UK Summary - Negative Shaft Friction

Chris Raison

Negative Shaft Friction $Q_{nsf} = q_s A_s$

$q_s = \sigma'_v \beta$ for sands, gravels and long term clay

$\beta = 0.25$ to $0.30$

$q_s = \alpha c_u$ for short term clay

$\alpha = 1.0$

$Q_{nsf;d}$ Computed using M2 material factors

$\gamma_{m,\phi',c'} = 1.25$

$\gamma_{m,Cu} = 1.4$

Worst case assumptions.

Use soil-structure interaction software to compute location of neutral axis and actual $Q_{nsf}$ for SLS case. No $Q_{nsf}$ if pile settlement greater than settlement of soft soil.

Under ULS conditions, negative shaft friction often reduces to zero or even positive shaft friction.

Negative shaft friction limited by driving overburden stress for $Q_{nsf}$ caused by backfilling.

## Example Problem

## Under test:

$Q_s$ = 725kN including 392kN from soft clay

$Q_b$ = 969kN

$Q_{ult}$ = 1694kN  (cf Load test 1587kN at 40mm settlement)

## Short term conditions:

$Q_s$ = 474kN

$Q_b$ = 1317kN

$Q_{ult}$ = 1791kN

$Q_{nsf,k}$ = 410kN and $Q_{nsf,d}$ = 572kN (M2 factors)

$R_{cd}$ = 464kN

$F_d$ = 450kN < $R_{cd}$ OK

## Long term conditions:

$Q_s$ = 474kN

$Q_b$ = 1317kN

$Q_{ult}$ = 1791kN

$Q_{nsf,k}$ = 316kN and $Q_{nsf,d}$ = 395kN (M2 factors)

$R_{cd}$ = 690kN

$F_d$ = 450kN < $R_{cd}$ OK

## PILE BEARING CAPACITY

Pile System Precast  Pile size 350 mm

| Soil Description | Top Level (mOD) | Soil Type | Shaft Stress Top (kPa) | Shaft Stress Base (kPa) | Shaft Friction (kN) |
|---|---|---|---|---|---|
| Soft CLAY | 0 | Undrained | 35 | 35 | 392 |
| Medium dense SAND | -8.00 | Drained | 65 | 94 | 333 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | 0 kN |
| Base stress | 7913 | kPa | SHAFT CAPACITY | 725 kN |
| | | | END BEARING CAPACITY | 969 kN |
| | | | ULTIMATE CAPACITY | 1694 kN |

Maintained load test to ultimate capacity  EC7 Model Factor 1.2

| | |
|---|---|
| Characteristic Shaft Resistance Rsk | 604 kN |
| Characteristic End Bearing Resistance Rbk | 808 kN |
| Characteristic Pile Resistance Rk | 1412 kN |

Settlement verified by load test  EC7 Resistance Factors

| | |
|---|---|
| Shaft Factor | 1.3 |
| End Bearing Factor | 1.5 |
| Shaft Tension Factor | 1.7 |

UK National Annex to EC7 Factor Set R4

| | |
|---|---|
| EC7 DESIGN RESISTANCE Rcd | 1003 kN |
| EC7 DESIGN TENSION RESISTANCE Rtd | 355 kN |
| PILE LENGTH | 13.00 m |

