A14.4 – Redevelopment of 81 King William Street (Site Investigation) (Wembley Laboratories Ltd)

J2923
81 King William Street

S512

Wembley Laboratories Limited

Site Investigation Report

KING WILLIAM STREET/NICHOLAS LANE,
LONDON, E.C.4.

Client

MESSRS. SWIRES

BYLANDER WADDELL PARTNERSHIP,
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Wembley Laboratories Limited

SITE INVESTIGATIONS
SOIL CONSULTANTS

SITE INVESTIGATION REPORT

KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.

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2187/TSR

APRIL, 1982.

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FOREWORD

NOTES ON SITE INVESTIGATION

GENERAL

The Boring Records are compiled from the driller's description of the strata encountered, a laboratory examination of the samples and the results of site and laboratory tests. Based on this data, the report may suggest an opinion on a possible configuration of strata within the site. However, such reasonable assumptions are given for guidance only and no liability can be accepted for changes in ground conditions between or near the borehole positions.

BORING METHOD

The shell and auger technique of boring is normally employed. This percussive equipment allows the ground conditions to be reasonably well established. Some disturbances of the ground is inevitable and therefore some mixing of layered soils may well occur. In particular, the presence of thin layers of different soils within a particular stratum may not be detected. If some evidence of such features is observed, then attention is drawn to this factor in the report.

GROUND WATER

The depth at which ground water was struck is entered on the Boring Record. Such a level may not truly indicate the water level at that period. Due to the speed of boring and the relatively small diameter of the borehole, natural ground water may be present at a depth slightly higher than the water strike. Moreover, ground water levels are subject to variations caused by changes in the local drainage conditions and by seasonal effects.

An estimate of the rate of inflow of water is also given. This is only a relative term and serves as a guide only to the probable flow of water into an excavation.

Observations of water within the borehole are recorded in tabular form on the Boring Record. The overnight standing water level is recorded and, if applicable, the depth at which water was sealed off by the borehole casing.

Whilst drilling through granular soils, water is necessarily introduced into the borehole to permit boring. Where the addition of water has a significant masking effect this factor is further amplified in the report.

SAMPLING

Undisturbed samples of predominantly cohesive soils are obtained using a 100mm. dia. open-drive sampler, generally complying with the requirements of British Standard Code of Practice C.P. 2001. Bulk disturbed samples of soils are taken and placed into polythene bags. Small jar samples are taken at frequent intervals and also at changes of strata, and used for subsequent visual classification. Where ground water is encountered in sufficient quantity, a sample of the ground water is also taken.

IN-SITU STANDARD PENETRATION TESTS

The penetration resistances, quoted as "N" values on the Boring Records, have been obtained generally in accordance with the procedure given in B.S. 1377; 1967. In some instances, full penetration may not be attained. In such cases the suffix* indicates that the result has been extrapolated from a limited extent of penetration.

1.0 INTRODUCTION

It is proposed to redevelop this site by the replacement of an 8 storey banking style building including basements with an 8 storey office block, again including basements. The facade along King William Street frontage is to be retained.

A site investigation has therefore been carried out to determine the ground conditions and to provide the necessary data for foundation design. This includes an assessment of the effect of a development on a large diameter sewer which crosses the site at depth and the Bank underground railway station which lies beneath King William Street.

This report presents the borehole records, the results of the laboratory tests and describes the ground conditions. Recommendations are made for foundation design including both a raft foundation and piles. The implications of the settlement analyses with respect to the deep sewer and railway station are also discussed.

2.0 THE SITE

The site is located in the City of London on ground which is sloping gently southwards towards the River Thames. Surrounding buildings are generally of a similar age and style to the existing building on the site and of six to eight storeys in height. However, immediately adjacent to the North-west side of the site is a modern bank building of 8 storey height with a deep basement.

The building at present on the site is a six storey brick structure with a double basement and was constructed in 1929. Part of the basement of a previously existing building has been incorporated into this building, including the vaulting at the upper basement level, which extends partly beneath the King William Street pavement.

At a depth of around 17 m and running in a roughly East-west orientation is a large diameter sewer. Adjacent to the site beneath King William Street lies the Bank railway station tunnel, at a depth of about 25 m and extending to about 39 m depth. The locations of the tunnels are shown on the Site Plan in the Appendix.

The 6 inch to 1 mile Geological Survey Map of the area shows that the site lies within the Flood Plain Gravel of the River Thames, overlying more than 40 m of the London Clay. At depths greater than 50 m the Woolwich and Reading Beds are present.

3.0 EXPLORATORY WORK

An Engineer from this Company visited the site and after discussions with the Consulting Engineer, it was proposed to construct 4 boreholes to depths of about 35 m below basement level to provide data for foundation design and settlement analyses. It was also proposed to carry out 12 horizontal coreholes through the retaining walls of the lower and upper basements. This field work was carried out during February, 1982, using a specially constructed basement rig for use in confined working areas. The final depths drilled ranged between 30 m and 43 m below basement level, although drilling was carried out from the ground floor and all measurements were taken from this level. The horizontal coreholes were also carried out during this period under the supervision of a Soils Engineer from this Company. A Site Plan showing the location of the boreholes and the horizontal coreholes is given in the Appendix, together with the borehole and corehole records.

A programme of laboratory testing was devised in order to provide data for both shallow or deep foundation solutions and settlement analyses.

The boreholes were constructed from ground floor level and the reduced levels of the floor at each borehole location are derived from the Site Survey Drawing No. S5, carried out by Gordon Tomalin and Partners, January, 1982.

4.0 GROUND CONDITIONS

Strata depths are measured from the ground floor for which the reduced level is approximately 16.60 m O.D.

At each borehole position the concrete floor of the lower basement was found to rest directly upon the in-situ Flood Plain Gravel. This gravel overlies the London Clay which was not fully penetrated in any borehole.

4.1 Flood Plain Gravel

The Flood Plain Gravel was encountered immediately beneath the lower basement concrete floor in each borehole at depth of about 7 m (9.60 m O.D. approx.) and is generally 4 m thick extending to about 11 m depth (5.60 m O.D. approx.). The gravel is generally sub-angular with brown silty sand, becoming clayey in parts, and layers of sand can generally be expected within the upper 2.0 m in some areas.

The gravel is generally in a dense to very dense condition with many of the S.P.T. 'N' values being well in excess of 100, althoug some values are appreciably less than 100, which indicates local variability in the gravel deposits.

4.2 London Clay

The top of the London Clay was encountered at depths of about 11 m (5.60 m O.D. approx.) as a generally stiff brown/orange mottled fissured clay. This upper weathered zone, however, is only about 0.70 m thickness, giving way to the unweathered grey fissured clay generally stiff rapidly becoming very stiff with depth. At depths of between about 20 m to 28 m a zone of very stiff clay becoming slightly silty in parts and containing frequent partings of fine grey sand was encountered. This zone extends to depths of about 33 m to 35 m where it gives way to very stiff grey fissured clay with only occasional fine sand partings. In two of the boreholes which penetrated appreciably beyond 40 m depth, a second zone containing frequent fine partings was encountered, and in Borehole No. 4 this extended to the base of the borehole at 50 m depth.

4.3 Ground Water

Ground water was only observed in two of the boreholes, although water was added within the gravel stratum to assist drilling which may have masked very slow inflows. In Borehole No. 1 a "seepage" was encountered at the top of the grey fissured clay at a depth of 12 m (4.60 m O.D. approx.) with a short term rest level of 11.9 m. In Borehole No. 4 a small inflow was encountered upon withdrawal of the casing with a short term rest level at 10.45 m.

4.4 Horizontal Coreholes

These exploratory holes generally indicate that the lower basement retaining wall consists of between 0.7 m and 0.9 m of brickwork with an outer bitumen sealing layer. Beyond this bitumen layer, gravel with brown sand was encountered in two of the coreholes whilst at the other positions a very weak poorly cemented concrete was present. At one point (Corehole A1) the brickwork was only 0.2 m thick with a backing of weak uncompacted concrete to at least 0.7 m depth. At the upper basement level the walls were more variable in thickness, including the less substantial brick vaulting and light well area. Generally the walls were again of brickwork, the bitumen sealing layer only being present in parts. These walls are backed by fill which at several locations was clayey in nature. Ground water was not observed in any corehole.

5.0 DISCUSSION

The proposed building is to be six storeys above ground level and will incorporate a double basement to the same depth of the existing double basement. In plan this building will cover the same area and shape as the existing building and will retain the existing facade on King William Street and part of Nicholas Lane. This new building will, however, be of a modern layout supported on columns and will exert slightly higher loadings. Along its northern side the existing building abuts against the modern eigh storey National Westminster Bank building, which has three baseme floors. This northern wall has been underpinned to a depth of approximately 13 m (+3.0 m O.D. approx.) below ground level. The remainder of the building is supported on strip footings, no doubt founded upon the gravel.

A large, 3 m diameter, storm sewer built in 1907 and probably of brick construction, runs West to East beneath the King William Street frontage and northern flank wall. The soffit of this sewe is approximately 16.5 m (-0.70 m O.D. approx.) below ground level The Bank station on the northern line underground railway lies beneath King William Street. This railway tunnel has its norther boundary directly beneath the frontage of the site and is of abou 13.7 m diameter. The soffit of this tunnel lies at about 25 m (-9.2 m O.D. approx.) below ground level.

It has been estimated that the existing building imposes a gross dead load of 65,000 kN with a probable live load of 25,000 kN. T proposed building would have a load of about 81,000 kN with a gross live load of 40,000 kN. Although the live load of the existing building is not known it is reasonable to assume that about 60% of the above figure would reasonably have been applied over the life of the building. Thus, based on this estimate and a building area of 776 m^2, the overall existing long term loading would be 105 kN/m^2. Similarly for the proposed building, and incorporating a live load reduction the overall gross loading would be about 140 kN/m^2. Thus, the net increase in load is estimated to be:-

$$140 - 105 = 35 \text{ kN/m}^2$$

This loading is an average for the whole building area, however both the existing and proposed buildings include a heavily loaded core area. These core loadings have been estimated as 130 kN/m^2 for the existing building and 160 kN/m^2 for the proposed building, allowing for about 60% of the estimated live loads. Thus, the net increase in loading in this core area of 30 kN/m^2, which is not appreciably different to the average net loading for the whole raft. Therefore, the average increase in loading of 35 kN/m^2 may be reasonably adopted for the whole building.

