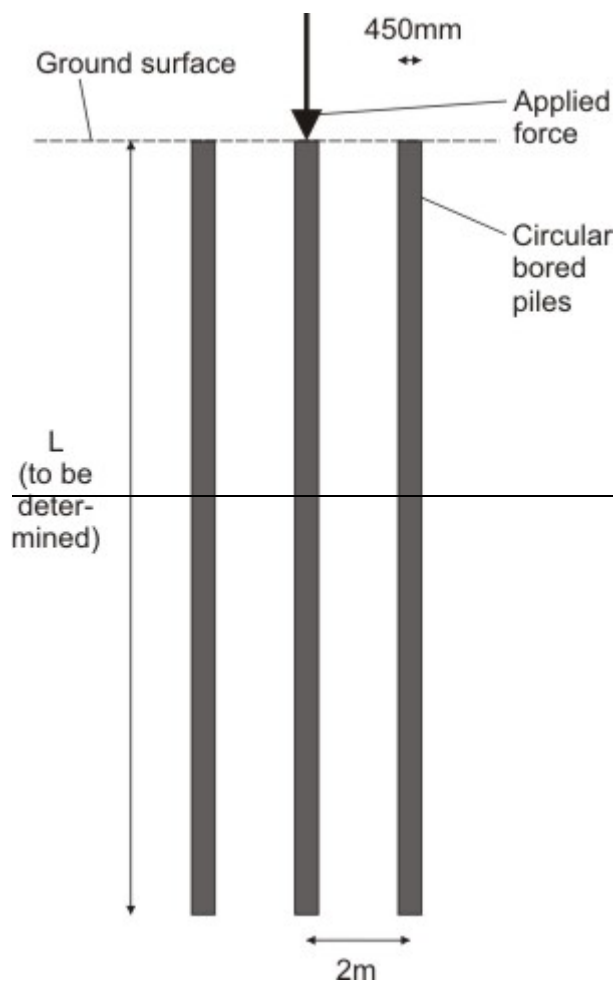


### Example 2.3 Pile foundation in stiff clay

A building is to be supported on 450 mm diameter bored piles founded entirely in a stiff clay and spaced at 2m centres. The piles are bored dry, without casing, and concreted on the same day as boring. Each pile carries a characteristic vertical permanent load of 300 kN and a characteristic vertical variable load of 150 kN. This is a small project for which there will be no load testing. Settlement in service is to be limited to 20 mm. The pile's design working life is 50 years. The clay is an over-consolidated marine clay of Miocene age, containing fissures and occasional claystones. Bedding is essentially horizontal.

The undrained shear strength of the clay at different depths can be determined from the results of four different types of tests that were carried out on the site: triaxial tests on samples from 6 percussion bored boreholes SG 11, SG 12, SG 14, SG 15, SG 16 and SG 17, SPTs in the 6 percussion bored boreholes, 1 CPT test and 2 self-boring pressuremeter (SBP) tests, carried out at the locations shown in Figure 2.3a. The results of the undrained triaxial tests are presented in Figure 2.3b. the results of the CPT tests in Figure 2.3c, the logs of boreholes SG14 and RC13 in Figures 2.3d and 2.3e, the results of the SPT blowcounts from the 6 boreholes in Figure 2.3f, and the results of the 2 SBP tests in Figure 2.3g. The designer may select any or all of these data. Appropriate correlations are to be used to determine characteristic values for design. Below 20 m depth, the undrained shear strength is assumed to increase no further-



The water table is at the surface of the clay, and water pressures may be taken to be hydrostatic. The weight density of the clay may be taken as  $20\text{kN/m}^3$ . At this location the ground surface should be taken to be +17m OD (OD = Ordnance Datum, i.e. reference level), which is also the level of the surface of the stiff clay.

Using Eurocode 7, determine the design length of the pile at the location shown in Figure 2.3a.