## PILE BEARING CAPACITY - FULL OUTPUT DETAILS - EC7 Design Resistance

Pile System Precast  Pile size 350 mm

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

| Soil Description | Increment Level (mOD) | Vertical Eff Str (kPa) | Water Pressure (kPa) | Shaft Stress (kPa) | Total Shaft (kN) |
|---|---|---|---|---|---|
| Soft CLAY | 0 | 0 | 0 | 35.0 | 0 |
| | -0.01 | 0.1 | 0.1 | 35.0 | 0.5 |
| | -0.02 | 0.2 | 0.2 | 35.0 | 1.0 |
| | -0.03 | 0.2 | 0.3 | 35.0 | 1.5 |
| | -0.04 | 0.3 | 0.4 | 35.0 | 2.0 |
| | -0.50 | 3.9 | 4.9 | 35.0 | 24.5 |
| | -1.00 | 7.7 | 9.8 | 35.0 | 49.0 |
| | -1.50 | 11.6 | 14.7 | 35.0 | 73.5 |
| | -2.00 | 15.4 | 19.6 | 35.0 | 98.0 |
| | -2.50 | 19.3 | 24.5 | 35.0 | 122.5 |
| | -3.00 | 23.1 | 29.4 | 35.0 | 147.0 |
| | -3.50 | 27.0 | 34.3 | 35.0 | 171.5 |
| | -4.00 | 30.8 | 39.2 | 35.0 | 196.0 |
| | -4.50 | 34.7 | 44.1 | 35.0 | 220.5 |
| | -5.00 | 38.5 | 49.0 | 35.0 | 245.0 |
| | -5.50 | 42.4 | 53.9 | 35.0 | 269.5 |
| | -6.00 | 46.2 | 58.8 | 35.0 | 294.0 |
| | -6.50 | 50.1 | 63.7 | 35.0 | 318.5 |
| | -7.00 | 53.9 | 68.6 | 35.0 | 343.0 |
| | -7.50 | 57.8 | 73.5 | 35.0 | 367.5 |
| | -8.00 | 61.6 | 78.4 | 35.0 | 392.0 |
| Medium dense SAND | -8.00 | 61.6 | 78.4 | 64.7 | 392.0 |
| | -8.50 | 66.2 | 83.3 | 69.5 | 439.0 |
| | -9.00 | 70.8 | 88.2 | 74.3 | 489.4 |
| | -9.50 | 75.4 | 93.1 | 79.2 | 543.1 |
| | -10.00 | 80.0 | 98.0 | 84.0 | 600.3 |
| | -10.50 | 84.6 | 102.9 | 88.8 | 660.8 |
| | -11.00 | 89.2 | 107.8 | 93.7 | 724.7 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | 0 kN |
| Base stress | 7913 | kPa | SHAFT CAPACITY | 725 kN |
| Vertical eff stress | 89.2 | kPa | END BEARING CAPACITY | 969 kN |
| Nq | 33.2 | | ULTIMATE CAPACITY | 1694 kN |
| Sc.dc | 2.67 | | | |
| Effective Nq | 88.7 | | EC7 DESIGN RESISTANCE | 1003 kN |
| | | | EC7 TENSION RESISTANCE | 355 kN |
| | | | PILE LENGTH | 13.00 m |

## PILE DATA

Pile system Precast

Pile size : 350 mm

Shaft perimeter : 1.400 m
Base area : 0.123 m2

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

## SOIL STRATA DATA

| Soil Layer | Soil Description | Top Level (mOD) | Soil Type |
|---|---|---|---|
| 1 | Soft CLAY | 0 | Undrained |
| 2 | Medium dense SAND | -8.00 | Drained |

Rigid base level : -15.00

## WATER DATA

Unit weight of water : 9.80 kN/m3

Hydrostatic profile
Water table level : 0 mOD

## CALCULATION DATA

User selected calculation options
Design Approach : EC7 design resistance
Shaft Friction Ks : Ks from empirical relationships
Bearing capacity Nq : Brinch Hansen bearing capacity
Confining stress : Not considered
Pile Settlements : Not considered

Maximum allowable stresses
Shaft fs : 500 kPa
Base fb : 15000 kPa
Concrete fcu : 60.00 N/mm2

## EC7 PARTIAL FACTORS

UK National Annex to EC7 Factor Set R4

Maintained load test to ultimate capacity
Model Factor : 1.2

Settlement verified by load test
Shaft Factor : 1.3
End Bearing Factor : 1.5
Shaft Tension Factor : 1.7

