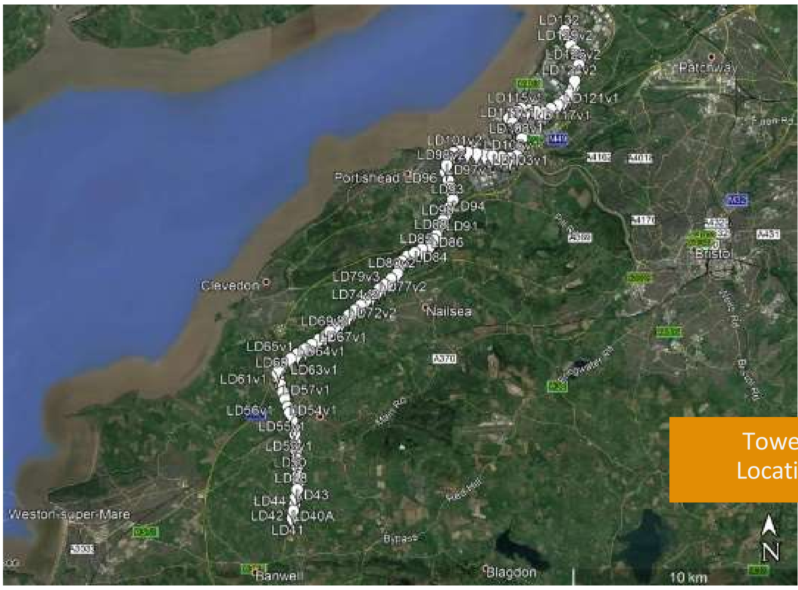
Balfour Beatty
Ground Engineering

Technical Case Study

Hinkley Connection Project

The project is a new high-voltage connection between Bridgewater and Avonmouth. This will supply new sources of low-carbon energy including Hinkley Point C Nuclear Power Station to six million homes and businesses.
The proposed new build overhead line (OHL) comprises combination of T-pylon (first new design for a pylon in Great Britain in nearly 100 years) and traditional lattice towers.



LOCATION
Sandford to Avoumouth

CONTRACT VALUE
£17.9M

PILING TECHNIQUES

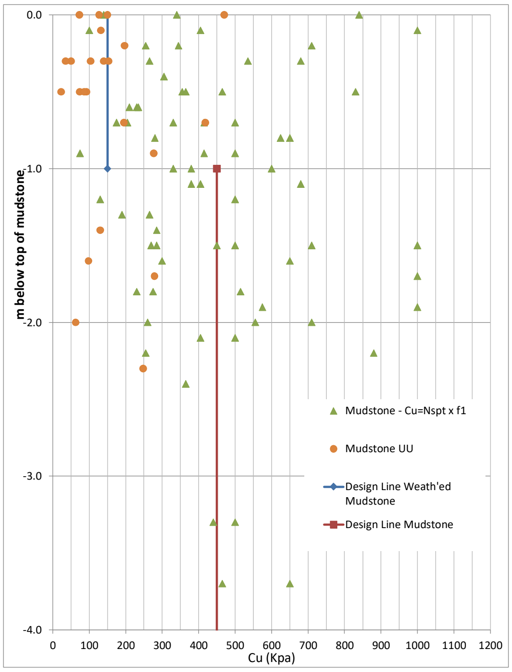
- **Continuous Flight Auger**
- **Mini Piles**
- **Driven Precast Concrete Piles**

The Scheme

BBGE designed and constructed the bearing piles to support the transmission towers between Sandford substation and Avounmouth river crossing (OHL North Section).
Variability in the loading and underlying ground conditions required different pile techniques including driven precast concrete, contiguous flight auger and mini piling.

