Advances in Understanding of Base Grouted Pile Performance in Very Dense Sand

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Mark Connolly - Keller

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Chris Raison - Formerly Keller

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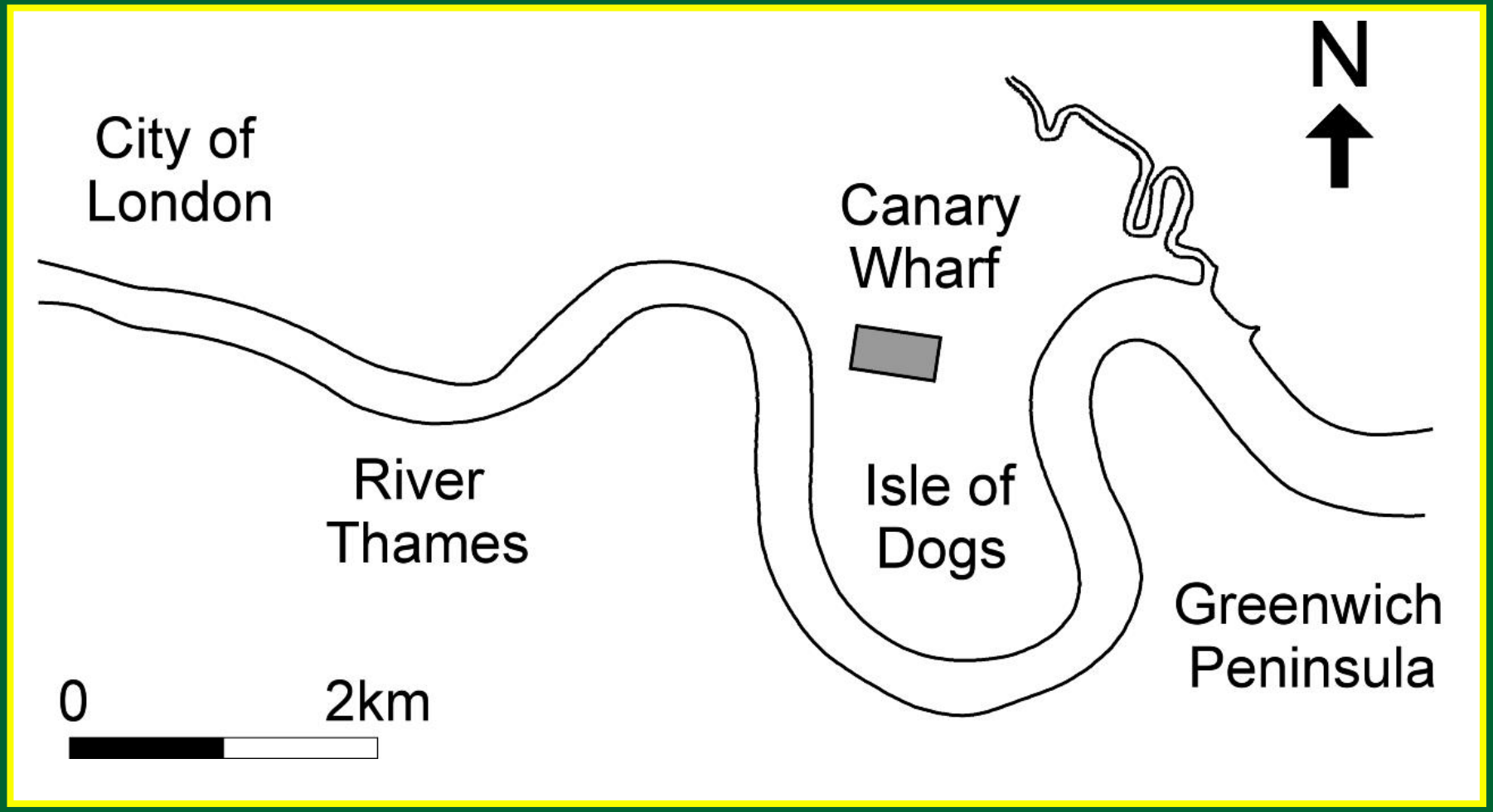
N
City of London
Canary Wharf
River Thames
Isle of Dogs
Greenwich Peninsula
0
2km