## SOIL PROPERTIES DATA FOR LAYER 1

Soft CLAY Top level 0 mOD

Undrained Properties

| | Unit weight (kN/m3) | Cu (kPa) | Alpha | Nc | Shaft stress (kPa) | Base stress (kPa) |
|---|---|---|---|---|---|---|
| Top | 17.50 | 35.0 | 1.00 | 9.0 | 35 | 315 |
| Base | | 35.0 | 1.00 | | 35 | 315 |

## SOIL PROPERTIES DATA FOR LAYER 2

Medium dense SAND Top level -8.00 mOD

Drained Properties

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 19.00 | 0 | | 35.0 | 1.50 | 0.70 | 65 |
| Base | | | | | | | | 132 |

| | Eff Phi' (deg) | Nq | D/B ratio | Sc.dc | Eff Nq | Base stress (kPa) |
|---|---|---|---|---|---|---|
| Top | 35.0 | 33.2 | 0 | 1.32 | 43.7 | 2695 |
| Base | | | 20.00 | 3.00 | 99.7 | 12557 |

## PILE BEARING CAPACITY

Pile System Precast  Pile size 350 mm

| Soil Description | Top Level (mOD) | Soil Type | Shaft Stress Top (kPa) | Shaft Stress Base (kPa) | Shaft Friction (kN) |
|---|---|---|---|---|---|
| Granular BACKFILL | 2.00 | Negative | 0 | -16 | -23 |
| Soft CLAY | 0 | Negative | -49 | -49 | -549 |
| Medium dense SAND | -8.00 | Drained | 98 | 127 | 474 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | -572 kN |
| Base stress | 10752 | kPa | SHAFT CAPACITY | 474 kN |
| | | | END BEARING CAPACITY | 1317 kN |
| | | | ULTIMATE CAPACITY | 1791 kN |

Maintained load test to ultimate capacity

EC7 Model Factor 1.2

| | |
|---|---|
| Characteristic Shaft Resistance Rsk | 395 kN |
| Characteristic End Bearing Resistance Rbk | 1098 kN |
| Characteristic Pile Resistance Rk | 1492 kN |

Settlement verified by load test

EC7 Resistance Factors

| | |
|---|---|
| Shaft Factor | 1.3 |
| End Bearing Factor | 1.5 |
| Shaft Tension Factor | 1.7 |

UK National Annex to EC7 Factor Set R4

| | |
|---|---|
| EC7 DESIGN RESISTANCE Rcd | 464 kN |
| EC7 DESIGN TENSION RESISTANCE Rtd | 232 kN |
| PILE LENGTH | 13.00 m |