Geotechical Conditions

The general ground condition underlying the towers comprised a variable thick layer (between 2-18m) of superficial deposits principally consisting of Tidal Flat Deposits of interbedded Sand, Silt and Clay with organic Peat bands, overlying a bedrock of Mudstone, Sandstones and Limestones of Pennant Sandstone.
Geotechnical parameters have been derived based on a moderate conservative approach. The undrained shear strength has been obtained from a combination of SPT 'N' results and unconsolidated undrained triaxial compression tests. Axial and diametric point loads tests were also considered in assessing the design parameters of the the bedrock.
The small and large shear strain values used for the pile group analysis have been derived based on pressure meter testing and empirical correlations.



Design Parameters

Geological Unit		Unit Weight	N SPT	UCS	STRENGTH			SMALL-STRAIN STIFFNESS				
					Undrained	Drained		Gmax	Drained		Undrained	
		γ			Cu	ϕ'	C'		E'max	ν'max	Eumax	νu
		[kN/m³]	[-]	[MPa]	[kPa]	[-]	[kPa]	[MPa]	[MPa]	[-]	[MPa]	[-]
Tidal Flat Deposits	Cohesive (soft clay)	16	1 to 41	-	20	23	0	10	24	0.2	30	0.5
	Peat	12		-	20	23	0	0.7	1.6	0.2	2.0	0.5
	Cohesionless (Sand/Gravel)	19	1 to 53	-	-	32	0	13.4	35	0.3	-	-
Bedrock	Weathered Mudstone	20	15 to 80	-	150	25	2	60	144	0.2	180	0.5
	Mudstone	21	50 to >500	0.24 to 35	450	35	15	100	240	0.2	300	0.5
	Sandstone/Limestone	21		1 to 109	450	35	15	100	240	0.2	300	0.5

Design Approach

A preliminary assessment was undertaken to determine the most suitable pile technique based on foundation loading, ground conditions, access and environmental constraints. These conditions were rationalised and grouped to find design efficencies and then analysed using pile group analyses to:

- Determine the most efficient solution to minimize the the number of piles and the pile cap size – this will identify material, cost and environmental savings.
- Evaluate the actions on the single pile.
- Undertake the structural and geotechnical design of piles.
- Confirm compliance with the foundation settlement criteria.

Loading

Foundation load cases were provided for each tower subject to tri-dimensional loading acting in different directions. The loads were processed to align with the convention sign used in repute software program.
The self-weigth of the pile cap and the bolt cage was added to the vertical component using a partial factor of 0.9 and 1.1 to calculate pile in tension and compression respectively.

LD61 Tower Loading

Tower Number		Fx	Fy	Fz	Mx	My	Mz	Bending Moment	Shear Loads	Load Case
LD61v2	Fx max	1124.7	193.6	790.6	4.7	18154.5	4556.3	18717.5	814.0	HI,C NA+
LD61v2	FY max	866.2	714.0	189.4	120.1	4308.9	16360.0	16917.9	738.7	TWo Circuit Broken_A,C NA+
LD61v2	Fz max	1124.7	193.6	790.6	4.7	18154.5	4556.3	18717.5	814.0	HI,C NA+
LD61v2	Mx max	896.4	340.2	280.0	4097.6	6857.8	7825.3	10405.0	440.6	one Circuit Broken_B,C NA+
LD61v2	My Max	1124.7	193.6	790.6	4.7	18154.5	4556.3	18717.5	814.0	HI,C NA+
LD61v2	Mz Max	866.2	714.0	189.4	120.1	4308.9	16360.0	16917.9	738.7	TWo Circuit Broken_A,C NA+
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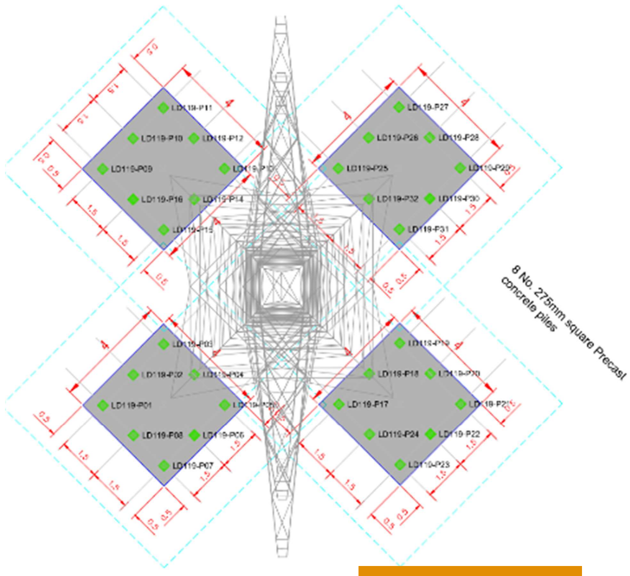
Pile Group Analysis and Pile Design