At present it is envisaged that the new building will be constructed on a 1.0 m thick raft foundation at the same level as the basement floor of the existing building. The distribution of the load bearing walls of the existing building and the thickness of the gravel is such that the stresses will be spread to a virtually uniform loading at the top of the London Clay. It is, therefore, reasonable to compare the building loadings and obtain a net increase in pressure for a raft foundation as shown above.

Piles are unlikely to be used on this site but the pile bearing characteristics have been included in this report for completenes

Settlement analyses have been carried out to determine the effect of the new development on the sewer and adjacent railway tunnel a depth.

5.1 Raft Foundation

A uniformly distributed load from the proposed building will stre a considerable depth of the underlying London Clay and therefore the settlement induced within this clay will be more critical to the design and behaviour of the raft than the proposed gross loading of the 140 kN/m^2, which is well within the bearing capaci of the gravel and the upper parts of the London Clay. Therefore, the stress increases at various depths and points around the raft have been calculated using Newmark influence charts; a method suitable for the analysis of irregular shaped foundations. These points are indicated on the Key Plan for Settlement Analyses show in the Appendix.

The immediate elastic settlements of the gravel and London Clay have been estimated using data from the in-situ Standard Penetration Tests and Triaxial Tests. With reference to the Key Section for Settlement Analyses, the calculated immediate settlement at the centre (point No. 1) of the proposed raft is shown in Table 1 in the Appendix. Immediate settlements mid-way along the length of the external walls will be approximately half of this value and a quarter of this value at the corners.

Similarly, the long term consolidation settlements are calculated for each point as shown in Table 2 in the Appendix.

A summary of these settlements is given in the following table:-

Settlement	Centroid	Edge	Corner
Immediate	5.4	2.7	1.4
Consolidation	18.2	13.1	10.0
Total	25	15	10

The proportion of settlement resulting from consolidation will take place over a relatively long period of time, of the order of 50 to 100 years.

It should be noted that for practical purposes the total settlements have been rounded to the nearest 5 mm and that the calculated settlements are shown to the first decimal place in the Tables for comparative purposes only.

Thus, the angular distortion of the raft would be of the order of 1:1,000 to 1:1,500 which should be well within acceptable limits.

5.2 Piled Foundations

It is not proposed to discuss piles in any great detail. On this site a bored pile would be necessary, either parallel shafted or with an under-reamed base. The following pile bearing characteristics are recommended for preliminary pile design:-

Ultimate Skin Friction (α= 0.45)		kN/m^2
In gravel from 7.0 m to 8.5 m depth	=	Ignore
In gravel from 8.5 m to 11.0 m depth	=	50
In London Clay from 11.0 m to 25 m depth	=	80
In London Clay below 25 m depth	=	100

Ultimate End Bearing (9 x 'lower bound' value)		
In London Clay at 25 m depth	=	1850
" " " " 30 m "	=	1900
" " " " 35 m "	=	1950
" " " " 40 m "	=	2000
" " " " 45 m "	=	2550
" " " " 50 m "	=	3150

(N.B. Depths measured from ground floor level, 16.60 m O.D. approx.).

The skin friction values have been determined from the average values of the cohesions shown by the Cohesion/Depth Graph. The end bearing values, however, are based on a lower bound curve to take into account the effect of fissures on the strength of the London Clay in mass.

5.3 Settlement of the Sewer and Railway Tunnel

The calculated settlements for deeper zones of the London Clay in Tables 1 and 2 can be used to estimate the deflection of the sewer. Thus, referring to points 3, 4, 5 and 7 on the Key Plan for Settlement Analyses, it can be seen that total settlements beneath the sewer could be of the order of 8 mm, 5 mm, 3 mm and 7 mm respectively. Thus, the angular distortion along the line of the sewer could lie between 1:2,500 and 1:4,000 which should also be well within acceptable limits.

The Bank railway station tunnel lies between 25 m and 40 m below ground level. The low level of stress increase due to the proposed building should have little or no effect on the soil at these depths and certainly no appreciable effect at greater depths Referring again to the tables of calculated settlements it can be seen that small movements of the order of 2 mm may occur within the zone of soil between the upper and lower invert levels of the railway tunnel. Such orders of movement are unlikely to have any effect upon this large diameter tunnel.

5.4 Effects on the Adjacent Structure and the Retained Frontage

The northern wall of the existing building has been underpinned to about 13 m depth (+3.0 m O.D. approx.) to transfer the building loads to below the basement level of the adjacent National Westminster Bank. This underpinning constitutes a rigid zone beneath the edge of the proposed raft and, although expected settlements are small, founding directly upon the underpinning could result in local distress of the raft concrete. It is, therefore, recommended that the upper 200 mm to 250 mm of under-pinning is removed and replaced with granular fill or hardcore.

Thus, as settlement proceeds, the granular fill will compact and the underpinning will gradually transfer the edge stresses to depth and avoid disturbance to the adjacent foundations.

During the removal of the existing building the stress relief will result in slight heave of the foundation strata. This elastic recovery will take place immediately and, at the centroid of the building, could be of the order of 10 mm. Towards the edges and corners of the building the elastic recovery will be considerably less, of the order of a half to a quarter of this value. The retaining walls and, in particular, the retained frontage would be affected to an even lesser extent due to the restraining pressures of the retained soil.

The foundation of the existing frontage on King William Street and part of Nicholas Lane is no doubt bearing upon the Flood Plain Gravel. The proposed raft will, therefore, have a very similar founding level to that of this frontage. In plan the strip footing of this existing wall is locally extended beneath each pier position, as indicated on the Site Plan and therefore, the raft would have to be constructed around these extensions. The stresses resulting from the raft would, therefore, extend beneath the foundation of the frontage and appreciably beyond. Thus, the consolidation settlement induced beneath the raft will also be experienced by this adjacent footing. The existing footing and the new raft should settle at similar rates and could therefore be tied in together to form a continuous foundation. Should it be necessary to keep these foundations separate from one another, the differential settlement between them is only likely to occur during construction, when elastic settlements take place beneath the raft. This differential movement is likely to be less than 5 mm and thus, for practical purposes can be ignored.

5.5 Effect of Sulphates

The tests on selected samples of soil and ground water, indicate that only low concentrations of sulphur trioxide are present. Therefore, in accordance with Class 1 of the enclosed Sulphate Classification Table, a normal mix of Ordinary Portland Cement may be used for all foundation concrete.

T. S. Rickeard, B.Sc. M.Sc.
Geotechnical Engineer

Dr. J. A. Dixon, B.Sc. Ph.D. F.G.S.
Senior Geotechnical Engineer

APPENDIX

Boring Records

Standard Penetration Test Results

Corehole Records

Particle Size Distribution Tests

Triaxial Compression Tests

Consolidation Tests

Chemical Analyses

Sulphate Classification Table

Cohesion/Penetration Depth Graph

Table 1

Table 2

Key Section for Settlement Analyses

Key Plan for Settlement Analyses

Site Plan

Location Plan

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4	BOREHOLE No.:	1
CLIENT / Cons. Engs.:	Messrs. Swires / Bylander Waddell Partnership	REPORT No.:	2187/TSR
Method of Boring	Cable Percussion 200 mm diameter - cased to 14.00 m	Boring Started: / Boring Finished:	17.2.82 / 20.2.82

GROUND WATER

Water Strikes	Rate of Inflow:	Sealed off at:
1st: 12.00	Seepage	Not sealed
2nd:		
3rd:		

Date	17.2.82	17.2.82	18.2.82	
Time	16.00	16.20	08.00	
B/hole Depth	12.00	12.00	13.00	
Casing Depth	11.50	11.50	11.50	
Water Level	12.00	11.90	11.90	

Remarks: Water added to borehole from 7.00 m to 11.30 m. Chiselling on claystone at 13 m, 21.50 m, 34.00 m and 39.30 m for 4 hours.

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Depth (Scale: 20mm=1m)	Description (O.D.=16.601 m)
				0.20	Ground floor reinforced concrete and hollow brick
				3.50	Upper basement void
				3.90	Upper basement floor - reinforced concrete
				6.60	Lower basement void
				7.00	Lower basement floor - concrete
					Dense to very dense sub-angular gravel with brown silty sand
-	CPT	7.80	70*		
0880	B	7.80			
-	CPT	8.80	36		
0881	B	8.80			
-	CPT	9.80	104*		
0882	B	9.80			

Key: U = Undisturbed
B = Bulk
J = Jar
W = Water

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 1 Continuation Sheet No.: 1
Remarks:	Water added to borehole from 7.00 m to 11.30 m. Chiselling on claystone at 13.00 m, 21.50 m. 34.00 m and 39.30 m for 4 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Scale: 20mm = 1m Depth	O.D. =16.601 m	Description
						Dense to very dense sub-angular gravel with brown silty sand
-	CPT	10.80	63			
0883	B	10.80				
				11.30		
0884	J	11.35				Stiff brown/orange mottled fissured clay
0885	U	11.35 - 11.80				
0886	J	11.85		12.00		
0887	J	12.15				Stiff grey fissured clay
0888	U	12.50 - 12.95				
0889	J	13.50				
0890	U	14.40 - 14.45				
0891	J	15.00				
0892	U	15.50 - 15.95				
0893	J	16.50				
0894	U	17.00 - 17.45				
0895	J	18.00				
0896	U	18.50 - 18.95		19.00		
0897	J	19.50				Very stiff grey fissured clay with frequent fine sand partings
0898	U	20.00 - 20.45				
0899	J	21.00				

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 1 Continuation Sheet No.: 2
Remarks:	Chiselling on claystones at 13 m, 21.50 m, 34.0 m and 39.30 m for 4 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Legend	Depth	O.D.=16.601 m	Description
0900	U	22.00 - 22.45					Very stiff grey fissured clay with frequent fine sand partings
0901	J	23.00					
0902	U	23.50 - 23.95					
0903	J	24.50					
0904	U	25.00 - 25.45					
0905	J	26.00					
0906	U	26.50 - 26.95					
0907	J	27.50					
0908	U	28.00 - 28.45					
0909	J	29.00					
0910	U	29.50 - 29.95					
0911	J	30.50					
0912	U	31.00 - 31.45					
0914	J	32.00					
0915	U	32.50 - 32.95			33.00		
0916	J	33.50					Very stiff grey fissured clay with occasional fine sand partings