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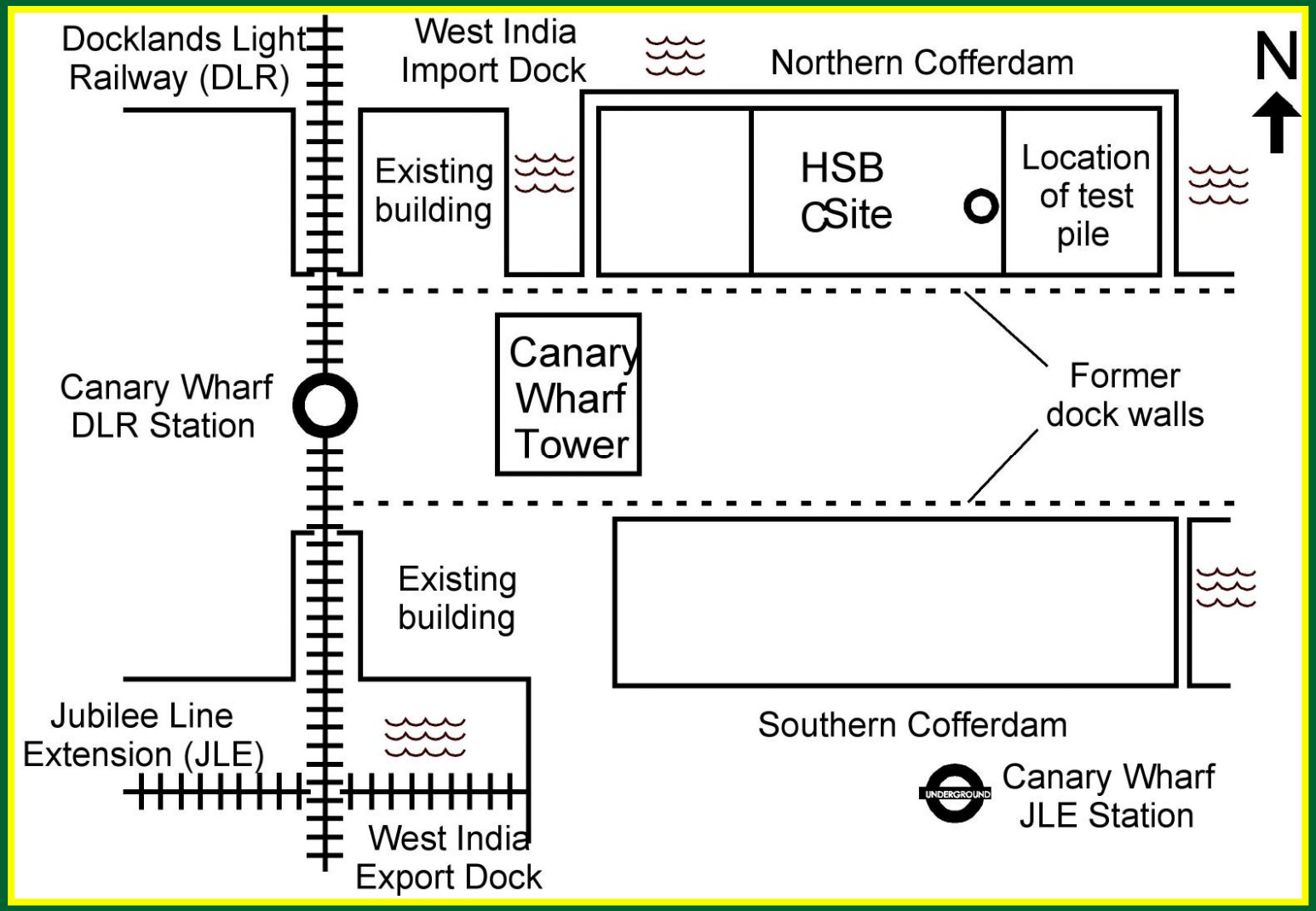
Docklands Light Railway (DLR)
West India Import Dock
Northern Cofferdam
N
Existing building
HSB Site
Location of test pile
Canary Wharf DLR Station
Canary Wharf Tower
Former dock walls
Existing building
Jubilee Line Extension (JLE)
Southern Cofferdam
UNDERGROUND
Canary Wharf JLE Station
West India Export Dock