## PILE BEARING CAPACITY - FULL OUTPUT DETAILS - EC7 Design Resistance

Pile System Precast  Pile size 350 mm

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

| Soil Description | Increment Level (mOD) | Vertical Eff Str (kPa) | Water Pressure (kPa) | Shaft Stress (kPa) | Total Shaft (kN) |
|---|---|---|---|---|---|
| Granular BACKFILL | 2.00 | 0 | 0 | 0 | 0 |
| | 1.50 | 8.0 | 0 | -4.1 | -1.5 |
| | 1.00 | 16.0 | 0 | -8.2 | -5.8 |
| | 0.50 | 24.0 | 0 | -12.2 | -12.9 |
| | 0 | 32.0 | 0 | -16.3 | -23.0 |
| Soft CLAY | 0 | 32.0 | 0 | -49.0 | -23.0 |
| | -0.50 | 35.9 | 4.9 | -49.0 | -57.3 |
| | -1.00 | 39.7 | 9.8 | -49.0 | -91.6 |
| | -1.50 | 43.6 | 14.7 | -49.0 | -125.9 |
| | -2.00 | 47.4 | 19.6 | -49.0 | -160.2 |
| | -2.50 | 51.3 | 24.5 | -49.0 | -194.5 |
| | -3.00 | 55.1 | 29.4 | -49.0 | -228.8 |
| | -3.50 | 59.0 | 34.3 | -49.0 | -263.1 |
| | -4.00 | 62.8 | 39.2 | -49.0 | -297.4 |
| | -4.50 | 66.7 | 44.1 | -49.0 | -331.7 |
| | -5.00 | 70.5 | 49.0 | -49.0 | -366.0 |
| | -5.50 | 74.4 | 53.9 | -49.0 | -400.3 |
| | -6.00 | 78.2 | 58.8 | -49.0 | -434.6 |
| | -6.50 | 82.1 | 63.7 | -49.0 | -468.9 |
| | -7.00 | 85.9 | 68.6 | -49.0 | -503.2 |
| | -7.50 | 89.8 | 73.5 | -49.0 | -537.5 |
| | -8.00 | 93.6 | 78.4 | -49.0 | -571.8 |
| Medium dense SAND | -8.00 | 93.6 | 78.4 | 98.3 | -571.8 |
| | -8.50 | 98.2 | 83.3 | 103.1 | -501.3 |
| | -9.00 | 102.8 | 88.2 | 107.9 | -427.4 |
| | -9.50 | 107.4 | 93.1 | 112.8 | -350.1 |
| | -10.00 | 112.0 | 98.0 | 117.6 | -269.4 |
| | -10.50 | 116.6 | 102.9 | 122.4 | -185.4 |
| | -11.00 | 121.2 | 107.8 | 127.3 | -97.9 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | -572 kN |
| Base stress | 10752 | kPa | SHAFT CAPACITY | 474 kN |
| Vertical eff stress | 121.2 | kPa | END BEARING CAPACITY | 1317 kN |
| Nq | 33.2 | | ULTIMATE CAPACITY | 1791 kN |
| Sc.dc | 2.67 | | | |
| Effective Nq | 88.7 | | EC7 DESIGN RESISTANCE | 464 kN |
| | | | EC7 TENSION RESISTANCE | 232 kN |
| | | | PILE LENGTH | 13.00 m |

## PILE DATA

Pile system Precast

Pile size : 350 mm
Shaft perimeter : 1.400 m
Base area : 0.123 m2

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

## SOIL STRATA DATA

| Soil Layer | Soil Description | Top Level (mOD) | Soil Type |
|---|---|---|---|
| 1 | Granular BACKFILL | 2.00 | Negative |
| 2 | Soft CLAY | 0 | Negative |
| 3 | Medium dense SAND | -8.00 | Drained |

Rigid base level : -15.00

## WATER DATA

Unit weight of water : 9.80 kN/m3

Hydrostatic profile
Water table level : 0 mOD

## CALCULATION DATA

User selected calculation options
Design Approach : EC7 design resistance
Shaft Friction Ks : Ks from empirical relationships
Bearing capacity Nq : Brinch Hansen bearing capacity
Confining stress : Not considered
Pile Settlements : Not considered

Maximum allowable stresses
Shaft fs : 500 kPa
Base fb : 15000 kPa
Concrete fcu : 60.00 N/mm2

## EC7 PARTIAL FACTORS

UK National Annex to EC7 Factor Set R4

Maintained load test to ultimate capacity
Model Factor : 1.2

Settlement verified by load test
Shaft Factor : 1.3
End Bearing Factor : 1.5
Shaft Tension Factor : 1.7

## SOIL PROPERTIES DATA FOR LAYER 1

Granular BACKFILL Top level 2.00 mOD

Negative Shaft Friction Properties - Effective stress calculation

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 16.00 | 0 | | 30.0 | 0.88 | -0.58 | 0 |
| Base | | | | | | | | -16 |

## SOIL PROPERTIES DATA FOR LAYER 2

Soft CLAY Top level 0 mOD

Negative Shaft Friction Properties - Total stress calculation

| | Unit weight (kN/m3) | Cu (kPa) | Alpha | Shaft stress (kPa) |
|---|---|---|---|---|
| Top | 17.50 | 35.0 | -1.40 | -49 |
| Base | | 35.0 | -1.40 | -49 |

