# LOAD BEARING STEEL INTENSIVE BASEMENT

## - Press-in Method and Thorough Inspection Technique -

### Case Study


# Table of Contents

# Chapter 1 Design Criteria

| | |
|---|---|
| Design Life of Retaining Wall | 100 years |
| Basement Grade (BS 8102:2009) | Grade 1 (Car Park) and Grade 3 (Other area) |
| Working Load on Retaining Wall | 500kN/m run (300kN/pile) on U sheet pile wall and 1,100kN/m run (1,075kN/pile) on tubular pile wall |
| Surcharge Loading behind Retaining Wall | $10kN/m^2$ |
| Movement under Lateral Loads | Limit of vertical movement of wall elements; 25mm |
| | Limit of horizontal movement of wall elements; 20mm |
| | Limit of differential movement between adjacent columns and basement; 1 in 500 |
| Piling Tolerances | Deviation in plan normal to the wall line at the top of the pile; ±25mm |
| | Deviation of verticality along line of piles; 1 in 100 |

Table 1

Note : Basement Grade (BS 8102:2009)

| Grade | Example of use of structure[A)] | Performance level |
|---|---|---|
| 1 | Car parking; plant rooms (excluding Electrical equipment); workshops | Some seepage and damp areas tolerable, dependent on the intended use[B)]<br>Local drainage might be necessary to deal with seepage |
| 2 | Plant rooms and workshops requiring a drier environment (than Grade 1); storage areas | No water penetration acceptable<br>Damp areas tolerable; ventilation might be required |
| 3 | Ventilated residential and commercial areas, including office restaurant etc.; leisure centres | No water penetration acceptable<br>Ventilation, dehumidification or air conditioning necessary, appropriate to the intended use |

A) The previous edition of this standard referred to Grade 4 environments. However, this grade retained as its only difference from Grade 3 is the performance level related to ventilation, dehumidification or air conditioning (see BS5454 for recommendations for the storage and exhibition of archival documents). The structural form for Grade 4 could be the same or similar to Grade 3.

B) Seepage and damp areas for some forms of construction can be quantified by reference to industry standards, such as the ICE’s Specification for piling and embedded retaining walls.

Table 2

# Chapter 2 General Layout of Basement and Ground Conditions

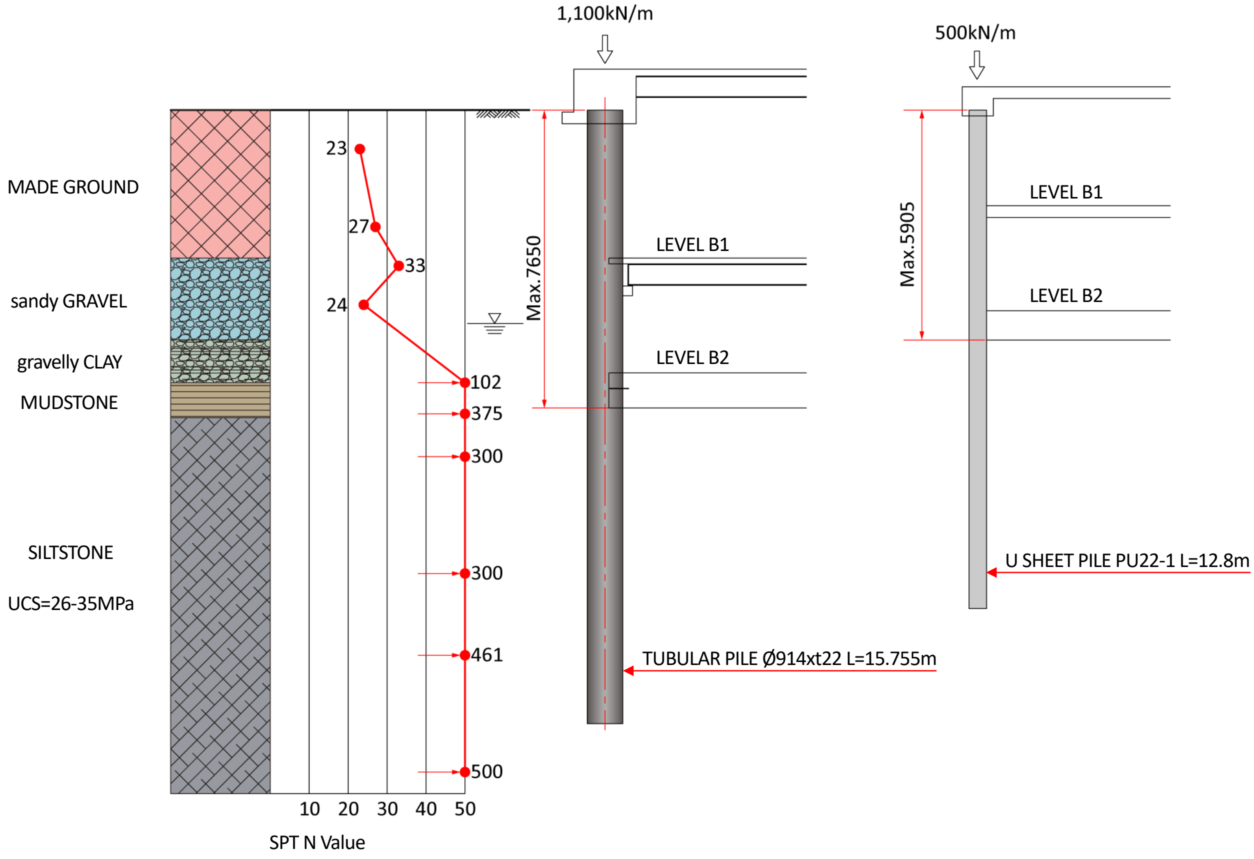



Figure 1

# Chapter 3 PPT (Pile Penetration Testing) Process for Bearing Capacity Assurance

Step 1. Test pile installation to measure toe resistance $R_t$ and shaft friction $R_f$.

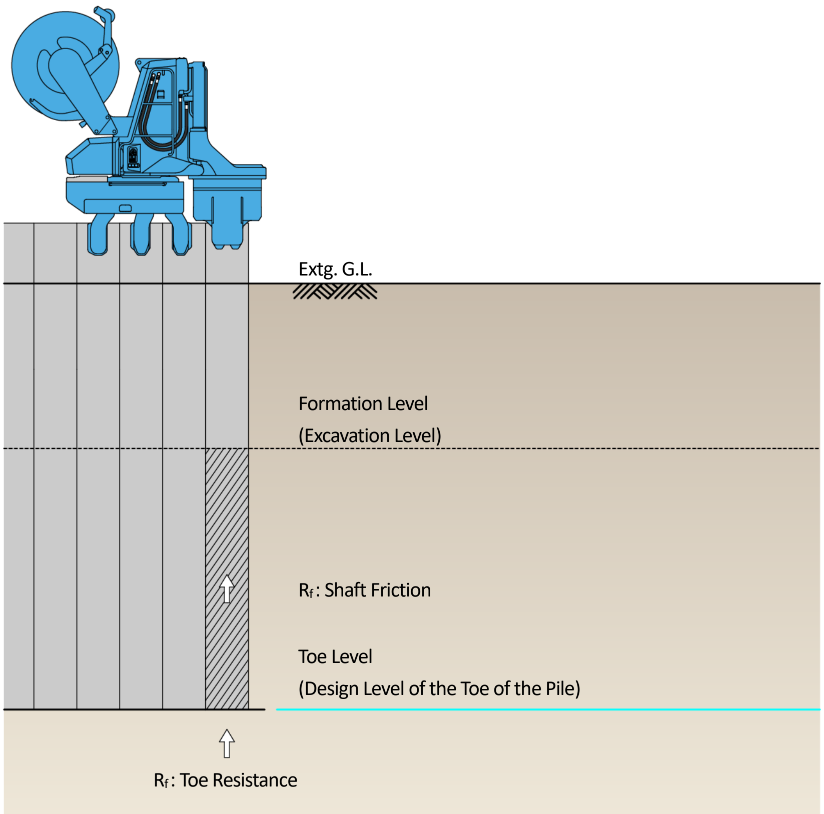



Figure 2

Step 2. Waiting for shaft friction recovery (mobile shaft friction $R_{fm}$ ⟶ static shaft friction $R_{fs}$) with time effect.

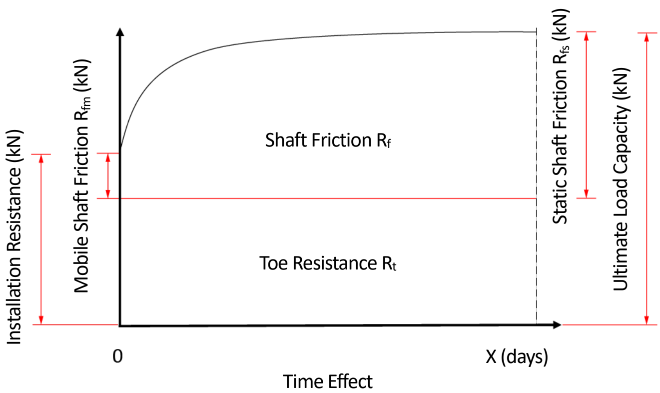



Figure 3

Step 3. Static load testing to determine required toe resistance i.e. “Net Toe Resistance $R_{tnet}$” to achieve required load capacity.

Figure 4

Step 4. Pile Installation with required net toe resistance $R_{tnet}$ or greater.