Scale: 20mm = 1m

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 1 Continuation Sheet No.: 3
Remarks:	Chiselling on claystones at 13 m, 21.50 m, 34.0 m and 39.30 m for 4 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Samples Type	Depth (m)	S.P.T. (N)	Scale: 20mm = 1m Legend	Scale: 20mm = 1m Depth	O.D. = 16.601 m	Description
							Very stiff grey fissured clay with occasional fine sand partings
0917	U	34.50 - 34.95					
0918	J	35.50					
0919	U	36.00 - 36.45					
0920	J	37.00					
0921	U	37.50 - 37.95					
0922	J	38.50					
0923	U	39.00 - 39.45					
0924	J	40.00					
0925	U	40.50 - 40.95					
0926	J	41.00			41.00		
0913	W	(11.90)					

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 2 Continuation Sheet No.: 2
Remarks:	Chiselling on claystones at 32.00 m and 36.50 m for 2 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)
0018	U	23.00 - 23.45	
0019	J	24.00	
0020	U	25.00 - 25.45	
0021	J	26.00	
0022	U	27.00 - 27.45	
0023	J	28.00	
0024	U	29.00 - 29.45	
0025	J	30.00	
0026	U	31.00 - 31.45	
0027	J	32.00	
0028	U	33.00 - 33.45	
0029	J	34.00	

Scale: 20mm = 1m. O.D. = 16.603 m

Depth (m)	Description
	Stiff becoming very stiff grey fissured clay, occasionally becoming slightly silty
28.00	Very stiff grey fissured slightly silty clay with frequent fine sand partings
32.50	Very stiff grey fissured clay with occasional discontinuous fine sand partings

Key: U = Undisturbed
B = Bulk
J = Jar

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 2 Continuation Sheet No.: 3
Remarks:	Chiselling on claystones at 32.00 m and 36.50 m for 2 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Legend	Depth	O.D. = 16.603 m	Description
							Very stiff grey fissured clay with occasional discontinous fine sand partings
0030	U	35.00 - 35.45					
0031	J	36.00					
0032	U	37.00 - 37.45					
0033	J	37.50			37.50		

Scale: 20mm = 1m

Key: U = Undisturbed
B = Bulk
J = Jar

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CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4	BOREHOLE No.:	3
CLIENT	Messrs. Swires	REPORT No.:	2187/TSR
Cons. Engs.:	Bylander Waddell Partnership		
Method of Boring	Cable Percussion 200 mm diameter - cased to 11.50 m.	Boring Started:	10.2.82
		Boring Finished:	15.2.82

GROUND WATER

Water Strikes	Rate of Inflow:	Sealed off at:
1st: None observed		
2nd:		
3rd:		

Date	12.2.82
Time	08.00
B/hole Depth	32.00
Casing Depth	11.50
Water Level	DRY

Remarks: Water added to borehole from 7.05 m to 11.00 m. Chiselling on claystone at 21.00 m, 28.90 m and 38.50 m for 3 hours

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Depth (Scale: 20mm = 1m)	O.D. = 16.603 m	Description
				0.25		Ground floor - reinforced concrete and hollow brick
				3.50		Upper basement void
				3.75		Upper basement floor - reinforced concrete and hollow brick
				6.70		Lower basement void
				7.05		Lower basement floor - concrete
						Very dense sub-angular gravel with brown silty sand, becoming clayey in parts
-	CPT	7.65	136*			
0833	B	7.65				
-	CPT	8.65	180*			
0834	B	8.65				
-	CPT	9.65	140*			
0835	B	9.65				

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.:	2
CLIENT	Messrs. Swires	REPORT No.:	2187/TSR
Cons. Engs.:	Bylander Waddell Partnership		
Method of Boring	Cable Percussion 200 mm diameter - cased to 11.50 m.	Boring Started:	3.3.82
		Boring Finished:	5.3.82

GROUND WATER							
Water Strikes	Rate of Inflow:	Sealed off at:	Date	4.3.82			
1st: None observed			Time	08.00			
2nd:			B/hole Depth	2.00			
3rd:			Casing Depth	11.50			
			Water Level	DRY			

Remarks: Water added to borehole from 7.10 m to 10.90 m. Chiselling on claystones at 32.00 m and 36.50 m for two hours.

Scale: 20mm = 1m — O.D. = 16.603 m

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Depth	Description
				0.35	Ground floor - reinforced concrete
				3.60	Upper basement void
				4.00	Upper basement floor - reinforced concrete
				6.70	Lower basement void
				7.10	Lower basement floor - concrete
-	CPT	7.65	225*		Very dense sub-angular gravel with brown silty sand
0001	B	7.65			
-	CPT	8.65	125*		
0002	B	8.65			
				9.30	
-	CPT	9.80	43		Dense brown medium sand with occasional pebbles
0003	B	9.80			
				10.00	

Key: U = Undisturbed
B = Bulk
J = Jar
W = Water

Wembley Laboratories Limited

CONTRACT & Location: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.

BOREHOLE No.: 2
Continuation Sheet No.: 1

Remarks: Water added to borehole from 7.10 m to 10.90 m
Chiselling on claystones at 32.00 m and 36.50 m for 2 hours

REPORT No.: 2187/TSR

Scale: 20mm = 1m

O.D. = 16.603m

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Depth	Description
					Very dense sub-angular gravel with brown silty sand
–	CPT	10.80	60		
0004	B	10.80		10.90	
0005	J	11.00			Stiff brown/grey fissured clay
0006	U	11.20 - 11.65		11.60	
0007	J	12.00			Stiff becoming very stiff grey fissured clay, occasionally becoming slightly silty
0008	U	13.00 - 13.45			
0009	J	14.00			
0010	U	15.00 - 15.45			
0011	J	16.00			
0012	U	17.00 - 17.45			
0013	J	18.00			
0014	U	19.00 - 19.45			
0015	J	20.00			
0016	U	21.00 - 21.45			
0017	J	22.00			

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 3 Continuation Sheet No.: 1
Remarks:	Water added to borehole from 7.05 m to 11.00 m. Chiselling on claystones at 21.00 m, 28.90 m and 38.50 m for 3 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Samples Type	Depth (m)	S.P.T. (N)	Scale: 20mm = 1m Depth	O.D. = 16.603 m	Description
-	CPT	10.65	108*			Very dense sub-angular gravel with brown silty sand, becoming clayey in parts
0836	B	10.65		11.00		
0837	J	11.20				Stiff brown/orange mottled fissured clay with traces of fine sand
0838	U	11.40 - 11.85		11.70		
0839	J	12.00				Stiff rapidly becoming very stiff, grey fissured clay
0840	U	13.00 - 13.45				
0841	J	14.00				
0842	U	14.50 - 14.95				
0843	J	15.50				
0844	U	16.00 - 16.45				
0845	J	17.00				
0846	U	17.50 - 17.95				
0847	J	18.50				
0848	U	19.00 - 19.45				
0849	J	20.00				
0850	U	20.50 - 20.95				
0851	J	21.50				

Key: U = Undisturbed
B = Bulk
J = Jar

Contract & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	Borehole No.: 3 Continuation Sheet No.: 2
Remarks:	Chiselling on claystones at 21.00 m, 28.90 m, and 38.50 m for 3 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Scale: 20mm = 1m Legend	Depth	O.D. = 16.603 m Description
0852	U	22.00 - 22.45				Stiff rapidly becoming very stiff, grey fissured clay
0853	J	23.00				
0854	U	23.50 - 23.95				
0855	J	24.50				
0856	U	25.00 - 25.45				
0857	J	26.00			26.00	
						Very stiff grey fissured clay with frequent fine sand partings; becoming slightly silty in parts
0858	U	26.50 - 26.95				
0859	J	27.50				
0860	U	28.50 - 28.95				
0861	J	29.00				
0862	U	30.00 - 30.45				
0863	J	31.00				
0864	U	31.50 - 31.95				
0865	J	32.50				
0866	U	33.00 - 33.45				
0867	J	34.00				

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 3 Continuation Sheet No.: 3
Remarks:	Chiselling on claystones at 21.00 m. 28.90 m and 38.5 m for 3 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Scale: 20mm = 1m Depth	O.D. = 16.603m Description
					Very stiff grey fissured clay with frequent fine sand partings; becoming slightly silty in parts
0868	U	34.50 - 34.95		35.00	
0869	J	35.50			Very stiff grey fissured clay with occasional fine sand partings
0870	U	36.00 - 36.45			
0871	J	37.00			
0872	U	37.50 - 37.95			
0873	J	38.50			
0874	U	39.00 - 39.45			
0875	J	40.00		40.00	
					Hard grey fissured slightly silty clay with frequent fine sand partings
0876	U	40.50 - 40.95			
0877	J	41.50			
0878	U	42.00 - 42.45		42.50	
0879	J	42.50			

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4	BOREHOLE No.:	4
CLIENT	Messrs. Swires	REPORT No.:	2187/TSR
Cons. Engs.:	Bylander Waddell Partnership		
Method of Boring	Cable Percussion 200 m diameter - cased to 11.50 m.	Boring Started:	24.2.82
		Boring Finished:	1.3.82

GROUND WATER

Water Strikes	Rate of Inflow:	Sealed off at:
1st: None	observed	
2nd:		
3rd:		

Date	1.3.82	1.3.82	1.3.82	
Time	08.00	17.00	17.20	
B/hole Depth	50.00	10.50	10.50	
Casing Depth	11.50	10.50	10.50	
Water Level	DRY	10.45	10.45	

Remarks: Water added to borehole from 7.00 m to 11.20 m. Chiselling on claystones at 20.0 m and 36.50 m for 2 hours

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Depth (Scale: 20mm = 1m)	Description (O.D. = 16.60 m)
				0.20	Ground floor - reinforced concrete and hollow brick
				3.50	Upper basement void
				4.05	Upper basement floor - reinforced concrete
				6.60	Lower basement void
				7.00	Lower basement floor - concrete
					Very dense sub-angular gravel with brown silty sand
-	CPT	7.65	104*		
0927	B	7.65			
-	CPT	8.65	140*		
0928	B	8.65			
-	CPT	9.80	120*		
0929	B	9.80			

Key: U = Undisturbed
B = Bulk
J = Jar
W = Water

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4	BOREHOLE No.: 4 Continuation Sheet No.: 1
Remarks:	Water added to borehole from 7.00 m to 11.20 m. Chiselling on claystones at 20 m and 36.50 m for 2 hours	REPORT No.: 2187/TSR

