PROJECT TECHNICAL SOLUTION SHEET

THE SHARD

LOCATION

LONDON

CONTRACT VALUE

£14.5M

KEY FEATURES

Large diameter piles

Hard-firm secant piled retaining wall

400+ multi strand ground anchors

Top down and bottom-up construction

Fault identified on site

The Scheme

The Shard at London Bridge is the tallest structure in the UK. It is founded on a three level basement formed with a Hard-Firm Secant Wall. Bearing piles are founded in the Thanet sand and had plunge columns to allow a top down construction. Contract value £14 Million.

Design of the piles and retaining wall sub-contracted to Byrne Looby

Parameters used:

(Note horizontal stiffness revised to 1000 C_u in final case)

STRATUM	BEARING PILE DESIGN		
Made Ground	Bulk Density	γ_b	= 18kN/m³
			(Skin Friction contribution ignored)
	Friction angle	ϕ'	= 30.0°
	Horizontal Stiffness	E	= 10000 kN/m²
River Terrace Gravels	Bulk Density	γ_b	= 20kN/m³
(Medium dense sand & gravels)	Friction angle	ϕ'	= 38.0°
	Horizontal Stiffness	E	= 2000N kN/m²
			(Skin Friction contribution ignored)
London CLAY	Bulk Density	γ_b	= 20kN/m³
(Stiff to Very stiff silty clay)	Undrained shear strength	c_u	90 kN/m² at -6.0 mOD
	Increasing at		9.5 kN/m² per meter depth
	Softening for wall		20%
	Adhesion factor	α	0.5 (0.45 for Plunge Column Piles)
	End bearing Factor	Nc	= 9.00 for bearing piles, 7.50 for wall
	Unit skin friction	q_s	Limited to 140kPa
	Horizontal undrained Stiffness	Eh	750 cu
	Drained shear strength	c'	= 5 kN/m²
	Friction angle	ϕ'	= 23.0°
	Drained stiffness	E'h	0.7Eu
Lambeth Group	Bulk Density	γ_b	= 20kN/m³
(V stiff clays & Dense sands)	Cohesion	c_u	400 kN/m²
	Adhesion factor	α	= 0.50 (0.45 for Plunge Column Piles)
	End bearing Factor	Nc	= 9.00 for bearing piles, 7.50 for wall
	Unit skin friction	q_s	Limited to 140kPa
Thanet SAND	Bulk Density	γ_b	= 20kN/m³
(Very dense sand)	Friction angle	ϕ'	= 36°
	Coeficient of earth pressure	ks	= 0.7
	Unit skin friction	q_s	Limited to 200kPa
	Limiting Bearing Capacity factor	Nq	= 48
	Unit base resistance	q_b	Limited to max 20,000kN/m²

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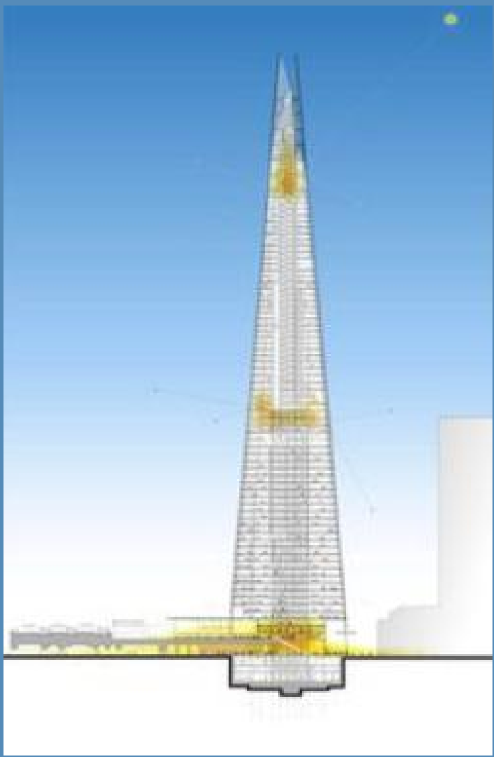

Slip Liner

During Construction

Bearing Pile Solution

183 No Bearing piles 450mm diameter to 1800mm diameter.

- Compressive loading up to 24MN.
- Max pile length 56.5m, founding in the Thanet sand.
- Preliminary Test pile carried out
  - 19.5m Bitument coated slip liner used
  - 1200mm diameter pile
  - Strain gauges at strata interfaces
  - 7kN/m^2 bond stress over slip liner
  - 161 kN/m^2 bond stress measured in London Clay
  - 113 kN/m^2 bond stress measure in lower London Clay and Upper Lambeth.
  - 176 kN/m^2 bond stress measured in the lower Lambeth.
  - Total pile settlement 37mm at 30 MN.
  - Pile left open 2 days with bentonite prior to testing.
- Piles designed to over FOS = 2.5

Retaining Wall Solution

- Piled wall 1000mm OD cased wall. Piles 1450mm c/c (Male Pile to male Pile). 300mm overlap
- 280m long, 55 changes in direction
- Typical excavation depth
- Typical Construction sequence : 15.5 dig. 4m excavation, ground floor slab cast, excavate to -9m depth, cast B2 slab, excavate to 15.5m depth,
- Additional surcharge to account for from London Bridge station.
- Overall sway analysis carried out in Plaxis
- Wall design using Frew and Plaxis
- Predicted deflections – see below:

Section	FREW mm	PLAXIS mm
1-1	29	n/a
2-2	34	n/a
3-3	37	22
4-4	37	n/a
5-5	32	n/a
7-7	25	n/a
8-8	36	26*
9-9	30	15*
10-10	34	n/a
11-11	27	n/a
12-12	39	n/a

* Note that these deflections include for the sway case as analysed by PLAXIS.

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Excavation showing ring beam

Excavation

Plunge Column with fins
To increase surface area

Technical Solution during Construction

- Existing piles. The bells of underream piles were cored through. The line of the secant wall was modified to locally avoid existing pile.
- The ground floor propping in the top down area was constructed as a ring beam. The superstructure was started from the B1 slab level not the ground floor level.
- There was an area of bottom up construction in the car-stacking area – this eased excavation of the basement.
- The plunge columns were used as support for the tower cranes.
- There was a concrete integrity issue with some piles in the secant wall. This was put down concrete being placed in the pile when it was too stiff. Delays in concreting or deliver meant that the concrete was at the limit of acceptance. When the casing was pulled it also pulled the concrete. The solution was casting a wall in front of the secant wall – this took space out of the drained cavity.
- Additional leaks in the secant wall appeared long after the wall was completed and signed off. This was attributed to the high loads on the secant wall. These were sealing by injection

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