4	11.73	0.1005	11.69	0.1309	15.68	0.1789	13.47	0.1267
1.5	10.9	0.1198	13.58	0.1363	13.83	0.1326	13.23	0.1407
1.6	10.9	0.1285	17.3	0.1596	13.7	0.1224	14.96	0.1539
1.7	13.32	0.1344	16.51	0.157	14.51	0.1214	17.2	0.1497
1.8	14.27	0.1283	13.15	0.1806	13.03	0.1272	16.74	0.2042
1.9	14.45	0.1594	12.81	0.186	12.15	0.1256	17.11	0.252
2	16.74	0.1895	13.49	0.1805	12.87	0.1252	16.14	0.2449
2.1	13.68	0.1963	12.98	0.1863	16.76	0.1384	18.47	0.2218
2.2	14.45	0.1812	14.21	0.1973	16.24	0.1452	17.88	0.2575
2.3	13.91	0.1863	14.36	0.1902	17.48	0.2689	14.89	0.2328
2.4	13.24	0.1997	14.38	0.1819	16.16	0.2628	16.82	0.2287
2.5	14.49	0.1891	13.46	0.1843	15.45	0.2399	15.02	0.2336
2.6	14.82	0.2034	12.83	0.1839	16.26	0.2196	15.51	0.2362
2.7	15.52	0.2155	12.76	0.1333	16.19	0.2172	16.03	0.1958
2.8	14.9	0.1703	12.84	0.1251	16.2	0.2146	16.26	0.221
2.9	15.32	0.1804	18.39	0.1727	13.98	0.2036	15.61	0.1997
3	15.83	0.1981	15.14	0.1697	16.4	0.1766	15.7	0.1957
3.1	13.77	0.2046	13.66	0.1425	16.69	0.1971	14.57	0.1989
3.2	15.46	0.1968	14.07	0.1205	16.03	0.2173	15.03	0.1968
3.3	16.06	0.1614	15.58	0.1205	15.66	0.2256	14.38	0.2025
3.4	18.37	0.1873	16.65	0.1337	17.1	0.1945	14.89	0.1804
3.5	21.66	0.2161	14.96	0.1833	18.51	0.1782	18.51	0.2051
3.6	21.45	0.2167	13.09	0.1957	20.37	0.191	19	0.2327
3.7	19.73	0.2286	14.6	0.1481	20.58	0.2043	18.57	0.1652
3.8	18.97	0.196	16.14	0.1641	20.97	0.1981	18.43	0.1783
3.9	16.32	0.2003	16.64	0.218	19.59	0.1829	15.58	0.1939
4	15.52	0.1845	13.87	0.2195	19.24	0.1955	13.94	0.1841
4.1	18.12	0.1878	13.88	0.2212	19.37	0.2548	14.76	0.1839
4.2	21.49	0.2314	15.71	0.2099	20.49	0.2896	16.08	0.1883
4.3	18.51	0.2241	16.12	0.1947	19.2	0.2535	16.18	0.1946
4.4	16.59	0.1911	15.82	0.1956	20.67	0.2575	17.46	0.1967
4.5	15.23	0.181	16.44	0.2184	19.29	0.2371	16.37	0.2006
4.6	16.24	0.1462	16.17	0.2565	17.94	0.2647	18.26	0.1836
4.7	17.48	0.1233	17.15	0.2688	17.52	0.2778	18.99	0.1959
4.8	20.49	0.1666	20.97	0.3435	18.88	0.2666	16.76	0.1509
4.9	22.4	0.3226	19.19	0.3638	18.99	0.2417	19.42	0.2472
5	18.86	0.3022	18.44	0.2685	18.39	0.2589	17.49	0.2781
5.1	18.79	0.1995	16.77	0.247	21.25	0.2896	17.22	0.2057
5.2	20.95	0.2331	17.83	0.2593	21.63	0.3431	18.56	0.232
5.3	21.94	0.2826	19.13	0.2539	21.26	0.377	18.82	0.2568
5.4	19.34	0.3098	21.96	0.2984	24.18	0.4499	17.37	0.2674

5.5	19.79	0.3037	21.79	0.3646	23.1	0.4483	17.5	0.2745
5.6	20.06	0.272	25.37	0.5256	21.26	0.3223	17.03	0.2394
5.7	20.21	0.2469	26.23	0.5613	19.04	0.2374	18.02	0.2141
5.8	21.38	0.2079	26.15	0.4091	19.49	0.255	17.86	0.1906
5.9	24.07	0.2759	24.37	0.3736	20.01	0.2432	19.2	0.2357
6	22.39	0.3553	24.16	0.3778	22.3	0.277	19.3	0.2755
6.1	21.4	0.3948	23.8	0.3794	20.67	0.3302	18.95	0.3225
6.2	22.06	0.4171	22.8	0.3397	22.23	0.4567	17.92	0.3375
6.3	25.15	0.4709	20.55	0.2823	24.64	0.6028	20.81	0.3665
6.4	26.22	0.474	21.33	0.2552	24.05	0.4456	18.32	0.3227
6.5	24.08	0.4017	22.85	0.2486	24.78	0.3561	17.01	0.2473
6.6	21.27	0.3302	22.4	0.2364	23.66	0.3468	15.9	0.1839
6.7	20.71	0.268	21.32	0.2045	22.54	0.353	17.08	0.2063
6.8	19.95	0.2294	20.93	0.1784	21	0.2887	18.61	0.1867
6.9	20.17	0.2382	20.75	0.1945	20.99	0.2573	18	0.2669
7	19.91	0.2898	20.87	0.2028	21.9	0.2354	16.93	0.3406
7.1	28.56	0.4545	21.03	0.2127	22.5	0.2319	20.94	0.4388
7.2	27.3	0.6968	22.68	0.2196	23.28	0.2376	23.82	0.5012
7.3	28.15	0.5824	23.21	0.2312	21.13	0.1858	24.02	0.3832
7.4	29	0.4758	21.44	0.2045	20.11	0.157	22.17	0.3495
7.5	24.37	0.3958	20.23	0.1833	18.98	0.1341	22.38	0.3718
7.6	25.31	0.3811	20.76	0.1839	18.99	0.1403	22.16	0.3466
7.7	24.62	0.38	21.58	0.1433	22.24	0.1832	20.69	0.267
7.8	24.3	0.2647	23.01	0.1574	22.11	0.2003	20.28	0.2246
7.9	22.44	0.2615	21.88	0.1779	19.49	0.1754	21.43	0.2264
8	21.99	0.2348	22.02	0.1903	19.85	0.1667	20.72	0.2184

Example 2.1 Pad foundation with vertical central load on dense sand
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

Question		Instruction	Answer		
			GENERAL		
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address		
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6		
3	Having completed your design to Eurocode 7, how confident are you that the design is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident		
4	How did you account for the location of cone tests relative to the foundation?	Tick one	☐ Did not consider test location ☐ Considered nearest test only ☐ Considered 'average' of all tests ☐ Considered trend of all tests, biased towards nearest ☐ Other (specify) …		
5	Please explain the reasons for your answer to Q4	Free text			
			SERVICEABILITY LIMIT STATE		
6	Which parameters did you use for the SLS design of the spread foundation?	Tick all that apply	☐ Cone resistance q_c ☐ Cone sleeve friction f_s ☐ Young's modulus of elasticity E´ ☐ Poisson's ratio ν ☐ Shear modulus of elasticity G ☐ Other (specify) …		
7	What correlations did you use to derive soil parameter values (if used) for the SLS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:		
7a	Any other correlations? (please give same info as above)	Free text			
8	What assumptions did you make in choosing these correlations?	Free text			
9	How did you account for any variation in parameters with depth?	Tick one	☐ Ignored variation with depth ☐ Assumed linear variation ☐ Assumed bi-linear variation ☐ Assumed stepped variation ☐ Other (specify) …		
10	Please explain the reasons for your answer to Q9	Free text			
11	What is the characteristic value of q_c at these depths?	Provide values in units of MPa	At 1 m, q_c =	At 2 m, q_c =	At 4 m, q_c =
12	What is the characteristic value of E´ for a linear elastic calculation at these depths?	Provide values in units of MPa	At 1 m, E´ =	At 2 m, E´ =	At 4 m, E´ =
13	How did you assess these values?	Tick all that apply	☐ By eye ☐ By linear regression ☐ By statistical analysis ☐ From an existing standard (specify) … ☐ From a published correlation (specify) … ☐ Comparison with a previous design ☐ From the soil description, not using the data ☐ Other (specify) …		
14	Which calculation model did you use to determine settlement?	Tick one	☐ Annex F.1 from EN 1997-1 ☐ Annex F.2 from EN 1997-1 ☐ Annex D.3 from EN 1997-2 ☐ Annex D.4 from EN 1997-2 ☐ Annex D.5 from EN 1997-2 ☐ Alternative from national annex (specify) … ☐ Alternative from national standard (specify) … ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …		
15	What width does the foundation need to avoid a serviceability limit state?	Provide value in m	B_{SLS} =		
			ULTIMATE LIMIT STATE		
16	Which parameters did you use for the ULS design of the spread foundation?	Tick all that apply	☐ Cone resistance q_c ☐ Cone sleeve friction f_s ☐ Angle of shearing resistance φ´ ☐ Effective cohesion c´ ☐ Angle of interface friction δ ☐ Other (specify) …		

17	What correlations did you use to derive soil parameter values (if used) for the ULS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:			
17a	Any other correlations? (please give same info as above)	Free text				
18	What assumptions did you make in choosing these correlations?	Free text				
19	What is the characteristic value of ϕ' at these depths?	Provide values in degrees	At 1 m, ϕ' =	At 2 m, ϕ' =	At 4 m, ϕ' =	
20	Which calculation model did you use to determine bearing resistance?	Tick one	☐ Annex D from EN 1997-1 ☐ Alternative given in a national annex (specify) … ☐ Alternative given in a national standard (specify) … ☐ Terzaghi ☐ Meyerhof ☐ Brinch-Hansen ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …			
21	Which country's National Annex did you use to interpret EN 1997-1?	Free text				
22	Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?	Tick one	☐ Design Approach 1 Combinations 1 and 2 ☐ Design Approach 1 Combination 1 only ☐ Design Approach 1 Combination 2 only ☐ Design Approach 2 ☐ Design Approach 2* ☐ Design Approach 3 ☐ Other (specify) …			
23 23a	What values of partial factors did you use for this ULS verification?	Provide values	1st combination		2nd combination (if used)	
			γ_G	γ_Q	γ_G	γ_Q
			γ_ϕ	γ_c	γ_ϕ	γ_c
			γ_{Rv}	γ_{Rd}	γ_{Rv}	γ_{Rd}
24	What width does the foundation need to avoid an ultimate limit state?	Provide value in m	B_{ULS} =			
25	What are the structural forces (at its centre-line) that the foundation must be designed for according to Eurocode 2?	Provide values in kNm and kN	Design bending moment M_{Ed} =		Design shear force V_{Ed} =	
CONCLUDING QUESTIONS						
26	What other assumptions did you need to make to complete your design?	Free text				
27	Please specify any other data that you would have liked to have had to design this type of foundation	Free text				
28	How conservative do you consider your previous national practice to be for this design example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative			
29	How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative			
30	How does your Eurocode 7 design compare with your previous national practice?	Tick one	☐ Much more conservative ☐ More conservative ☐ About the same ☐ Less conservative ☐ Much less conservative			
31	Please provide any other relevant information needed to understand your solution to this design exercise	Free text				

PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.1
THANK YOU FOR YOUR CONTRIBUTION!

Example 2.2 Pad foundation with inclined eccentric load on boulder clay

The square pad foundation shown in Figure 2.2a, with an embedment depth of 0.8 m, which is below any topsoil and disturbed ground, is required to support the following characteristic loads:

Permanent:	Vertical	$G_{v,k}$	= 1000 kN, excluding weight of foundation
	Horizontal	$G_{h,k}$	= 0
Variable:	Vertical	$Q_{v,k}$	= 750 kN
	Horizontal	$Q_{h,k}$	= 500 kN, at 2m above the top of the foundation
Concrete weight density		γ_c	= 25 kN/m^3

The variable loads are independent or each other. Assume the variable loads are repeated several times at this magnitude.

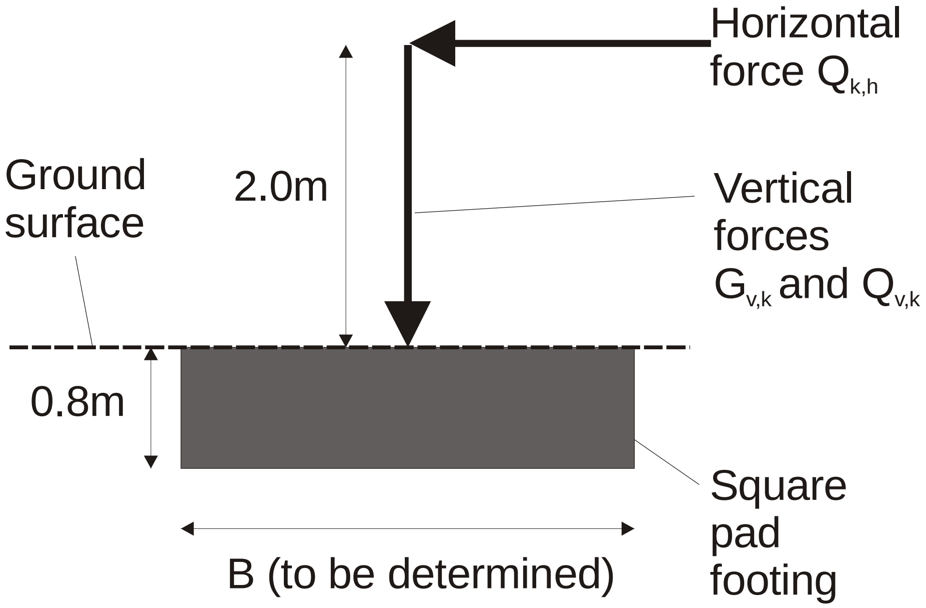


Figure 2.2a: Pad foundation (square on plan)

The soil consists of boulder clay. A site plan showing the location of the foundation and the locations where five SPT tests were carried out is given in Figure 2.2b. N values obtained from SPT tests are plotted in Figure 2.2c, the water contents and index tests determined from samples are presented in Figure 2.2d. The soil has a bulk weight density of 21.4 kN/m^3 and the ground water level is 1.0 m below the ground level. The width of the foundation when designed to Eurocode 7 is to be determined, assuming the foundation is for a conventional concrete framed structure. There is no need to consider any effects due to frost or vegetation. The foundations' design working life is 50 years.