Site Photograph

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Assembly Photograph

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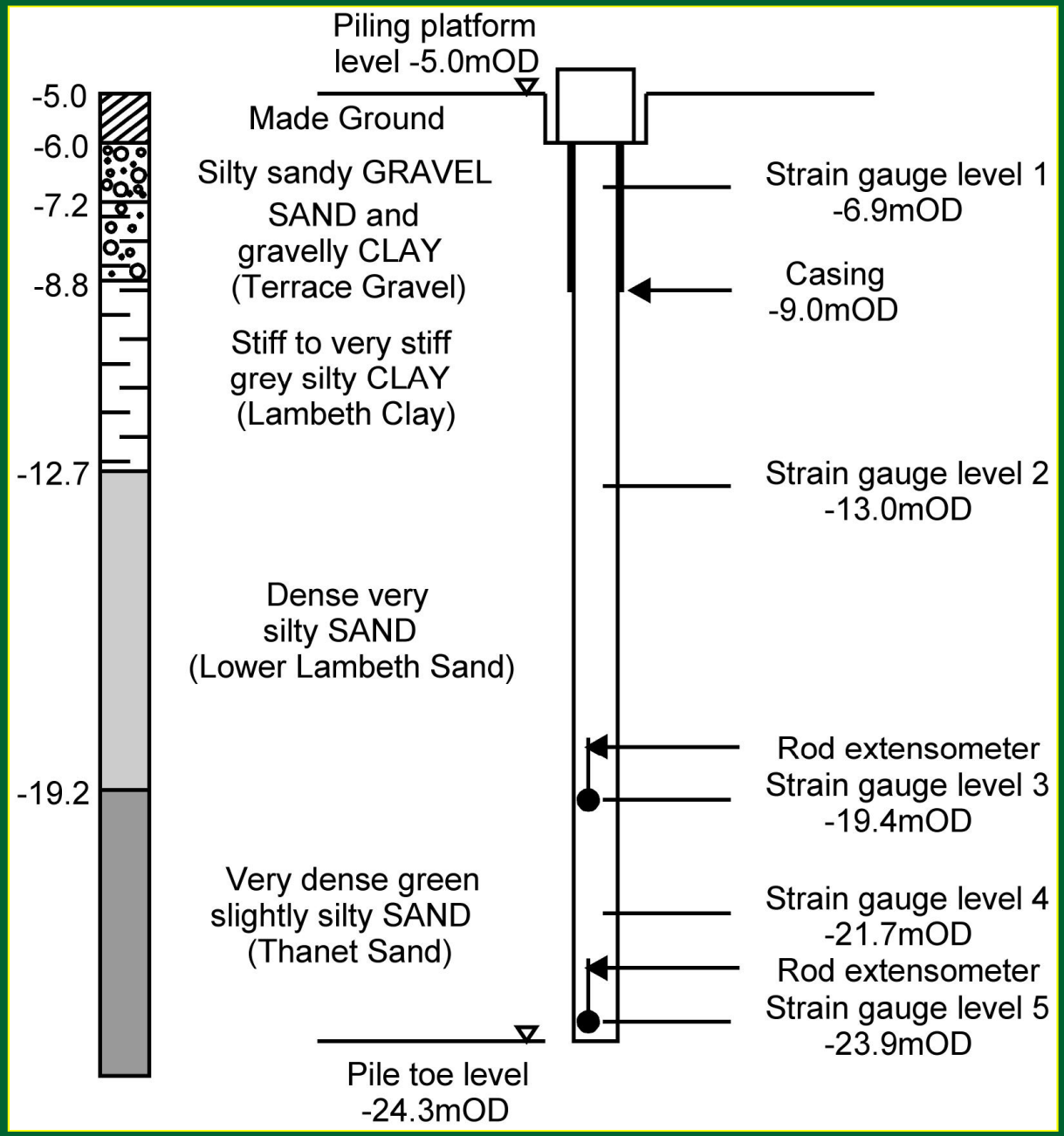
Piling platform
level -5.0mOD
-5.0
-6.0
-7.2
-8.8
-12.7
-19.2
Made Ground
Silty sandy GRAVEL
SAND and
gravelly CLAY
(Terrace Gravel)
Stiff to very stiff
grey silty CLAY
(Lambeth Clay)
Dense very
silty SAND
(Lower Lambeth Sand)
Very dense green
slightly silty SAND
(Thanet Sand)
Pile toe level
-24.3mOD
Strain gauge level 1
-6.9mOD
Casing
-9.0mOD
Strain gauge level 2
-13.0mOD
Rod extensometer
Strain gauge level 3
-19.4mOD
Strain gauge level 4
-21.7mOD
Rod extensometer
Strain gauge level 5
-23.9mOD