## SOIL PROPERTIES DATA FOR LAYER 3

Medium dense SAND  Top level -8.00 mOD

Drained Properties

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 19.00 | 0 | | 35.0 | 1.50 | 0.70 | 98 |
| Base | | | | | | | | 166 |

| | Eff Phi' (deg) | Nq | D/B ratio | Sc.dc | Eff Nq | Base stress (kPa) |
|---|---|---|---|---|---|---|
| Top | 35.0 | 33.2 | 0 | 1.32 | 43.7 | 4095 |
| Base | | | 20.00 | 3.00 | 99.7 | 15747 |

## PILE BEARING CAPACITY

Pile System Precast  Pile size 350 mm

| Soil Description | Top Level (mOD) | Soil Type | Shaft Stress Top (kPa) | Shaft Stress Base (kPa) | Shaft Friction (kN) |
|---|---|---|---|---|---|
| Granular BACKFILL | 2.00 | Negative | 0 | -16 | -23 |
| Soft CLAY | 0 | Negative | -20 | -38 | -322 |
| Medium dense SAND | -8.00 | Drained | 98 | 127 | 474 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | -345 kN |
| Base stress | 10752 | kPa | SHAFT CAPACITY | 474 kN |
| | | | END BEARING CAPACITY | 1317 kN |
| | | | ULTIMATE CAPACITY | 1791 kN |

Maintained load test to ultimate capacity

EC7 Model Factor 1.2

| | |
|---|---|
| Characteristic Shaft Resistance Rsk | 395 kN |
| Characteristic End Bearing Resistance Rbk | 1098 kN |
| Characteristic Pile Resistance Rk | 1492 kN |

Settlement verified by load test

EC7 Resistance Factors

| | |
|---|---|
| Shaft Factor | 1.3 |
| End Bearing Factor | 1.5 |
| Shaft Tension Factor | 1.7 |

UK National Annex to EC7 Factor Set R4

| | |
|---|---|
| EC7 DESIGN RESISTANCE Rcd | 690 kN |
| EC7 DESIGN TENSION RESISTANCE Rtd | 232 kN |
| PILE LENGTH | 13.00 m |

## PILE BEARING CAPACITY - FULL OUTPUT DETAILS - EC7 Design Resistance

Pile System Precast Pile size 350 mm

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

| Soil Description | Increment Level (mOD) | Vertical Eff Str (kPa) | Water Pressure (kPa) | Shaft Stress (kPa) | Total Shaft (kN) |
|---|---|---|---|---|---|
| Granular BACKFILL | 2.00 | 0 | 0 | 0 | 0 |
| | 1.50 | 8.0 | 0 | -4.1 | -1.5 |
| | 1.00 | 16.0 | 0 | -8.2 | -5.8 |
| | 0.50 | 24.0 | 0 | -12.2 | -12.9 |
| | 0 | 32.0 | 0 | -16.3 | -23.0 |
| Soft CLAY | 0 | 32.0 | 0 | -19.6 | -23.0 |
| | -0.50 | 35.9 | 4.9 | -20.7 | -37.1 |
| | -1.00 | 39.7 | 9.8 | -21.9 | -52.0 |
| | -1.50 | 43.6 | 14.7 | -23.0 | -67.7 |
| | -2.00 | 47.4 | 19.6 | -24.2 | -84.2 |
| | -2.50 | 51.3 | 24.5 | -25.3 | -101.6 |
| | -3.00 | 55.1 | 29.4 | -26.5 | -119.7 |
| | -3.50 | 59.0 | 34.3 | -27.6 | -138.6 |
| | -4.00 | 62.8 | 39.2 | -28.8 | -158.4 |
| | -4.50 | 66.7 | 44.1 | -29.9 | -178.9 |
| | -5.00 | 70.5 | 49.0 | -31.1 | -200.3 |
| | -5.50 | 74.4 | 53.9 | -32.2 | -222.4 |
| | -6.00 | 78.2 | 58.8 | -33.4 | -245.4 |
| | -6.50 | 82.1 | 63.7 | -34.5 | -269.1 |
| | -7.00 | 85.9 | 68.6 | -35.7 | -293.7 |
| | -7.50 | 89.8 | 73.5 | -36.8 | -319.1 |
| | -8.00 | 93.6 | 78.4 | -38.0 | -345.3 |
| Medium dense SAND | -8.00 | 93.6 | 78.4 | 98.3 | -345.3 |
| | -8.50 | 98.2 | 83.3 | 103.1 | -274.8 |
| | -9.00 | 102.8 | 88.2 | 107.9 | -200.9 |
| | -9.50 | 107.4 | 93.1 | 112.8 | -123.6 |
| | -10.00 | 112.0 | 98.0 | 117.6 | -42.9 |
| | -10.50 | 116.6 | 102.9 | 122.4 | 41.1 |
| | -11.00 | 121.2 | 107.8 | 127.3 | 128.6 |

