UK National Annex to BS EN 1997-1:2004

Pile Design
UK Design Approach

UK Design Approach

- DA1 – Two Calculations for the STR and GEO limit States:
  - 1 A1 + R1
  - 2 A2 + R4

Partial Factors on Actions or the Effect of Actions

Action		UK NA Factor Set		EC7 Factor Set	
		A1	A2	A1	A2
Permanent	Unfavourable	1.35	1.0	1.35	1.0
	Favourable	1.0	1.0	1.0	1.0
Variable	Unfavourable	1.5	1.3	1.5	1.3
	Favourable	0	0	0	0

Notes:

1. Factors given above are for buildings which remain unchanged from EC7 values.
2. Combination factors for actions that can exist simultaneously are given in the UK NA to BS EN 1990.
3. There are a wider range of factors for bridges.

Partial Factors on Soil Parameters

Soil Property	UK NA Factor Set		EC7 Factor Set	
	M1	M2	M1	M2
Friction Angle tan ϕ’	1.0	1.25	1.0	1.25
Effective Cohesion c’	1.0	1.25	1.0	1.25
Undrained Shear Strength Cu	1.0	1.4	1.0	1.4
Unconfined Strength UCS	1.0	1.4	1.0	1.4
Unit Weight γ			1.0	1.0

UK NA gives no factor for unit weight so presume 1.0; other factors remain unchanged.
Not used for pile design, but may be used for Negative Shaft Friction.

Partial Resistance Factors for Driven Piles

Component	UK NA Factor Set			EC7 Factor Set			
	R1	R4 (No SLS)	R4 (SLS)	R1	R2	R3	R4
Base	1.0	1.7	1.5	1.0	1.1	1.0	1.3
Shaft	1.0	1.5	1.3	1.0	1.1	1.0	1.3
Total	1.0	1.7	1.5	1.0	1.1	1.0	1.3
Tension	1.0	2.0	1.7	1.25	1.15	1.1	1.6

Main differences for resistance factors relate to:

1. Factor set R4 where different values depend on whether SLS behaviour is verified or not (test or calculation).
2. Model factor to be applied to ground properties to derive characteristic values or directly to the calculated shaft or end bearing capacities.
3. Model factor 1.4, but can be reduced to 1.2 if a load test is completed to calculated unfactored ultimate resistance (ULS check).

Partial Resistance Factors for Bored Piles

Component	UK NA Factor Set			EC7 Factor Set			
	R1	R4 (No SLS)	R4 (SLS)	R1	R2	R3	R4
Base	1.0	2.0	1.7	1.25	1.1	1.0	1.6
Shaft	1.0	1.6	1.4	1.0	1.1	1.0	1.3
Total	1.0	2.0	1.7	1.15	1.1	1.0	1.5
Tension	1.0	2.0	1.7	1.25	1.15	1.1	1.6

Main differences for resistance factors relate to:

1. Factor set R4 where different values depend on whether SLS behaviour is verified or not (test or calculation).
2. Model factor to be applied to ground properties to derive characteristic values or directly to the calculated shaft or end bearing capacities.
3. Model factor 1.4, but can be reduced to 1.2 if a load test is completed to calculated unfactored ultimate resistance (ULS check).

Partial Resistance Factors for Cfa Piles

Component	UK NA Factor Set			EC7 Factor Set			
	R1	R4 (No SLS)	R4 (SLS)	R1	R2	R3	R4
Base	1.0	2.0	1.7	1.1	1.1	1.0	1.45
Shaft	1.0	1.6	1.4	1.0	1.1	1.0	1.3
Total	1.0	2.0	1.7	1.1	1.1	1.0	1.4
Tension	1.0	2.0	1.7	1.25	1.15	1.1	1.6

Main differences for resistance factors relate to:

1. Factor set R4 where different values depend on whether SLS behaviour is verified or not (test or calculation).
2. Model factor to be applied to ground properties to derive characteristic values or directly to the calculated shaft or end bearing capacities.
3. Model factor 1.4, but can be reduced to 1.2 if a load test is completed to calculated unfactored ultimate resistance (ULS check).

Equivalent Lumped FoS – UK Design Approach

Pile Type	Actions	Resistance Factors		Model Factor	Lumped FoS
	A2	R4 (No SLS)	R4 (SLS)		
Driven End Bearing	1.1	1.7	1.5	1.4	2.6/2.3
				1.2	2.2/2.0
Driven End & Shaft	1.1	1.7/1.5	1.5/1.3	1.4	2.5/2.0
				1.2	2.1/1.9
Bored Shaft Friction	1.1	1.6	1.4	1.4	2.5/2.2
				1.2	2.1/1.9

1. Partial factor on actions assumes 70% permanent and 30% variable.
2. British Standard BS 8004 lumped FoS ranged from 2.0 to 3.0.
3. Model factor 1.2 requires load test to be completed to calculated unfactored ultimate resistance.
4. Lower value for resistance factors dependent on SLS behaviour being verified (by load test or reliable calculation).