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PILE STATISTICS

Diameter		900mm
Length		19.3m
Penetration into Thanet Sand		5.1m
Reaction		6 no. 1500mm piles
Reaction capacity		21MN
Over break		12%
Base grouting:	Uplift	0.35mm
	Volume	231 litres
	Max pressure	60 bar

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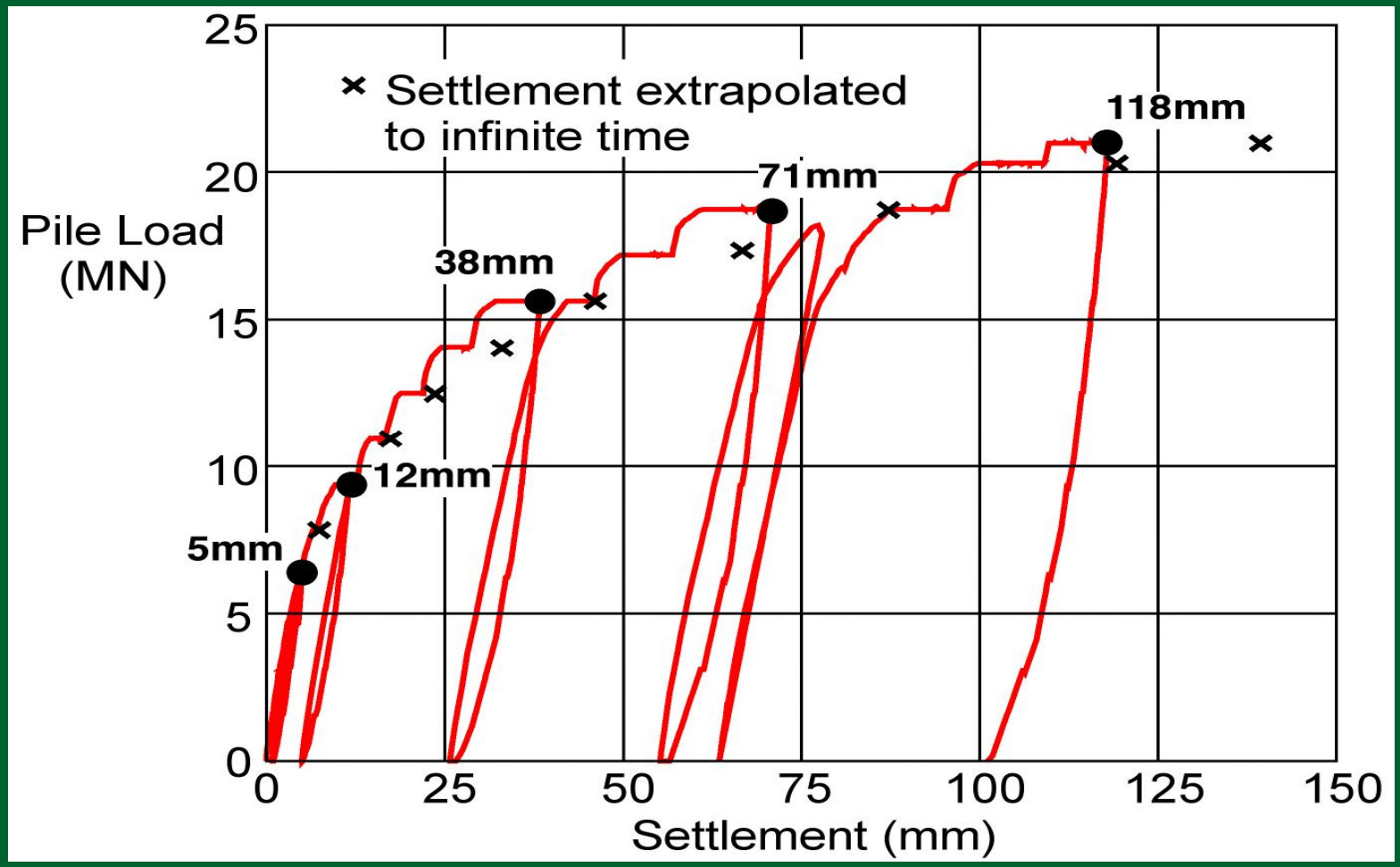