Scale: 20mm = 1m

O.D. = 16.60 m

Samples Ref. No.	Samples Type	Depth (m)	S.P.T. (N)	Legend	Depth	Description
						Very dense sub-angular gravel with brown silty sand
-	CPT	10.80	35			
0930	B	10.80				
					11.20	
0931	J	11.30				Stiff to very stiff brown/orange mottled fissured slightly silty clay
0932	U	11.40 - 11.85				
0933	J	11.87				
					11.90	
0934	J	12.20				Very stiff grey fissured clay
0935	U	13.40 - 13.85				
0936	J	14.00				
0937	U	15.00 - 15.45				
0938	J	16.00				
0939	U	17.00 - 17.45				
0940	J	18.00				
0941	U	19.00 - 19.45				
0942	J	20.00				
0943	U	21.00 - 21.45				
0944	J	22.00				

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 4 Continuation Sheet No.: 2
Remarks:	Chiselling on claystones at 20.00 m and 36.50 m for 2 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Legend	Depth (Scale: 20mm = 1m)	O.D. = 16.60 m Description
						Very stiff grey fissured clay
0945	U	23.00 - 23.45				
0946	J	24.00				
0947	U	25.00 - 25.45				
0948	J	26.00				
0949	U	27.00 - 27.45			27.30	
0950	J	27.50			27.60	"very stiff" grey clayey sandy silt
						Very stiff grey fissured clay with frequent fine sand partings; becoming slightly silty in parts
0951	U	29.00 - 29.45				
0952	J	30.00				
0953	U	31.00 - 31.45				
0954	J	32.00				
0955	U	33.00 - 33.45				
0956	J	34.00				

Key: U = Undisturbed
B = Bulk
J = Jar

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 4 Continuation Sheet No.: 3
Remarks:	Chiselling on claystones at 20.00 m and 36.50 m for 2 hours	REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Legend	Depth (Scale: 20mm = 1m)	O.D. = 16.60 m / Description
						Very stiff grey fissured clay with frequent fine sand partings; becoming slightly silty in parts
0957	U	35.00 - 35.45			35.50	
						Very stiff grey fissured clay
0958	J	36.00				
0959	U	37.00 - 37.45				
0960	J	38.00				
0961	U	39.00 - 39.45				
0962	J	40.00			40.00	
						Hard grey fissured silty clay with fine sand partings, becoming frequent with depth
0963	U	41.00 - 41.45				
0964	J	42.00				
0965	U	43.00 - 43.45				
0966	J	44.00				
0967	U	45.00 - 45.45				
0968	J	46.00				

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	BOREHOLE No.: 4 Continuation Sheet No.: 4
Remarks:		REPORT No.: 2187/TSR

Samples Ref. No.	Type	Depth (m)	S.P.T. (N)	Legend	Depth	O.D. = 16.60 m	Description
							Hard grey fissured silty clay with fine sand partings, becoming frequent with depth
0969	U	47.00 - 47.45					
0970	J	48.00					
0971	U	49.50 - 49.95					
0972	J	50.00			50.00		
0973	W	(10.45)					

Scale: 20mm = 1m

Key: U = Undisturbed
B = Bulk
J = Jar

Wembley Laboratories Limited

CONTRACT & Location: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4. REPORT No.: 2187/TSR

STANDARD PENETRATION TEST RESULTS

Depth at Start of Test	Spoon or Cone	Blows for each successive 75 mm. penetration								Water Level	Is Hole Blowing
BOREHOLE	No1										
7.50	C	5	10	14	15	20	–	–	–	7.0	No
8.50	C	1	2	7	11	8	10	10	12	8.10	No
9.50	C	6	11	17	35	–	–	–	–	8.90	No
10.50	C	5	9	14	15	16	18	–	–	10.00	No
BOREHOLE	No2										
7.50	C	16	37	25/25mm	–	–	–	–	–	7.30	NO
8.50	C	10	27	35	–	–	–	–	–	8.20	No
9.50	C	2	5	8	10	11	14	15	15	9.30	No
10.50	C	3	6	12	12	19	17	14	9	10.40	No
BOREHOLE	No3										
7.50	C	12	26	42	–	–	–	–	–	7.30	No
8.50	C	12	35	30/40mm	–	–	–	–	–	8.20	No
9.50	C	8	12	25	25/40mm	–	–	–	–	9.20	No
10.50	C	11	25	29	28	–	–	–	–	10.10	No
BOREHOLE	No4										
7.50	C	10	17	35	–	–	–	–	–	7.30	No
8.50	C	15	30	20/37mm	–	–	–	–	–	8.20	No
9.50	C	10	15	19	26	34	–	–	–	9.40	No
10.50	C	7	10	10	8	9	8	8	9	DRY	–

WL 450

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HORIZONTAL COREHOLE RECORDS

Horizontal coreholes of 75 mm diameter carried out on 18th, 19th and 22nd February, 1982 using electrically powered diamond drilling equipment.

LOWER BASEMENT LEVEL

COREHOLE A1

0 m - 0.210 m	Brickwork.
0.210 m - 0.235 m	Bitumen waterproofing layer.
0.235 m - 0.610 m	Weak uncompacted concrete with brick and flint aggregate and numerous air voids.
0.610 m - 0.700 m	Very weak poorly cemented concrete - fragmenting rapidly during drilling.

Remarks: Further progress not possible due to fragmentation of weak concrete.

COREHOLE B1

0 m - 0.930 m	Brickwork.
0.930 m - 0.950 m	Bitumen sealing layer.
Beyond 0.050 m	Gravel with brown sand.

COREHOLE C1

0 m - 0.907 m	Brickwork.
0.907 m - 0.930 m	Bitumen sealing layer.
Beyond 0.930 m	Gravel with brown sand.

COREHOLE D1

0 m - 0.820 m	Brickwork.
0.820 m - 0.840 m	Bitumen sealing layer.
Beyond 0.840 m	Very weak poorly cemented concrete.

Remarks: Further progress not possible due to fragmentation of weak concrete.

COREHOLE E1

0 m	- 0.810 m	Brickwork.
0.810 m	- 0.835 m	Bitumen sealing layer.
Beyond	0.835 m	Very weak poorly cemented concrete, fragmenting during drilling.

Remarks: Further drilling not possible due to fragmentation of weak concrete.

COREHOLE F1

0 m	- 0.030 m	Cement rendering.
0.030 m	- 0.760 m	Brickwork.
0.760 m	- 0.780 m	Bitumen sealing layer.
Beyond	0.780 m	Very weak poorly cemented concrete.

Remarks: Further drilling not possible due to fragmentation of weak concrete.

UPPER BASEMENT LEVEL

COREHOLE A2

0 m	- 0.02 m	Rendering.
0.02 m	- 0.450 m	Brickwork.
Beyond	0.450 m	Clay and chalk fill with stones.

COREHOLE B2

0 m	- 0.400 m	Brickwork.
Beyond	0.400 m	Clay and chalk fill with stones.

COREHOLE C2

0 m	- 0.03 m	Rendering.
0.03 m	- 0.400 m	Brickwork.
Beyond	0.400 m	Heavy timbering.

Remarks: Further drilling not possible in wood.

CORЕHOLE D2

0 m - 0.01 m	Rendering.
0.01 m - 0.720 m	Brickwork.
0.720 m - 0.740 m	Bitumen sealing layer.
0.740 m - 1.01 m	Mass concrete fill with bricks.
1.01 m - 1.10 m	Very weak mass concrete fill with bricks - fragmenting during drilling.
Beyond 1.10 m	Stones - possibly gravel.

COREHOLE E2

0 m - 0.05 m	Ceramic tile.
0.05 m - 0.40 m	Brickwork.
Beyond 0.40 m	Clay fill with abundant brick fragments and stones.

COREHOLE F2

0 m - 0.005 m	Ceramic wall tile.
0.005 m - 0.730 m	Brickwork.
0.730 m - 0.750 m	Bitumen sealing layer.
0.750 m - 1.700 m	Strong compacted concrete.
1.700 m - 1.900 m	Brickwork.
Beyond 1.900 m	Black clay fill.

REMARKS: Ground water was not observed in any corehole.