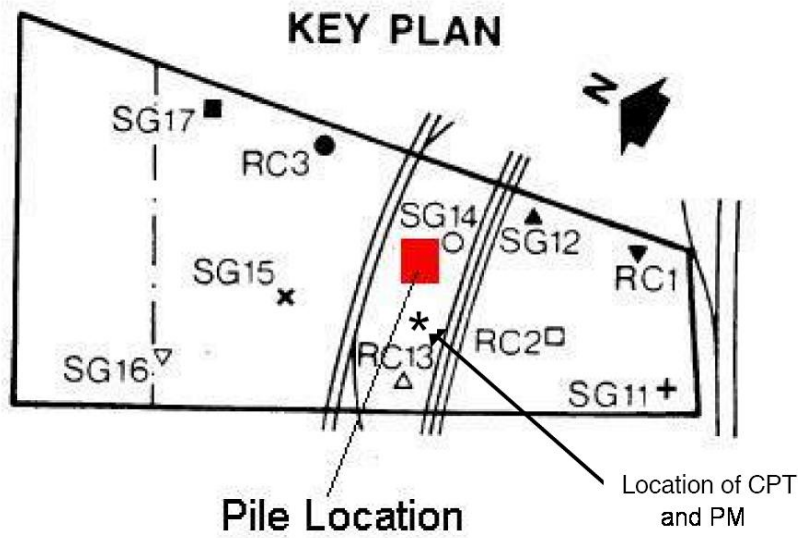


Figure 2.3a: Site plan showing the locations of the boreholes (SG11-17), cone penetration test (CPT), and two profiles of self-boring pressuremeter tests (marked PM on this figure)