Loads at Failure (kN) SHAFT

Terrace Gravel - assumed Low

Lambeth Clay - 1,000

Lambeth Sand - 2,000

Thanet Sand - 3,000

BASE - 15,000

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Back - analysed parameters

Strata Description	Failure Stress	Design Approach	Design Parameters	Back Analysed Parameters
Lambeth Clay	84kPa	$\alpha.c_u$	c_u = 100kPa	α = 0.8
Lambeth Sand	105kPa	$\sigma_v'K\tan\delta$	σ_v' = 155kPa $\delta = \phi'$ = 33°	β = 0.68 K = 1.05
Thanet Sand	223kPa	$\sigma_v'K\tan\delta$	σ_v' = 210kPa $\delta = \phi'$ = 36°	β = 1.06 K = 1.46

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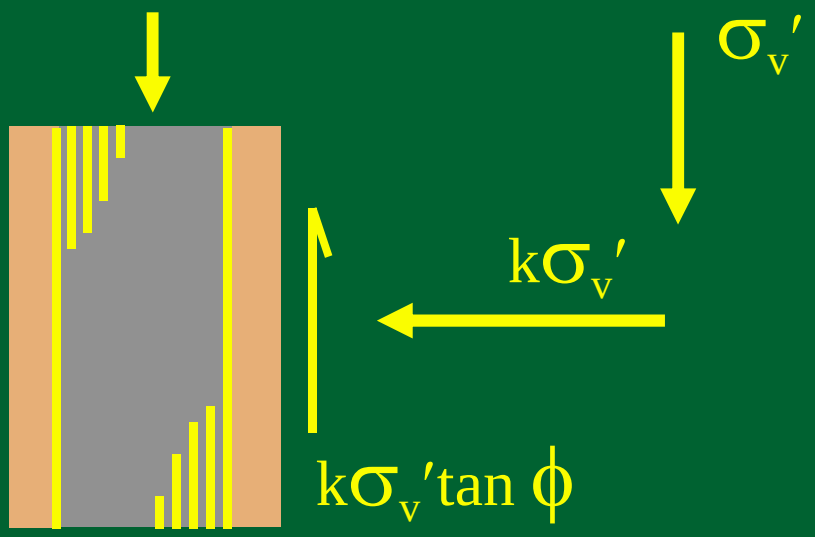
Conventional Pile Design



- Ignores stress history of soil !

$Q_s = k\sigma_v'\tan\phi\ \pi\ DL$

If $k = a.k_o$ where a is factor for stress relief / piling disturbance

- Then $Q_s = a.[k_o\ \sigma_v']\tan\phi\ \pi\ DL = a\ \sigma_h'\tan\phi\ \pi\ DL$

  with σ_h' taking stress history into account

- σ_h' limited to $\left(\frac{1}{1 - \sin\phi}\right) \sigma_v'$ for passive failure

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Factor a values used in design

Strata Description	Calculated σ_h'	Interpreted Friction	Calculated Factor a	Design Factor a	Limiting K used in design $a.k_o$
Lambeth Sand	300kPa	105kPa	0.54	0.4	0.88
Thanet Sand	379kPa	223kPa	0.81	0.6	1.44

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Pile capacities calculated using the proposed design approach

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Strata Description	Computed Capacities			Proposed Design Parameters
	Original Design Approach	Measured Loads	Proposed Design Approach	
Lambeth Clay	566kN	1,000kN	283kN	α = 0.2
Lambeth Sand	793kN	2,000kN	1,420kN	a = 0.4 δ = ϕ'
Thanet Sand	915kN	3,000kN	2,376kN	a = 0.6 δ = ϕ'
SHAFT Q_s	2,274kN	6,000kN	4,361kN	
BASE Q_b	10,340kN	15,000kN	10,340kN	Nq* = 47
TOTAL Q_{ult}	12,614kN	**21,000kN**	14,701kN	$\frac{21,000}{6,534}$ = 0.31
Design Capacity $Q_{ult}/2.25$	5,606kN	9,333kN	**6,534kN**	