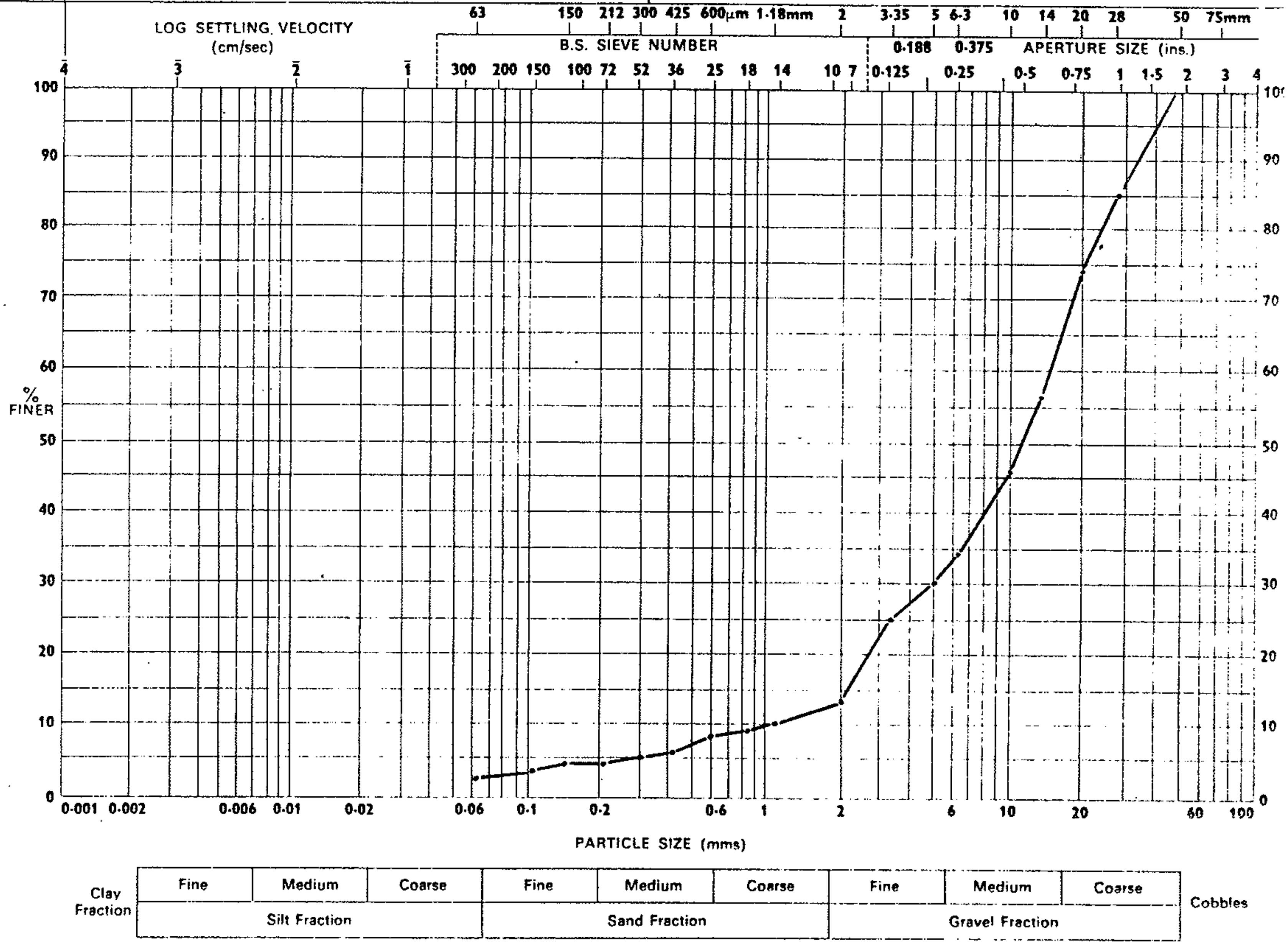
Wembley Laboratories Limited

CONTRACT KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.
REPORT No.: 2187/TSR

Borehole No.	Sample No.	Depth m
1	0880	7.80

Visual Description:

Sub-angular gravel with brown silty sand.



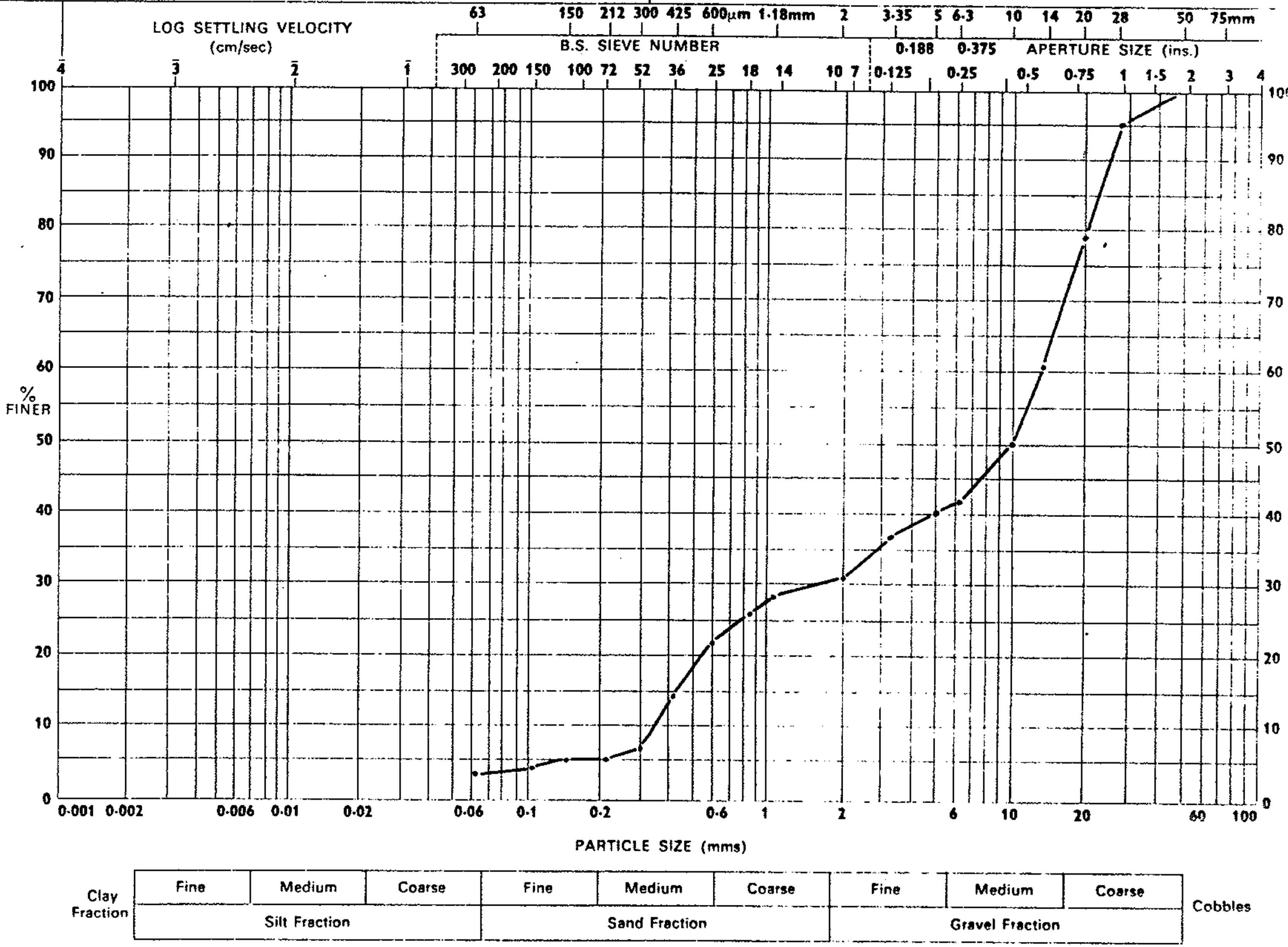
PARTICLE SIZE DISTRIBUTION

CONTRACT KING WILLIAM STREET/NICHOLAS LANE, E.C.4.
REPORT No.: 2187/TSR

Borehole No.	Sample No.	Depth m
3	0833	7.80

Visual Description:

Sub-angular gravel with brown slightly silty sand.



PARTICLE SIZE DISTRIBUTION

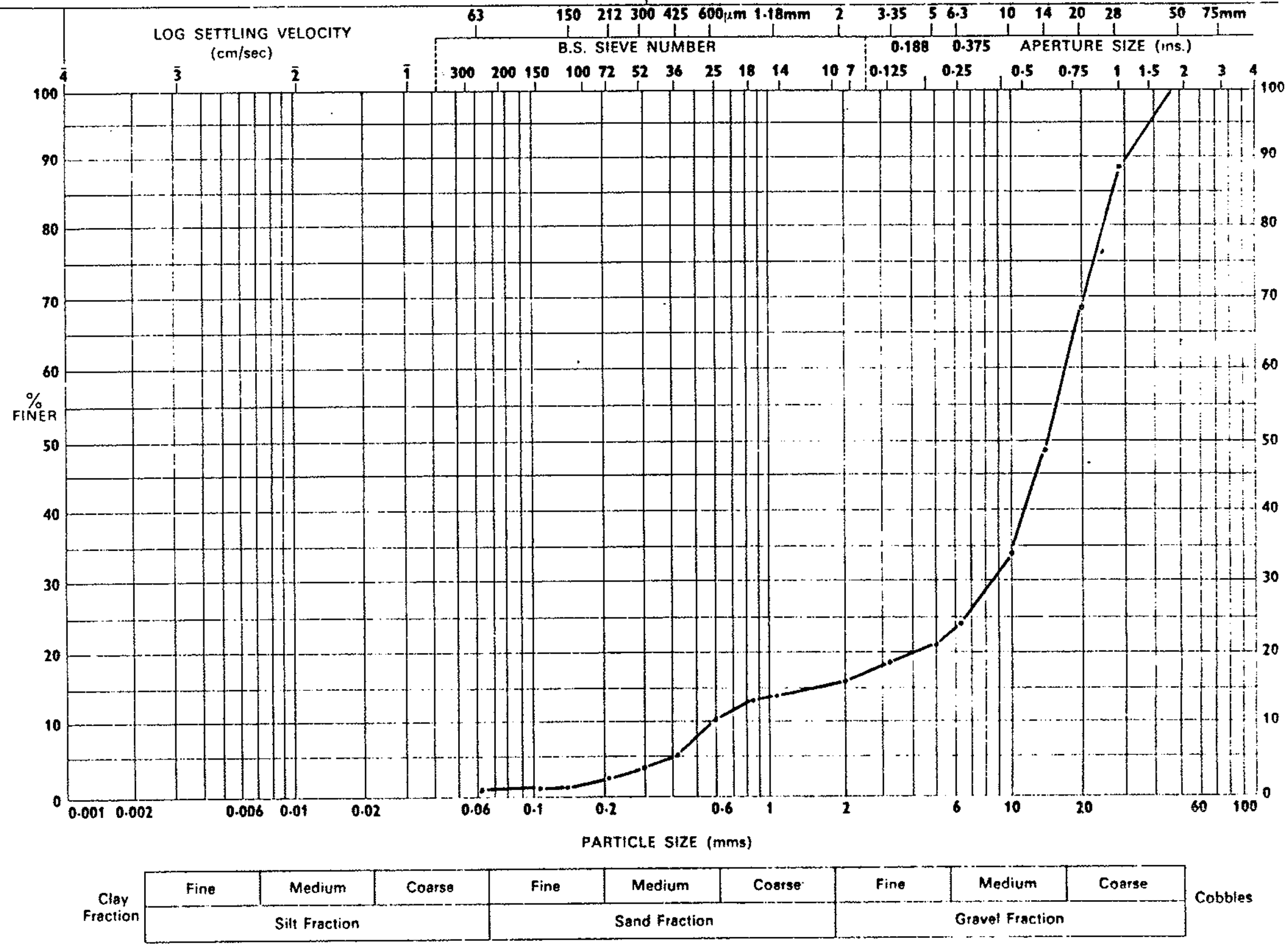
Wembley Laboratories Limited

CONTRACT KING WILLIAM STREET/NICHOLAS LANE, E.C.4.
REPORT No.: 2187/TSR

Borehole No.	Sample No.	Depth m
4	0927	7.80

Visual Description:

Sub-angular gravel with brown sand.