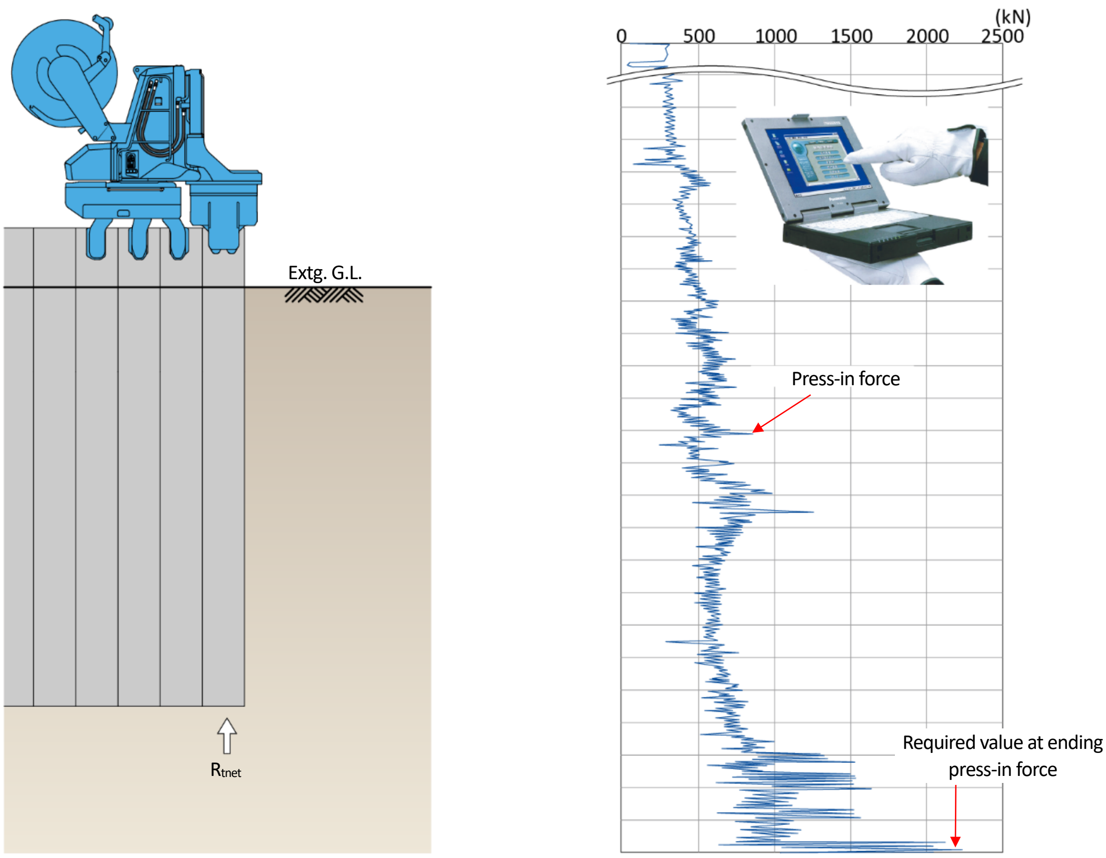



Figure 5

| Type of Pile | Ultimate Load (kN/pile) | Specified Working Load (kN/pile) | FOS | Required Net Toe Resistance ($R_{tnet}$) to achieve specified load capacity (kN/pile) |
|---|---|---|---|---|
| Sheet Pile | 600 | 300 | 2.0 | 230 |
| Tubular Pile | 2,150 | 1,075 | 2.0 | 650 |

Table 3

# Chapter 4 Test Piling and Static Load Testing (Sheet Pile)

## 4-1 Installation of Test Piles (unclutched piles) : T1-T8

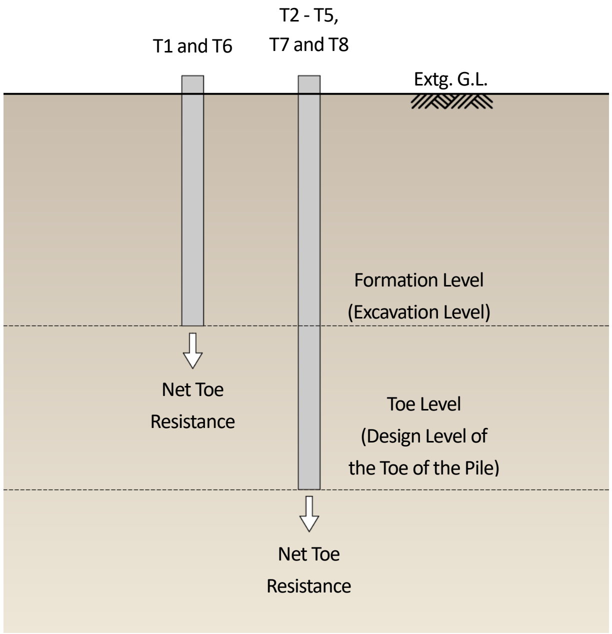



Figure 6

| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| Net Toe Resistance | N/A | 90 kN | 290 kN | 400 kN | 480 kN | N/A | 190 kN | 180 kN |

Table 4

## 4-2 Extraction of Test Piles T1 and T6 (7 days after their installation)

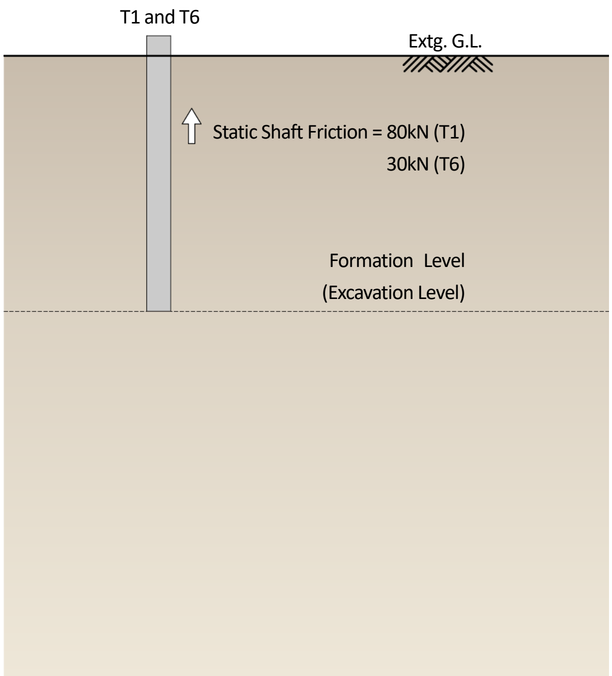



Figure 7

## 4-3 Calculation of Maximum Test Load in Static Load Testing

The Design Verification Load (DVL) is calculated as the Specified Working Load (SWL) of 300kN per pile plus the friction contribution of the soil above the future excavation level, 80kN. The factor of safety is 2.0, giving:

Maximum test load = DVL + 1.0 x SWL

= 2.0 x SWL + Friction above excavation level

= 2.0 x 300 + 80

= 680kN

## 4-4 Static Load Testing Results

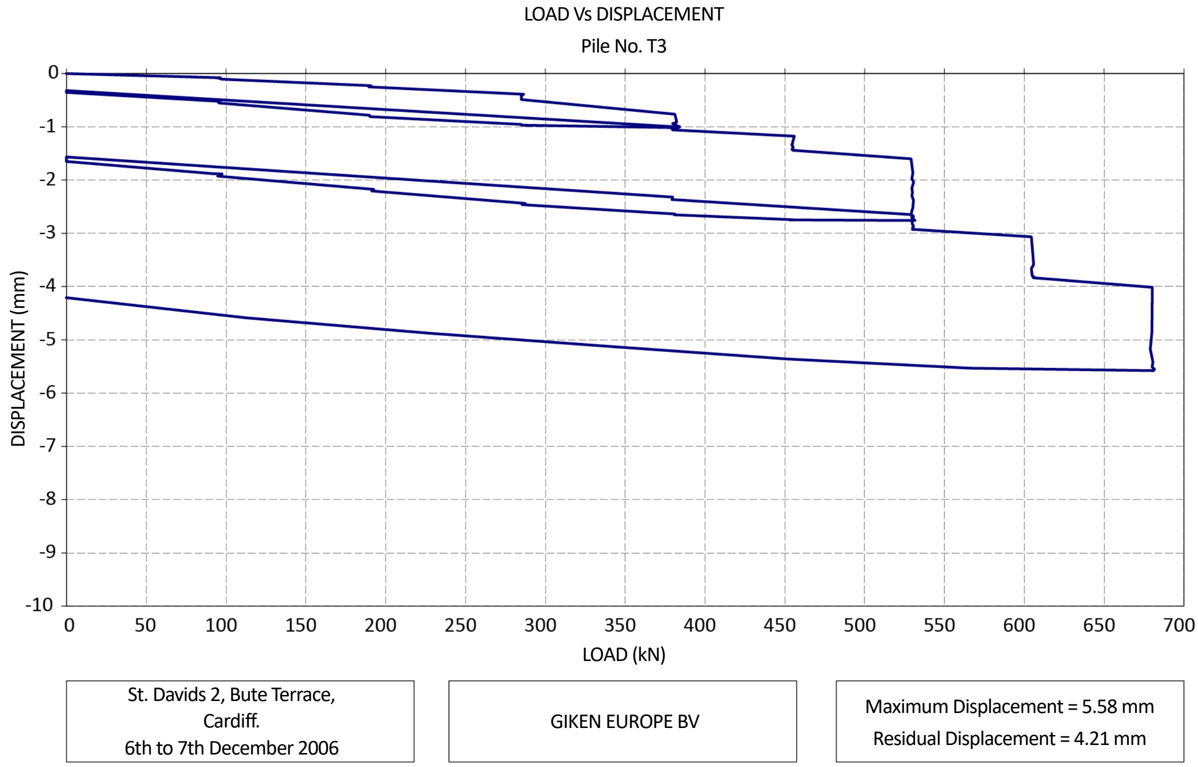



Figure 8 e.g. Static Load Testing Result (T3)

Test piles T2 to T5, T7 and T8 were tested in compression 18-28 days after their installation. The test results are summarized in Table 5 below.

| Pile No | Max applied test load (kN) | Max settlement (mm) | Residual settlement after DVL (mm) | Residual settlement after DVL +50% SWL (mm) | Interval between installation and testing |
|---|---|---|---|---|---|
| T2 | 680 | 36.0 | 2.70 | 22.25 | 18 days |
| T3 | 681 | 5.58 | 0.32 | 1.56 | 26 days |
| T4 | 682 | 8.46 | 0.19 | 1.99 | 27 days |
| T5 | 682 | 2.30 | 0.32 | 0.50 | 25 days |
| T7 | 530 | 44.12 | 0.72 | 41.27 | 28 days |
| T8 | 680 | 70.68 | 1.43 | 21.12 | 23 days |

Table 5

## 4-5 Analysis by Fleming Method

The settlements have been assessed using the Fleming method, which was developed for bored piles. The pile shaft and base diameters have been adjusted to equivalent values to allow the method to be used. The method does not allow for any locked-in load due to the installation process; for example preload of the base. These effects cause the pile to react stiffer than the ground parameters would suggest (ref. Single Pile Settlement Prediction and Analysis for Driven Piles, DFI Conference, Amsterdam 2006).