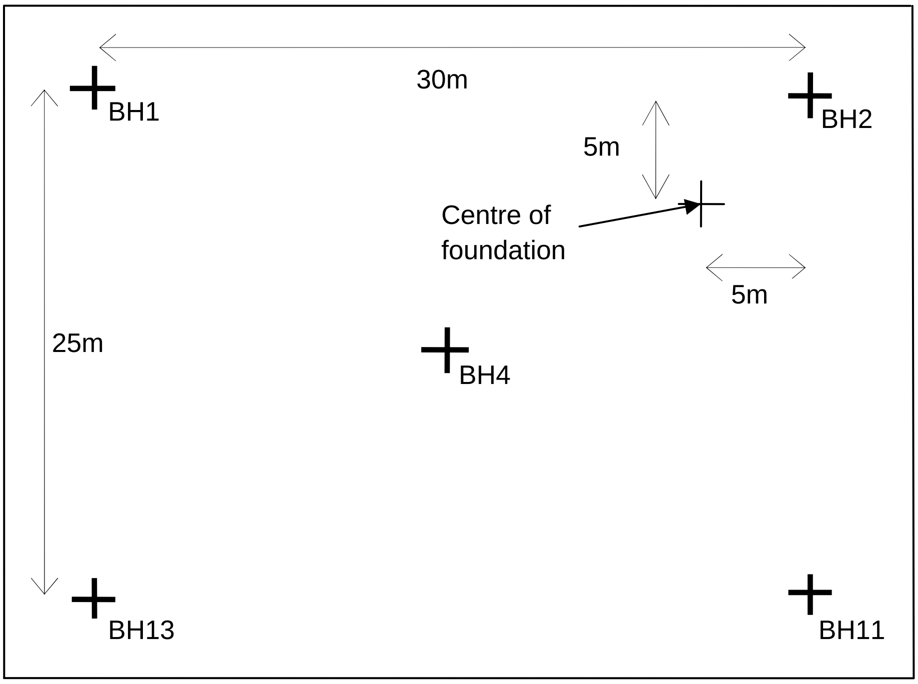


Figure 2.2b: Example 2.2 Site plan and location of SPT tests

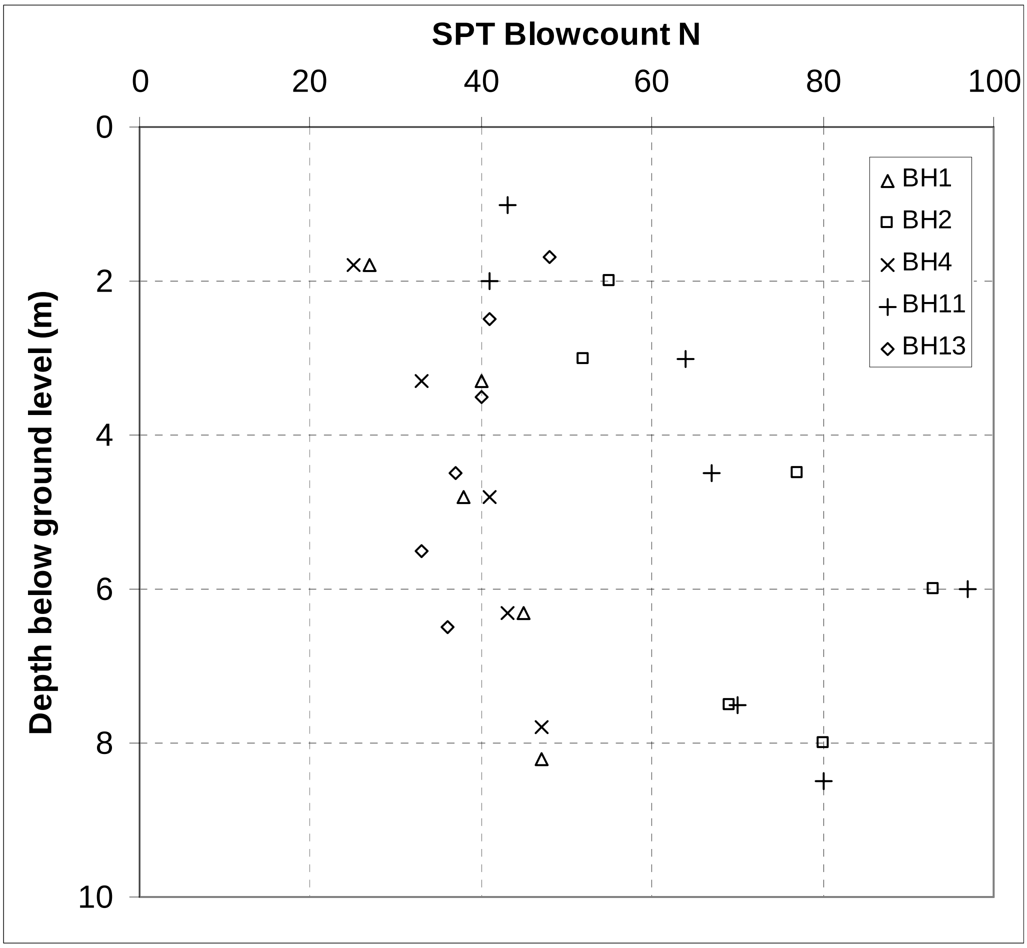


Figure 2.2c: SPT N values recorded at the site

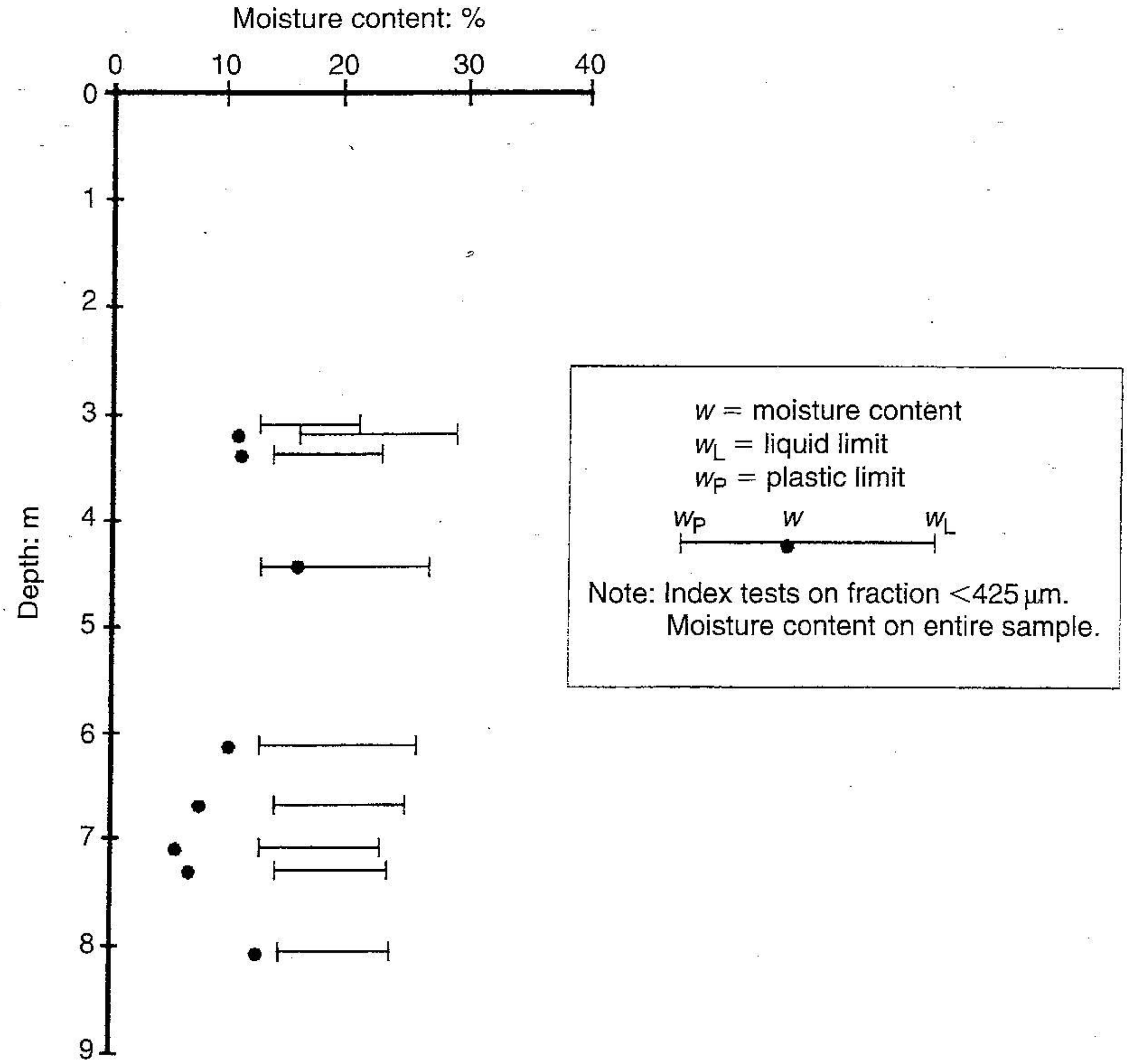


Figure 2.2d: Measured water contents and index values

Design Example 2.2

BOREHOLE No. 1

Type and Dia. of Boring	SHELL & AUGER - 200mm DIAMETER

Water Strikes	Water Levels Recorded During Boring									
1. None	Hole Depth									
2.	Casing Depth									
3.	Water Level									

Remarks

Description	Scale Depth	Legend	Samples & S.P.T. Ref. No.	Type	Depth		N
TOP SOIL	0.30						
Very stiff brown sandy gravelly CLAY with cobbles (Boulder Clay)			9998	U	1.00		
			9351	D	1.50		
			9905	D	2.00	(1.80)	27
			9352	D	2.50		
	2.90		9997	D	3.00		
Very stiff black silty sandy gravelly CLAY with cobbles and boulders (Boulder Clay)						(3.30)	40
			9920	D	5.00	(4.80)	38
			9923	D	6.00		
						(6.30)	45
			9921	D	7.50		
	8.00		9924	D	8.00	(7.80)	47

Code : U—Undisturbed Sample D—Large Disturbed Sample J—Jar Sample W—Water Sample

Figure 2.2e: Borehole Log 1

Design Example 2.2

BOREHOLE No. 2

Type and Dia. of Boring	SHELL & AUGER - 200mm DIAMETER

Water Strikes	Water Levels Recorded During Boring									
1. 2.20	Hole Depth	5.00	8.00	8.00						
2.	Casing Depth	5.00	7.40	Nil						
3.	Water Level	Nil	Nil	3.00						

Remarks: Chiselling total of 4 hours
PVC pipe installed.

Description	Scale Depth	Legend	Ref. No.	Type	Depth	Samples & S.P.T. Depth	N
TOPSOIL	0.20						
Firm brownish grey mottled silty sandy CLAY (some organic flecks at upper levels)			10088	U	0.50		
			10089	D	0.50		
			10090	U	1.50		
			10091	D	1.50		
						(2.00)	55
	2.20		10092	D	2.20		
Stiff to hard black sandy very silty gravelly CLAY containing cobbles and boulders (Boulder Clay)						(3.00)	52
			10093	D	3.80		
						(4.50)	77
			10093	D	5.00		
			10094	D	5.20		
						(6.00)	93
			10095	D	7.10		
						(7.50)	69
			10096	D	8.00	(8.00)	80
Borehole completed at	8.50						

Code : U—Undisturbed Sample D—Large Disturbed Sample J—Jar Sample W—Water Sample

Figure 2.2f: Borehole Log 2

Design Example 2.2

BOREHOLE No. 4

Type and Dia. of Boring	SHELL & AUGER - 200mm DIAMETER

Water Strikes	Water Levels Recorded During Boring									
1. 3.20	Hole Depth									
2.	Casing Depth									
3.	Water Level									

Remarks Seepage at 3.20 metres. Sealed off in Black Boulder Clay.

Description	Scale Depth	Legend	Samples & S.P.T. Ref. No.	Type	Depth	N
TOPSOIL	0.30					
Firm to stiff brown sandy gravelly CLAY (Boulder Clay)			9914	D	1.50	
					(1.80)	25
	3.20		9202	D	3.20 (3.30)	33
Very stiff black silty gravelly CLAY with cobbles and boulders (Boulder Clay)					(4.80)	41
			9989	D	6.00	
					(6.30)	43
					(7.80)	47
	8.00		9990	D	8.00	

Code : U—Undisturbed Sample D—Large Disturbed Sample J—Jar Sample W—Water Sample

Figure 2.2g: Borehole Log 4

Design Example 2.2

BOREHOLE No. 11

Type and Dia. of Boring	SHELL & AUGER - 450mm DIAMETER

Water Strikes	Water Levels Recorded During Boring									
1. 2.80	Hole Depth	6.30	8.50	8.50						
2.	Casing Depth	6.30	7.30	--						
3.	Water Level	Nil	Nil	3.50						

Remarks: Total - 3 hrs. chiselling
PVC pipe installed.