PARTICLE SIZE DISTRIBUTION

Wembley Laboratories Limited

CONTRACT & Location: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.

REPORT No.: 2187/TSR

TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m²	Compr. Strength kN/m²	Bulk Density kg/m³	Water Content %	Cohesion kN/m²	Angle of Friction degrees	Remarks
1	11.35 - 11.80	38 U	200 300 450	275 295 285	1950 1900 1950	28.6 30.5 29.8	140	0	
	12.50 - 12.95	38 U	200 300 450	225 245 285	1960 1940 1950	27.5 27.4 28.0	125	0	
	14.00 - 14.45	38 U	200 300 450	310 335 340	1980 2000 1950	25.6 26.2 26.1	165	0	
	15.50 - 15.95	38 U	200 300 450	285 300 255	1970 1970 1970	26.3 25.9 26.3	140	0	
	17.00 - 17.45	38 U	200 300 450	275 620 515	1950 1970 2020	25.5 25.7 24.7	235	0	
	18.50 - 18.95	38 U	200 300 450	185 230 270	1970 1970 1980	27.6 27.5 27.4	115	0	
	20.00 - 20.45	38 U	450 600 750	265 450 450	1970 1970 1960	25.2 25.1 25.7	195	0	
	22.00 - 22.45	38 U	450 600 750	460 555 450	1940 1930 1950	27.2 27.7 26.8	245	0	
	23.50 - 23.95	38 U	450 600 750	730 810 810	1980 1950 1930	25.4 26.3 26.0	390	0	
	25.00 - 25.45	38 U	450 600 750	495 565 640	1970 1950 1930	27.2 27.0 27.3	285	0	
	26.50 - 26.95	38 U	450 600 750	755 640 350	1960 2000 1900	25.9 22.3 26.3	290	0	
	28.50 - 28.45	102 U	600	670	2020	23.1	335	0	
	29.50 - 29.95	38 U	450 600 750	715 485 805	1900 1970 2000	23.7 24.7 23.4	335	0	
	31.00 - 31.45	102 U	650	645	2050	23.4	320	0	

Test Code: U = undrained M = multi-stage

CONTRACT & Location: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.

REPORT No.: 2187/TSR

TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m²	Compr. Strength kN/m²	Bulk Density kg/m³	Water Content %	Cohesion kN/m²	Angle of Friction degrees	Remarks
1	32.50 - 32.95	38 U	450 750	675 660	1950 1950	22.6 23.3	335	0	
	34.50 - 34.95	38 U	750	355	1890	24.3	175	0	Specimen failed along fissure - 2 specimens water softened
	36.00 - 36.45	102 U	750	485	2010	25.0	240	0	
	37.50 - 37.95	38 U	450 600 750	445 550 620	1910 1940 1910	26.2 26.2 25.9	270	0	
	39.00 - 39.45	102 U	800	310	1940	26.3	155	0	
	40.50 - 40.95	102 U	850	320	1850	28.8	160	0	Sample contaminated with wax
2	11.20 - 11.65	38 U	200 300 450	225 265 350	1930 1890 1890	27.9 28.6 28.8	140	0	
	13.00 - 13.45	38 U	200 300 450	240 250 285	1910 1930 1960	27.9 28.5 27.3	130	0	
	15.00 - 15.45	38 U	200 300 450	235 360 315	1930 1960 1950	26.7 26.4 25.8	150	0	
	17.00 - 17.45	38 U	200 300 450	195 325 395	1960 1960 1960	26.1 26.6 25.7	150	0	
	19.00 - 19.45	38 U	200 300 450	385 410 345	1930 1930 1960	26.9 27.3 27.0	190	0	
	21.00 - 21.45	38 U	450 600 750	460 590 690	2000 1900 1940	25.5 25.2 25.8	290	0	
	23.00 - 23.45	38 U	450 750	345 360	1900 1950	27.2 27.5	175	0	
	25.00 - 25.45	38 U	450 600 750	310 325 280	1870 1870 1870	26.8 26.9 27.2	150	0	

Test Code: U = undrained, M = multi-stage

CONTRACT & Location	KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	REPORT No.: 2187/TSR

TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m²	Compr. Strength kN/m²	Bulk Density kg/m³	Water Content %	Cohesion kN/m²	Angle of Friction degrees	Remarks
2	27.00 - 27.45	38 U	450 600 750	635 485 490	1940 1860 1910	26.1 26.7 26.9	270	0	
	29.00 - 29.45	102 U	600	565	2000	24.4	280	0	
	31.00 - 31.45	38 U	450 600 750	990 730 675	2000 2000 2000	22.3 21.8 19.6	400	0	
	33.00 - 33.45	102 U	700	460	2000	23.7	230	0	
	35.00 - 35.45	38 U	450 600 750	375 460 305	1900 1940 1910	26.1 26.4 26.2	190	0	
	37.00 - 37.45	102 U	750	460	1990	24.8	230	0	
3	11.40 - 11.85	38 U	200 300 450	365 365 195	1960 1950 1930	28.2 28.4 28.7	155	0	
	13.00 - 13.45	38 U	200 300 450	485 560 430	1970 2040 1960	26.4 26.1 24.4	245	0	
	14.50 - 14.95	38 U	200 300 450	355 365 525	1940 1890 1910	26.5 26.1 26.5	210	0	
	16.00 - 16.45	38 U	200 300 450	320 345 470	1950 1940 1940	25.4 24.9 25.0	190	0	
	17.50 - 17.95	38 U	200 300 450	185 365 475	1930 1950 1950	26.4 26.2 26.1	170	0	
	19.00 - 19.45	38 U	200 300 450	455 490 430	1930 1960 1930	27.1 26.8 27.3	230	0	
	20.50 - 20.95	38 U	450 600 750	265 390 385	1930 1960 1950	27.7 25.8 25.8	175	0	
	22.00 - 22.45	38 U	450 600 750	495 490 480	1950 1950 1950	26.7 25.8 26.8	245	0	
	23.50 - 23.95	38 U	450 600 750	445 465 480	1970 1970 1980	25.7 26.4 25.2	230	0	

Test Code: U = undrained
M = multi-stage

TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m²	Compr. Strength kN/m²	Bulk Density kg/m³	Water Content %	Cohesion kN/m²	Angle of Friction degrees	Remarks
3	25.00 - 25.45	38 U	450 600 750	585 705 710	1960 1930 1970	26.4 26.8 26.2	335	0	
	26.50 - 26.95	38 U	450 600 750	655 725 775	1950 1950 1950	25.1 24.3 24.2	360	0	
	28.50 - 28.95	102 U	600	670	1970	23.4	335	0	
	30.00 - 30.45	38 U	450 600 750	525 410 545	2000 1950 2000	25.1 23.3 21.3	245	0	
	31.50 - 31.95	38 U	450 600 750	585 525 625	1970 2000 1960	23.9 21.9 24.8	290	0	
	33.00 - 33.45	102 U	700	550	2000	24.4	275	0	
	34.50 - 34.95	38 U	450 600 750	365 465 450	1930 1960 1950	25.5 23.2 23.1	215	0	
	36.00 - 36.45	38 U	450 750	605 625	1950 1900	25.0 25.2	305	0	
	37.50 - 37.95	102 U	750	680	1960	27.4	340	0	
	39.00 - 39.45	38 U	450 600 750	370 405 510	1880 1880 1890	29.0 25.2 26.6	215	0	
	40.50 - 40.95	38 U	450 600 750	780 665 730	1950 1960 1940	22.7 25.7 25.2	360	0	
	42.00 - 42.45	102 U	850	1070	2050	21.7	535	0	
4	11.40 - 11.85	38 U	200 300 450	325 400 375	1970 1900 1930	27.0 27.3 27.0	185	0	
	13.40 - 13.85	38 U	200 300 450	365 435 295	1950 2010 2000	26.1 25.2 25.1	185	0	
	15.00 - 15.45	38 U	200 300 450	440 430 470	2000 2010 1970	24.4 24.9 24.2	225	0	

Test Code: U = undrained M = multi-stage

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TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m²	Compr. Strength kN/m²	Bulk Density kg/m³	Water Content %	Cohesion kN/m²	Angle of Friction degrees	Remarks
4	17.00 - 17.45	38 U	200 300 450	340 305 360	2000 1950 1940	27.2 27.4 27.4	170	0	
	19.00 - 19.45	38 U	200 300 450	240 630 245	1970 2010 1950	25.7 26.2 25.4	185	0	
	21.00 - 21.45	38 U	450 600 750	400 365 365	1970 1960 1970	26.3 26.2 26.6	190	0	
	23.00 - 23.45	38 U	450 600 750	280 415 490	1900 1960 1970	28.0 27.6 27.7	200	0	
	25.00 - 25.45	38 U	450 600 750	375 500 360	1970 1980 1930	24.7 26.3 24.9	205	0	
	27.00 - 27.45	102 U	550	505	1960	23.3	255	0	
	29.00 - 29.45	38 U	450 600 750	450 325 465	1940 1980 1980	21.8 23.0 20.8	205	0	
	31.00 - 31.45	38 U	450 600 750	425 490 565	1890 1940 1940	25.1 24.7 24.7	245	0	
	33.00 - 33.45	38 U	450 600 750	265 290 245	1910 2010 1940	24.5 25.1 22.8	135	0	
	35.00 - 35.45	102 U	700	485	1990	23.9	240	0	
	37.00 - 37.45	38 U	450 750	350 460	1910 1900	28.7 27.5	205	0	
	39.00 - 39.45	38 U	450 600 750	350 (115) 395	1810 1890 1910	24.9 25.0 24.4	185	0	
	41.00 - 41.45	38 U	450 600 750	435 505 415	1820 1890 1880	26.8 26.0 26.3	225	0	
	43.00 - 43.45	102 U	900	930	1960	23.9	465	0	
	45.00 - 45.45	38 U	450 600 750	730 890 615	1950 2000 2000	20.2 20.7 20.6	375	0	

Test Code: U = undrained
M = multi-stage

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TRIAXIAL COMPRESSION

Borehole No.	Depth m	Test Code	Lateral Pressure kN/m^2	Compr. Strength kN/m^2	Bulk Density kg/m^3	Water Content %	Cohesion kN/m^2	Angle of Friction degrees	Remarks
4	47.00 - 47.45	38 U	450 600 750	545 425 455	1910 1880 1900	25.0 26.5 24.6	235	0	
	49.50 - 49.95	102 U	1000	850	1970	24.2	425	0	