Each pile exhibits an initial stiff response based on the static shaft friction. This represents the likely response in service. Once the static shaft friction is exceeded, the pile adopts a mobile or dynamic shaft friction with an increasing base capacity as the pile is pushed further into the ground, mobilising the base capacity. The mobile or dynamic friction plus the end bearing resistance should be at least as great as the force originally required to install the pile. Two different curves are generated by the Fleming method to replicate these two phases, varying the flexibility factor (Ms) as used by Fleming. For the dynamic case, a flexibility factor of 0.03 is generally adopted and for the static case a very low figure of 0.0001 is used, based on achieving a best-fit for the curves. The base capacities have been maintained as constant for the static and dynamic analyses. The results are summarized in Table 5 and the analyses are included in Figure 9 and Figure 10.

| | Job No | C106070 | Ref | Sheet No | |
|---|---|---|---|---|---|
| | Project | Cardiff St Davids 2 | | | |
| | Calculations for | Test Pile T3 | | Date | 16/01/2007 |
| | | | | By | DRB |

PILE SETTLEMENT ANALYSIS (after Fleming, 1992)

INPUT DATA

| | |
|---|---|
| Equivalent pile shaft diameter ($D_S$)= | 0.55 m |
| Equivalent pile base diameter ($D_B$)= | 0.13 m |
| Deformation modulus below base ($E_B$)= | 4,000,000 kN/m$^2$ |
| Equivalent Young's modulus of steel ($E_C$)= | 1.17E+07 kN/m$^2$ |
| Friction length coefficient ($K_E$)= | 0.55 |
| Upper pile length carrying no load ($L_O$)= | 0 m |
| Pile length transferring load by friction ($L_F$)= | 11.4 m |
| Flexibility factor ($M_S$)= | 0.0001 |
| Pile design load ($P_T$)= | 300 kN |
| Ultimate shaft friction load ($U_S$)= | 350 kN |
| Ultimate pile base load ($U_B$)= | 580 kN |
| Total ultimate load = | 930 kN |
| Max plotted predicted ult.load = | 90% 837 kN |
| Maximum settlement = | 6.35 mm |

| Load kN | %Ult.Load | Settlement mm | % Dia. |
|---|---|---|---|
| 0 | 0.0% | 0 | 0.00% |
| 97 | 10.4% | 0.1 | 0.02% |
| 190 | 20.4% | 0.25 | 0.05% |
| 285 | 30.6% | 0.49 | 0.09% |
| 380 | 40.9% | 1.06 | 0.19% |
| 455 | 48.9% | 1.44 | 0.26% |
| 531 | 57.1% | 2.93 | 0.53% |
| 606 | 65.2% | 3.83 | 0.70% |
| 681 | 73.2% | 5.58 | 1.01% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |

OUTPUT DATA

| Load kN | Settlement mm | Shortening mm | Movement mm |
|---|---|---|---|
| 0 | | 0.00 | 0.00 |
| 25 | 0.00 | 0.06 | 0.06 |
| 51 | 0.00 | 0.11 | 0.12 |
| 76 | 0.00 | 0.17 | 0.18 |
| 101 | 0.00 | 0.23 | 0.23 |
| 127 | 0.01 | 0.29 | 0.29 |
| 152 | 0.01 | 0.34 | 0.35 |
| 178 | 0.01 | 0.40 | 0.41 |
| 203 | 0.02 | 0.46 | 0.47 |
| 228 | 0.02 | 0.51 | 0.53 |
| 254 | 0.03 | 0.57 | 0.60 |
| 279 | 0.03 | 0.63 | 0.66 |
| 304 | 0.04 | 0.69 | 0.73 |
| 330 | 0.06 | 0.74 | 0.80 |
| 355 | 0.07 | 0.81 | 0.88 |
| 380 | 0.10 | 0.91 | 1.01 |
| 406 | 0.12 | 1.02 | 1.14 |
| 431 | 0.15 | 1.12 | 1.28 |
| 457 | 0.19 | 1.23 | 1.42 |
| 482 | 0.23 | 1.33 | 1.56 |
| 507 | 0.28 | 1.43 | 1.72 |
| 533 | 0.34 | 1.54 | 1.88 |
| 558 | 0.41 | 1.64 | 2.05 |
| 583 | 0.48 | 1.75 | 2.23 |
| 609 | 0.57 | 1.85 | 2.42 |
| 634 | 0.67 | 1.95 | 2.63 |
| 659 | 0.80 | 2.06 | 2.85 |
| 685 | 0.95 | 2.16 | 3.11 |
| 710 | 1.13 | 2.27 | 3.40 |
| 736 | 1.36 | 2.37 | 3.73 |
| 761 | 1.66 | 2.47 | 4.14 |
| 786 | 2.07 | 2.58 | 4.65 |
| 812 | 2.66 | 2.68 | 5.34 |
| 837 | 3.56 | 2.79 | 6.35 |

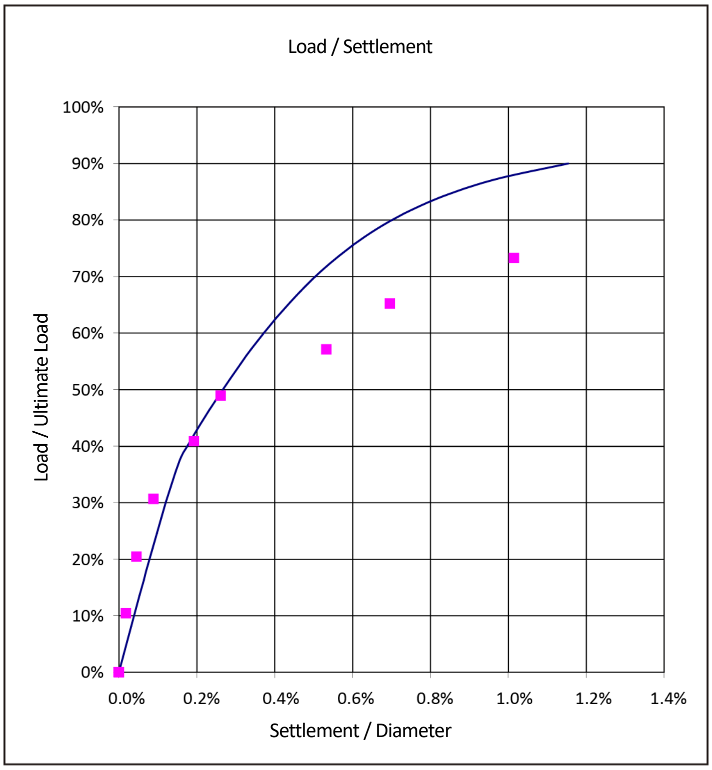



Figure 9 e.g. Fleming Method Analysis (Test Pile T3, Static Friction)

| | | | | |
|---|---|---|---|---|
| | Job No | C106070 | Ref | Sheet No |
| | Project | Cardiff St Davids 2 | | |
| | Calculations for | Test Pile T3 | | Date 16/01/2007 |
| | | | | By DRB |

PILE SETTLEMENT ANALYSIS (after Fleming, 1992)

INPUT DATA

| | | |
|---|---|---|
| Equivalent pile shaft diameter ($D_S$)= | | 0.55 m |
| Equivalent pile base diameter ($D_B$)= | | 0.13 m |
| Deformation modulus below base ($E_B$)= | | 4,000,000 kN/m² |
| Equivalent Young's modulus of steel ($E_C$)= | | 1.17E+07 kN/m² |
| Friction length coefficient ($K_E$)= | | 0.55 |
| Upper pile length carrying no load ($L_O$)= | | 0 m |
| Pile length transferring load by friction ($L_F$)= | | 11.4 m |
| Flexibility factor ($M_S$)= | | 0.003 |
| Pile design load ($P_T$)= | | 300 kN |
| Ultimate shaft friction load ($U_S$)= | | 230 kN |
| Ultimate pile base load ($U_B$)= | | 580 kN |
| Total ultimate load = | | 810 kN |
| Max plotted predicted ult.load = | 90% | 729 kN |
| Maximum settlement = | | 7.85 mm |

| Load kN | %Ult.Load | Settlement mm | % Dia. |
|---|---|---|---|
| 0 | 0.0% | 0 | 0.00% |
| 97 | 12.0% | 0.1 | 0.02% |
| 190 | 23.5% | 0.25 | 0.05% |
| 285 | 35.2% | 0.49 | 0.09% |
| 380 | 46.9% | 1.06 | 0.19% |
| 455 | 56.2% | 1.44 | 0.26% |
| 531 | 65.6% | 2.93 | 0.53% |
| 606 | 74.8% | 3.83 | 0.70% |
| 681 | 84.1 % | 5.58 | 1.01% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |

OUTPUT DATA

| Load kN | Settlement mm | Shortening mm | Movement mm |
|---|---|---|---|
| 0 | | 0.00 | 0.00 |
| 22 | 0.02 | 0.05 | 0.07 |
| 44 | 0.03 | 0.10 | 0.13 |
| 66 | 0.05 | 0.15 | 0.20 |
| 88 | 0.07 | 0.20 | 0.27 |
| 110 | 0.09 | 0.25 | 0.34 |
| 133 | 0.11 | 0.30 | 0.41 |
| 155 | 0.13 | 0.35 | 0.48 |
| 177 | 0.16 | 0.40 | 0.56 |
| 199 | 0.18 | 0.45 | 0.63 |
| 221 | 0.21 | 0.50 | 0.71 |
| 243 | 0.24 | 0.57 | 0.82 |
| 265 | 0.28 | 0.66 | 0.94 |
| 287 | 0.31 | 0.75 | 1.07 |
| 309 | 0.35 | 0.84 | 1.20 |
| 331 | 0.40 | 0.93 | 1.33 |
| 353 | 0.44 | 1.03 | 1.47 |
| 376 | 0.50 | 1.12 | 1.61 |
| 398 | 0.55 | 1.21 | 1.76 |
| 420 | 0.62 | 1.30 | 1.92 |
| 442 | 0.69 | 1.39 | 2.08 |
| 464 | 0.77 | 1.48 | 2.25 |
| 486 | 0.87 | 1.57 | 2.44 |
| 508 | 0.97 | 1.66 | 2.63 |
| 530 | 1.10 | 1.75 | 2.85 |
| 552 | 1.24 | 1.84 | 3.08 |
| 574 | 1.42 | 1.93 | 3.35 |
| 596 | 1.63 | 2.02 | 3.65 |
| 619 | 1.88 | 2.11 | 4.00 |
| 641 | 2.21 | 2.20 | 4.41 |
| 663 | 2.63 | 2.29 | 4.93 |
| 685 | 3.20 | 2.38 | 5.59 |
| 707 | 4.02 | 2.47 | 6.50 |
| 729 | 5.28 | 2.57 | 7.85 |