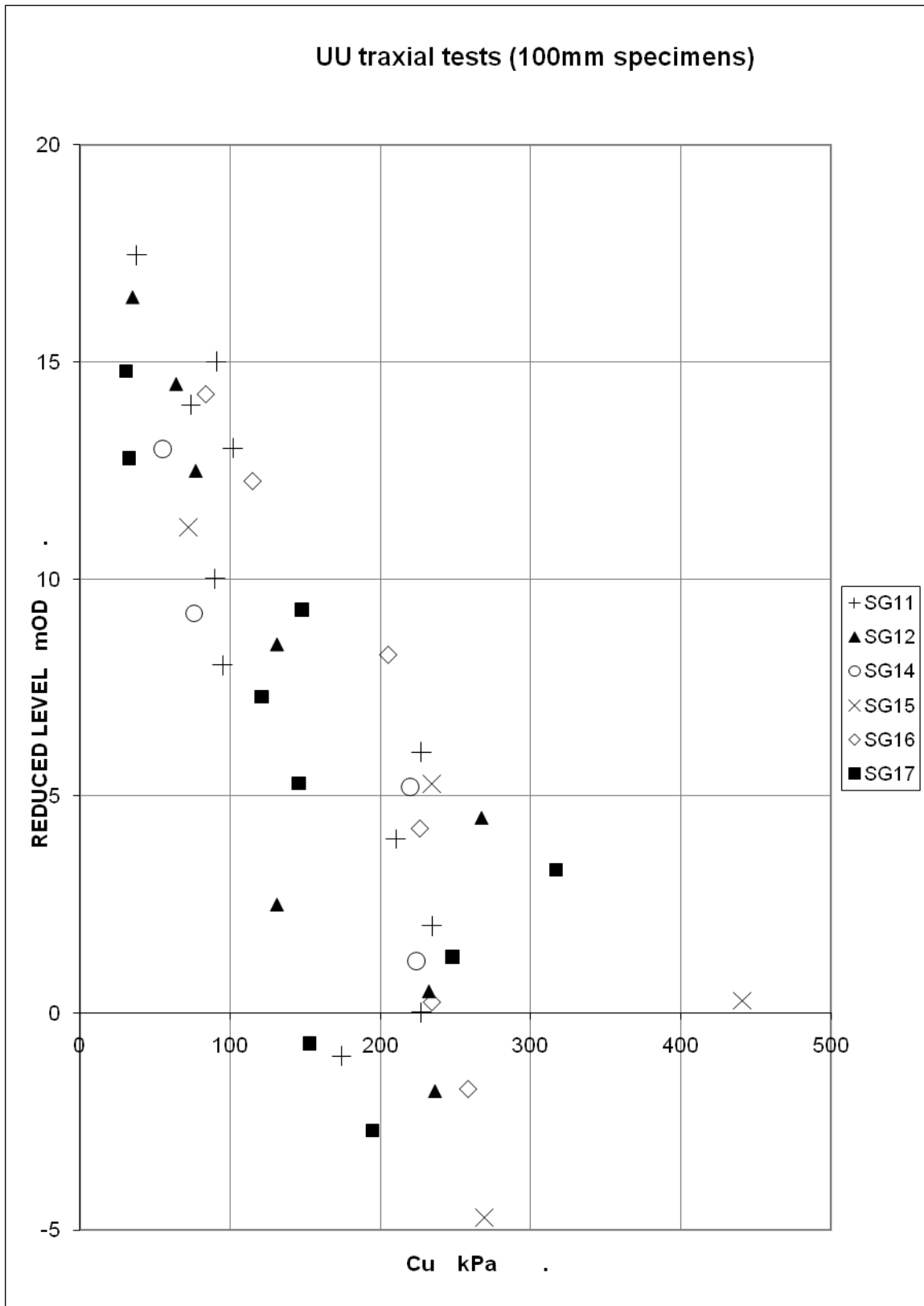


Figure 2.3b: Undrained Triaxial Test Results

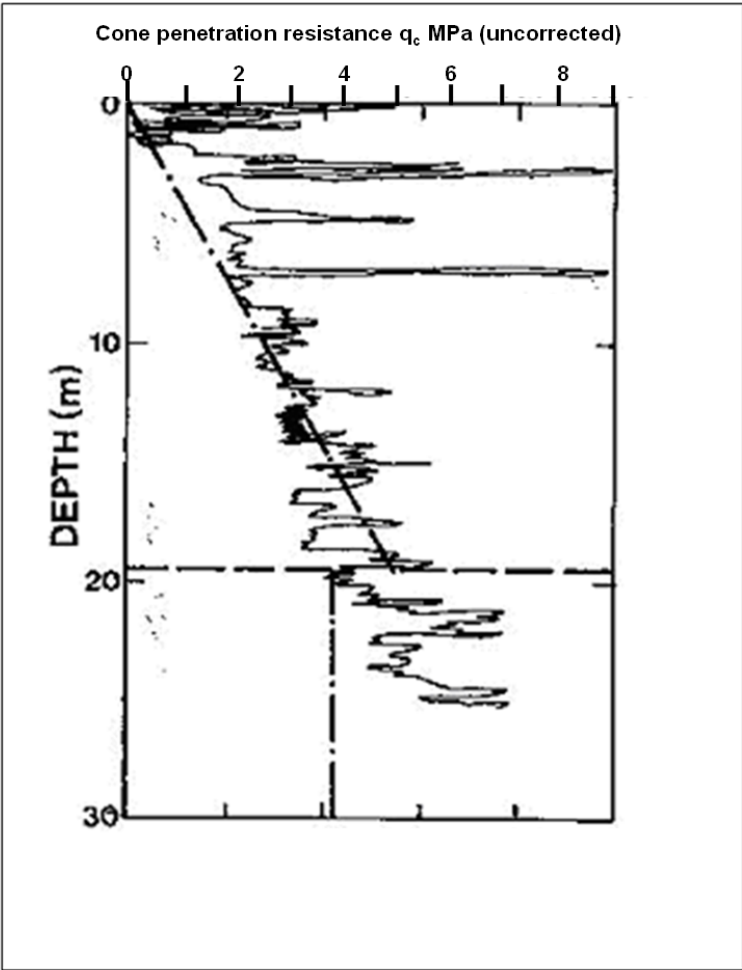


Figure 2.3c: Cone penetration resistance from CPT test

Design Example 2.3

Record of Borehole No. SG 14

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES		LEG- END	DEPTH (m)	REDUCED LEVEL (m above OD)	DESCRIPTION OF STRATA	
			DEPTH FROM	TO					TYPE
						GL	19.45		
10.12.75			1.15	1.45	S 4	0.40	19.05	GRANITE SETTS on lean-mix CONCRETE	
							1.00	18.45	Sandy gravelly RUBBLE, comprising broken bricks, pieces of concrete and stones. Clayey towards the bottom.
			1.50	2.00	3D			Very soft to soft, brown, sandy silty CLAY with small stones and occasional brick fragments. Also pieces of china, tile and flint gravel.	
		1.70	2.15	2.45	S 3				
			2.00	2.50	3D				
			3.15	3.45	S 1			Old pipe encountered at 3.6 m (approx 150 mm diameter), pipe virtually dry. (FILL - possibly trench for placing pipe)	
			3.70	4.00	3D	3.70	19.25		
			4.00	4.50	E 100			Firm to stiff, brown mottled grey silty CLAY with patches of orange-brown SAND/SILT and numerous gypsum crystals. Less mottled with depth.	
5.0	DRY	4.70	5.15	5.45	S 18			Small CLAYSTONE at 5.7 m.	
11.12.75	DRY	4.70	5.70	6.00	3D			(LONDON CLAY)	
			6.00	6.50	E 100	6.00	19.45	Stiff, grey-brown or grey fissured silty CLAY with traces of fine SAND/SILT.	
			7.15	7.45	S 19				
			7.50	7.80	3D				