| | | | | |
|---|---|---|---|---|
| Pile Toe Level | -11.00 | mOD | NEGATIVE SHAFT FRICTION | -345 kN |
| Base stress | 10752 | kPa | SHAFT CAPACITY | 474 kN |
| Vertical eff stress | 121.2 | kPa | END BEARING CAPACITY | 1317 kN |
| Nq | 33.2 | | ULTIMATE CAPACITY | 1791 kN |
| Sc.dc | 2.67 | | | |
| Effective Nq | 88.7 | | EC7 DESIGN RESISTANCE | 690 kN |
| | | | EC7 TENSION RESISTANCE | 232 kN |
| | | | PILE LENGTH | 13.00 m |

## PILE DATA

Pile system Precast

Pile size : 350 mm

Shaft perimeter : 1.400 m
Base area : 0.123 m2

Pile platform level : 2.00 mOD
Pile cut off level : 2.00 mOD

## SOIL STRATA DATA

| Soil Layer | Soil Description | Top Level (mOD) | Soil Type |
|---|---|---|---|
| 1 | Granular BACKFILL | 2.00 | Negative |
| 2 | Soft CLAY | 0 | Negative |
| 3 | Medium dense SAND | -8.00 | Drained |

Rigid base level : -15.00

## WATER DATA

Unit weight of water : 9.80 kN/m3

Hydrostatic profile
Water table level : 0 mOD

## CALCULATION DATA

User selected calculation options
Design Approach : EC7 design resistance
Shaft Friction Ks : Ks from empirical relationships
Bearing capacity Nq : Brinch Hansen bearing capacity
Confining stress : Not considered
Pile Settlements : Not considered

Maximum allowable stresses
Shaft fs : 500 kPa
Base fb : 15000 kPa
Concrete fcu : 60.00 N/mm2

## EC7 PARTIAL FACTORS

UK National Annex to EC7 Factor Set R4

Maintained load test to ultimate capacity
Model Factor : 1.2

Settlement verified by load test
Shaft Factor : 1.3
End Bearing Factor : 1.5
Shaft Tension Factor : 1.7

## SOIL PROPERTIES DATA FOR LAYER 1

Granular BACKFILL Top level 2.00 mOD

Negative Shaft Friction Properties - Effective stress calculation

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 16.00 | 0 | | 30.0 | 0.88 | -0.58 | 0 |
| Base | | | | | | | | -16 |

## SOIL PROPERTIES DATA FOR LAYER 2

Soft CLAY Top level 0 mOD

Negative Shaft Friction Properties - Effective stress calculation

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 17.50 | -10.0 | | 20.0 | 0.83 | -0.36 | -20 |
| Base | | | | | | | | -38 |