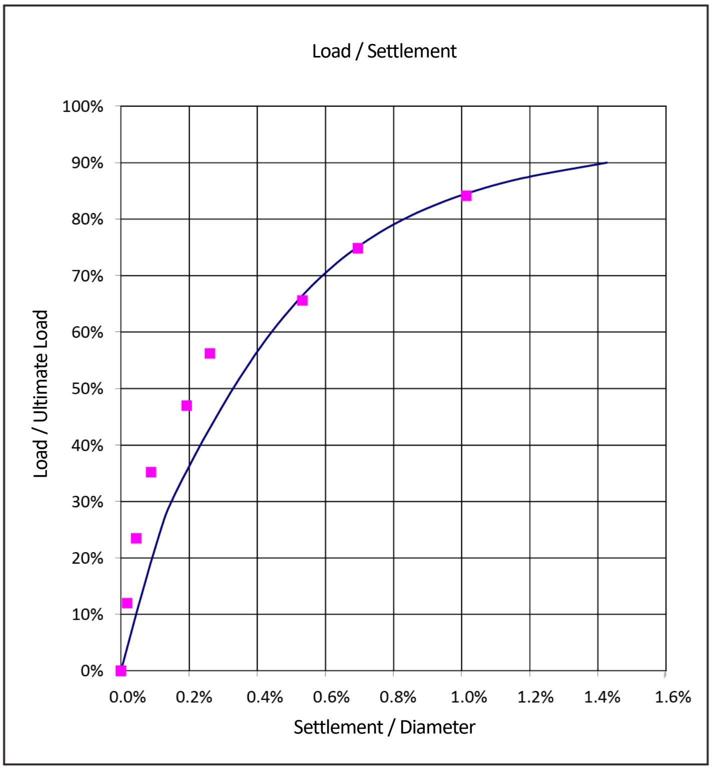



Figure 10 e.g. Fleming Method Analysis (Test Pile T3, Mobile Friction)

## 4-6 Back Analysis

The ultimate capacity of each pile based on the Fleming analysis is tabulated below. The specified working load (SWL) is assessed from the static friction results for a factor of safety of 2.0 on the total capacity and allowing for 80kN friction above basement level (i.e. SWL = (Total capacity – 80)/2) for piles T2 to T5 and 30kN for piles T7 and T8.

| Pile No | Static friction (i.e. initial stage of test) | | | Mobile friction (i.e. final stage of test) | | |
|---|---|---|---|---|---|---|
| | Assessed shaft capacity (kN) | Assessed base capacity (kN) | Total capacity /SWL (kN) | Assessed shaft capacity (kN) | Assessed base capacity (kN) | Total capacity /SWL (kN) |
| T2 | 280 | 140 | 420/170 | Pile continually pushed into the ground | | |
| T3 | 350 | 580 | 930/425 | 230 | 580 | 810 |
| T4 | 310 | 675 | 985/452 | 160 | 675 | 835 |
| T5 | 450 | 850 | 1300/610 | Test did not reach this stage | | |
| T7 | 365 | 195 | 560/265 | Pile continually pushed into the ground | | |
| T8 | 400 | 175 | 575/272 | Pile continually pushed into the ground | | |

Table 6

Plotting the above static friction results against the Net Toe Resistance (see figure 7) illustrates the trend of increasing Specified Working Load with increasing Net Toe Resistance. Taking a lower bound line through the data indicates a minimum Net Toe Resistance of 230kN is required to justify a Specified Working Load of 300kN per pile. Note that the Net Toe Resistance implies that an additional push force is applied to the ground of (2 x weight of chuck, auger, casing and sheet pile) approximately 250kN.
For back analysis of the piles as installed, the proposed lower bound line can be used to assess the Safe Working Load of each piles.

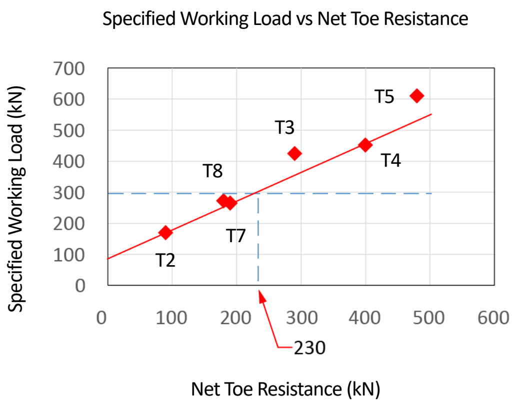



Figure 11 Plot of Specified Working Load vs Net Toe Resistance

## 4-7 Conclusion

All the test piles illustrate that the ground is capable of supporting the required ultimate load. The settlement at working load is approximately 1mm for all piles except T2, T7 and T8, which settle up to 4 mm.

The predicted ultimate capacity is satisfactory for all piles except for T2, T7 and T8 (the Net Toe Resistance applied to these piles is less than the recommended 230 kN). Plotting the data indicates a lower bound design line for the relationship between Net Toe Resistance and Specified Working Load, giving a minimum Net Toe Resistance of 230kN for a specified working load of 300kN per pile (with a factor of safety of 2.0)

# Chapter 5 Test Piling and Static Load Testing (Tubular Pile)

## 5-1 Installation of Test Piles : W28 and W86

The test piles, W28 and W86, were installed at the initial stage of the tubular pile installation works. They have already been used as a part of the proposed basement wall. The status of the test piles is as follows.

| Pile No. | Profile | Top of Pile (mOD) | Toe Level (mOD) | Pile Length (m) | Formation Level (mOD) |
|---|---|---|---|---|---|
| W28 | $\phi$ 914mm O.D. x 20mm | 8.755 | - 4.1 | 12.855 | 2.055 |
| W86 | $\phi$ 914mm O.D. x 20mm | 9.255 | - 3.0 | 12.255 | 1.605 |

Table 7

## 5-2 Calculation of Maximum Test Load in Static Load Testing

The Design Verification Load (DVL) is calculated as the Specified Working Load (SWL) of 1,075kN per pile plus the friction contribution of the soil above the future excavation level, 414kN*. The factor of safety is 2.0, giving:

Maximum test load = DVL + 1.0 x SWL

= 2.0 x SWL + Friction above excavation level

= 2.0 x 1,075 + 414

= 2,564kN

* The calculation method for static skin friction, assuming cohesionless material is based on the effective vertical stress and a conversion factor to horizontal shaft friction of $K_s.\tan\delta$. Taking ground water level at a conservatively low level of 6m below ground level and assuming a range of values for $K_s.\tan\delta$ calculation sheets gives a static skin friction from ground level to excavation level of between 207kN and 414kN. The lower values compare well with the measured dynamic friction. It is proposed to adopt the higher value as the value of skin friction and allow for this value in the pile test, such that it is not necessary to undertake a separate test to determine the value of the skin friction.

## 5-3 Static Load Testing Results

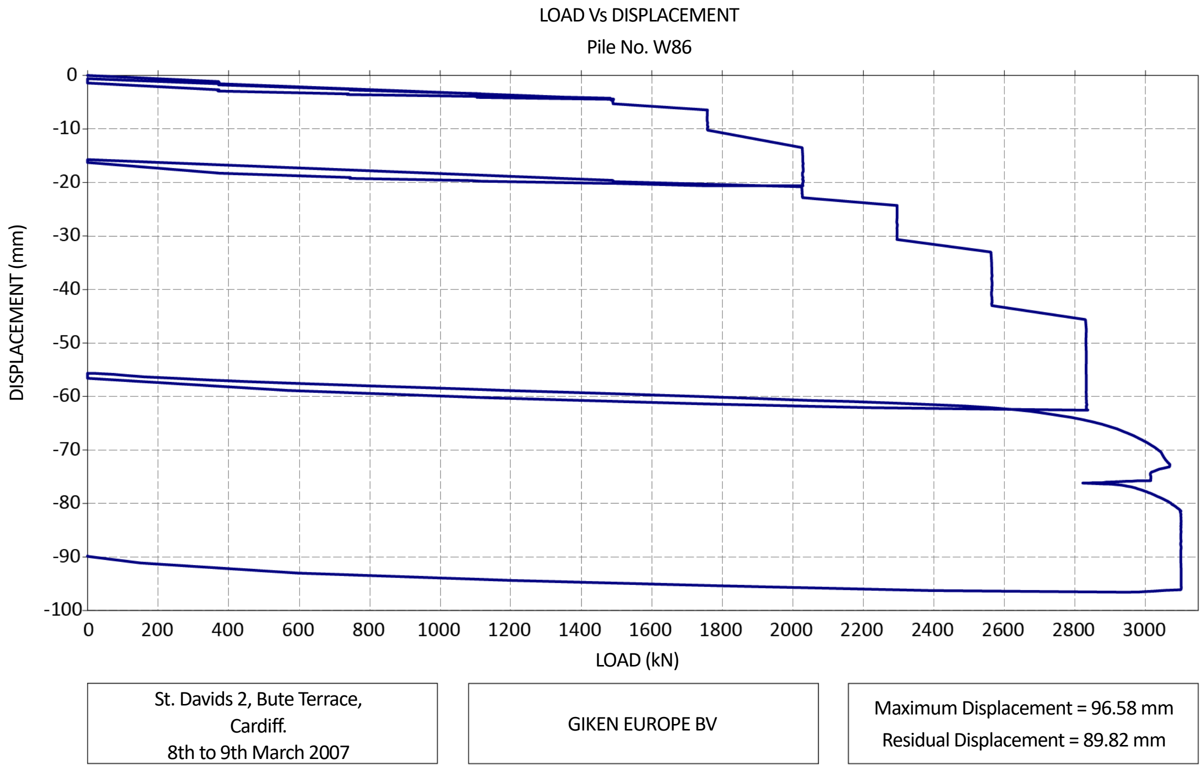



Figure 12 e.g. Static Load Testing Result (W86)

Test piles W28 and W86 were tested in compression 17-54 days after their installation. The test results are summarized in Table 8 below.

| Pile No | Max applied test load (kN) | Max settlement (mm) | Residual settlement after DVL (mm) | Residual settlement after DVL +50% SWL (mm) | Interval between installation and testing |
|---|---|---|---|---|---|
| W28 | 2,400 | 54.77 | 2.30 | 32.41 | 54 days |
| W86 | 3,100 | 96.58 | 0.63 | 18.21 | 17 days |

Table 8

## 5-4 Analysis by Fleming Method

### Pile W28

The analysis using the Fleming method indicates that the pile behaved normally up to about 2,000kN. The Fleming curve fits the data up to 1,758kN, but not for 2,028kN and 2,300kN. Beyond about 2,000kN, the pile is pushed further into the ground, replicating the installation process and further load is sustained at greater depth. The back analysis indicates an ultimate shaft friction of 650kN and ultimate base capacity of 1,400kN, giving a total capacity of 2,050kN.

