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/m³. 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

| | | | | SAMPLES | | | 1 | 1) | 1 | |
|----------|--------------------------|----------------|----------|-----------|---------------------|-----------|---------------|-----------------|---|--|
| DAILY | DEPTH TO | DEPTHS OF | DEP | DEPTH | | LEG- | DEPTH | REDUCED | DESCRIPTION OF STRATA | |
| PRUGRESS | WATER | CASING | FROM | то | TYPE | END | (m) | (m above | b | |
| | \mapsto | t | | <u>↓</u> | | 1 | GL | 19.4= | | |
| 10,12.75 | $\leftarrow \rightarrow$ | t | + | t1 | 1 | | 0.40 | 19.05 | GRANITE SETTS on Lean-mix CONCRETE | |
| | | | 1.15 | 1.45 | S 4 | 1 XX | | | Sandy gravelly RUBBLE, comprising broken bricks, piec | |
| | | | | \square | <u>ц</u> | × | 1.00 | 16.45 | towards the bottom. | |
| | | \square | 1.50 | 5*00 | 3D | \otimes | 1 | 1 | Very soft to soft, brown, saidy silty CLAY with scall stones and occasional brief from the little scale | |
| | ļ | 1 | 2 | 21-1 | - | ₩ | ┞ | <u> </u> | china, tile and flint gravel. | |
| | | 1.70 | 2.00 | 2.50 | | 1 🕅 | | <u> </u> | T | |
| | tł | | <u></u> | 0.50 | 1 | ĸ | | · · · · · | Old pipe encountered at 3.6 m (approx 150 mm diameter | |
| | | | 3.15 | 3.45 | S 1 | × | 3.20 | 15.25 | pipe virtually dry. (FILL - possibly trench for place | |
| | | | 3.70 | 11.00 | 30 | É | | | Pine to chiff have a state of the state | |
| | | \vdash | 4.00 | 4.50 | 0 100 | ÷ | | | of orange-brown SAND/SILT and numerous synchronic evicts | |
| 5-0 | DRV | 4.70 | 5.15 | 5.be | 5 44 | F | 1 | <u> </u> | Less mottled with depth. | |
| 11.12-20 | DRY | 4.20 | 5.20 | 6.00 | 10 | | t | <u> </u> | Scall CLANSTONE at 5.7 c. | |
| | | | | | | E | 6.00 | 13.45 | (LOTECT CLAY) | |
| | | | 6.00 | 6.50 | U 100 | Ē | | | Stiff, grey-brown or grey fiscured silty CLAY with to | |
| | \Box | | | | ųЕ | EE | | | of fine SAND/SILT. | |
| | | \square | 7.15 | 7.45 | S 19 | Ē | \vdash | <u> </u>] | 1 | |
| | \square | ├ | 7.50 | 7.80 | 130 | F | 1 | | | |
| | \vdash | | 3.00 | 2.=0 | 11 1000 | ŧĒ | 0.10 | 11-DE | (TCHDOM GTYX) | |
| | <u>+ </u> } | t | 1.00 | | 1/100 | E | ····· | 1.05 | Stiff to very stiff. grey silty and candy CINY with | |
| | <u>t</u> | t | 9.15 | 9.45 | S 25 | E | | | patches of fine SAMD/SILT. | |
| | \Box | | | | Ť, | E | | | Numerous patches and partings of SILF/SAND below 11. | |
| | | | | | | E | | | Gand content increases sufficiently around 12.0 m to | |
| | | \square | 10.00 | 10.50 | 0 100 | ΈĒ. | [] | \vdash | classily as a clayer SAND. | |
| | \square | L | 1 | L | | E | \mapsto | ├ | 1 | |
| | └──┤ | [i | 11.15 | 11.45 | 3 29 | ŧ≡ | 1 | <u> </u> | 1 | |
| | t | t | t | t | + | Ē | | | 1 | |
| | | | 12.00 | 12.50 | U 100 | E | | | 1 | |
| | | | | | ΨĒ. | | 13.00 | E.hr | (LOHDON CLAY) | |
| 7 | | I | 13.15 | 13.45 | 3 27 | Έ÷ | | F | Stiff to very stiff, snow eilts SIAT with and | |
| 2.12 | 12 20 | 4.20 | łł | \mapsto | 4 | | ├ ──-) | \vdash | concentrations of SILT. Lawinar structure visible. | |
| -• (4+75 | 124.50 | +•70 | 14.00 | 14,50 | 1100 | Ē | t | $t \rightarrow$ | Occasional small pyritised nodules. | |
| | <u> </u> | | | | TT. | E | | | Slight seepage of water from 14.0 m. | |
| | | | 15.15 | 15.45 | \$ 39 | Ē | | | ١ | |
| | | <u> </u> | | | Ψ | | | \square | | |
| | L] | ļi | 10 - | 45 | L. | F. | | ├ → | Small pieces of CLAYSTONE recovered from 15.5 m to 16 Slight seepage of water. | |
| | └── ┤ | \leftarrow | 179.00 | 13.50 | 100 | 15 | \vdash | | | |
| | | | 17.15 | 17.45 | B 51 | 1 一 | 17.00 | 2.45 | | |
| | | | | | Щ ^щ | | | | and pockets of SILF/fine SAED. | |
| | | | | | Ψ <u></u> | | | | | |
| | \square | () | 18.00 | 17.50 | P:100 | ΈĒ | |] | Numerous and all all and all all all all all all all all all al | |
| | \square | ↓ −−−→ | 10 45 | 10 1- | 1 | = | + | | Recoging very samely around 10.0 m | |
| | } | () | 17.15 | 17+95 | + * 45 | Ē | 1 | 11 | | |
| | t | 1 | 1 | (······ | t <u>H</u> | E | 20,00 | -0.55 | (LCNDON CLAY) | |
| | | | | | | | | | | |
| REMARKS | 1 | | | | | | | | TYPE OF BORING | |
| (1 | 1) Dict | turbed a | sample (| (Jar) ta | tten fre | on the | e cuttin | ng shoe | of all U100 Shell-and-sucar | |
| | nnd | from S. | 27. | | | | | | 1 ton Isler | |
| | | | | | | | | | DIAMETER OF ROPING | |
| | | | | | | | | | 210 mm - to 20. | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | CASING TUBES | |
| | | | | | | | | | 250 mm = to 4. | |
| | | | | | | | | | I | |
| | | | | | | | | | I | |
| | | | | | | | | | | |
| | | | | | | | | | BOREHOLE | |