## SOIL PROPERTIES DATA FOR LAYER 3

Medium dense SAND  Top level -8.00 mOD

Drained Properties

| | SPT N value (blows/300mm) | Unit weight (kN/m3) | c' (kPa) | Phi' (deg) | Eff Phi' (deg) | Ks | Tan delta | Shaft stress (kPa) |
|---|---|---|---|---|---|---|---|---|
| Top | | 19.00 | 0 | | 35.0 | 1.50 | 0.70 | 98 |
| Base | | | | | | | | 166 |

| | Eff Phi' (deg) | Nq | D/B ratio | Sc.dc | Eff Nq | Base stress (kPa) |
|---|---|---|---|---|---|---|
| Top | 35.0 | 33.2 | 0 | 1.32 | 43.7 | 4095 |
| Base | | | 20.00 | 3.00 | 99.7 | 15747 |

# UK Summary - Negative Shaft Friction

| | | BS 8004 Correct Method $Q_w - Q_{nsf}$ | BS 8004 Common Approach $(Q_s - Q_{nsf})/F_s$ | BS 8004 Structural Check $Q_{app} + Q_{nsf}$ | | | EC7 Combination 2 M2 Material $R_{c,d} - Q_{nsf,d}$ | EC7 Combination 2 M2 Material $F_d + Q_{nsf,d}$ | EC7 Combination 1 M1 Material $R_{c,d} - Q_{nsf,d}$ | EC7 Combination 1 M1 Material $F_d + Q_{nsf,d}$ | | | EC7 Combination 2 A2 Load $R_{c,d} - Q_{nsf,d}$ | EC7 Combination 2 A2 Load $F_d + Q_{nsf,d}$ | EC7 Combination 1 A1 Load $R_{c,d} - Q_{nsf,d}$ | EC7 Combination 1 A1 Load $F_d + Q_{nsf,d}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Q_b$ | | 1317 | 1317 | 1317 | | $R_b$ | 1317 | 1317 | 1317 | 1317 | | $R_b$ | 1317 | 1317 | 1317 | 1317 |
| $Q_s$ | | 474 | 474 | 474 | | $R_s$ | 474 | 474 | 474 | 474 | | $R_s$ | 474 | 474 | 474 | 474 |
| $Q_{nsf}$ | | 410 | 410 | 410 | | $Q_{nsf}$ | 410 | 410 | 410 | 410 | | $Q_{nsf}$ | 410 | 410 | 410 | 410 |
| Backfill | | 18 | 18 | 18 | | Backfill | 18 | 18 | 18 | 18 | | Backfill | 18 | 18 | 18 | 18 |
| Soft Clay | | 392 | 392 | 392 | | Soft Clay | 392 | 392 | 392 | 392 | | Soft Clay | 392 | 392 | 392 | 392 |
| | | | | | Model | $\gamma_d$ | 1.2 | 1.2 | 1.2 | 1.2 | Model | $\gamma_d$ | 1.2 | 1.2 | 1.2 | 1.2 |
| | | | | | Factor | $R_{b,k}$ | 1098 | 1098 | 1098 | 1098 | Factor | $R_{b,k}$ | 1098 | 1098 | 1098 | 1098 |
| | | | | | | $R_{s,k}$ | 395 | 395 | 395 | 395 | | $R_{s,k}$ | 395 | 395 | 395 | 395 |
| $Q_{ult}$ | | 1791 | 1791 | 1791 | | $R_k$ | 1493 | 1493 | 1493 | 1493 | | $R_k$ | 1493 | 1493 | 1493 | 1493 |
| | | | | | | $Q_{nsf,k}$ | 410 | 410 | 410 | 410 | | $Q_{nsf,k}$ | 410 | 410 | 410 | 410 |