### Pile W86

The initial settlement readings are rather high, suggesting that perhaps there is a "bedding-in" settlement for this pile of the order of 1mm. The analysis using the Fleming method indicates that the pile behaved normally up to about 2,000kN. The back analysis of the initial stages of the test, when static friction conditions exist, indicates an ultimate shaft friction of 800kN and ultimate base capacity of 1,250kN, giving a total capacity of 2,050kN. Once the initial static friction is exceeded, the friction reduces to a dynamic value (350kN) and as the pile is pushed into the ground, the end bearing capacity increases to 2,875kN, using the Fleming curve-fitting procedure.

| Pile No | Static friction (i.e. initial stage of test) | | | Mobile friction (i.e. final stage of test) | | |
|---|---|---|---|---|---|---|
| | Assessed shaft capacity (kN) | Assessed base capacity (kN) | Total capacity(kN) | Assessed shaft capacity (kN) | Assessed base capacity (kN) | Total capacity (kN) |
| W28 | 650 | 1400 | 2050 | Pile continually pushed into the ground | | |
| W86 | 800 | 1250 | 2050 | 350 | 2875 | 3225 |

Table 9

| TONY GEE and PARTNERS<br>Consulting Engineers<br>Cobham Surrey<br>Ashford Kent<br>Halesowen W.Midlands | Job No | C106070 | Ref | Sheet No |
|---|---|---|---|---|
| | Project | Cardiff St Davids 2 | | |
| | Calculations for | Tubular Test Pile W28 | | Date 12/03/2007 |
| | | | | By DRB |

PILE SETTLEMENT ANALYSIS (after Fleming, 1992)

INPUT DATA

| | |
|---|---|
| Equivalent pile shaft diameter ($D_S$)= | 0.914 m |
| Equivalent pile base diameter ($D_B$)= | 0.267 m |
| Deformation modulus below base ($E_B$)= | 2,000,000 kN/m$^2$ |
| Equivalent Young's modulus of steel ($E_C$)= | 1.84E+07 kN/m$^2$ |
| Friction length coefficient ($K_E$)= | 0.55 |
| Upper pile length carrying no load ($L_O$)= | 0 m |
| Pile length transferring load by friction ($L_F$)= | 12.855 m |
| Flexibility factor ($M_S$)= | 0.003 |
| Pile design load ($P_T$)= | 1075 kN |
| Ultimate shaft friction load ($U_S$)= | 650 kN |
| Ultimate pile base load ($U_B$)= | 1400 kN |
| Total ultimate load = | 2050 kN |
| Max plotted predicted ult.load = 97% | 1988.5 kN |
| Maximum settlement = | 44.66 mm |

| Load kN | %Ult.Load | Settlement mm | % Dia. |
|---|---|---|---|
| 0 | 0.0% | 0 | 0.00% |
| 373 | 18.2% | 0.705 | 0.08% |
| 744 | 36.3% | 1.761 | 0.19% |
| 1117 | 54.5% | 2.595 | 0.28% |
| 1490 | 72.7% | 4.65 | 0.51% |
| 1758 | 85.8% | 9.673 | 1.06% |
| 2028 | 98.9% | 37.281 | 4.08% |
| 2300 | 112.2% | 54.77 | 5.99% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |
| 0 | 0.0% | 0 | 0.00% |

OUTPUT DATA

| Load kN | Settlement mm | Shortening mm | Movement mm |
|---|---|---|---|
| 0 | 0.00 | | 0.00 |
| 60 | 0.04 | 0.04 | 0.07 |
| 121 | 0.08 | 0.07 | 0.15 |
| 181 | 0.12 | 0.11 | 0.22 |
| 241 | 0.16 | 0.14 | 0.30 |
| 301 | 0.21 | 0.18 | 0.39 |
| 362 | 0.26 | 0.21 | 0.48 |
| 422 | 0.32 | 0.25 | 0.57 |
| 482 | 0.38 | 0.28 | 0.66 |
| 542 | 0.45 | 0.32 | 0.76 |
| 603 | 0.52 | 0.35 | 0.87 |
| 663 | 0.60 | 0.39 | 0.99 |
| 723 | 0.68 | 0.46 | 1.14 |
| 783 | 0.78 | 0.52 | 1.30 |
| 844 | 0.88 | 0.59 | 1.47 |
| 904 | 1.00 | 0.65 | 1.65 |
| 964 | 1.13 | 0.72 | 1.84 |
| 1024 | 1.27 | 0.78 | 2.05 |
| 1085 | 1.43 | 0.84 | 2.28 |
| 1145 | 1.62 | 0.91 | 2.53 |
| 1205 | 1.83 | 0.97 | 2.80 |
| 1265 | 2.08 | 1.04 | 3.11 |
| 1326 | 2.36 | 1.10 | 3.46 |
| 1386 | 2.70 | 1.16 | 3.86 |
| 1446 | 3.11 | 1.23 | 4.34 |
| 1506 | 3.60 | 1.29 | 4.90 |
| 1567 | 4.23 | 1.36 | 5.58 |
| 1627 | 5.03 | 1.42 | 6.45 |
| 1687 | 6.09 | 1.49 | 7.58 |
| 1747 | 7.59 | 1.55 | 9.14 |
| 1808 | 9.82 | 1.61 | 11.44 |
| 1868 | 13.54 | 1.68 | 15.22 |
| 1928 | 20.94 | 1.74 | 22.68 |
| 1989 | 42.85 | 1.81 | 44.66 |

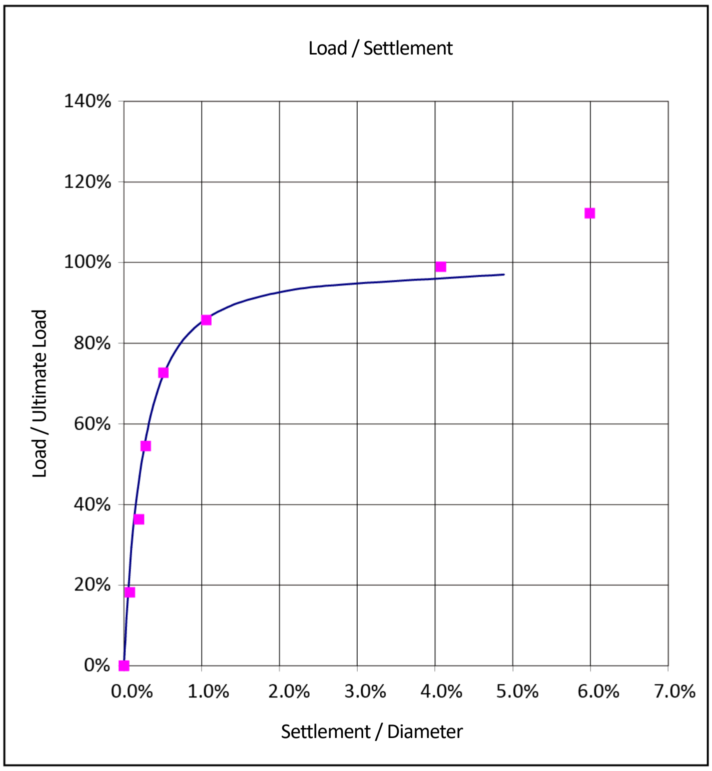



Figure 13

| TONY GEE and PARTNERS<br>Consulting Engineers<br>Cobham Surrey<br>Ashford Kent<br>Halesowen W.Midlands | Job No | C106070 | Ref | Sheet No |
|---|---|---|---|---|
| | Project | Cardiff St Davids 2 | | |
| | Calculations for | Tubular test pile W86 | | Date 12/03/2007 |
| | | | | By DRB |

PILE SETTLEMENT ANALYSIS (after Fleming, 1992)

INPUT DATA

| | |
|---|---|
| Equivalent pile shaft diameter ($D_S$)= | 0.914 m |
| Equivalent pile base diameter ($D_B$)= | 0.267 m |
| Deformation modulus below base ($E_B$)= | 2,000,000 kN/m$^2$ |
| Equivalent Young's modulus of steel ($E_C$)= | 1.84E+07 kN/m$^2$ |
| Friction length coefficient ($K_E$)= | 0.55 |
| Upper pile length carrying no load ($L_O$)= | 0 m |
| Pile length transferring load by friction ($L_F$)= | 12.255 m |
| Flexibility factor ($M_S$)= | 0.003 |
| Pile design load ($P_T$)= | 1075 kN |
| Ultimate shaft friction load ($U_S$)= | 800k N |
| Ultimate pile base load ($U_B$)= | 1250 kN |
| Total ultimate load = | 2050 kN |
| Max plotted predicted ult.load = 98% | 2009 kN |
| Maximum settlement = | 60.08 mm |

| Load kN | %Ult.Load | Settlement mm | % Dia. |
|---|---|---|---|
| 0 | 0.0% | 0 | 0.00% |
| 372 | 18.0% | 1.76 | 0.19% |
| 744 | 36.3% | 2.74 | 0.30% |
| 1116 | 54.4% | 3.70 | 0.40% |
| 1492 | 72.8% | 5.29 | 0.58% |
| 1758 | 85.8% | 10.22 | 1.12% |
| 2028 | 98.8% | 22.87 | 2.50% |
| 2295 | 112.0% | 30.65 | 3.35% |
| 2565 | 125.1 % | 43.00 | 4.70% |
| 2825 | 137.8% | 64.36 | 7.04% |
| 2942 | 143.5% | 96.58 | 10.57% |
| 0 | 0.0% | 0 | 0.00% |