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



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

| Addy model width wi | | | | | SAMPLES | | Т | | | |
|--|-----------------|------------------|--------------|-----------|---------------------|----------------------|---------------|----------------|------------------|---|
| Mark Value Value Mark Value </th <th>DAILY</th> <th>DEPTH TO</th> <th>DEPTHS OF</th> <th>DE</th> <th>ртн</th> <th>TYOP</th> <th>LEG-</th> <th>DEPTH</th> <th>REDUCED LEVEL</th> <th>DESCRIPTION OF STRATA</th> | DAILY | DEPTH TO | DEPTHS OF | DE | ртн | TYOP | LEG- | DEPTH | REDUCED LEVEL | DESCRIPTION OF STRATA |
| No.00 No.00 <th< th=""><th></th><th>WATER</th><th>CASING</th><th>FROM</th><th>τo</th><th>1</th><th></th><th></th><th></th><th></th></th<> | | WATER | CASING | FROM | τo | 1 | | | | |
| 35.00 39.00 40.00 30.00 Descent (d) gray, filte, filte-presing & S.D. General (d) gray, filte-presing | | | | | - | | - | 10.00 | -20, 55 | |
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| 33.50 X.00 35.00 | | | | 41.50 | 41.65 | S (4 | <u>)</u> | - | | (THANET SAND) |
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| 3.50 State 3.50 9.20 9.40 T 2.20 3.60 < | 1 - 0- | -9.44 | | La Or | 1.7 00 | | | 17.80 | <u> </u> | |
| Ab. 60 (3) 27.00 14.60 14.60 10 1 10 </td <td>43.50</td> <td>30,00</td> <td>35.00</td> <td>43.80</td> <td>43.55</td> <td>3 (</td> <td>"=</td> <td>- <u>00,00</u></td> <td></td> <td>Hard, white CHAIK.</td> | 43.50 | 30,00 | 35.00 | 43.80 | 43.55 | 3 (| "= | - <u>00,00</u> | | Hard, white CHAIK. |
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| REMARKS (4) Test torminated after "senting blows". (5) Loweter level measurement - borehole prouted on completion of boring. (6) koretale collapsed overnight to 32.5 m, 35.0m and 35.0m on 7, 3 and 9 Jan respectively. Diameter of BO 240 cm - 1 100 cm - | | | | | | | | | | |
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| REMARKS (4) Test terminated after "seating blows". (5) No water level measurement - borchole grouted on completion of boring. (6) borchole collipsed overnight to 30.5 m, 35.0m and 35.0m on 7, 3 and 9 Jan respectively. DIAMETER OF BO 240 nm - 1 102 cm - 1 102 cm - 1 102 cm - 1 102 cm - 1 103 cm - 1 103 cm - 1 104 cm - 1 105 cm - | | | | | | | | | | |
| REMARKS (4) Test terminated after "seating blows". (5) No water level measurement - borchole grouted on completion of boring. (6) Norohole collapsed overnight to 39.5 m, 35.0m and 35.0m on 7, 3 and 9 Jan respectively. DIAMETER OF NO 240 nm - 192 cm - 143 cm - 200 cm - 150 cm - 150 cm - | | 1 | 1 | | | | L_ | | | |
| (4) Test terminated after "seating blows". (5) To water lovel seasurement - borchole grouted on completion of boring. (6) borchole collapsed overnight to 30.5 m, 35.0m and 35.0m on 7, 3 and 9 Jan respectively. | REMARK | 5 | | | | | | | | TYPE OF BORING |
| (5) pressie collapsed oversaget to 50.5 m, 30.0m and 30.0m on 7, 5 dmb 9 out respectively. DIAMETER OF BO 240 nm - 190 mm - 140 nm - 140 nm - 140 nm - 140 nm - 150 nm - 200 nm - 150 nm - | (4) (5) | Test t Jo vat | orminat | ed after | er "seat proment | ing b - bor | lows". | grouted | on com | letion of boring. Or on Z. 2 and 9 Jan respectively. |
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Figure 2.3d(3): Log for Borehole No. SG 14 with SPT results – Sheet 3



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



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