Description	Scale Depth	Legend	Samples & S.P.T. Ref. No.	Type	Depth	N
TOPSOIL	0.30					
Stiff brown silty very stony CLAY, some cobbles			10096	U	0.50	
			10097	D	0.50	
	1.00				(1.00)	43
Stiff brown sandy gravelly CLAY with cobbles (Boulder Clay)			10098	D	1.50	
				U	1.50 (Abortive)	
					(2.00)	41
	3.00		10099	D	3.00 (3.00)	64
Very stiff black sandy silty gravelly CLAY, cobbles and some boulders (Boulder Clay)			10100	D	4.50 (4.50)	67
					(6.00)	97
			10101	D	6.50	
					(7.50)	70
			10102	D	7.80	
Borehole completed at	9.00				(8.50)	80

Code: U—Undisturbed Sample D—Large Disturbed Sample J—Jar Sample W—Water Sample

Figure 2.2h: Borehole Log 11

Design Example 2.2

BOREHOLE No. 13

Type and Dia. of Boring	SHELL & AUGER - 250mm DIAMETER

Water Strikes	Water Levels Recorded During Boring										
1. 2.50	Hole Depth	3.00	8.00								
2.	Casing Depth	3.00	8.00								
3.	Water Level	--	4.50								

Remarks: Chiselling boulders - total 3½ hrs.
PVC pipe inserted

Description	Scale Depth	Ref. No.	Type	Depth	N
TOPSOIL, stony	0.50				
Stiff brown sandy gravelly CLAY with cobbles and boulders (Boulder Clay)		10063	U	1.20	
		10062	D	1.50	
				(1.70)	48
				(2.50)	41
	2.90	10064	D	3.00	
Stiff black sandy silty gravelly Boulder Clay with cobbles and boulders and thin layers of sand and gravel				(3.50)	40
		10079	D	4.50 (4.50)	37
				(5.50)	33
		10080	D	6.00	
				(6.50)	36
				(7.50)	42
Borehole completed at	8.00	10081	D	8.00	

Code : U—Undisturbed Sample D—Large Disturbed Sample J—Jar Sample W—Water Sample

Figure 2.2i: Borehole Log 13

Example 2.2 Pad foundation with inclined eccentric load on boulder clay
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

Question		Instruction	Answer
			GENERAL
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6
3	Having completed your design to Eurocode 7, how confident are you that the design is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident
4	How did you account for the location of boreholes relative to the foundation?	Tick one	☐ Did not consider borehole location ☐ Considered nearest borehole only ☐ Considered 'average' of all boreholes ☐ Considered trend of all boreholes, biased towards nearest ☐ Other (specify) …
5	Please explain the reasons for your answer to Q4	Free text	
			SERVICEABILITY LIMIT STATE
6	Which parameters did you use for the SLS design of the spread foundation?	Tick all that apply	☐ Water content w ☐ Plasticity index I_P ☐ Liquidity index I_L ☐ SPT blow count N ☐ Corrected SPT blow count $(N_1)_{60}$ ☐ Undrained Young's modulus of elasticity E_u ☐ Drained Young's modulus of elasticity E' ☐ Poisson's ratio ν ☐ Shear modulus of elasticity G ☐ Permeability k ☐ Other (specify) …
7	What correlations did you use to derive soil parameter values (if used) for the SLS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:
7a	Any other correlations? (please give same info as above)	Free text	
8	What assumptions did you make in choosing these correlations?	Free text	
9	How did you account for any variation in parameters with depth?	Tick one	☐ Ignored variation with depth ☐ Assumed linear variation ☐ Assumed bi-linear variation ☐ Assumed stepped variation ☐ Other (specify) …
10	Please explain the reasons for your answer to Q9	Free text	
11	What is the characteristic value of N at these depths?	Provide uncorrected values	At 1 m, N = | At 2 m, N = | At 4 m, N =
12	What is the characteristic value of E_u for a linear elastic calculation at these depths?	Provide values in units of MPa	At 1 m, E_u = | At 2 m, E_u = | At 4 m, E_u =
13	How did you assess these values?	Tick all that apply	☐ By eye ☐ By linear regression ☐ By statistical analysis ☐ From an existing standard (specify) … ☐ From a published correlation (specify) … ☐ Comparison with a previous design ☐ From the soil description, not using the data ☐ Other (specify) …
14	Which calculation model did you use to determine settlement?	Tick one	☐ Annex F.1 from EN 1997-1 ☐ Annex F.2 from EN 1997-1 ☐ Annex F.3 from EN 1997-2 ☐ Alternative from national annex (specify) … ☐ Alternative from national standard (specify) … ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …
15	What limiting values of settlement and tilt are appropriate for this foundation?	Provide values in mm and 1/x	C_d = (settlement) C_d = (tilt)
16	What width does the foundation need to avoid a serviceability limit state?	Provide value in m	B_{SLS} =

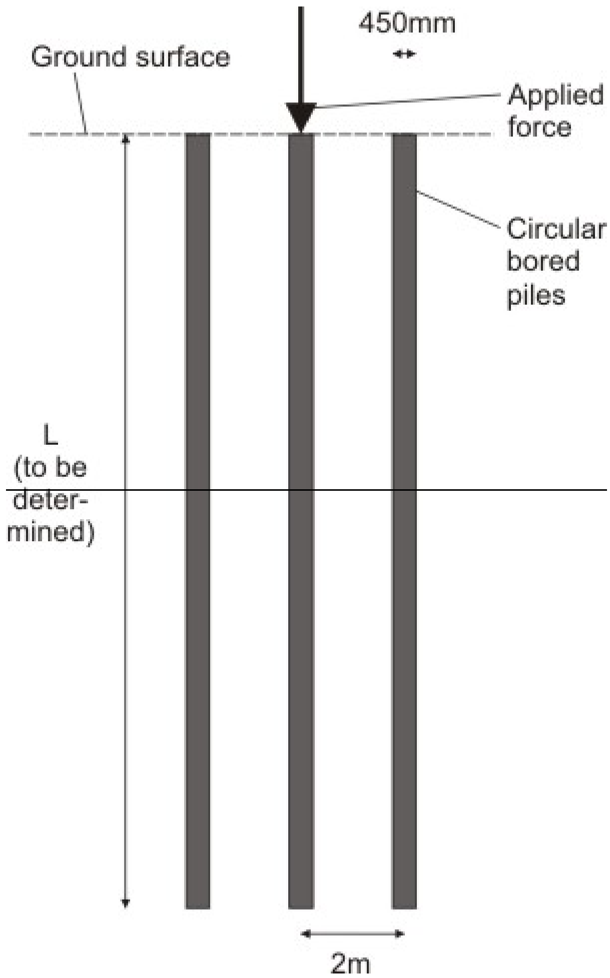
ULTIMATE LIMIT STATE			
17	Which parameters did you use for the ULS design of the spread foundation?	Tick all that apply	☐ Water content w ☐ Plasticity index I_P ☐ Liquidity index I_L ☐ SPT blow count N ☐ Corrected SPT blow count $(N_1)_{60}$ ☐ Undrained shear strength c_u ☐ Angle of shearing resistance ϕ' ☐ Effective cohesion c' ☐ Angle of interface friction δ ☐ Permeability k ☐ Other (specify) …
18	What correlations did you use to derive soil parameter values (if used) for the ULS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:
18a	Any other correlations? (please give same info as above)	Free text	
19	What assumptions did you make in choosing these correlations?	Free text	
20	What is the characteristic value of c_u at these depths?	Provide values in units of kPa	At 1 m, c_u = | At 2 m, c_u = | At 4 m, c_u =
21	Which calculation model did you use to determine bearing resistance?	Tick one	☐ Annex D from EN 1997-1 ☐ Alternative given in a national annex (specify) … ☐ Alternative given in a national standard (specify) … ☐ Terzaghi ☐ Meyerhof ☐ Brinch-Hansen ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …
22	Which country's National Annex did you use to interpret EN 1997-1?	Free text	
23	Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?	Tick one	☐ Design Approach 1 Combinations 1 and 2 ☐ Design Approach 1 Combination 1 only ☐ Design Approach 1 Combination 2 only ☐ Design Approach 2 ☐ Design Approach 2* ☐ Design Approach 3 ☐ Other (specify) …
24 24a	What values of partial factors did you use for this ULS verification?	Provide values	1st combination: γ_G | γ_Q | γ_ϕ | γ_c | γ_{cu} | γ_{Rv} | γ_{Rh} | γ_{Rd} 2nd combination (if used): γ_G | γ_Q | γ_ϕ | γ_c | γ_{cu} | γ_{Rv} | γ_{Rh} | γ_{Rd}
25	What width does the foundation need to avoid an ultimate limit state?	Provide value in m	B_{ULS} =
26	What are the structural forces (at its centreline) that the foundation must be designed for according to Eurocode 2?	Provide values in kNm and kN	Design bending moment M_{Ed} = | Design shear force V_{Ed} =
CONCLUDING QUESTIONS			
27	What other assumptions did you need to make to complete your design?	Free text	
28	Please specify any other data that you would have liked to have had to design this type of foundation	Free text	
29	How conservative do you consider your previous national practice to be for this design example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative
30	How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative
31	How does your Eurocode 7 design compare with your previous national practice?	Tick one	☐ Much more conservative ☐ More conservative ☐ About the same ☐ Less conservative ☐ Much less conservative
32	Please provide any other relevant information needed to understand	Free text	

	your solution to this design exercise		
PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.2 **THANK YOU FOR YOUR CONTRIBUTION!**			

Example 2.3 Pile foundation in stiff clay

A building is to be supported on 450 mm diameter bored piles founded entirely in a stiff clay and spaced at 2m centres. The piles are bored dry, without casing, and concreted on the same day as boring. Each pile carries a characteristic vertical permanent load of 300 kN and a characteristic vertical variable load of 150 kN. This is a small project for which there will be no load testing. Settlement in service is to be limited to 20 mm. The pile's design working life is 50 years. The clay is an over-consolidated marine clay of Miocene age, containing fissures and occasional claystones. Bedding is essentially horizontal.

The undrained shear strength of the clay at different depths can be determined from the results of four different types of tests that were carried out on the site: triaxial tests on samples from 6 percussion bored boreholes SG 11, SG 12, SG 14, SG 15, SG 16 and SG 17, SPTs in the 6 percussion bored boreholes, 1 CPT test and 2 self-boring pressuremeter (SBP) tests, carried out at the locations shown in Figure 2.3a. The results of the undrained triaxial tests are presented in Figure 2.3b. the results of the CPT tests in Figure 2.3c, the logs of boreholes SG14 and RC13 in Figures 2.3d and 2.3e, the results of the SPT blowcounts from the 6 boreholes in Figure 2.3f, and the results of the 2 SBP tests in Figure 2.3g. The designer may select any or all of these data. Appropriate correlations are to be used to determine characteristic values for design. Below 20 m depth, the undrained shear strength is assumed to increase no further.



The water table is at the surface of the clay, and water pressures may be taken to be hydrostatic. The weight density of the clay may be taken as 20kN/m^3. At this location the ground surface should be taken to be +17m OD (OD = Ordnance Datum, i.e. reference level), which is also the level of the surface of the stiff clay.

Using Eurocode 7, determine the design length of the pile at the location shown in Figure 2.3a.

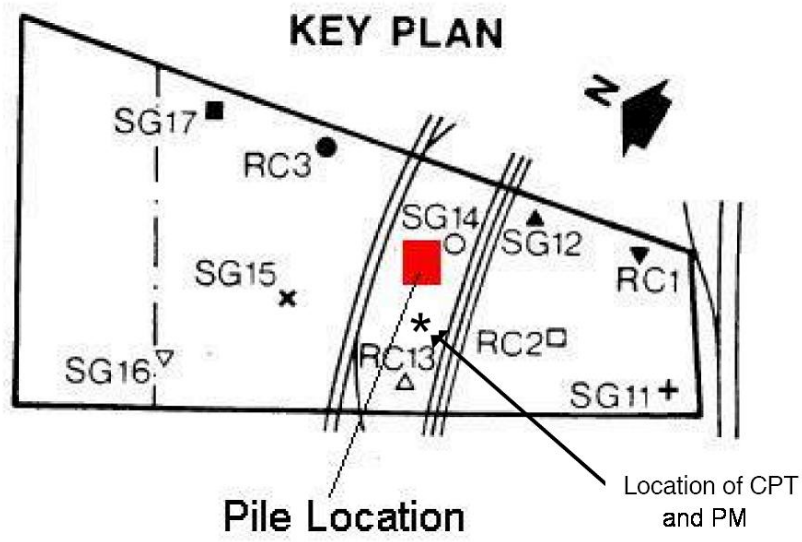


Figure 2.3a: Site plan showing the locations of the boreholes (SG11-17), cone penetration test (CPT), and two profiles of self-boring pressuremeter tests (marked PM on this figure)