The pile group analysis has been undertaken using the software programme Repute 2.5.
The software includes a Boundary Element Analysis calculation which predicts the load vs displacement behaviour of a single pile or pile group under vertical, horizontal and moment loading using the calculation engine PGroupN. This provided a more realistic prediction of the deformation and the load distribution between piles.
The non-linear soil behaviour has been incorporated by assuming that the Young's modulus of soil varies with the stress level at the pile-soil interface. This behaviour was modelled using the Hyperbolic function specifying small and large strain parameters.
The program output provided the axial, lateral and moment forces in the piles, together with displacements which have been checked against the pile capacity outside of the software program.
The geotechnical and the structural pile design were undertaken using Oasys software (Pile & AdSec) and internal Microsoft Excel spreadsheets.



Pile Cap Arrangement

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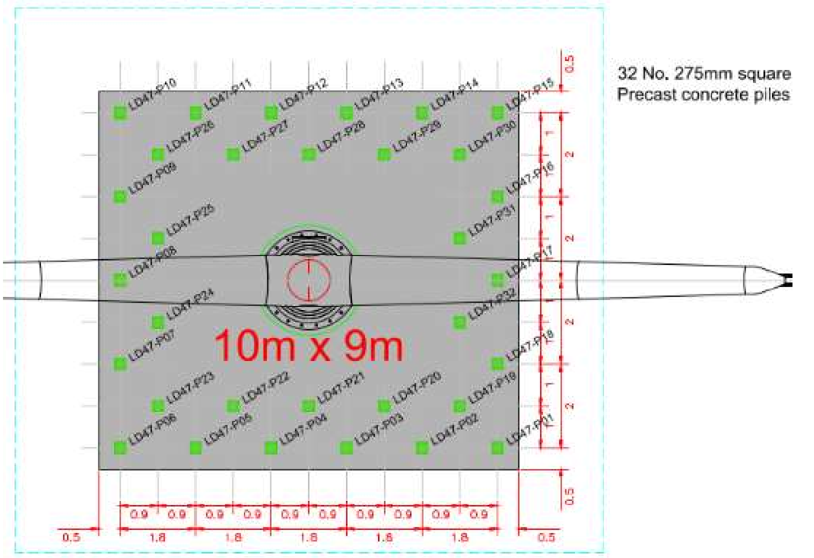
T Pylon

- 20No. Mini Piles, Pile Cap Size 7.0x7.0x1.6m
- 14No. Mini Piles, Pile Cap Size 6.0x5.4x1.4m
- 18No. CFA, Pile Cap Size 7.0x7.0x1.6m
- 12No. CFA, Pile Cap Size 5.8x5.2x1.4m
- 32No. Precast, Pile Cap Size 10.0x9.0x1.4m



Lattice Tower (per single leg)

- 8No. Mini Piles, Pile Cap Size 3.6x3.6x1.5m
- 6No. Mini Piles, Pile Cap Size 3.6x3.0x1.5m
- 8No. CFA, Pile Cap Size 3.6x3.6x1.5m
- 6No. CFA, Pile Cap Size 3.6x3.0x1.5m
- 8No. Precast, Pile Cap Size 4.0x4.0x1.5m
- 12No. Precast, Pile Cap Size 4.6x4.6x1.5m
- 16No. Precast, Pile Cap Size 6.4x6.4x1.5m

Bearing Pile Solution

Approximately 2300 bearing piles were designed ranging from 9.5m to 27.0m in length.
Mini piling and CFA have been installed where shallow/strong bedrock is present and where precast piles did not represent the most efficient or practible solution.
The scope of the works comprised:

- 86No. towers piled (93No. total tower).
- 682No. CFA 450mm diameter.
- 137No. Mini piles 323.9mm O/D.
- 1475No. driven precast piles 275mm square section.
- 12No. Preliminary tests pile (compression/tension).
- Compression loads up to 1100 kN.
- Tension loads up to 700 kN.