			8.00	8.50	E 100	8.40	11.05	(LONDON CLAY)	
			9.15	9.45	S 25			Stiff to very stiff, grey silty and sandy CLAY, with patches of fine SAND/SILT.	
			10.00	10.50	E 100			Numerous patches and partings of SILT/SAND below 11.0 m.	
			11.15	11.45	S 28			Sand content increases sufficiently around 12.0 m to classify as a clayey SAND.	
			12.00	12.50	E 100				
			13.15	13.45	S 27	13.00	6.45	(LONDON CLAY)	
13.50	DRY	4.70						Stiff to very stiff, grey silty CLAY with occasional concentrations of SILT. Laminar structure visible.	
12.12.75	13.70	4.70	14.00	14.50	E 100			Occasional small pyritised nodules.	
			15.15	15.45	S 30			Slight seepage of water from 14.0 m.	
			16.00	16.50	E 100			Small pieces of CLAYSTONE recovered from 15.5 m to 16.0 m. Slight seepage of water.	
			17.15	17.45	S 44	17.00	2.45	Stiff to very stiff, silty and sandy CLAY, with patches and pockets of SILT/fine SAND.	
			18.00	18.50	E 100				
			19.15	19.45	S 45			Numerous shell fragments around 18.6 m. Becoming very sandy around 19.0 m.	
						20.00	-0.55	(LONDON CLAY)	

REMARKS	TYPE OF BORING
(1) Disturbed sample (Jar) taken from the cutting shoe of all U100 and from SPT.	Shell-and-ruger 1 ton Isler
	DIAMETER OF BORING 240 mm - to 20.5 m
	CASING TUBES 250 mm - to 4.7 m.
	<b>BOREHOLE NO.</b> SG 14

Figure 2.3d(1): Log for percussion bored Borehole No. SG 14 – Sheet 1

Design Example 2.3

Record of Borehole No. .... SG 14 (contd.) ..

DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES			LEG- END	DEPTH	REDUCED LEVEL	DESCRIPTION OF STRATA
			DEPTH		TYPE				
			FROM	TO					
			20.00	20.50	S 100		20.00 -3.55	Very stiff brown mottled green fissured silty CLAY; very silty in patches.	
20.50	DRY	4.70							
12.12.75	17.50	20.50	17.50	21.30	S 77			(WOOLWICH and READING BEDS)	
			21.80	22.00	S 30		21.80 -2.35	Dense brown slightly clayey and silty, fine-grained SAND.	
			22.15	22.23	S 75				
			22.90	22.98	S 30				
23.5	DRY	23.5						Casing sinking under its own weight during boring, borehole dry from 22.0 m - water added.	
15.12.75	22.50	23.50	23.50	23.90	S 30		24.00 -4.55	Very stiff brown mottled grey-green fissured silty CLAY.	
			23.65	23.95	S 67				
			24.00	24.50	S 30				
			24.65	24.95	S 37				
			25.00	25.00	U 100				
26.0	DRY	25.30					26.00 -6.45		
16.12.75	22.00	25.30	(2)	26.55	26.95	S 40		Very stiff light-grey mottled greenish-brown fissured silty CLAY. Numerous polished surfaces. Slight seepage of water following casing of sand layer.	
				27.50	28.00	U 100			
				28.65	28.95	S 50		28.50 -9.05	Dense alternating thin bands of light grey sandy SILT and dark grey silty CLAY. Horizontally bedded.
				29.00	29.50	S 30		29.00 -9.55	
				29.50	30.00	U 100			Very stiff, reddish-brown, mottled light grey-green and orange brown fissured silty CLAY, becoming darker and predominantly brown with depth.
30.00	25.00	25.30							
17.12.75	25.00	25.30	(3)	30.65	30.95	S 67			
				31.30	32.00	U 100			(WOOLWICH and READING BEDS)
				32.65	32.90	S 95			
33.00	23.00	25.30							
18.12.75	27.00	25.30	(3)	33.65	35.05	S 72			
				34.50	34.90	S 30		34.30 -14.35	Dense, very clayey, silty fine-grained SAND, with occasional small flint fragments. (REARER SAND - reworked?)
12.12.75	DRY	34.50		34.65	34.90	S 114		34.20 -15.35	
				34.90	35.00	S 30			Dense grey/green silty SAND with numerous thin bands and pockets of multicoloured (red, brown and green) silty CLAY.
				35.65	35.90	S 104			
35.30	DRY	34.50						35.30 -16.35	
8.1.76	22.00	34.50		36.50	36.38	S 97			Dense dark greenish-grey, very sandy CLAY with numerous partings and pockets of light grey, silty fine-grained SAND.
				37.55	37.33	S 105			becoming clayey SAND with thin layers of light grey medium-grained SAND. Occasional pebbles with blackened surfaces, usually small. (REARER SAND - reworked?)
				38.65	38.73	S 144			
								38.70 -19.25	Dense light grey silty fine SAND.
39.5	25.00	35.00							
7.1.76	23.00	35.00		39.50	39.65	S (4)		40.00 20.55	(CHANGED SAND)

REMARKS  
 (2) Unable to drive casing below 25.30 m; water not sealed off.  
 (3) Collapse of borehole overnight; approximately 3 m of collapsed material.  
 (4) Test terminated after "seating blows".

TYPE OF BORING  
 Shell-and-auger  
 1 ton Isler

DIAMETER OF BORING  
 240 mm - to 20.5 m  
 120 mm - to 24.3 m  
 140 mm - to 44.6 m

CASING TUBES  
 350 mm - to 4.7 m  
 200 mm - to 25.3 m  
 150 mm - to 35.0 m

**BOREHOLE NO. SG 14 (Continued)**

Figure 2.3d(2): Log for percussion bored Borehole No. SG 14 with SPT results – Sheet 2