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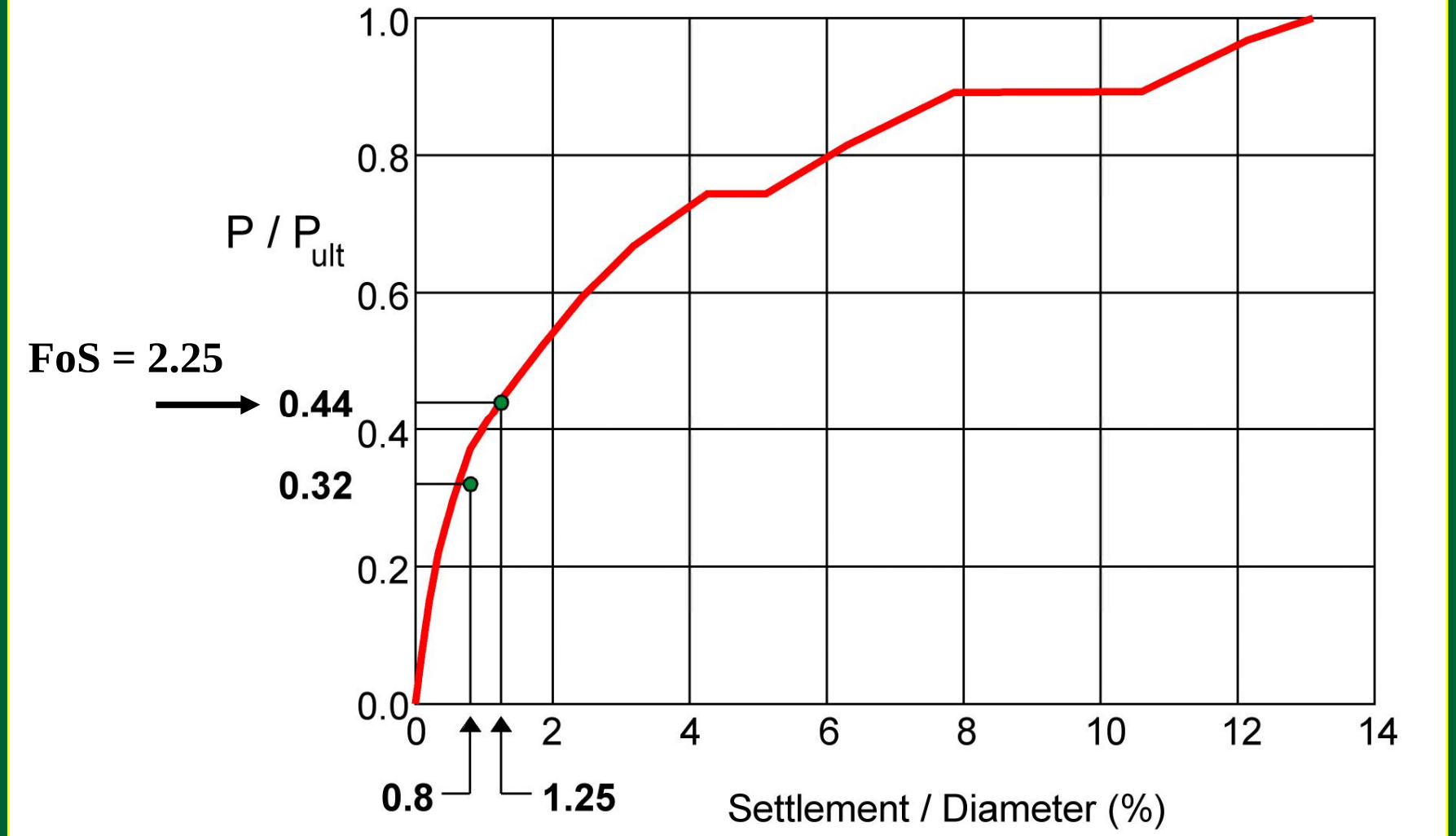
Normalised load settlement behaviour



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P/P_{ult} =0.31 to 0.32

Chosen to limit settlements

- Normalised plot shows $\frac{\delta}{D} = 0.8\%$
- Allow 25% variation $\frac{\delta}{D} = \mathbf{1.0\%}$
- Plot also shows that settlement at 1.5 x DVL = 1.6%
- allow 25% variation gives **2.0%**
- Implies settlement limits for 1.5m Ø piles

  DVL - 15mm

  DVL x 1.5 - 30mm

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