Example Bearing Capacity – No SLS Check

TC250/SC7
Evolution Group 7

Raison Foster Associates

EC7 Pile Design - TC250/SC7
Evolution Group 7 - FPS/AGS Mirror Group
GE Example 1 - No SLS check

Job No.	Sheet No.	Rev.
C11/		

Drg. Ref.

Made by CAR Date 19-Dec-11 Data GE_EX1.KPL Checked

PILE BEARING CAPACITY

Pile System: Rotary auger bored — Diameter: 1000 mm

Soil Description	Top Level (mOD)	Soil Type	Shaft Stress Top (kPa)	Shaft Stress Base (kPa)	Shaft Friction (kN)
Stiff to very stiff CLAY	0	Undrained	30	137	8077
Very stiff CLAY	-35.00	Undrained			

Pile Toe Level	-30.70	mOD	NEGATIVE SHAFT FRICTION	0 kN
Base stress	2474	kPa	SHAFT CAPACITY	8077 kN
			END BEARING CAPACITY	1943 kN
			ULTIMATE CAPACITY	10020 kN

No maintained load test

EC7 Model Factor 1.4

Characteristic Shaft Resistance Rsk	5769 kN
Characteristic End Bearing Resistance Rbk	1388 kN
Characteristic Pile Resistance Rk	7157 kN

No verification of settlement

EC7 Resistance Factors

Shaft Factor	1.6
End Bearing Factor	2.0
Shaft Tension Factor	2.0

UK National Annex to EC7 Factor Set R4

EC7 DESIGN RESISTANCE Rcd	4300 kN
EC7 DESIGN TENSION RESISTANCE Rtd	2885 kN
PILE LENGTH	30.70 m

Example Bearing Capacity – SLS Check

TC250/SC7 Evolution Group 7	Raison Foster Associates	Job No. C11/	Sheet No.	Rev.
EC7 Pile Design - TC250/SC7 Evolution Group 7 - FPS/AGS Mirror Group GE Example 1 - SLS check		Drg. Ref.		
		Made by CAR	Date 19-Dec-11	Data GE_EX2.KPL Checked

PILE BEARING CAPACITY

Pile System Rotary auger bored Diameter 1000 mm

Soil Description	Top Level (mOD)	Soil Type	Shaft Stress Top (kPa)	Base (kPa)	Shaft Friction (kN)
Stiff to very stiff CLAY	0	Undrained	30	128	6939
Very stiff CLAY	-35.00	Undrained			

Pile Toe Level	-27.97	mOD	NEGATIVE SHAFT FRICTION	0	kN
Base stress	2302	kPa	SHAFT CAPACITY	6939	kN
			END BEARING CAPACITY	1808	kN
			ULTIMATE CAPACITY	8747	kN

No maintained load test	EC7 Model Factor	1.4	
	Characteristic Shaft Resistance Rsk	4956	kN
	Characteristic End Bearing Resistance Rbk	1291	kN
	Characteristic Pile Resistance Rk	6248	kN
Settlement verified by load test	EC7 Resistance Factors		
	Shaft Factor	1.4	
	End Bearing Factor	1.7	
	Shaft Tension Factor	1.7	

UK National Annex to EC7 Factor Set R4	EC7 DESIGN RESISTANCE Rcd	4300	kN
	EC7 DESIGN TENSION RESISTANCE Rtd	2915	kN
	PILE LENGTH	27.97	m

Example Bearing Capacity – ULS & SLS Check

TC250/SC7 Evolution Group 7 — Raison Foster Associates

EC7 Pile Design - TC250/SC7
Evolution Group 7 - FPS/AGS Mirror Group
GE Example 1 - ULS & SLS check

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PILE BEARING CAPACITY

Pile System: Rotary auger bored — Diameter: 1000 mm

Soil Description	Top Level (mOD)	Soil Type	Shaft Stress Top (kPa)	Shaft Stress Base (kPa)	Shaft Friction (kN)
Stiff to very stiff CLAY	0	Undrained	30	118	5849
Very stiff CLAY	-35.00	Undrained			

Pile Toe Level	-25.15	mOD	NEGATIVE SHAFT FRICTION	0 kN
Base stress	2124	kPa	SHAFT CAPACITY	5849 kN
			END BEARING CAPACITY	1669 kN
			ULTIMATE CAPACITY	7518 kN

Maintained load test to ultimate capacity — EC7 Model Factor 1.2

Characteristic Shaft Resistance Rsk	4874 kN
Characteristic End Bearing Resistance Rbk	1390 kN
Characteristic Pile Resistance Rk	6265 kN

Settlement verified by load test

EC7 Resistance Factors

Shaft Factor	1.4
End Bearing Factor	1.7
Shaft Tension Factor	1.7

UK National Annex to EC7 Factor Set R4

EC7 DESIGN RESISTANCE Rcd	4300 kN
EC7 DESIGN TENSION RESISTANCE Rtd	2867 kN
PILE LENGTH	25.15 m