Assessed settlement at zero load = 1.20 mm

OUTPUT DATA

| Load kN | Settlement mm | Shortening mm | Movement mm |
|---|---|---|---|
| 0 | 1.20 | 0.00 | 1.20 |
| 61 | 1.23 | 0.03 | 1.27 |
| 122 | 1.27 | 0.07 | 1.34 |
| 183 | 1.31 | 0.10 | 1.41 |
| 244 | 1.35 | 0.14 | 1.48 |
| 304 | 1.39 | 0.17 | 1.56 |
| 365 | 1.44 | 0.20 | 1.64 |
| 426 | 1.49 | 0.24 | 1.73 |
| 487 | 1.54 | 0.27 | 1.82 |
| 548 | 1.60 | 0.31 | 1.91 |
| 609 | 1.67 | 0.34 | 2.01 |
| 670 | 1.74 | 0.37 | 2.11 |
| 731 | 1.82 | 0.41 | 2.23 |
| 791 | 1.90 | 0.44 | 2.35 |
| 852 | 2.00 | 0.50 | 2.50 |
| 913 | 2.10 | 0.56 | 2.66 |
| 974 | 2.22 | 0.62 | 2.84 |
| 1035 | 2.35 | 0.69 | 3.04 |
| 1096 | 2.50 | 0.75 | 3.25 |
| 1157 | 2.67 | 0.81 | 3.48 |
| 1218 | 2.86 | 0.87 | 3.73 |
| 1278 | 3.09 | 0.93 | 4.02 |
| 1339 | 3.35 | 0.99 | 4.35 |
| 1400 | 3.67 | 1.06 | 4.72 |
| 1461 | 4.04 | 1.12 | 5.16 |
| 1522 | 4.51 | 1.18 | 5.69 |
| 1583 | 5.10 | 1.24 | 6.34 |
| 1644 | 5.87 | 1.30 | 7.17 |
| 1705 | 6.91 | 1.36 | 8.27 |
| 1765 | 8.39 | 1.43 | 9.82 |
| 1826 | 10.68 | 1.49 | 12.17 |
| 1887 | 14.69 | 1.55 | 16.24 |
| 1948 | 23.48 | 1.61 | 25.09 |
| 2009 | 58.41 | 1.67 | 60.08 |

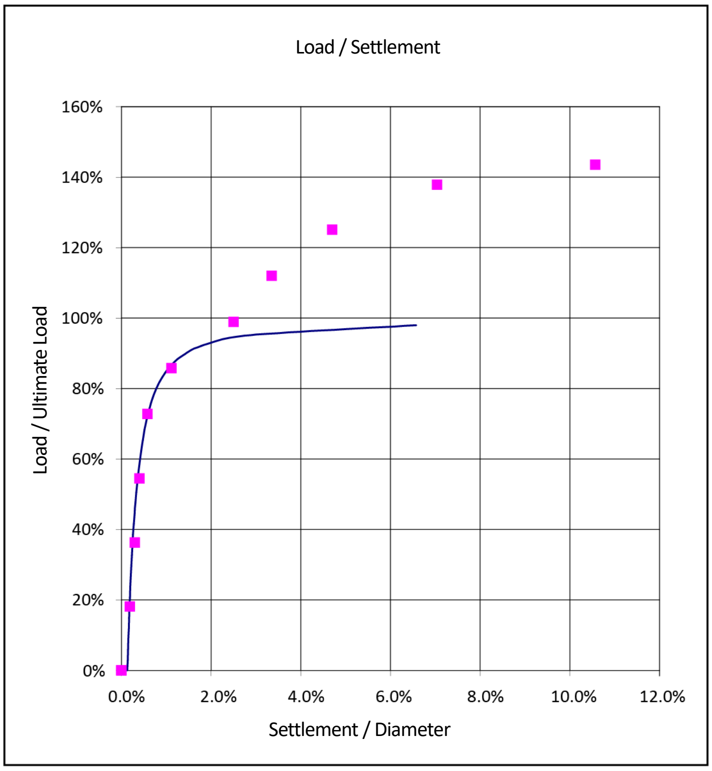



Figure 14

## 5-5 Back Analysis

For the purposes of back analysis of the as-built piles, the recorded net push force can be compared to the pile capacity. To determine the skin friction from ground level to basement level, take the average of the uplift force measured for piles W1 to W97 (498kN) and deduct the weight of the pile, chuck and auger (258kN) to give 240kN as the average skin friction down to basement level.

Taking a conservative view of the ultimate load capacities from the test results as summarised in the table below, a graph of push force vs working capacity is plotted, assuming a factor of safety of 2.0 and taking the skin friction to basement level as discussed above as 240kN (i.e. DVL = 1,075 + 240 = 1,315kN):

| Pile No. | Net Toe Resistance (kN) | Ultimate Capacity (kN) | Working Capacity (kN) |
|---|---|---|---|
| W28 | 460 | 2050 | = (2050-240)/2 = 905 |
| W86 | 990 | 3100 | = (3100-240)/2 = 1430 |

Table 10 Working capacity, ultimate capacity and net toe resistance

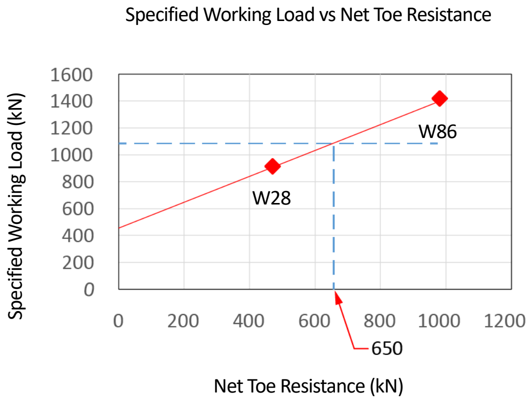



Figure 15 Plot of Specified Working Load vs Net Toe Resistance

## 5-6 Conclusion

The tests have indicated an ultimate capacity of 2,050kN for the initial stage of each test. At additional settlements, higher base capacity is mobilised such that the maximum load of 3,100kN is achieved for pile W86 at a settlement of 96mm, which suggests that the ultimate capacity has increased to approximately 3,225kN.

At working load (1,075kN), which is increased to the design verification load of 1,489kN to allow for the potential skin friction above the basement level, the settlements of the first loading are small (4.32mm and 4.47mm).

# Chapter 6 Quality Control Procedure for Pile Installation

## 6-1 Sheet Pile

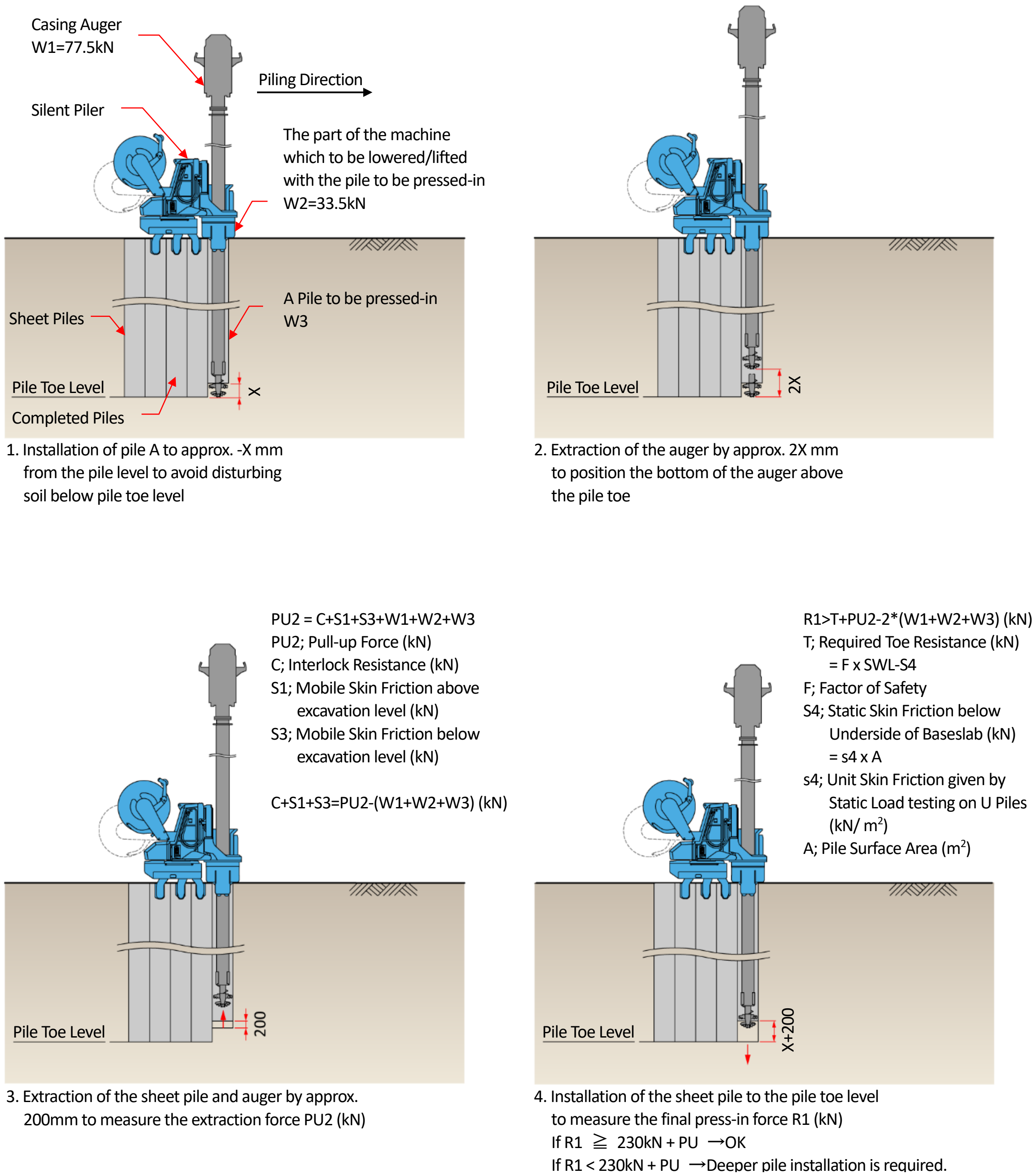



Figure 16 Quality Control Procedure (Sheet Pile)