Test Code: U = undrained, M = multi-stage

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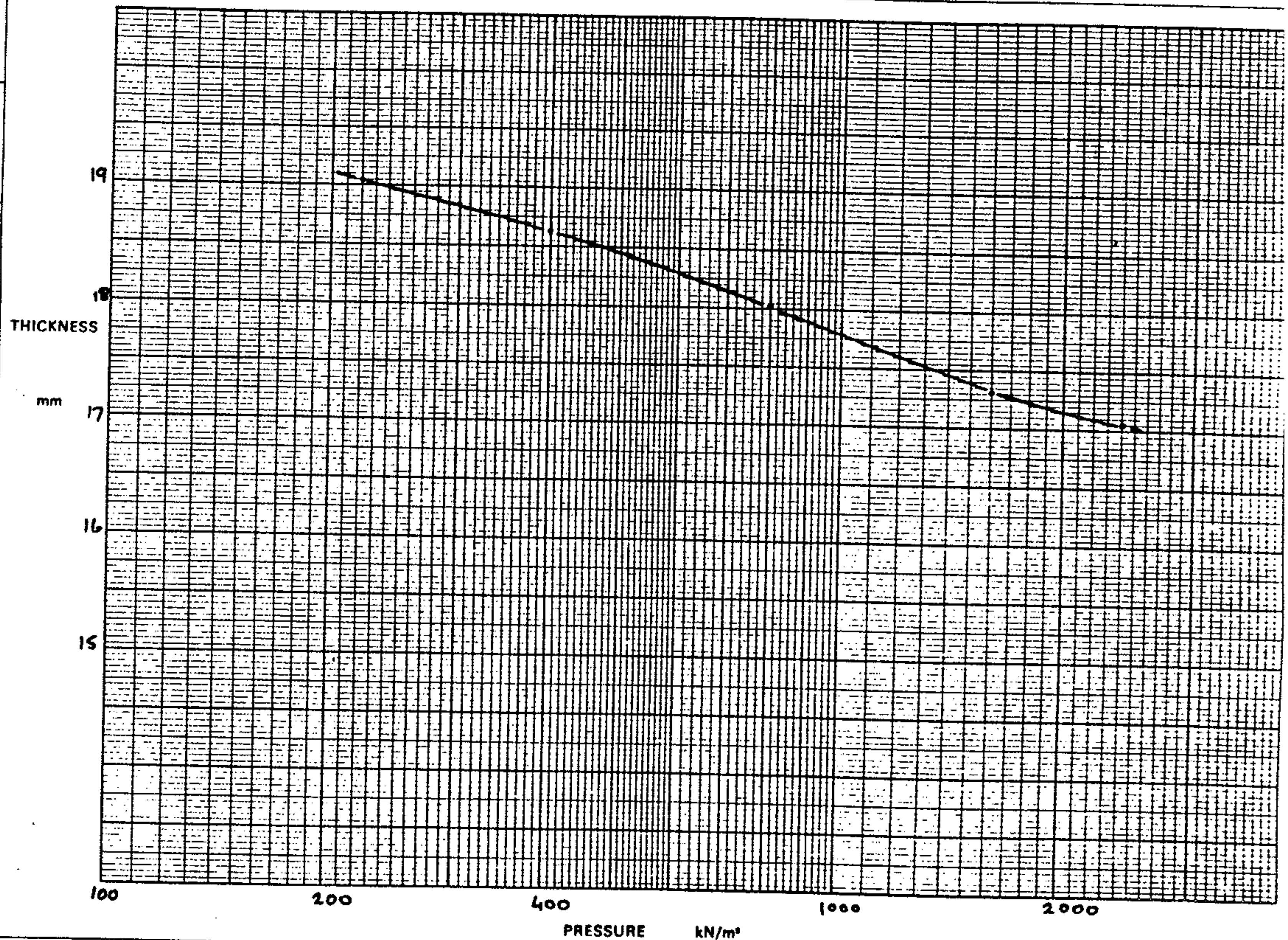
Borehole No.	Sample No.	Depth m
1	0885	11.35 - 11.80

Description:

Brown fissured clay.

Natural Water Content %	Bulk Density kg/m³	
28·8	1930	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
220		
	120	1·40
400		
	85	0·85
800		
	50	0·50
1600		
	35	0·40
2400		



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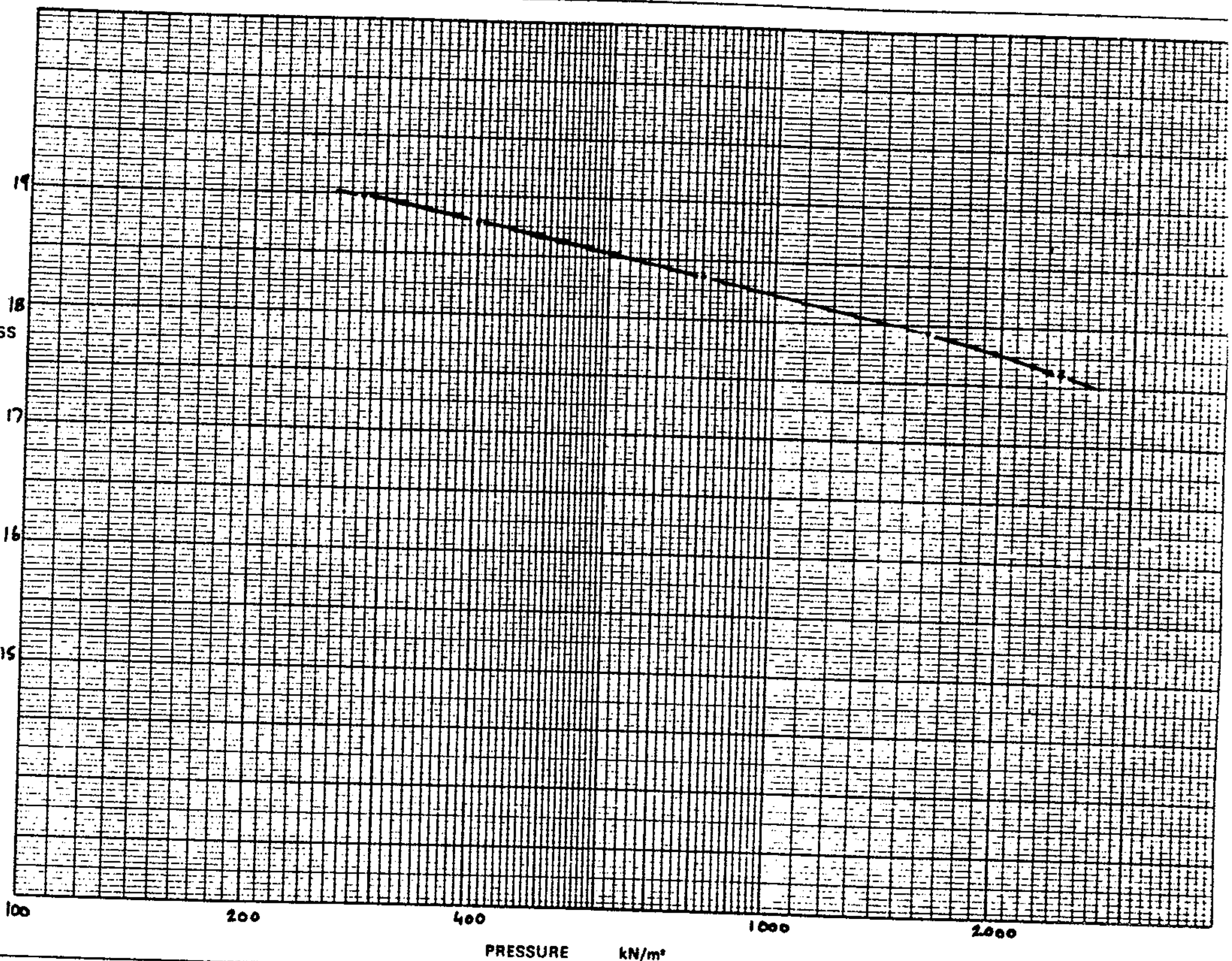
REPORT No.: 2187/TSR

Borehole No.	Sample No.	Depth m
1	0890	14.00 - 14.45

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
26.0	1980	



Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
280		
400	90	3·25
800	55	1·85
1600	30	1·60
2400	25	1·20