Design Example 2.3

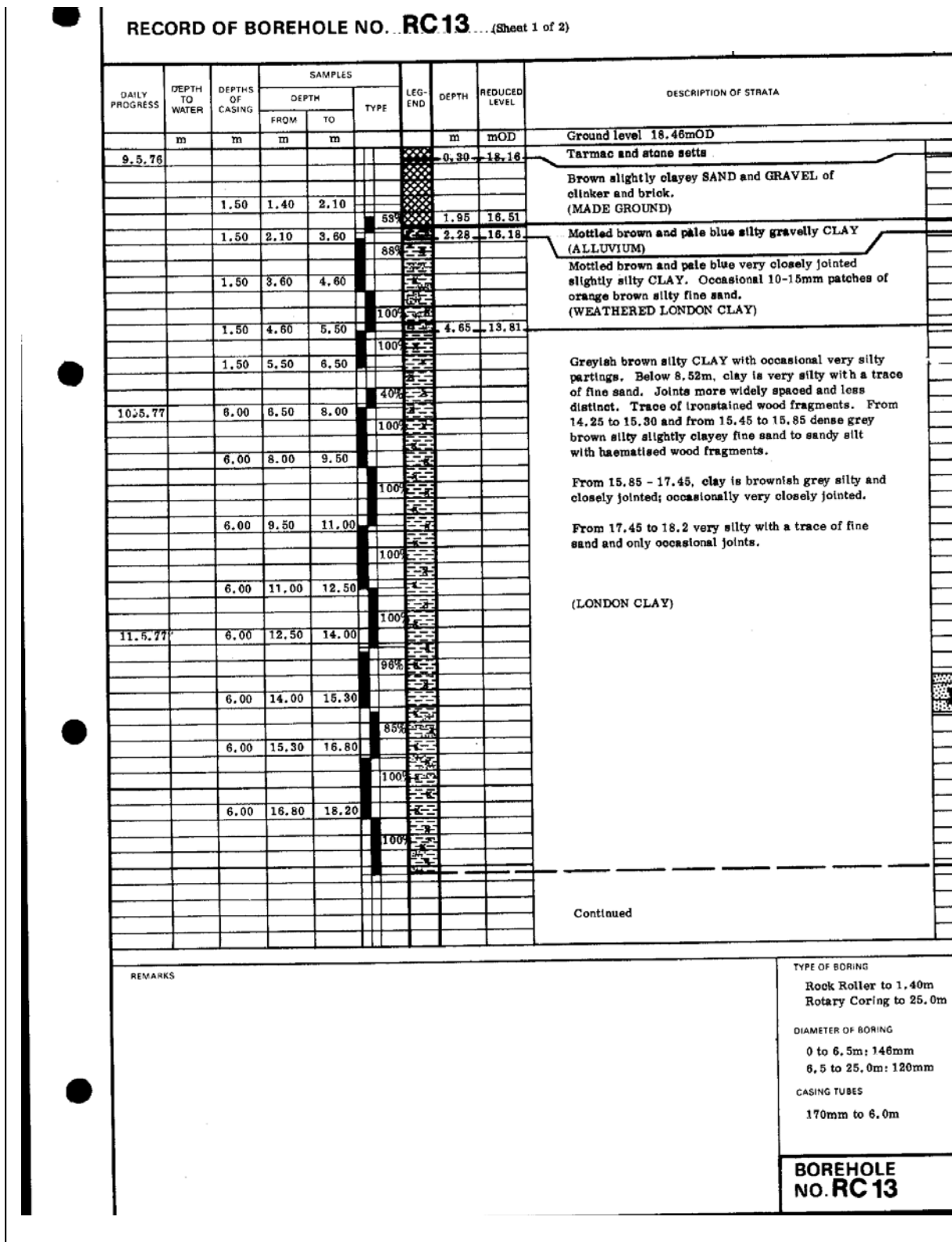


Figure 2.3e(1): Log for rotary cored Borehole No. RC 13 – Sheet 1



Design Example 2.3

RECORD OF BOREHOLE NO. <b>RC13</b> (Sheet 2 of 2)									
DAILY PROGRESS	DEPTH TO WATER	DEPTHS OF CASING	SAMPLES		LEG-END	DEPTH	REDUCED LEVEL	DESCRIPTION OF STRATA	
			FROM	TO					
	m	m	m	m		m	mOD		
11.5.78		6.00	18.20	19.70	100%				
		6.00	19.70	21.00	100%	20.40	-1.94	Brownish grey silty to very silty closely, occasionally very closely jointed CLAY. Occasional 10-15mm patches of blue grey iron rich sand. Below 18.95m with fine sand and numerous wood fragments. (LONDON CLAY)	
		6.00	21.00	22.50	100%			Mottled pale brown and very pale blue slightly silty becoming silty closely jointed CLAY with occasional haematised wood fragments. Below 21.1m mottled rust red.	
		6.00	22.50	23.80	92%			(WOOLWICH AND READING BEDS)	
		6.00	23.80	25.00	72%	25.00	-6.54	END OF BOREHOLE	
REMARKS							TYPE OF BORING		
							DIAMETER OF BORING		
							CASING TUBES		
							<b>BOREHOLE NO. RC13</b>		