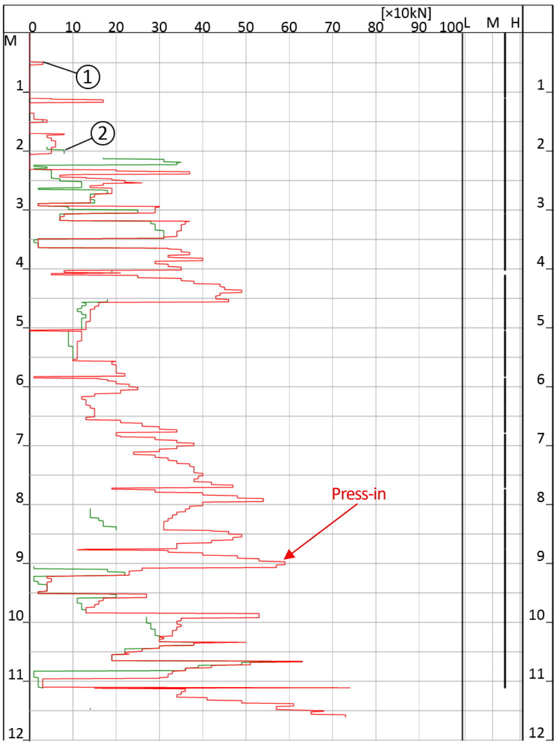
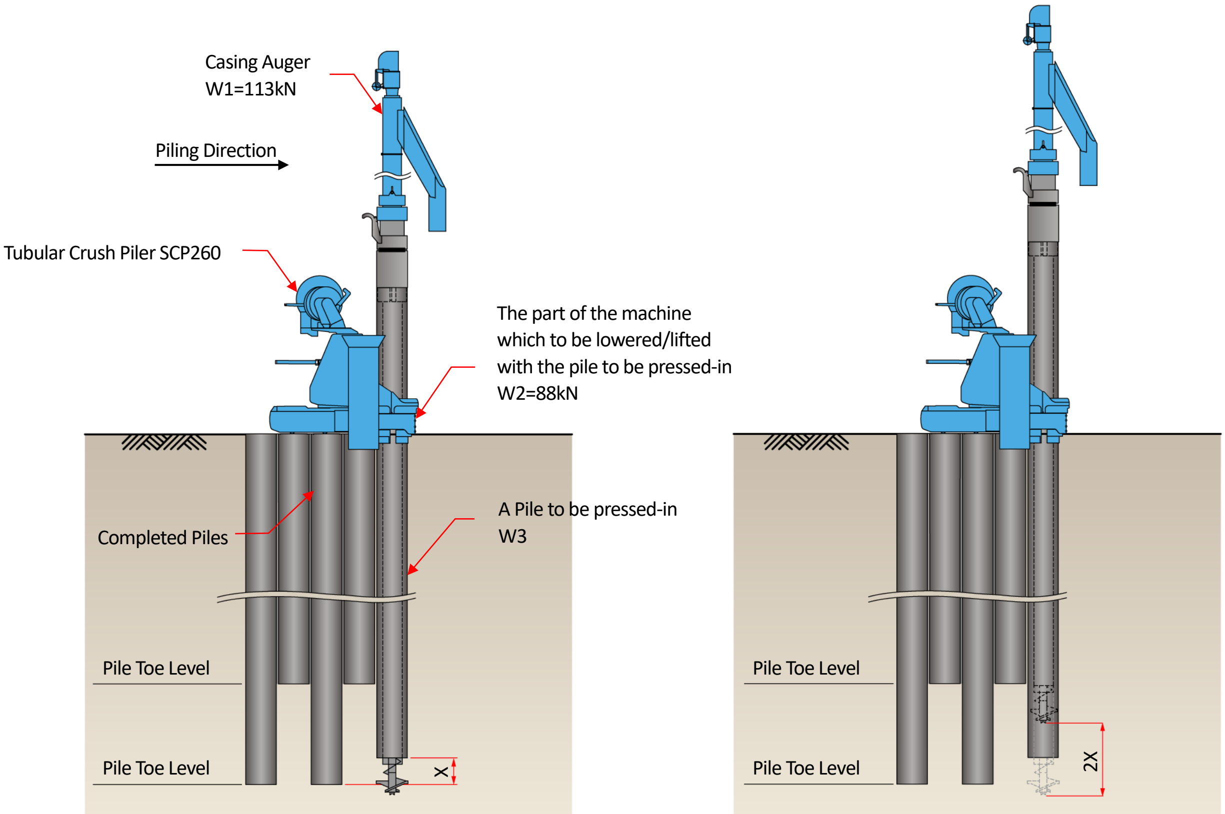


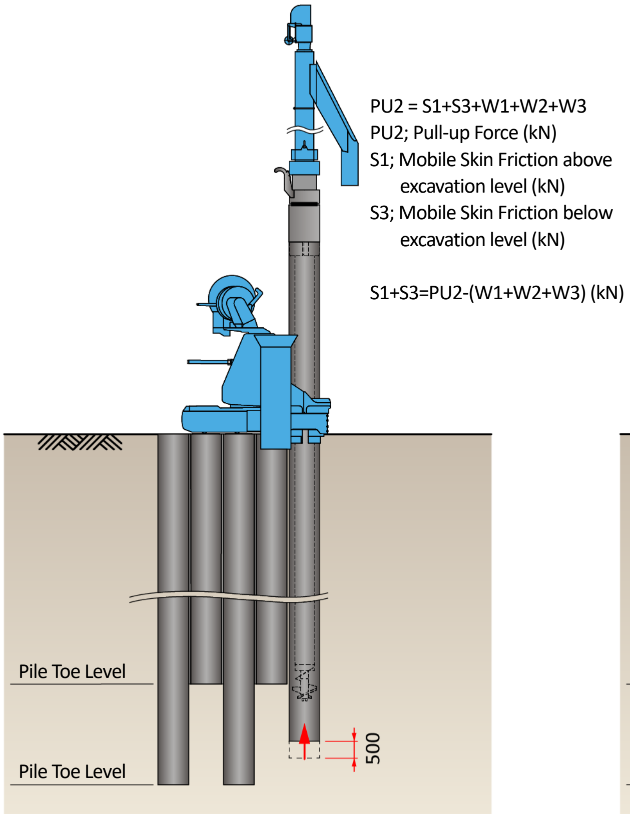

Figure 17 e.g. Press-in Force Monitoring Results

## 6-2 Tubular Pile

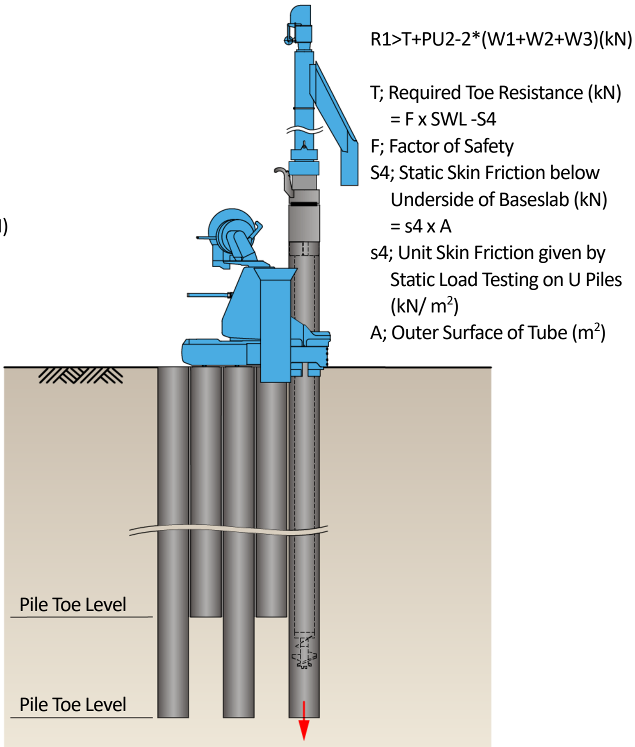



1. Installation of the pile to approx. –Xmm from the pile toe level to minimize soil disturbance below pile toe level

2. Extraction of the auger casing by approx. 2x mm to position the bottom of the auger above the pile toe




3. Extraction of the tubular pile and casing by approx. 500mm to measure the extraction force PU2 (kN)




4. Installation of the tubular pile to the pile toe level to measure the final press-in force R1 (kN)
If R1 ≧ 650 kN + PU2 →OK
If R1 < 650 kN + PU2 →Deeper pile installation is required

Figure 18 Quality Control Procedure (Tubular Pile)