| $\gamma_f$ | | | | 1.4 | Load, | $\gamma_f$ | 1.0 | 1.0 | 1.35 | 1.35 | Load, | $\gamma_f$ | 1.0 | 1.0 | 1.35 | 1.35 |
| | | | | | Resistance | $\gamma_s$ | 1.0 | 1.0 | 1.0 | 1.0 | Resistance | $\gamma_s$ | 1.3 | 1.3 | 1.0 | 1.0 |
| | | | | | & Material | $\gamma_{m,\varphi',c'}$ | 1.25 | 1.25 | 1.0 | 1.0 | & Material | $\gamma_{m,\varphi',c'}$ | 1.0 | 1.0 | 1.0 | 1.0 |
| | | | | | Factors | $\gamma_{m,Cu}$ | 1.4 | 1.4 | 1.0 | 1.0 | Factors | $\gamma_{m,Cu}$ | 1.0 | 1.0 | 1.0 | 1.0 |
| $Q_{nsf}$ | | 410 | 410 | 574 | | $Q_{nsf,d}$ | 571 | 571 | 554 | 554 | | $Q_{nsf,d}$ | 533 | 533 | 554 | 554 |
| Factors of | $F_b$ | 2.0 | 2.0 | 2.0 | Resistance | $\gamma_b$ | 1.5 | 1.5 | 1.0 | 1.0 | Resistance | $\gamma_b$ | 1.5 | 1.5 | 1.0 | 1.0 |
| Safety | $F_s$ | 2.0 | 2.0 | 2.0 | Factors | $\gamma_s$ | 1.3 | 1.3 | 1.0 | 1.0 | Factors | $\gamma_s$ | 1.3 | 1.3 | 1.0 | 1.0 |
| Design | $Q_w$ | 896 | 896 | 896 | | $R_{c,d}$ | 1036 | 1036 | 1493 | 1493 | Design | $R_{c,d}$ | 1036 | 1036 | 1493 | 1493 |
| Capacity | $Q_w$ | 486 with $Q_{nsf}$ | 691 with $Q_{nsf}$ | | | $R_{c,d}$ | 464 with $Q_{nsf}$ | 1036 with $Q_{nsf}$ | 939 with $Q_{nsf}$ | 1493 with $Q_{nsf}$ | Resistance | $R_{c,d}$ | 503 with $Q_{nsf}$ | 1036 with $Q_{nsf}$ | 939 with $Q_{nsf}$ | 1493 with $Q_{nsf}$ |
| Dead | | 450 | 450 | 450 | | $F_{G,k}$ | 450 | 450 | 450 | 450 | | $F_{G,k}$ | 450 | 450 | 450 | 450 |
| Live | | 0 | 0 | 0 | | $F_{Q,k}$ | 0 | 0 | 0 | 0 | | $F_{Q,k}$ | 0 | 0 | 0 | 0 |
| $\gamma_{G,f}$ | | | | 1.4 | | $\gamma_{G,f}$ | 1.0 | 1.0 | 1.35 | 1.35 | | $\gamma_{G,f}$ | 1.0 | 1.0 | 1.35 | 1.35 |
| $\gamma_{Q,f}$ | | | | 1.6 | | $\gamma_{Q,f}$ | 1.3 | 1.3 | 1.5 | 1.5 | | $\gamma_{Q,f}$ | 1.3 | 1.3 | 1.5 | 1.5 |
| | | | | | | $\psi$ | 1.0 | 1.0 | 1.0 | 1.0 | | $\psi$ | 1.0 | 1.0 | 1.0 | 1.0 |
| | | | | | | $F_{rep}$ | 450 | 450 | 450 | 450 | | $F_{rep}$ | 450 | 450 | 450 | 450 |
| Applied | $Q_{app}$ | 450 | 450 | 1204 | | $F_d$ | 450 | 1021 | 608 | 1161 | Design | $F_d$ | 450 | 983 | 608 | 1161 |
| Load | | $Q_w > Q_{app}$ | $Q_w > Q_{app}$ | | | | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ | Action | | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ | $R_{c,d} > F_d$ |