Figure 5.3e(2): Log for rotary cored Borehole No. RC 13 – Sheet 2

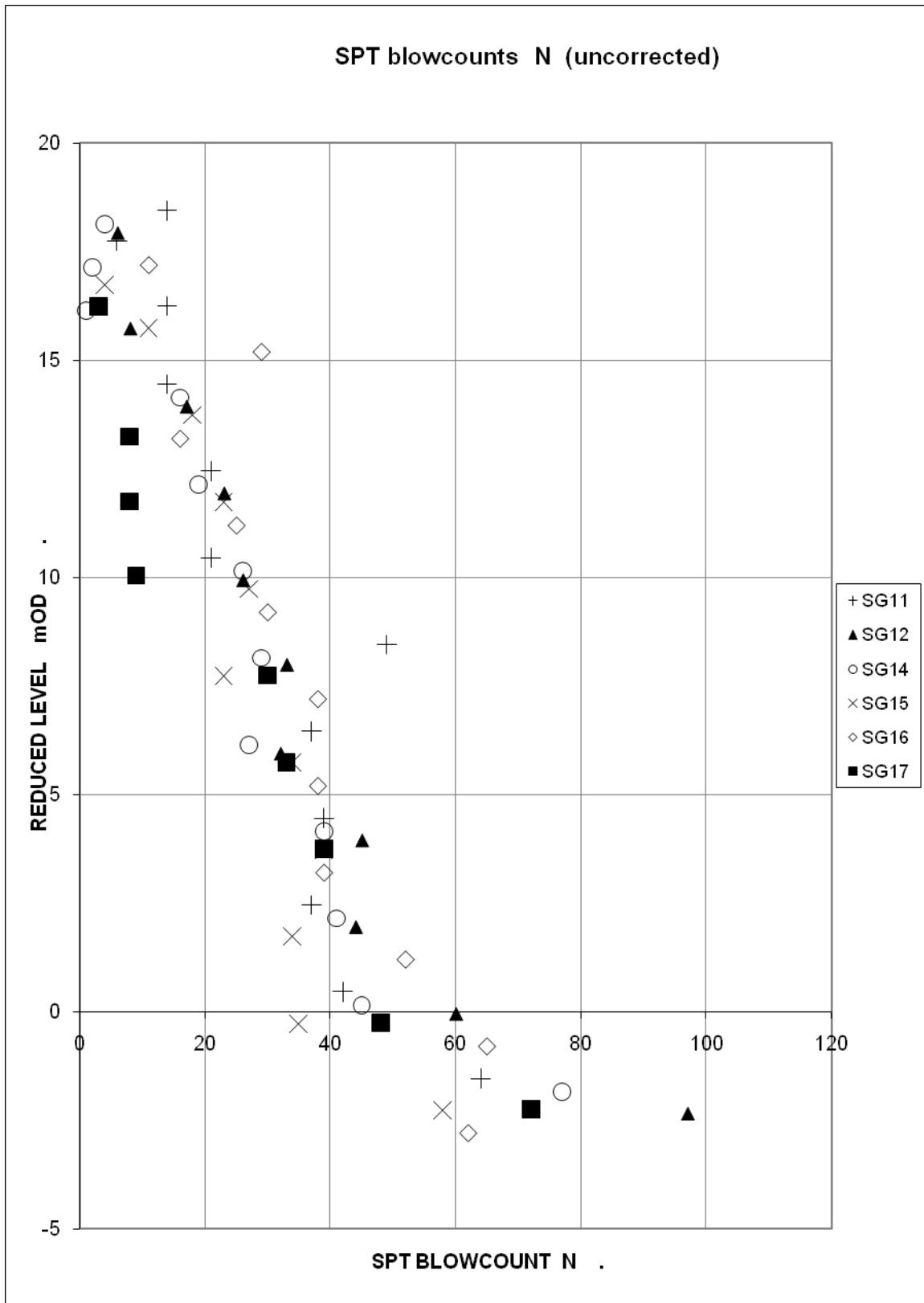


Figure 2.3f: Combined SPT blowcounts from Boreholes SG 11, SG 12, SG 14, SG 15, SG 16 and SG 17