# Chapter 7 Slab Connection

## 7-1 Sheet Pile Wall

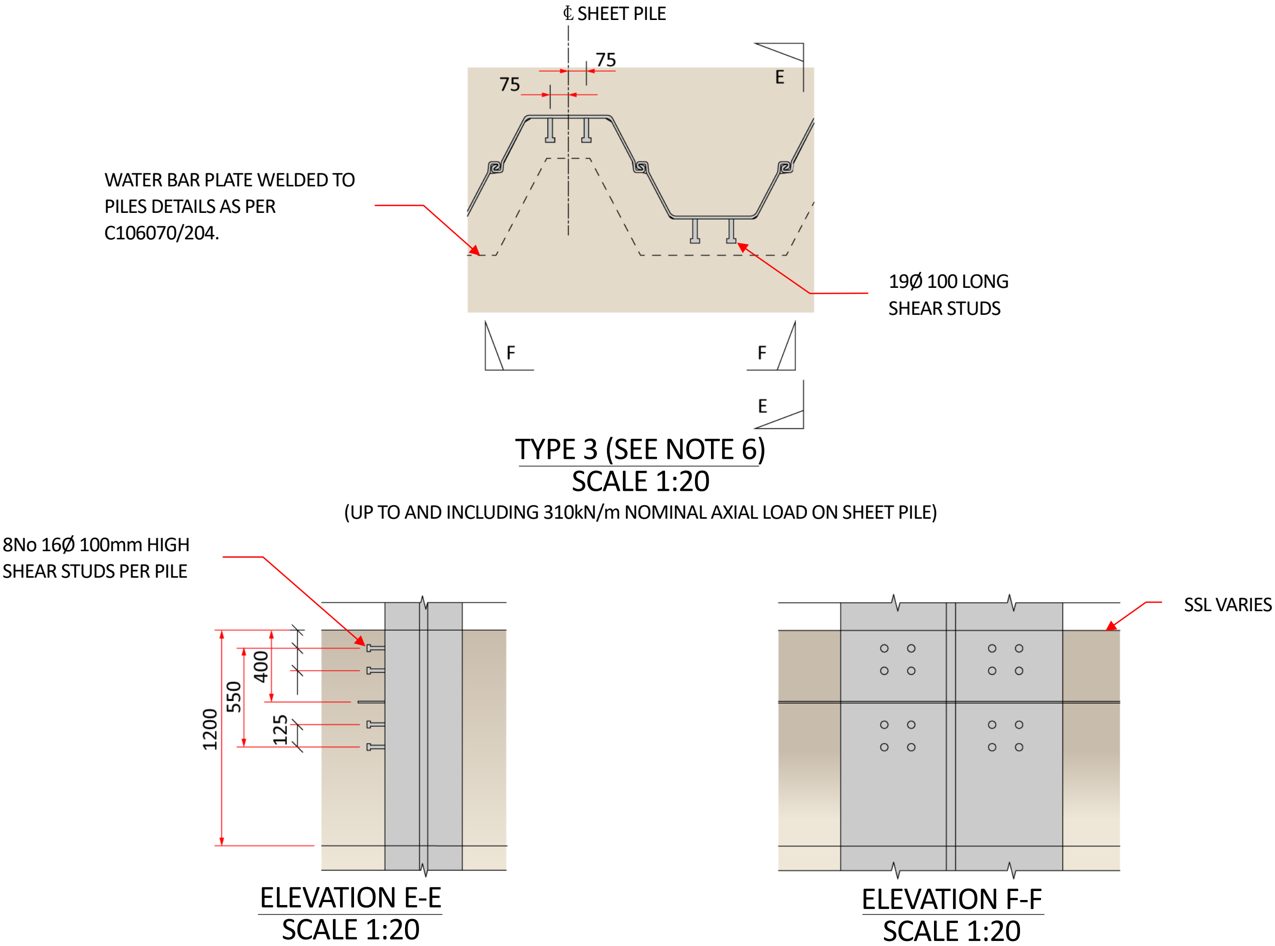



Figure 19 Slab Connection Details (Sheet Pile) – 1

Figure 20 Slab Connection Details（Sheet Pile）- 2

## 7-2 Tubular Pile Wall

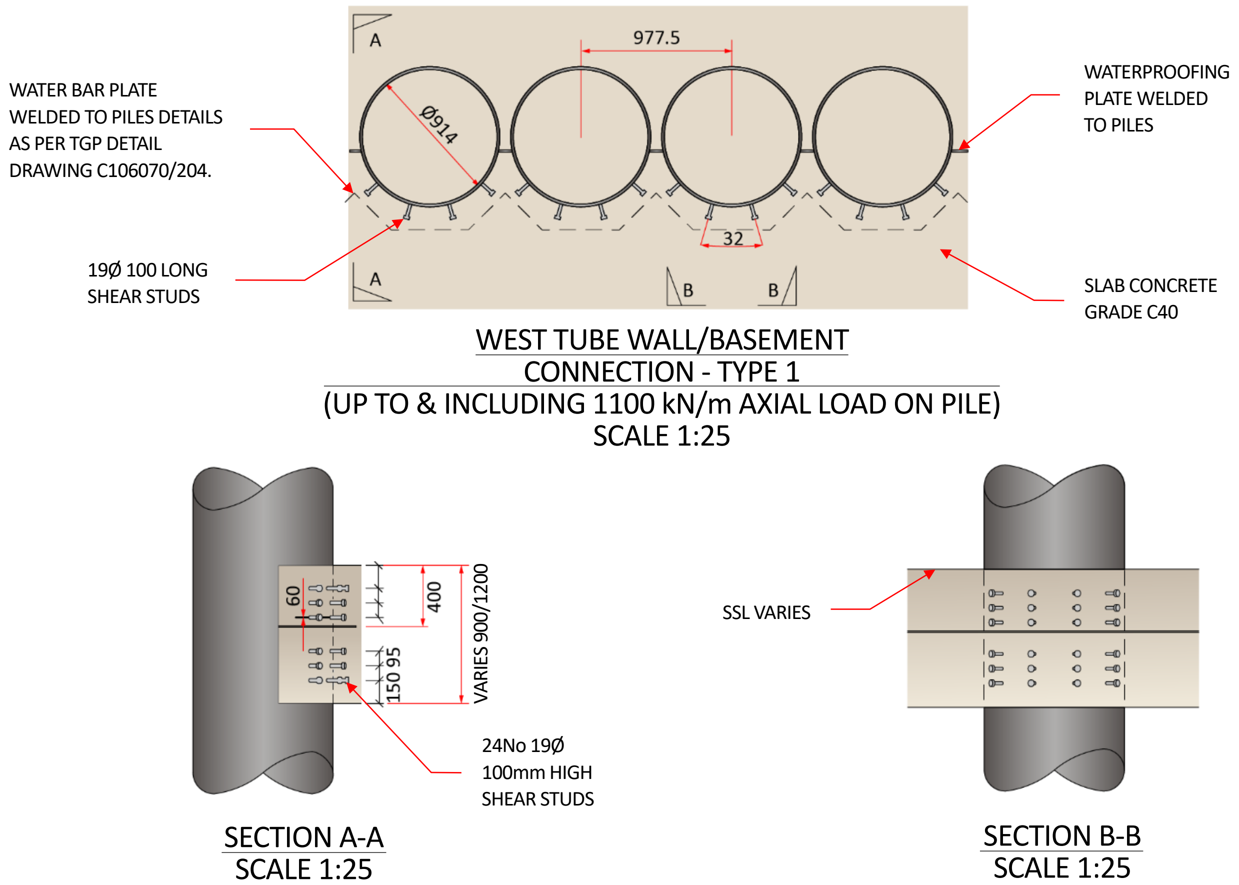



Figure 21 Slab Connection Details (Tubular Pile) – 1

Figure 22 Slab Connection Details (Tubular Pile) – 2

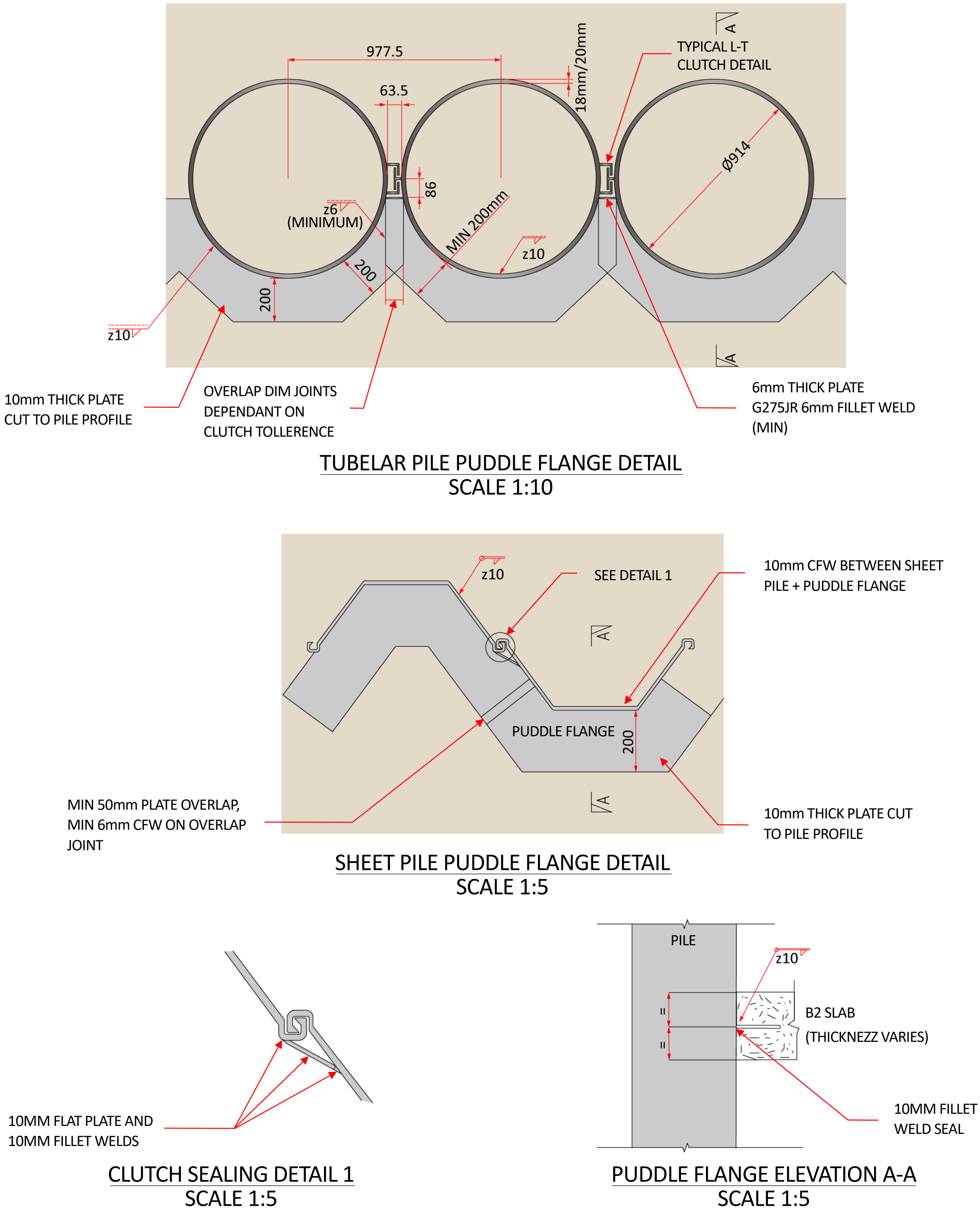



Figure 23 Waterproofing Details

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