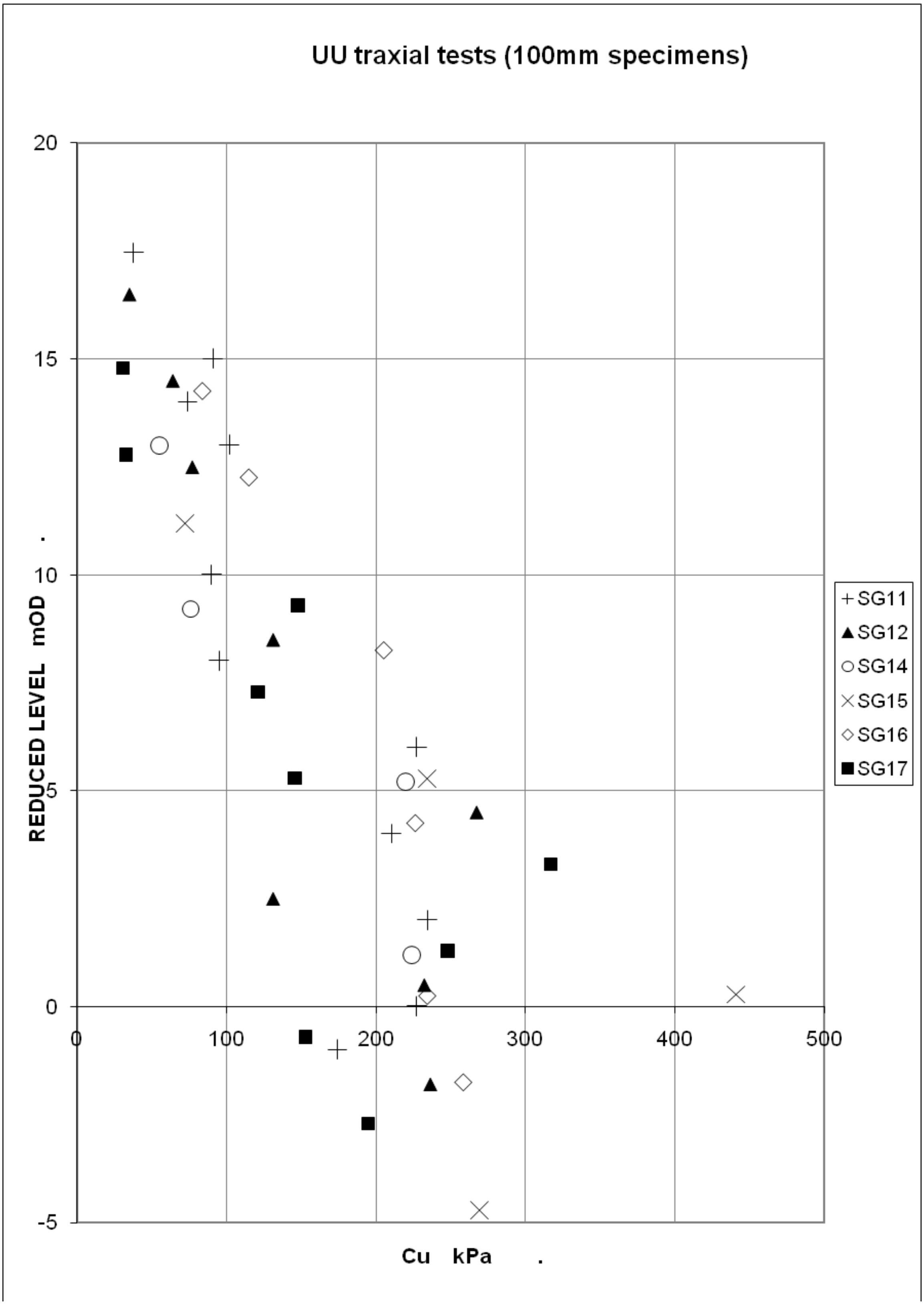


Figure 2.3b: Undrained Triaxial Test Results

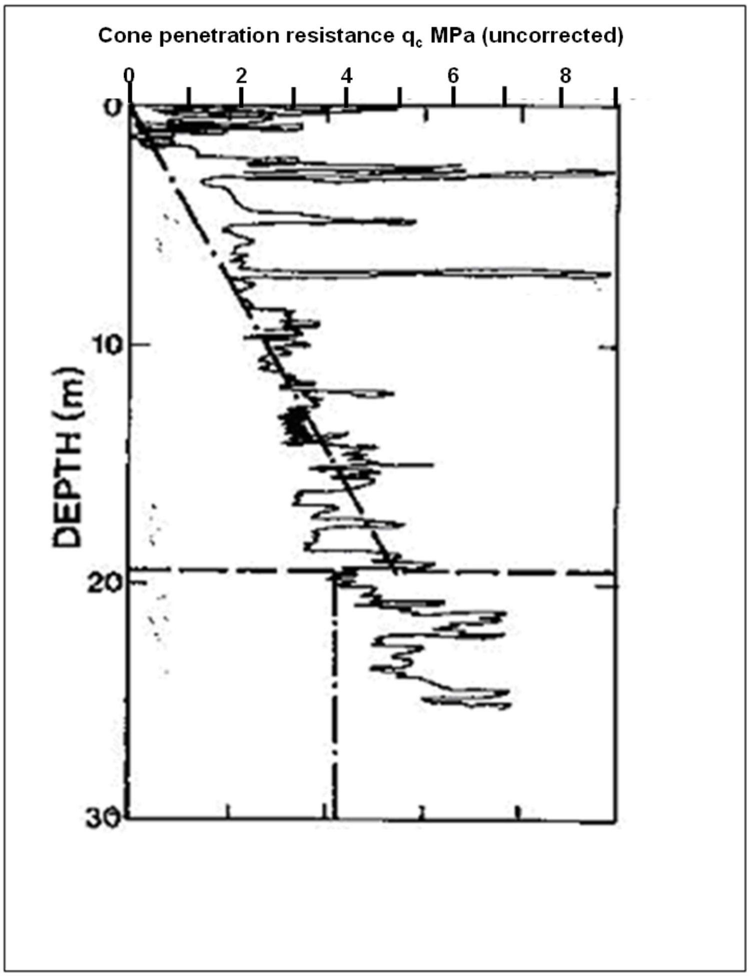


Figure 2.3c: Cone penetration resistance from CPT test

Design Example 2.3

Record of Borehole No. SG 14

Daily progress	Depth to water	Depths of casing	Samples depth from	Samples depth to	Type	Depth (m)	Reduced level (m above OD)	Description of strata	
						GL	19.45		
10.12.75						0.40	19.05	GRANITE SETTS on lean-mix CONCRETE	
			1.15	1.45	S 4	1.00	18.45	Sandy gravelly RUBBLE, comprising broken bricks, pieces of concrete and stones. Clayey towards the bottom.	
			1.50	2.00	BD			Very soft to soft, brown, sandy silty CLAY with small stones and occasional brick fragments. Also pieces of china, tile and flint gravel.	
		1.70	2.15	2.45	S 2				
			2.00	2.50	BD				
			3.15	3.45	S 1	3.70	15.75	Old pipe encountered at 3.6 m (approx 150 mm diameter), pipe virtually dry. (FILL - possibly trench for placing pipe)	
			3.70	4.00	BD				
			4.00	4.50	U 100			Firm to stiff, brown mottled grey silty CLAY with patches of orange-brown SAND/SILT and numerous gypsum crystals. Less mottled with depth.	
5.0	DRY	4.70	5.15	5.45	S 16			Small CLAYSTONE at 5.7 m.	
11.12.75	DRY	4.70	5.70	6.00	BD				X
						6.00	13.45	(LONDON CLAY)	
			6.00	6.50	U 100			Stiff, grey-brown or grey fissured silty CLAY with traces of fine SAND/SILT.	
			7.15	7.45	S 19				
			7.60	7.80	BD				
			8.00	8.50	U 100	8.40	11.05	(LONDON CLAY)	to 22.0
			9.15	9.45	S 26			Stiff to very stiff, grey silty and sandy CLAY, with patches of fine SAND/SILT. Numerous patches and partings of SILT/SAND below 11.0 m.	
			10.00	10.50	U 100			Sand content increases sufficiently around 12.0 m to classify as a clayey SAND.	
			11.15	11.45	S 29				
			12.00	12.50	U 100				
			13.15	13.45	S 27	13.00	6.45	(LONDON CLAY)	
13.50	DRY	4.70						Stiff to very stiff, grey silty CLAY with occasional concentrations of SILT. Laminar structure visible. Occasional small pyritised nodules.	
12.12.75	13.30	4.70							
			14.00	14.50	U 100			Slight seepage of water from 14.0 m.	
			15.15	15.45	S 39				
								Small pieces of CLAYSTONE recovered from 15.8 m to 16.0 m. Slight seepage of water.	
			16.00	16.50	U 100				
			17.15	17.45	S 41	17.00	2.45	Stiff to very stiff, silty and sandy CLAY, with patches and pockets of SILT/fine SAND.	
			18.00	18.50	U 100			Numerous shell fragments around 18.6 m.	
			19.15	19.45	S 45			Becoming very sandy around 19.0 m.	
						20.00	-0.55	(LONDON CLAY)	

REMARKS

(1) Disturbed sample (Jar) taken from the cutting shoe of all U100 and from SPT.

TYPE OF BORING

Shell-and-auger
1 ton Isler

DIAMETER OF BORING

240 mm - to 20.5 m

CASING TUBES

250 mm - to 4.7 m.

BOREHOLE NO. SG 14

Figure 2.3d(1): Log for percussion bored Borehole No. SG 14 – Sheet 1

Design Example 2.3

Record of Borehole No. SG 14 (contd.)

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES DEPTH FROM	SAMPLES DEPTH TO	SAMPLES TYPE	DEPTH	REDUCED LEVEL	DESCRIPTION OF STRATA
						20.00	-0.55	
			20.00	20.50	U 100			Very stiff brown mottled green fissured silty CLAY; very silty in patches.
20.50	DRY	4.70						
13.12.75	17.50	20.50	17.50		W			(WOOLWICH and READING BEDS)
			21.15	21.38	S77+			
			21.80	22.00	BD	21.80	-2.35	
			22.15	22.23	S176+			Dense brown slightly clayey and silty, fine-grained SAND.
			22.90	22.98	S180+			
23.5	DRY	23.5						Casing sinking under its own weight during boring, borehole dry from 22.0 m - water added.
15.12.75	20.50	23.50	23.50	23.80	BD	24.00	-4.55	
			23.65	23.95	S 67			Very stiff brown mottled grey-green fissured silty CLAY.
		24.00	24.00	24.50	BD			-6.0 ∇
			24.65	24.95	S 87			
		25.00	25.50	26.00	U 100			
26.0	DRY	25.30				26.00	-6.45	
16.12.75	22.00	25.30						Very stiff light-grey mottled greenish-brown fissured silty CLAY.
		(2)	26.55	26.95	S 40			Numerous polished surfaces.
			27.50	28.00	U 100			Slight seepage of water following casing of sand layer.
			28.65	28.95	S 50	28.50	-9.05	Dense alternating thin bands of light grey sandy SILT and dark grey silty CLAY. Horizontally bedded.
			29.00	29.50	BD	29.00	-9.55	
			29.50	30.00	U 100			Very stiff, reddish-brown, mottled light grey-green and orange brown fissured silty CLAY, becoming darker and predominantly brown with depth.
30.00	23.00	25.30						
17.12.75	25.00	25.30						
	(3)		30.65	30.95	S 67			
			31.50	32.00	U 100			-12 ∇ (WOOLWICH and READING BEDS)
			32.65	32.90	S 96+			
33.00	22.00	25.30						
18.12.75	27.00	25.30	33.65	33.95	S 72			
	(3)							
34.50	DRY	34.50	34.30	34.50	BD	34.30	-14.35	Dense, very clayey, silty fine-grained SAND, with occasional small flint fragments. (THANET SAND - reworked?)
19.12.75	DRY	34.50	34.65	34.80	S114+	34.80	-15.35	
			34.80	35.00	BD			Dense grey/green silty SAND with numerous thin bands and pockets of multicoloured (red, brown and green) silty CLAY.
			35.65	35.80	S106+			
35.30	DRY	34.50				35.80	-16.35	
6.1.76	22.00	34.50						Dense dark greenish-grey, very sandy CLAY with numerous partings and pockets of light grey, silty fine-grained SAND.
		35.00	36.55	36.38	S 97+			
			37.65	37.88	S103+			becoming clayey SAND with thin layers of light grey medium-grained SAND. Occasional pebbles with blackened surfaces, usually small. (THANET SAND - reworked?)
			38.65	38.73	S144+			
						38.70	-19.25	Dense light grey silty fine SAND.
39.5	26.00	35.00						(THANET SAND)
7.1.76	29.00	35.00	39.50	39.65	S (4)	40.00	-20.55	

REMARKS
(2) Unable to drive casing below 25.30 m; water not sealed off.
(3) Collapse of borehole overnight; approximately 3 m of collapsed material.
(4) Test terminated after "seating blows".

TYPE OF BORING
Shell-and-auger
1 ton Isler

DIAMETER OF BORING
240 mm - to 20.5 m
190 mm - to 34.3 m
140 mm - to 44.6 m

CASING TUBES
250 mm - to 4.7 m
200 mm - to 25.3 m
150 mm - to 35.0 m

BOREHOLE NO. SG 14 (Continued)

Figure 2.3d(2): Log for percussion bored Borehole No. SG 14 with SPT results – Sheet 2

Design Example 2.3

Record of Borehole No. SG 14 (contd.)

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES DEPTH FROM	SAMPLES DEPTH TO	SAMPLES TYPE	LEGEND	DEPTH	REDUCED LEVEL	DESCRIPTION OF STRATA
							40.00	-20.55	
		35.00	39.70	40.00	BD				Dense light grey, silty, fine-grained SAND. Occasional rounded flints and an increase in angular flint fragments towards base of stratum. (THANET SAND)
			40.00	40.50	BD				
			40.65	40.73	S 120+				
			41.50	41.65	S (4)				
42.50	36.00	35.00							
8.1.76	28.00	35.00							
			43.45	43.53	S 120+				
43.30	38.00	35.00	43.80	43.88	S (4)		43.30		Hard, white CHALK.
9.1.76	30.00	35.00							
44.60	(5)	35.50	44.60	44.63	S (4)		44.60	-25.15	End of borehole

REMARKS

(4) Test terminated after "seating blows".
(5) No water level measurement - borehole grouted on completion of boring.
(6) Borehole collapsed overnight to 39.5 m, 35.0m and 35.0m on 7, 8 and 9 Jan respectively.

TYPE OF BORING
Shell-and-auger
1 ton Isler

DIAMETER OF BORING
240 mm - to 20.5 m
190 mm - to 34.5 m
140 mm - to 44.6 m

CASING TUBES
250 mm - to 4.7 m
200 mm - to 25.3 m
150 mm - to 35.0 m

BOREHOLE NO. SG 14 (Continued)

Figure 2.3d(3): Log for Borehole No. SG 14 with SPT results – Sheet 3

Design Example 2.3

RECORD OF BOREHOLE NO. RC13 (Sheet 1 of 2)

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES DEPTH FROM	SAMPLES DEPTH TO	SAMPLES TYPE	LEGEND	DEPTH	REDUCED LEVEL
	m	m	m	m			m	mOD
9.5.76							0.30	18.16
		1.50	1.40	2.10				
					53%		1.95	16.51
		1.50	2.10	3.60			2.28	16.18
					88%			
		1.50	3.60	4.60				
					100%			
		1.50	4.60	5.50			4.65	13.81
					100%			
		1.50	5.50	6.50				
					40%			
10.5.77		6.00	6.50	8.00				
					100%			
		6.00	8.00	9.50				
					100%			
		6.00	9.50	11.00				
					100%			
		6.00	11.00	12.50				
					100%			
11.5.77		6.00	12.50	14.00				
					96%			
		6.00	14.00	15.30				
					85%			
		6.00	15.30	16.80				
					100%			
		6.00	16.80	18.20				
					100%			

DESCRIPTION OF STRATA

Ground level 18.46mOD

Tarmac and stone setts

Brown slightly clayey SAND and GRAVEL of clinker and brick.
(MADE GROUND)

Mottled brown and pale blue silty gravelly CLAY
(ALLUVIUM)

Mottled brown and pale blue very closely jointed slightly silty CLAY. Occasional 10-15mm patches of orange brown silty fine sand.
(WEATHERED LONDON CLAY)

Greyish brown silty CLAY with occasional very silty partings. Below 8.52m, clay is very silty with a trace of fine sand. Joints more widely spaced and less distinct. Trace of ironstained wood fragments. From 14.25 to 15.30 and from 15.45 to 15.85 dense grey brown silty slightly clayey fine sand to sandy silt with haematised wood fragments.

From 15.85 - 17.45, clay is brownish grey silty and closely jointed; occasionally very closely jointed.

From 17.45 to 18.2 very silty with a trace of fine sand and only occasional joints.