The design was been constantly updated in presence of early refusal, unexpected ground conditions, constraints, and installation issues.

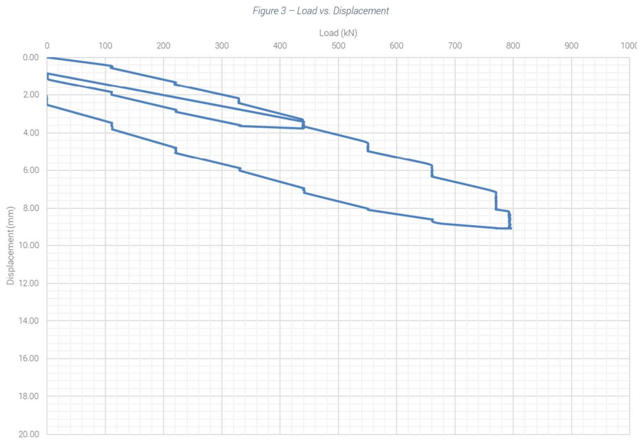
CFA Piling

Testing and Results

Six soil profiles were adopted - each profile was subject to preliminary tests in compression and tension to provide data on pile performance and prove the ground conditions.

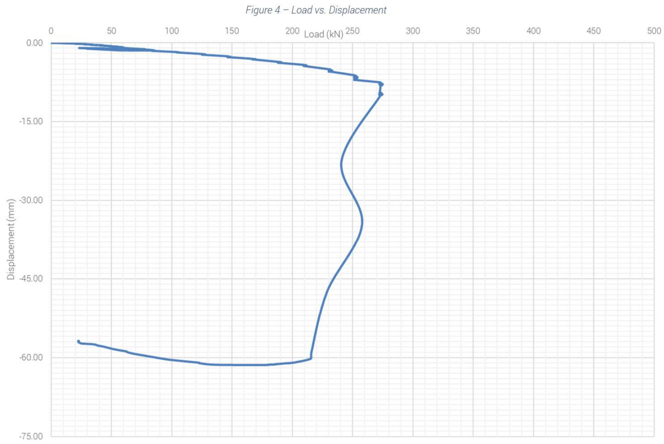
Testing performed by BBGE and Socotec confirmed:

- For all the techniques, the performance and load capacity of the piles is not less than expected.
- For some locations, the performance of the tests pile suggests an adhesion factor higher than 0.45 for the bedrock.
- Pile displacement is less than the specified settlement criteria of 25mm at DVL.



LD47 Static Compression and Tension Test

SOIL PROFILE	PILE TEST LOCATION and TECHNIQUE		PRELIMINARY TEST
	MINI PILE/CFA	PRECAST	
1	LD40		Compression & Tension
2	LD52	LD47 LD59 LD130	Compression & Tension
3	LD62 LD82		Compression & Tension
4	LD73 LD106	LD72	Compression & Tension
5	LD97		Compression & Tension
6		LD124	Compression & Tension



Value Engineering

- The original foundation designs were revised upon determining the most efficient solutions for the individual bases reducing the overall design cost. The majority of these savings are related to changing minipiling to CFA, CFA to driven and significant cost saving are related to driven precast piles instead of steel tube. This allowed savings to programme and material for an amount of about £1M.
- The spacing between the longitudinal bars has been reduced to 77.5mm using 10mm aggregate mix without any issue of concrete flowing around the bars. This maximised the steel cross sectional area within the piles to achieve the required capacity, reducing the number of piles (saved 44 piles in total) and the pile cap size without compromising the foundation's performance. CO_2 saved about 13 tonnes.