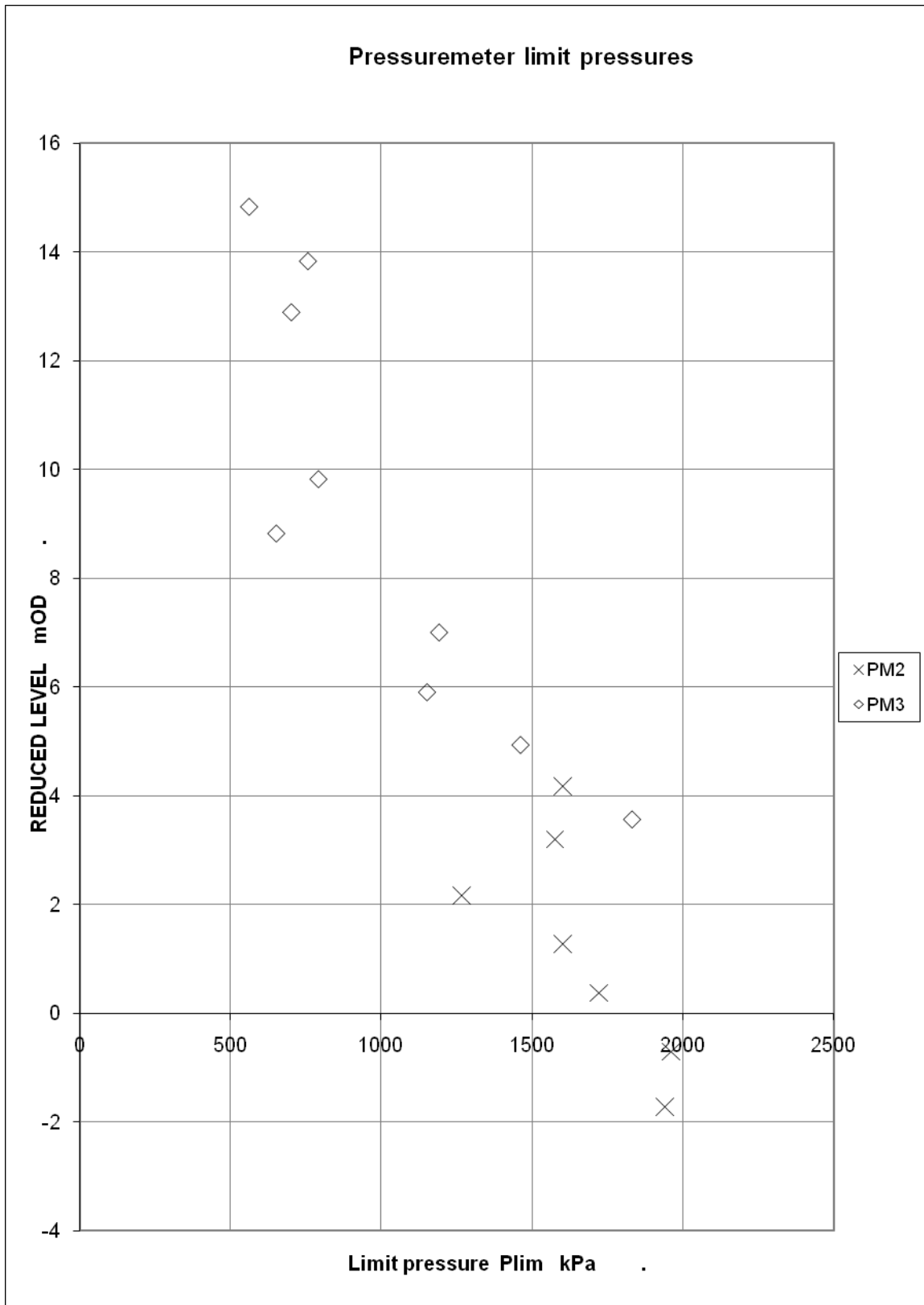


Figure 2.3g: Results of self-boring pressuremeter tests in two boreholes PM2 and PM3