(LONDON CLAY)

Continued

REMARKS

TYPE OF BORING
Rock Roller to 1.40m
Rotary Coring to 25.0m

DIAMETER OF BORING
0 to 6.5m: 146mm
6.5 to 25.0m: 120mm

CASING TUBES
170mm to 6.0m

BOREHOLE NO. RC13

Figure 2.3e(1): Log for rotary cored Borehole No. RC 13 – Sheet 1

Design Example 2.3

RECORD OF BOREHOLE NO. RC 13 (Sheet 2 of 2)

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES DEPTH FROM	SAMPLES DEPTH TO	SAMPLES TYPE	LEGEND	DEPTH	REDUCED LEVEL	DESCRIPTION OF STRATA
	m	m	m	m			m	mOD	
11.5.76		6.00	18.20	19.70					Brownish grey silty to very silty closely, occasionally very closely jointed CLAY. Occasional 10-15mm patches of blue grey iron rich sand. Below 18.95m with fine sand and numerous wood fragments. (LONDON CLAY)
					100%				
		6.00	19.70	21.00					
							20.40	-1.94	
					100%				Mottled pale brown and very pale blue slightly silty becoming silty closely jointed CLAY with occasional haematised wood fragments. Below 21.1m mottled rust red. (WOOLWICH AND READING BEDS)
		6.00	21.00	22.50					
					100%				
		6.00	22.50	23.80					
					92%				
		6.00	23.80	25.00					
					72%		25.00	-6.54	
									END OF BOREHOLE

REMARKS

TYPE OF BORING

DIAMETER OF BORING

CASING TUBES

BOREHOLE NO. RC13

Figure 5.3e(2): Log for rotary cored Borehole No. RC 13 – Sheet 2

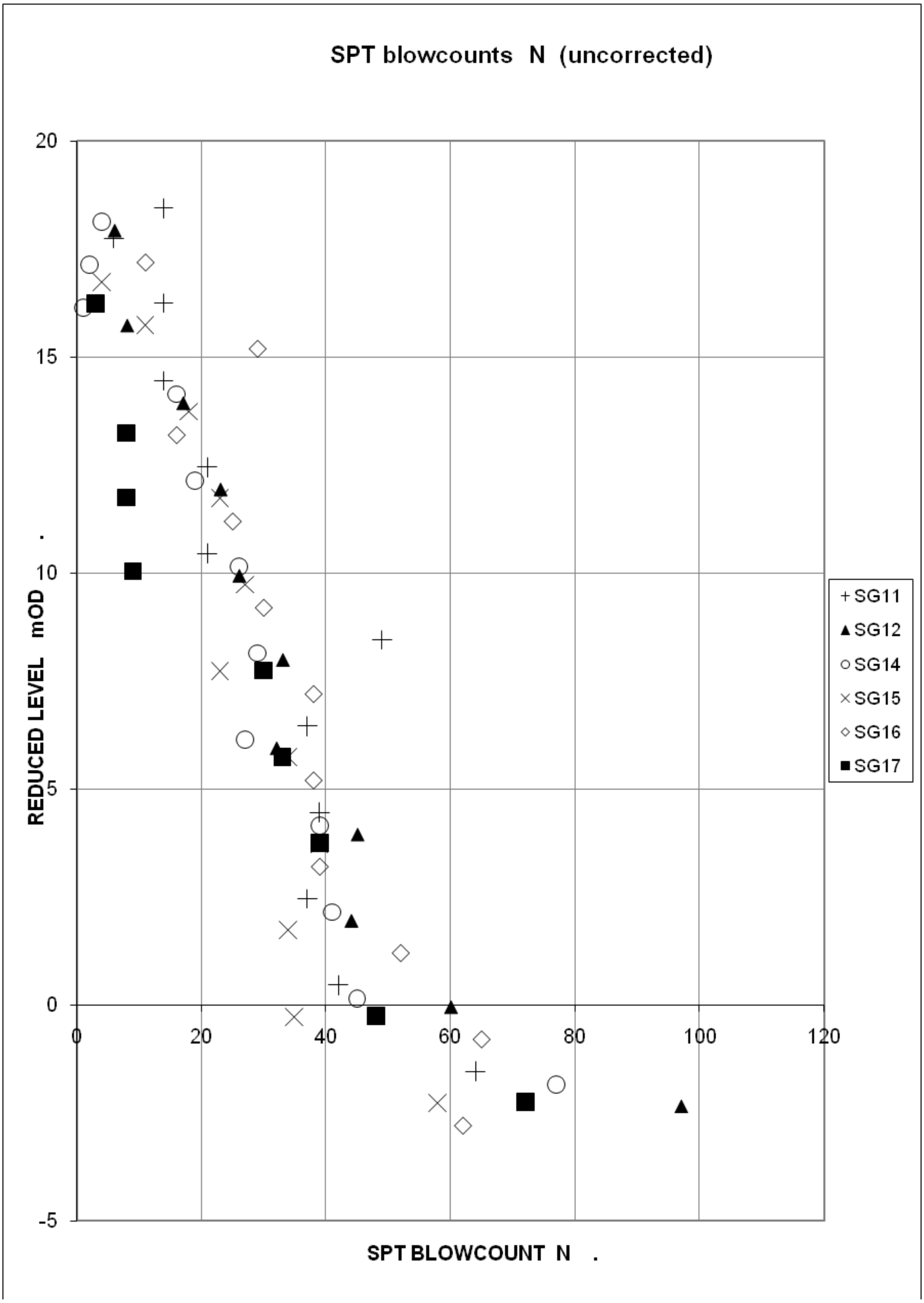


Figure 2.3f: Combined SPT blowcounts from Boreholes SG 11, SG 12. SG 14, SG 15 SG 16 and SG 17

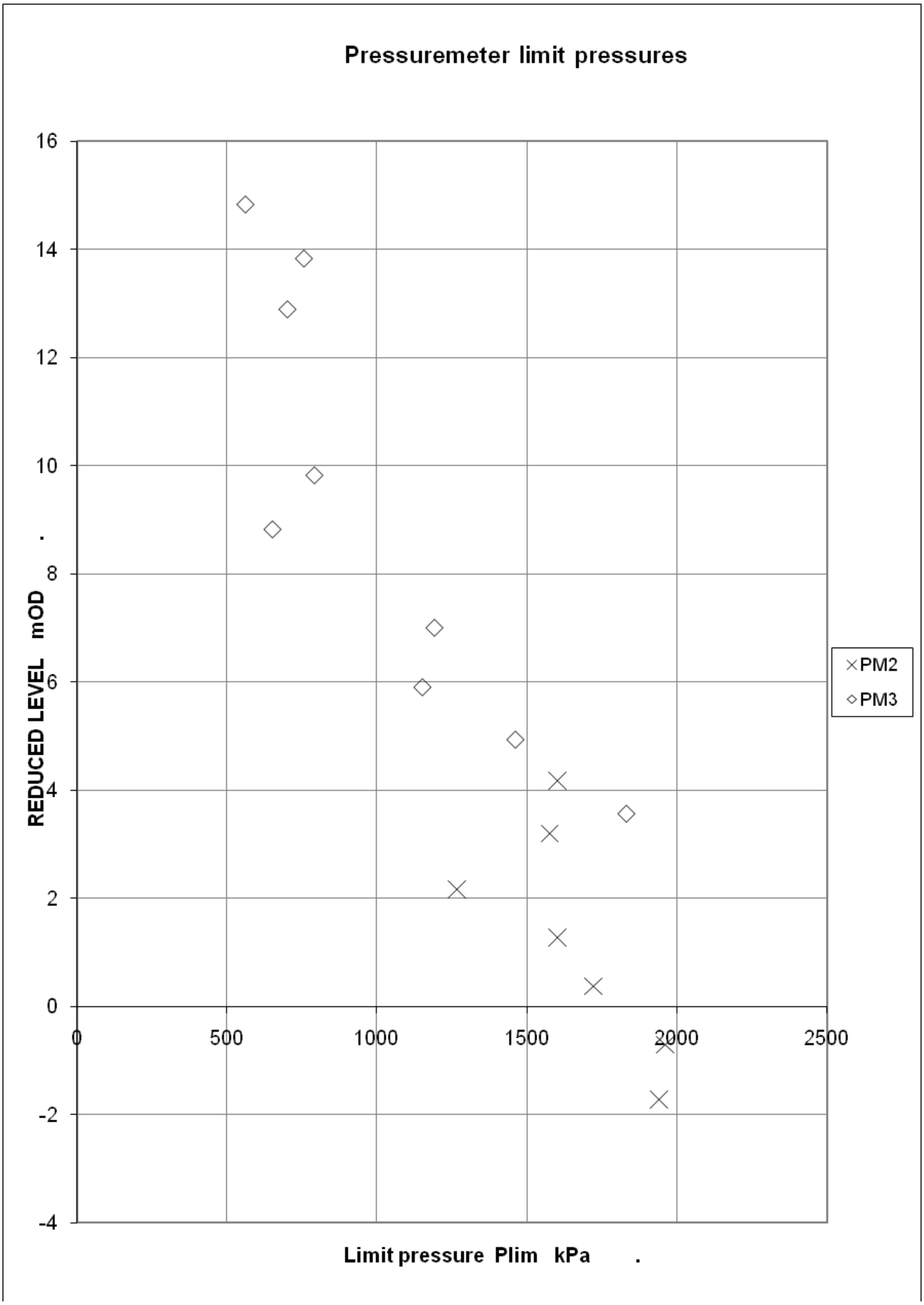


Figure 2.3g: Results of self-boring pressuremeter tests in two boreholes PM2 and PM3

Example 2.3 Pile foundation in stiff clay
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

Question		Instruction	Answer		
			GENERAL		
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address		
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6		
3	Having completed your design to Eurocode 7, how confident are you that the design is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident		
4	How did you account for the location of boreholes/cone tests relative to the foundation?	Tick one	☐ Did not consider borehole/test location ☐ Considered nearest borehole/test only ☐ Considered 'average' of all boreholes/tests ☐ Considered trend of all b'holes/tests, biased towards nearest ☐ Other (specify) …		
5	Please explain the reasons for your answer to Q4	Free text			
			SERVICEABILITY LIMIT STATE		
6	Which parameters did you use for the SLS design of the pile foundation?	Tick all that apply	☐ Cone resistance q_c ☐ Sleeve friction f_s ☐ SPT blow count N ☐ Corrected SPT blow count $(N_1)_{60}$ ☐ UU triaxial test strength c_u ☐ Pressuremeter limit pressure p_{lim} ☐ Undrained Young's modulus of elasticity E_u ☐ Drained Young's modulus of elasticity E' ☐ Poisson's ratio ν ☐ Shear modulus of elasticity G ☐ Other (specify) …		
7	What correlations did you use to derive soil parameter values (if used) for the SLS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:		
7a	Any other correlations? (please give same info as above)				
8	What assumptions did you make in choosing these correlations?	Free text			
9	How did you account for any variation in parameters with depth?	Tick one	☐ Ignored variation with depth ☐ Assumed linear variation ☐ Assumed bi-linear variation ☐ Assumed stepped variation ☐ Other (specify) …		
10	Please explain the reasons for your answer to Q9	Free text			
11	What is the characteristic value of N at these levels?	Provide uncorrected values	At +17 m, N =	At +7 m, N =	At –3 m, N =
12	What is the characteristic value of q_c at these levels?	Provide values in units of MPa	At +17 m, q_c =	At +7 m, q_c =	At –3 m, q_c =
13	What is the characteristic value of p_{lim} at these levels?	Provide values in units of MPa	At +17 m, p_{lim} =	At +7 m, p_{lim} =	At –3 m, p_{lim} =
14	What is the characteristic value of triaxial c_u at these levels?	Provide values in units of kPa	At +17 m, c_u =	At +7 m, c_u =	At –3 m, c_u =
15	How did you assess these values?	Tick all that apply	☐ By eye ☐ By linear regression ☐ By statistical analysis ☐ From an existing standard (specify) … ☐ From a published correlation (specify) … ☐ Comparison with a previous design ☐ From the soil description, not using the data ☐ Other (specify) …		
16	Which calculation model did you use to determine settlement?	Tick one	☐ Method from national annex (specify) … ☐ Method from national standard (specify) … ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …		
17	What length does the pile need to	Provide	L_{SLS} =		

<table>
<tr><td></td><td>avoid a serviceability limit state?</td><td>value in m</td><td colspan="4"></td></tr>
<tr><td colspan="7">ULTIMATE LIMIT STATE</td></tr>
<tr><td>18</td><td>Which parameters did you use for the ULS design of the pile foundation?</td><td>Tick all that apply</td><td colspan="4">☐ Cone resistance q_c ☐ Sleeve friction f_s
☐ SPT blow count N ☐ Corrected SPT blow count $(N_1)_{60}$
☐ UU triaxial test strength c_u
☐ Pressuremeter limit pressure p_{lim}
☐ Other (specify) …</td></tr>
<tr><td>19</td><td>What correlations did you use to derive soil parameter values (if used) for the ULS verification? If more than one, please list others below</td><td>Free text</td><td colspan="4">Description:

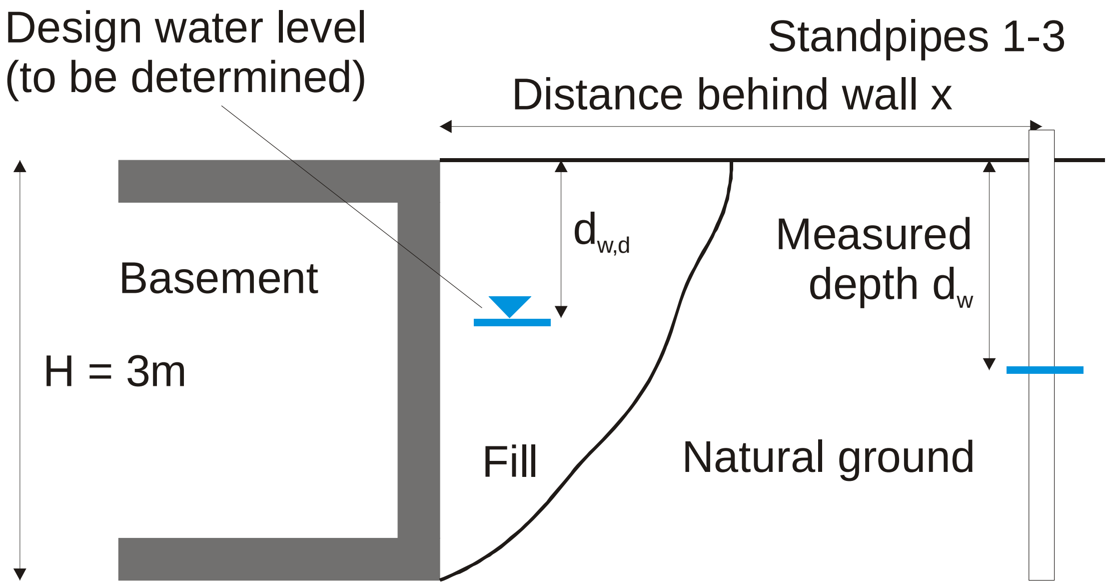
Author:

Title:

Pages:</td></tr>
<tr><td>19a</td><td>Any other correlations? (please give same info as above)</td><td></td><td colspan="4"></td></tr>
<tr><td>20</td><td>What assumptions did you make in choosing these correlations?</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>21</td><td>(If determined) What is the characteristic value of unit shaft resistance q_s at these levels?</td><td>Provide values in units of kPa</td><td>At +17 m, q_s =</td><td>At +7 m, q_s =</td><td colspan="2">At –3 m, q_s =</td></tr>
<tr><td>22</td><td>(If determined) What is the characteristic value of unit base resistance q_b at these levels?</td><td>Provide values in units of kPa</td><td>At +17 m, q_b =</td><td>At +7 m, q_b =</td><td colspan="2">At –3 m, q_b =</td></tr>
<tr><td>23</td><td>Which calculation model did you use to determine the pile's compressive resistance?</td><td>Tick one</td><td colspan="4">☐ Annex D.6 from EN 1997-2 ☐ Annex D.7 from EN 1997-2
☐ Annex E.3 from EN 1997-2
☐ Alternative given in a national annex (specify) …
☐ Alternative given in a national standard (specify) …
☐ Finite element analysis ☐ Finite difference analysis
☐ Other (specify) …</td></tr>
<tr><td>24</td><td>Which country's National Annex did you use to interpret EN 1997-1?</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>25</td><td>Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?</td><td>Tick one</td><td colspan="4">☐ Design Approach 1 Combinations 1 and 2
☐ Design Approach 1 Combination 1 only
☐ Design Approach 1 Combination 2 only
☐ Design Approach 2 ☐ Design Approach 2*
☐ Design Approach 3
☐ Other (specify) …</td></tr>
<tr><td rowspan="5">26
26a</td><td rowspan="5">What values of partial factors did you use for this ULS verification?</td><td rowspan="5">Provide values</td><td colspan="2">1st combination</td><td colspan="2">2nd combination (if used)</td></tr>
<tr><td>γ_G</td><td>γ_Q</td><td>γ_G</td><td>γ_Q</td></tr>
<tr><td>γ_ϕ</td><td>γ_c</td><td>γ_ϕ</td><td>γ_c</td></tr>
<tr><td>γ_{cu}</td><td>γ_s</td><td>γ_{cu}</td><td>γ_s</td></tr>
<tr><td>γ_b</td><td>γ_t</td><td>γ_b</td><td>γ_t</td></tr>
<tr><td>27</td><td>What correlation factors (if any) did you use for this verification?</td><td>Provide values</td><td colspan="2">ξ_3</td><td colspan="2">ξ_4</td></tr>
<tr><td>28</td><td>What model factor (if any) did you use for this verification?</td><td>Provide values</td><td colspan="4">γ_{Rd}</td></tr>
<tr><td>29</td><td>What length does the pile need to avoid an ultimate limit state?</td><td>Provide value in m</td><td colspan="4">L_{ULS} =</td></tr>
<tr><td>30</td><td>What is the design compressive force that the pile must be designed for according to Eurocode 2?</td><td>Provide values in kN</td><td colspan="4">Design compressive force F_{cd} =</td></tr>
<tr><td colspan="7">CONCLUDING QUESTIONS</td></tr>
<tr><td>31</td><td>What other assumptions did you need to make to complete your design?</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>32</td><td>Please specify any other data that you would have liked to have had to design this type of foundation</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>33</td><td>How conservative do you consider your previous national practice to be for this design example?</td><td>Tick one</td><td colspan="4">☐ Very conservative ☐ Conservative ☐ About right
☐ Unconservative ☐ Very unconservative</td></tr>
<tr><td>34</td><td>How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?</td><td>Tick one</td><td colspan="4">☐ Very conservative ☐ Conservative ☐ About right
☐ Unconservative ☐ Very unconservative</td></tr>
</table>

35	How does your Eurocode 7 design compare with your previous national practice?	Tick one	☐ Much more conservative ☐ More conservative ☐ About the same ☐ Less conservative ☐ Much less conservative
36	Please provide any other relevant information needed to understand your solution to this design exercise	Free text	
PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.3 **THANK YOU FOR YOUR CONTRIBUTION!**			

Example 2.4 Earth and pore water pressures on basement wall



This example is designed to compare engineers' assumptions about water pressures acting on the face of a basement wall. The wall will NOT be provided with a drainage system. Ground surface behind the wall is horizontal will be paved in the long term.

The natural water level has been measured in local standpipes as follows:

> Standpipe 1, distance x = 10m behind the wall, depth to water d_w = 2.2 m
> Standpipe 2, distance x = 25m behind the wall, depth to water d_w = 1.5 m
> Standpipe 3, distance x = 50m behind the wall, depth to water d_w = 3.1 m

Three situations are envisaged (with different materials involved):

Situation A: natural ground = clay, fill = clay fill (from excavated natural ground)
Natural clay: γ_k = 22 kN/m^3, $c_{u,k}$ = 35 kPa, ϕ'_k = 25°, c'_k = 0 kPa

Situation B: natural ground = clay, fill = imported granular fill
Natural clay: as above
Imported granular fill: γ_k = 18 kN/m^3, ϕ'_k = 35°, c'_k = 0 kPa

Situation C: natural ground = gravel, fill = imported granular fill
Natural gravel: γ_k = 19 kN/m^3, ϕ'_k = 40°, c'_k = 0 kPa
Imported granular fill: as above

For each situation A-C above, please determine:

1) The characteristic depth of the water table $d_{w,k}$
2) The characteristic thrust on the wall (over height H) owing to water pressures alone
3) The characteristic thrust on the wall (over height H) owing to effective earth pressures alone

Repeat 1-3 above using design values for the serviceability limit state (SLS)
Finally, repeat 1-3 above using design values for the ultimate limit state (ULS)

ETC10 Questionnaire 2.4 (version 07/07/2009)

Example 2.4 Earth and pore water pressures on basement wall
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

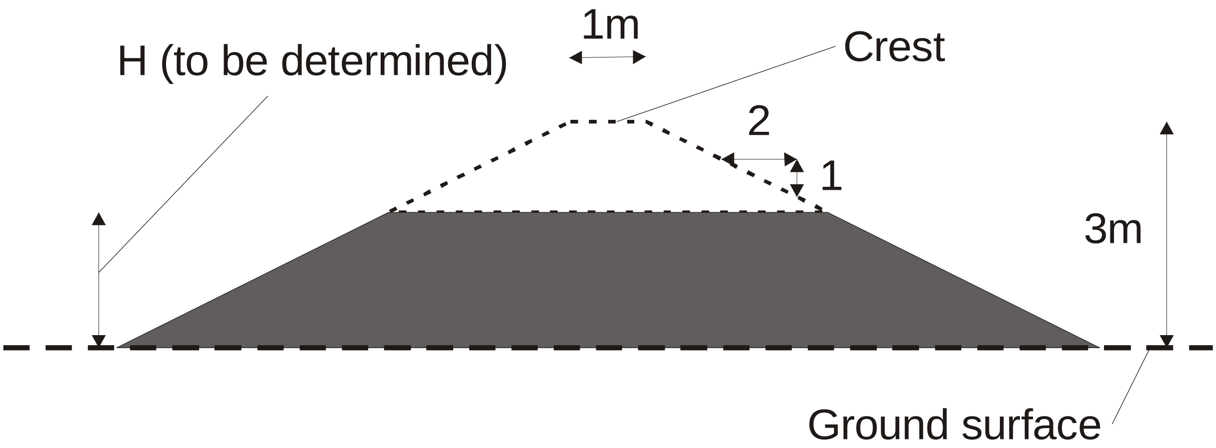
Question		Instruction	Answer		
GENERAL					
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address		
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6		
3	Having completed your assessment of pressures to Eurocode 7, how confident are you that the assessment is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident		
4	How did you account for the location of standpipes relative to the wall?	Tick one	☐ Did not consider standpipe location ☐ Considered nearest standpipe only ☐ Considered 'average' of all standpipes ☐ Considered trend of all standpipe, biased towards nearest ☐ Other (specify) …		
5	Please explain the reasons for your answer to Q4	Free text			
SELECTION OF CHARACTERISTIC VALUES					
6	What is the characteristic depth of the water table d_w for the three situations?	Provide values in units of m	Situation A, d_w =	Situation B, d_w =	Situation C, d_w =
7	How did you choose the characteristic water level?	Tick one	☐ Took average of measured water levels ☐ Took highest measured water level ☐ Took water level at ground surface ☐ Other (specify) …		
SERVICEABILITY LIMIT STATE					
8	What is the design depth of the water table $d_{w,d(SLS)}$ in the SLS for the three situations?	Provide values in units of m	Situation A, d_w =	Situation B, d_w =	Situation C, d_w =
9	How did you choose the design water level for the SLS?	Tick one	☐ Took average of measured water levels ☐ Took highest measured water level ☐ Took characteristic water level ☐ Took level higher than characteristic water level ☐ Took water level at ground surface ☐ Other (specify) …		
10	Please explain the reasons for your answer to Q9	Free text			
11	What is the design thrust on the wall due to water pressure P_w in the SLS?	Provide values in kN/m run	Situation A, P_w =	Situation B, P_w =	Situation C, P_w =
12	What is the design thrust due to effective earth pressure P'_a in the SLS?	Provide values in units of kN/m run	Situation A, P'_a =	Situation B, P'_a =	Situation C, P'_a =
13	How did you determine effective earth pressures on the wall for SLS?	Tick one	☐ Took active pressures (K_a) ☐ Took at-rest pressures (K_0) ☐ Took average of active and at-rest pressures $(K_a + K_0)/2$ ☐ Calculated approximate compaction pressures ☐ Other (specify) …		
14	Please explain the reasons for your answer to the previous question (plus any assumptions made)	Free text			
ULTIMATE LIMIT STATE					
15	What is the design depth of the water table $d_{w,d(ULS)}$ in the ULS for the three situations?	Provide values in units of m	Situation A, d_w =	Situation B, d_w =	Situation C, d_w =
16	How did you choose the design water level for the ULS?	Tick one	☐ Took average of measured water levels ☐ Took highest measured water level ☐ Took characteristic water level ☐ Took level higher than characteristic water level ☐ Took water level at ground surface ☐ Other (specify) …		
17	Please explain the reasons for your	Free text			

	answer to Q16		
18	Which country's National Annex did you use to interpret EN 1997-1?	Free text	
19	Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?	Tick one	☐ Design Approach 1 Combinations 1 and 2 ☐ Design Approach 1 Combination 1 only ☐ Design Approach 1 Combination 2 only ☐ Design Approach 2 ☐ Design Approach 2* ☐ Design Approach 3 ☐ Other (specify) …
20 20a	What values of partial factors did you use for this ULS verification?	Provide values	1st combination: γ_G / γ_Q / γ_ϕ / γ_c / γ_{Rv} / γ_{Rd} 2nd combination (if used): γ_G / γ_Q / γ_ϕ / γ_c / γ_{Rv} / γ_{Rd}
21	What partial factor did you apply to the action arising from characteristic water pressures?	Tick one	☐ None (γ = 1.0) ☐ γ_G = 1.35 ☐ γ_Q = 1.5 ☐ γ_G = 1.35 to permanent part, γ_Q = 1.5 to variable part ☐ Same γ as applied to effective earth pressure ☐ Other (specify)
22	What is the design thrust on the wall due to water pressure P_w in the ULS?	Provide values in kN/m run	Situation A, P_w = Situation B, P_w = Situation C, P_w =
23	What is the design thrust due to effective earth pressure P'_a in the ULS?	Provide values in units of kN/m run	Situation A, P'_a = Situation B, P'_a = Situation C, P'_a =
24	How did you determine effective earth pressures on the wall for ULS?	Tick one	☐ Took active pressures (K_a) ☐ Took at-rest pressures (K_0) ☐ Took average of active and at-rest pressures $(K_a + K_0)/2$ ☐ Calculated approximate compaction pressures ☐ Other (specify) …
25	Please explain the reasons for your answer to the previous question (plus any assumptions made)	Free text	
	CONCLUDING QUESTIONS		
26	What other assumptions did you need to make to determine design earth and water pressures?	Free text	
27	Please specify any other data that you would have liked to determine design earth and water pressures	Free text	
28	How conservative do you consider your previous national practice to be for this design example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative
29	How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative
30	How does your Eurocode 7 'design' compare with your previous national practice?	Tick one	☐ Much more conservative ☐ More conservative ☐ About the same ☐ Less conservative ☐ Much less conservative
31	Please provide any other relevant information needed to understand your solution to this design exercise	Free text	
	PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.4 **THANK YOU FOR YOUR CONTRIBUTION!**		

Example 2.5: Embankment on soft peat

An embankment is to be designed which shall enclose an area that will later be hydraulically filled with dredged material. The final height of the embankment will be 3 m, the inclination of the embankment slopes is to be 1:2, and the crest is to have a width of 1 m with no loading. The weight density of the sand fill to form the embankment is 19 kN/m^3 and its characteristic angle of shearing resistance is φ'_k = 32.5°.

The ground surface is effectively horizontal at a level of approximately NN -1.0 m. The ground consists of a few dm of topsoil and normally consolidated clay (weight density of γ = 18 kN/m³ and effective weight density of γ = 9 kN/m³) on a 3 to 7 m thick pseudo-fibrous to amorphous holocene peat layer with an effective weight density of γ' = 2 kN/m³ overlaying pleistocene sand of medium density having an effective weight density of 11 kN/m^3 and a characteristic angle of shearing resistance of φ'_k = 35°. The peat may be assumed to act in an undrained manner during the construction of the embankment. Figures 2.5a to 2.5e show the results of two borings and five vane tests, which have been performed and evaluated according to DIN 4094:2002 "Subsoil – Field testing – Part 4: Field vane tests". The vane had a width D = 75 mm and height H = 150 mm. The vane tests have a spacing of 40 to 50 m and are situated at the centreline of the embankment. Table 2.5a provides an explanation for the symbols and terms used on the borehole logs.



The objective of this design example is to predict how high the embankment can be constructed in a first phase, without any reinforcement between the embankment and the ground. The topsoil is not to be removed before constructing the embankment. Furthermore it should be assumed that the area within the embankment has not been filled with dredged material. No serviceability requirements have to be fulfilled. No accidental design situations to be checked. This is a persistent design situation, where no variable actions (due to construction machinery) have to be taken into account.

Details of the ground investigation are given below.

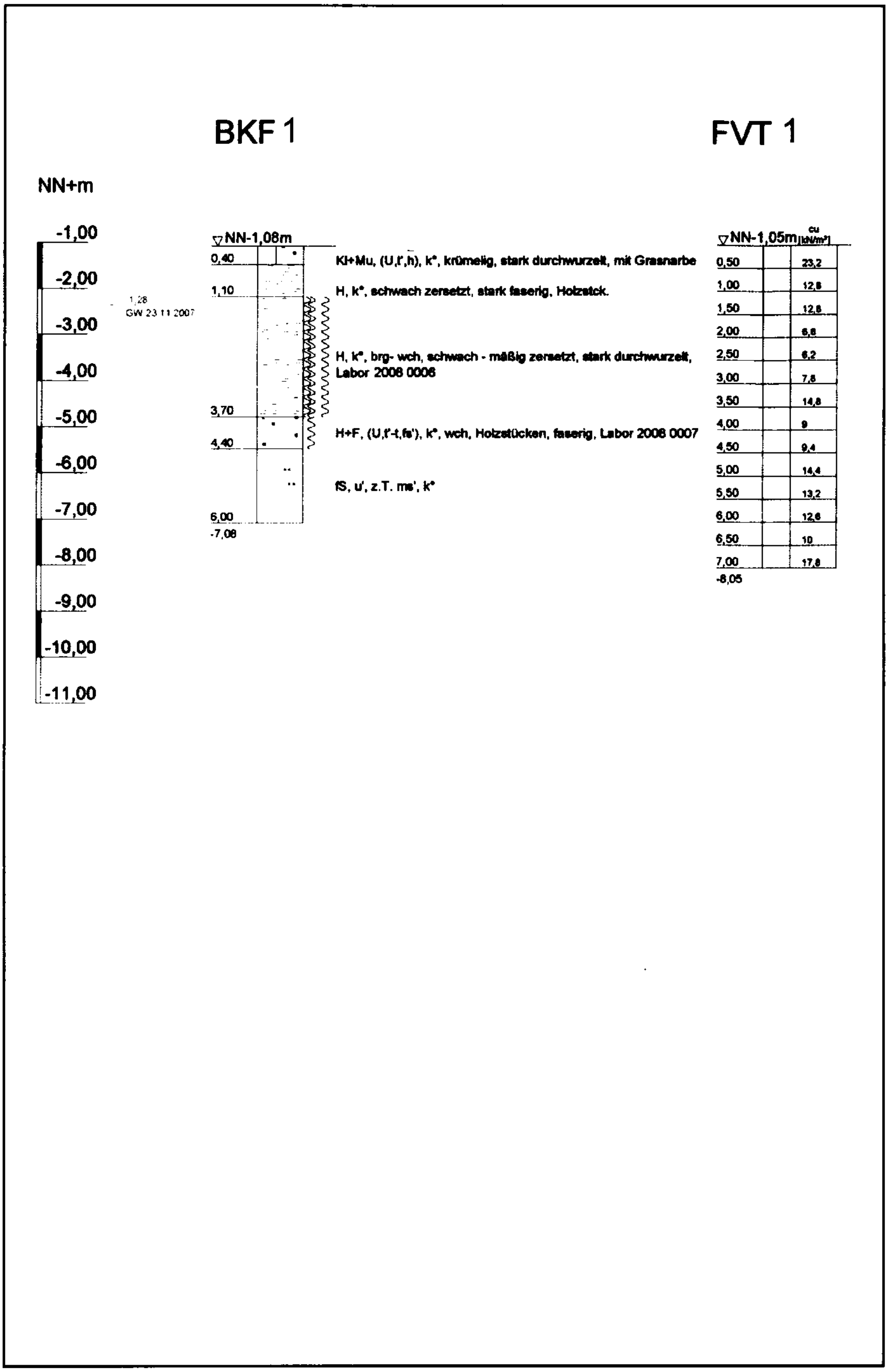


Figure 2.5a: Borehole log and vane test 1

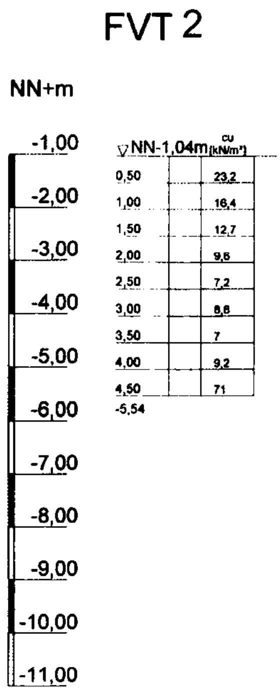


Figure 2.5b: Vane test 2

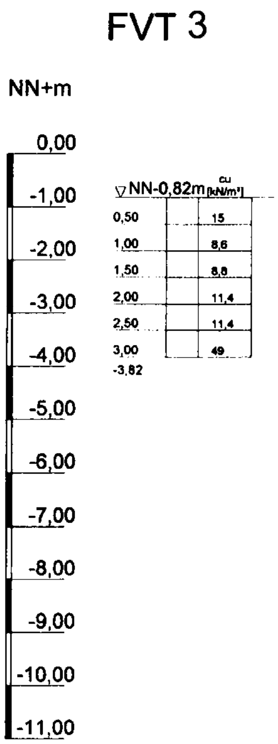


Figure 2.5c: Vane test 3

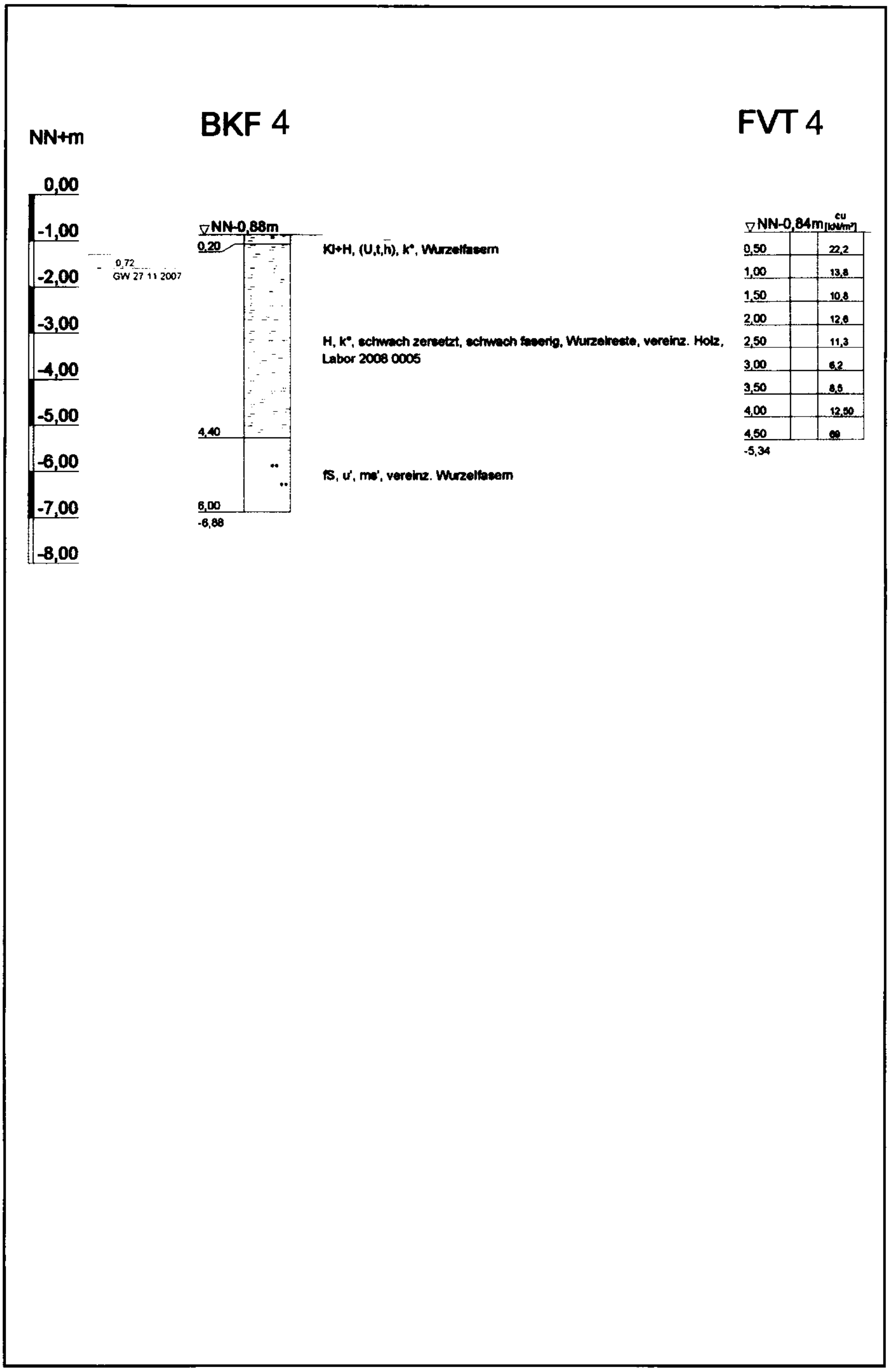


Figure 2.5d: Borehole log and vane test 4

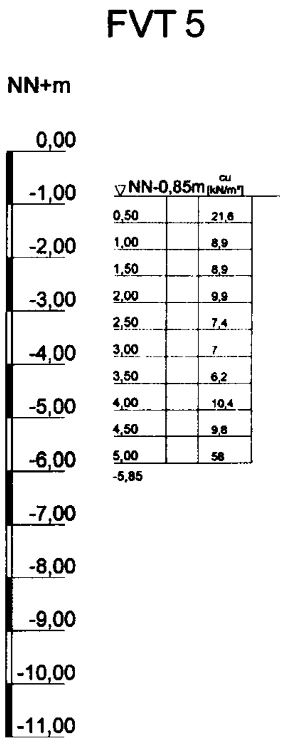


Figure 2.5e: Vane test 5

Table 2.5a: Symbols and terms used on the Borehole logs

Symbol/Term	Description
BKF	Boring, where cores are taken in a liner
F	Sapropel
fS, fs	fine sand, with fine sand
H, h	peat, peaty
Holzstücke	pieces of wood
k°	containing carbonate
Kl	clay
mäßig zersetzt	amorphous peat
mS, ms, ms´	medium sand, with medium sand, with little medium sand
Mu	topsoil
NN	sea level
S, s	sand, sandy
schwach zersetzt	pseudo-fibrous peat
stark faserig	fibrous peat
T, t	clay (fraction), clayey,
U, u, u´	silt, silty, with little silt
Wurzelfasern	root fibres
z	Depth

Table 2.5b: Undrained shear strength measured by field vane tests

Depth below ground level m	Undrained shear strength measured by field vane tests in kN/m²				
	FVT 1	FVT 2	FVT 3	FVT 4	FVT 5
0.5	23,20	23,20	15,00	22,20	21,60
1.0	12,80	16,40	8,60	13,80	8,90
1.5	12,80	12,70	8,80	10,80	8,90
2.0	6,60	9,60	11,40	12,60	9,90
2.5	6,20	7,20	11,40	11,30	7,40
3.0	7,80	8,80		6,20	7,00
3.5	14,80	7,00		8,50	6,20
4,0	9,00	9,20		12,50	10,40
4.5	9,40				9,80
5.0	14,40				
5.5	13,20				
6.0	12,60				
6.5	10,00				
7.0	17,80				

Example 2.5: Embankment on soft peat
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

Question		Instruction	Answer
		GENERAL	
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6
3	Having completed your design to Eurocode 7, how confident are you that the design is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident
		ULTIMATE LIMIT STATE	
4	Which calculation model did you use to determine the maximum height of the embankment?	Tick all that apply	☐ Annex D from EN 1997-1 ☐ Alternative given in a national annex (specify) … ☐ Alternative given in a national standard (specify) … ☐ Terzaghi ☐ Meyerhof ☐ Brinch-Hansen ☐ Limiting equilibrium (slip circle/method of slices) ☐ Limiting equilibrium (wedge mechanism) ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …
5	If you used a slip circle method, which variant of this method did you use?	Tick one	☐ Bishop with horizontal interslice forces ☐ Bishop with variably inclined interslice forces ☐ Spencer/Bishop with constantly inclined interslice forces ☐ Janbu with horizontal interslice forces ☐ Janbu with variably inclined interslice forces ☐ Janbu with constantly inclined interslice forces ☐ Swedish circle method ☐ Morgenstern and Price ☐ Other (specify) …
6	Which parameters did you use for the ULS design of the embankment?	Tick all that apply	☐ Measured vane strength c_{fv} ☐ Corrected vane strength c_u ☐ Other (specify) …
7	What correlations did you use to derive soil parameter values (if used) for the ULS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:
7a	Any other correlations? (please give same info as above)	Free text	
8	What assumptions did you make in choosing these correlations?	Free text	
9	How did you account for the location of boreholes/vane profiles relative to the embankment?	Tick one	☐ Did not consider borehole/profile location ☐ Considered nearest borehole/profile only ☐ Considered 'average' of all boreholes/profiles ☐ Considered trend of all boreholes/profiles, biased towards nearest ☐ Other (specify) …
10	Please explain the reasons for your answer to Q9	Free text	
11	How did you account for any variation in parameters with depth?	Tick one	☐ Ignored variation with depth ☐ Assumed linear variation ☐ Assumed bi-linear variation ☐ Assumed stepped variation ☐ Other (specify) …
12	Please explain the reasons for your answer to Q11	Free text	
13	What is the characteristic value of c_u at these depths?	Provide values in units of kPa	At 1 m, c_u = At 2 m, c_u = At 3 m, c_u = At 4 m, c_u = At 5 m, c_u = At 6 m, c_u =
14	How did you assess these values?	Tick all that apply	☐ By eye ☐ By linear regression ☐ By statistical analysis ☐ From an existing standard (specify) … ☐ From a published correlation (specify) … ☐ Comparison with a previous design ☐ From the soil description, not using the data ☐ Other (specify) …

<table>
<tr><td>15</td><td>Which country’s National Annex did you use to interpret EN 1997-1?</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>16</td><td>Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?</td><td>Tick one</td><td colspan="4">☐ Design Approach 1 Combinations 1 and 2
☐ Design Approach 1 Combination 1 only
☐ Design Approach 1 Combination 2 only
☐ Design Approach 2 ☐ Design Approach 2*
☐ Design Approach 3
☐ Other (specify) …</td></tr>
<tr><td rowspan="5">17
17a</td><td rowspan="5">What values of partial factors did you use for this ULS verification?</td><td rowspan="5">Provide values</td><td colspan="2">1st combination</td><td colspan="2">2nd combination (if used)</td></tr>
<tr><td>γ_G</td><td>γ_Q</td><td>γ_G</td><td>γ_Q</td></tr>
<tr><td>γ_ϕ</td><td>γ_c</td><td>γ_ϕ</td><td>γ_c</td></tr>
<tr><td>γ_{cu}</td><td>γ_{Rv}</td><td>γ_{cu}</td><td>γ_{Rv}</td></tr>
<tr><td>γ_{Rh}</td><td>γ_{Rd}</td><td>γ_{Rh}</td><td>γ_{Rd}</td></tr>
<tr><td>18</td><td>What is the embankment’s maximum height to avoid an ultimate limit state?</td><td>Provide value in m</td><td colspan="4">H =</td></tr>
<tr><td colspan="7">CONCLUDING QUESTIONS</td></tr>
<tr><td>19</td><td>What other assumptions did you need to make to complete your design?</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>20</td><td>Please specify any other data that you would have liked to have had to design this type of foundation</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td>21</td><td>How conservative do you consider your previous national practice to be for this design example?</td><td>Tick one</td><td colspan="4">☐ Very conservative ☐ Conservative ☐ About right
☐ Unconservative ☐ Very unconservative</td></tr>
<tr><td>22</td><td>How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?</td><td>Tick one</td><td colspan="4">☐ Very conservative ☐ Conservative ☐ About right
☐ Unconservative ☐ Very unconservative</td></tr>
<tr><td>23</td><td>How does your Eurocode 7 design compare with your previous national practice?</td><td>Tick one</td><td colspan="4">☐ Much more conservative ☐ More conservative
☐ About the same ☐ Less conservative
☐ Much less conservative</td></tr>
<tr><td>24</td><td>Please provide any other relevant information needed to understand your solution to this design exercise</td><td>Free text</td><td colspan="4"></td></tr>
<tr><td colspan="7">PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.5
THANK YOU FOR YOUR CONTRIBUTION!</td></tr>
</table>

Example 2.6 Pile foundation in sand

A building is to be supported on 450 mm diameter bored piles founded entirely in a medium dense to dense sand spaced at 2m centres. The piles are bored with temporary casing, filled with water, and concreted on the same day as boring. Each pile carries a characteristic vertical permanent load of 300 kN and a characteristic vertical variable load of 150 kN. This is a small project for which there will be no load testing. It is believed that settlement in service will not govern the design.

The sand is a Pleistocene fine and medium sand. Bedding is essentially horizontal. The sand is covered by Holocene layers of loose sand, soft clay, and peat (see Figure 2.6b). One CPT was carried out at a distance of 5 m from the boring to determine the strength profile of the ground (see Figure 2.6b). The CPT has been performed and evaluated according to DIN 4094:2002 “Subsoil – Field testing – Part 1: Cone penetration tests” using a tip of 10 cm² without measurement of sleeve friction and pore water pressure. The ground level is at about NN +2.5 m (where NN = reference level) and essentially horizontal. No fill will be placed on the ground. The water table is about 1.4 m below ground level.

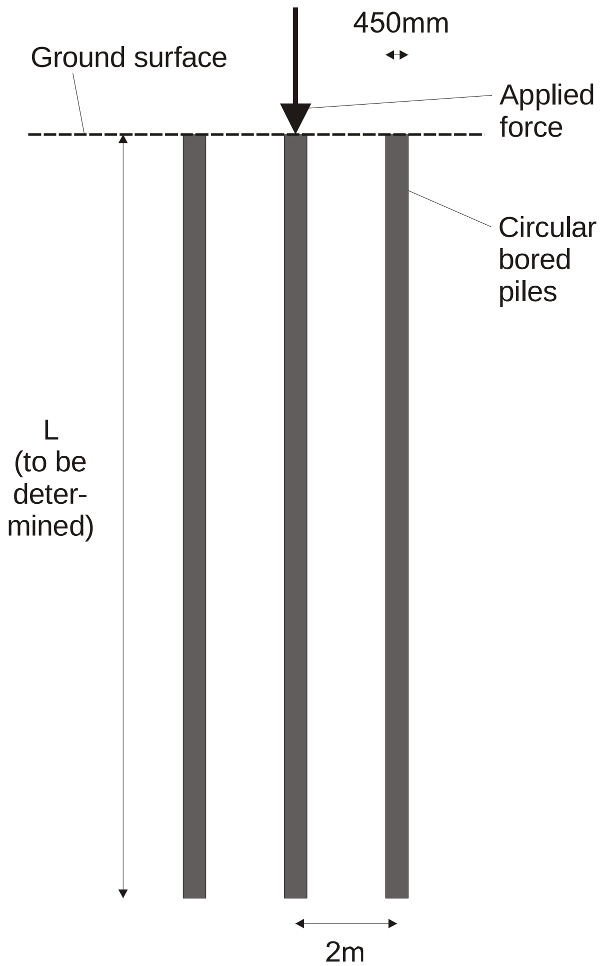


Figure 2.6a: Pile arrangement

Using Eurocode 7, determine the design length of the piles shown in the Figure 2.6a.

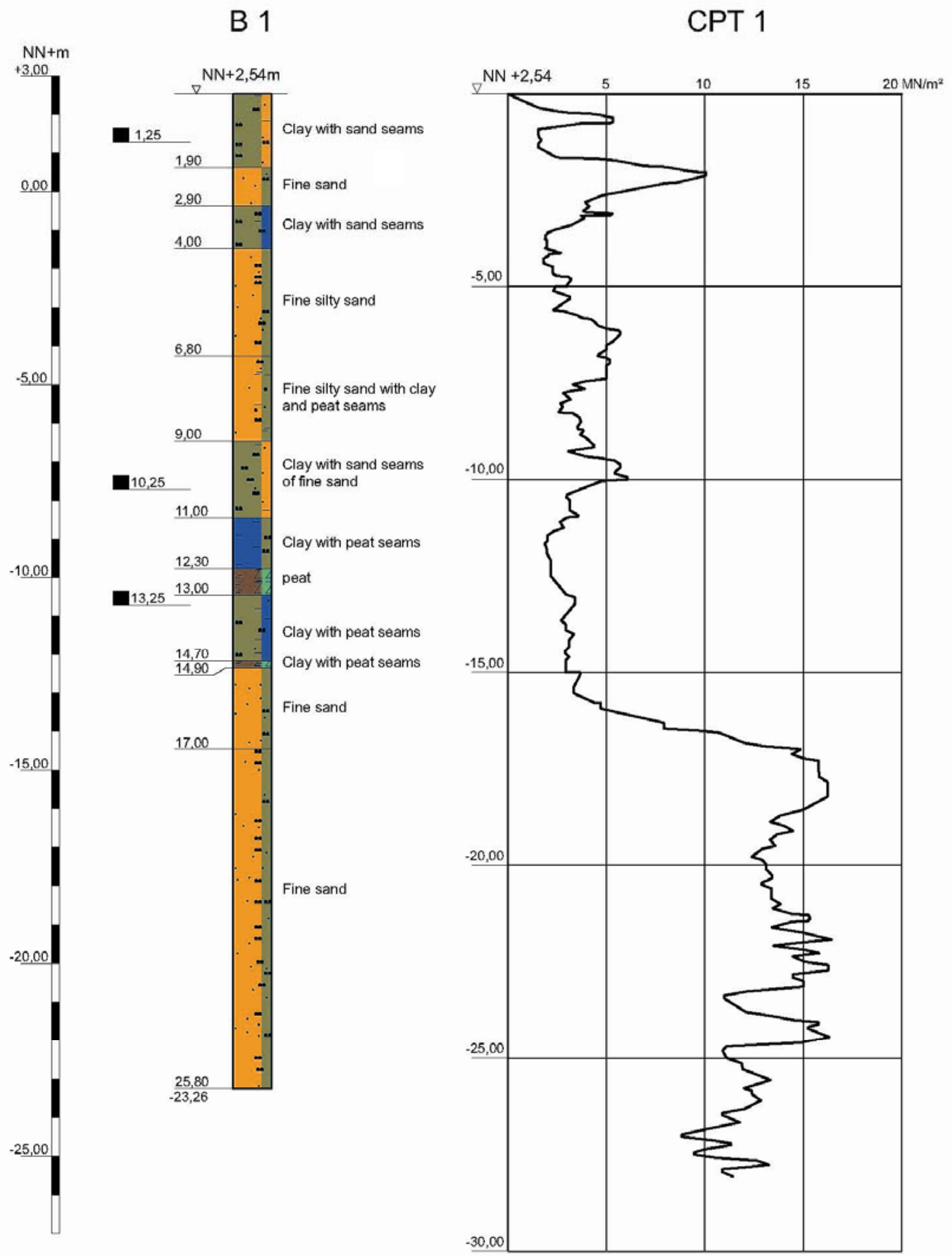


Figure 2.6b: Cone penetration resistance from CPT test

Example 2.6 Pile foundation in sand
Note: this is a persistent design situation; for simplicity, accidental design situations do NOT need to be checked.

Question		Instruction	Answer
GENERAL			
1	Please provide your contact details in case we need to clarify your submission*	*Will be kept strictly confidential	Name Affiliation Email address
2	How many structures of this kind have you previously designed?	Tick one	☐ None ☐ 1-2 ☐ 3-6 ☐ More than 6
3	Having completed your design to Eurocode 7, how confident are you that the design is sound?	Tick one	☐ Very unsure ☐ Unsure ☐ Confident ☐ Very confident
ULTIMATE LIMIT STATE			
4	What correlations did you use to derive soil parameter values (if used) for the ULS verification? If more than one, please list others below	Free text	Description: Author: Title: Pages:
4a	Any other correlations? (please give same info as above)		
5	What assumptions did you make in choosing these correlations?	Free text	
6	How did you account for any variation in parameters with depth?	Tick one	☐ Ignored variation with depth ☐ Assumed linear variation ☐ Assumed bi-linear variation ☐ Assumed stepped variation ☐ Other (specify) …
7	Please explain the reasons for your answer to Q6	Free text	
8	What is the characteristic value of q_c at these depths?	Provide values in units of MPa	At 7.5 m, q_c = | At 12.5 m, q_c = | At 12.5 m, q_c = At 17.5 m, q_c = | At 22.5 m, q_c =
9	How did you assess these values?	Tick all that apply	☐ By eye ☐ By linear regression ☐ By statistical analysis ☐ From an existing standard (specify) … ☐ From a published correlation (specify) … ☐ Comparison with a previous design ☐ From the soil description, not using the data ☐ Other (specify) …
10	(If determined) What is the characteristic value of unit shaft resistance q_s at these depths?	Provide values in units of kPa	At 2.5 m, q_s = | At 7.5 m, q_s = | At 12.5 m, q_s = At 17.5 m, q_s = | At 22.5 m, q_s =
11	(If determined) What is the characteristic value of unit base resistance q_b at these depths?	Provide values in units of kPa	At 2.5 m, q_b = | At 7.5 m, q_b = | At 12.5 m, q_b = At 17.5 m, q_b = | At 22.5 m, q_b =
12	Which calculation model did you use to determine the pile's compressive resistance?	Tick one	☐ Annex D.6 from EN 1997-2 ☐ Annex D.7 from EN 1997-2 ☐ Alternative given in a national annex (specify) … ☐ Alternative given in a national standard (specify) … ☐ Finite element analysis ☐ Finite difference analysis ☐ Other (specify) …
13	Which country's National Annex did you use to interpret EN 1997-1?	Free text	
14	Which Design Approach did you use for verification of the Ultimate Limit State (ULS)?	Tick one	☐ Design Approach 1 Combinations 1 and 2 ☐ Design Approach 1 Combination 1 only ☐ Design Approach 1 Combination 2 only ☐ Design Approach 2 ☐ Design Approach 2* ☐ Design Approach 3 ☐ Other (specify) …
15 15a	What values of partial factors did you use for this ULS verification?	Provide values	1st combination: γ_G | γ_Q | γ_ϕ | γ_c | γ_{cu} | γ_s | γ_b | γ_t 2nd combination (if used): γ_G | γ_Q | γ_ϕ | γ_c | γ_{cu} | γ_s | γ_b | γ_t

16	What correlation factors (if any) did you use for this verification?	Provide values	ξ_3	ξ_4
17	What model factor (if any) did you use for this verification?	Provide values	γ_{Rd}	
18	What length does the pile need to avoid an ultimate limit state?	Provide value in m	L_{ULS} =	
19	What is the design compressive force that the pile must be designed for according to Eurocode 2?	Provide values in kN	Design compressive force F_{cd} =	
	SERVICEABILITY LIMIT STATE			
20	(If determined) What is the settlement of the pile in the serviceability limit state?	Provide value in mm	s_{SLS} =	
	CONCLUDING QUESTIONS			
21	What other assumptions did you need to make to complete your design?	Free text		
22	Please specify any other data that you would have liked to have had to design this type of foundation	Free text		
23	How conservative do you consider your previous national practice to be for this design example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative	
24	How conservative do you consider Eurocode 7 (with your National Annex) to be for this example?	Tick one	☐ Very conservative ☐ Conservative ☐ About right ☐ Unconservative ☐ Very unconservative	
25	How does your Eurocode 7 design compare with your previous national practice?	Tick one	☐ Much more conservative ☐ More conservative ☐ About the same ☐ Less conservative ☐ Much less conservative	
26	Please provide any other relevant information needed to understand your solution to this design exercise	Free text		
	PLEASE SUBMIT YOUR ANSWERS AT www.eurocode7.com/etc10/Example 2.6 **THANK YOU FOR YOUR CONTRIBUTION!**			