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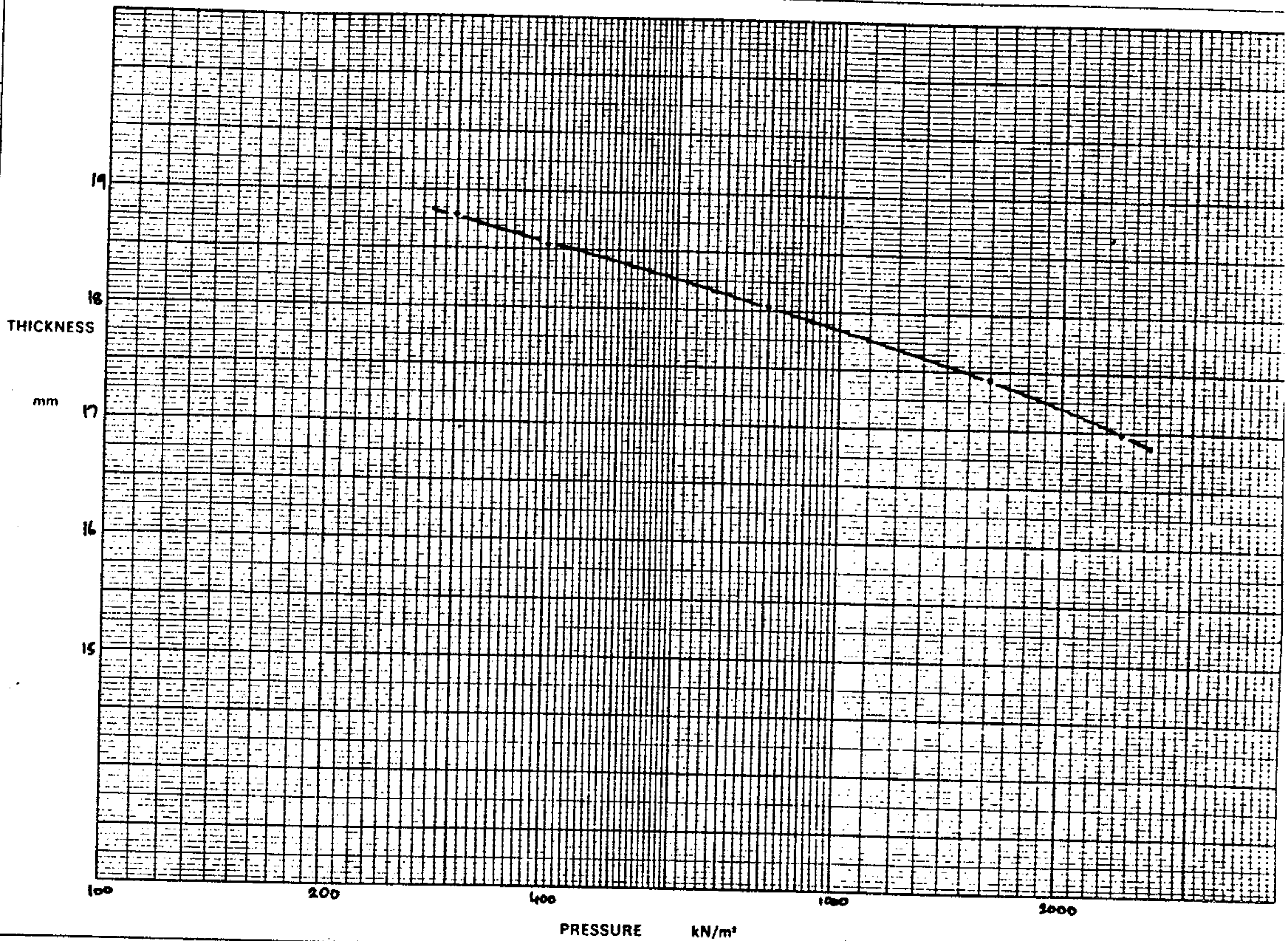
Borehole No.	Sample No.	Depth m
1	0894	17.00 - 17.45

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
25.0	1980	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
300		
	140	1.90
400		
	70	0.75
800		
	45	0.65
1600		
	30	0.55
2400		



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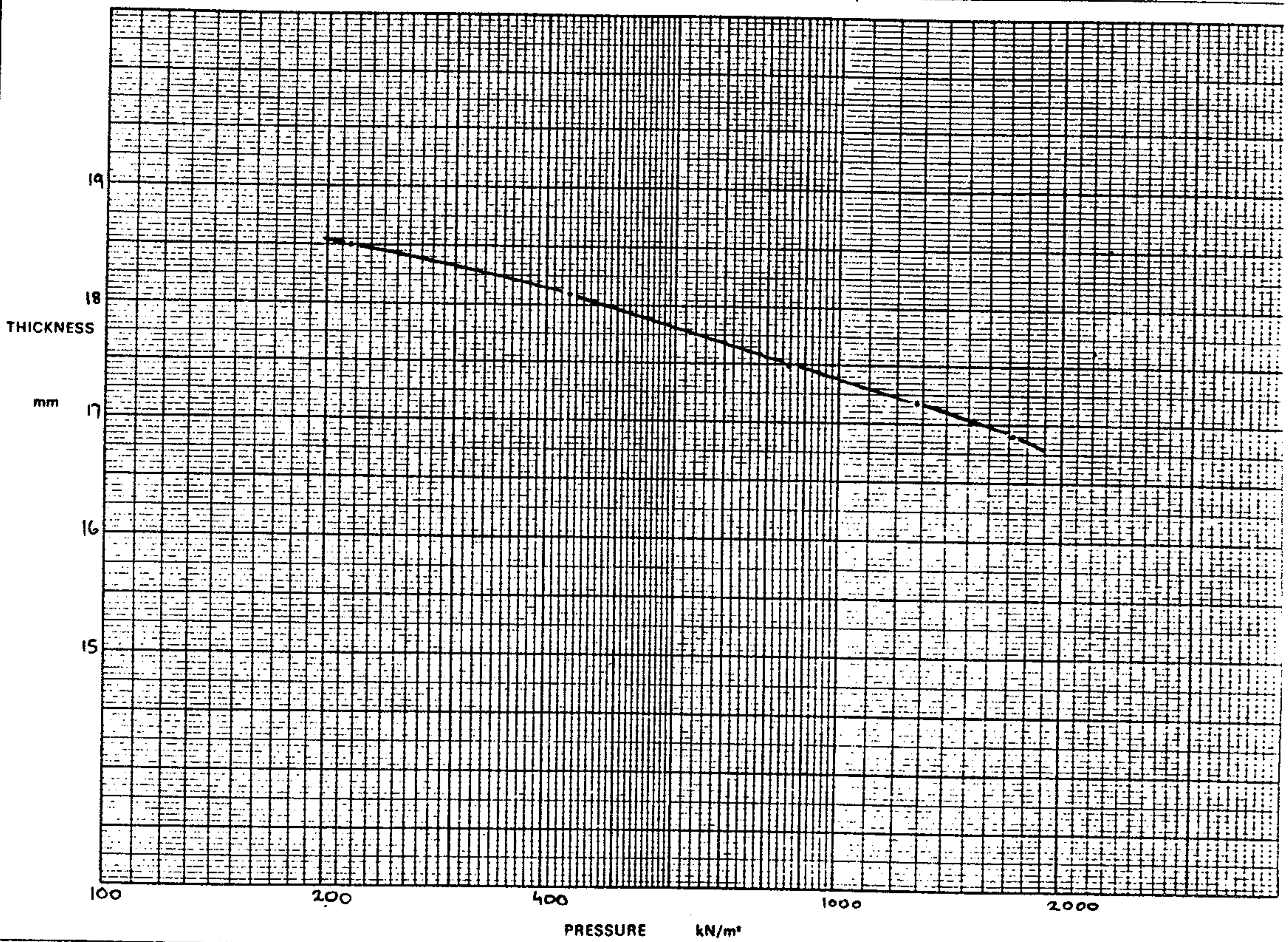
Borehole No.	Sample No.	Depth m
2	0006	11.20 - 11.65

Description:
Brown/grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
24.6	1900	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
215		
	105	2.55
430		
	80	1.90
855		
	45	1.25
1285		
	40	1.10
1710		



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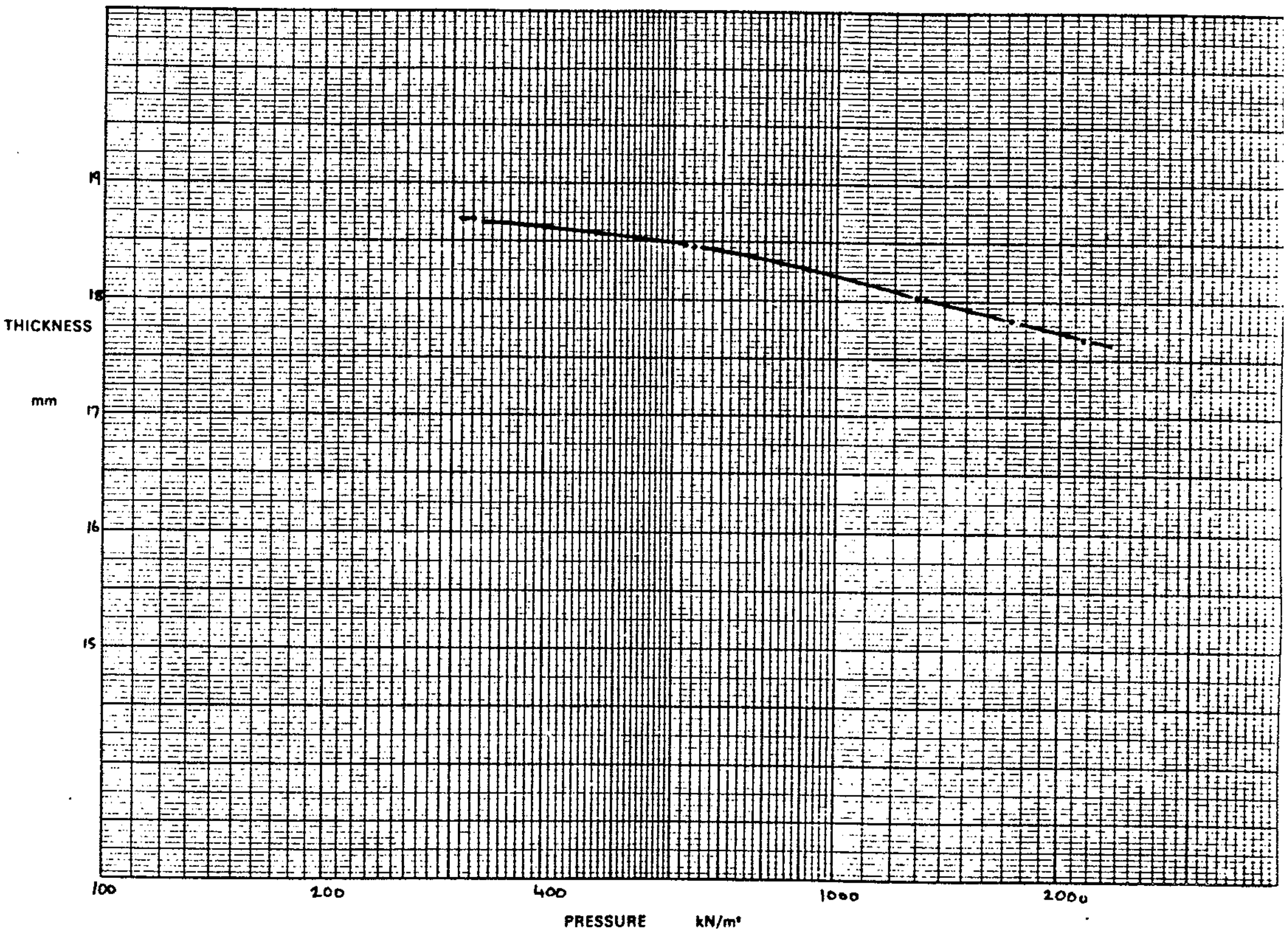
Borehole No.	Sample No.	Depth m
2	0016	21.00 - 21.45

Description:
Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
22.9	1950	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
320		
	40	3.10
640		
	35	1.10
1285		
	25	1.00
1710		
	20	0.95
2140		



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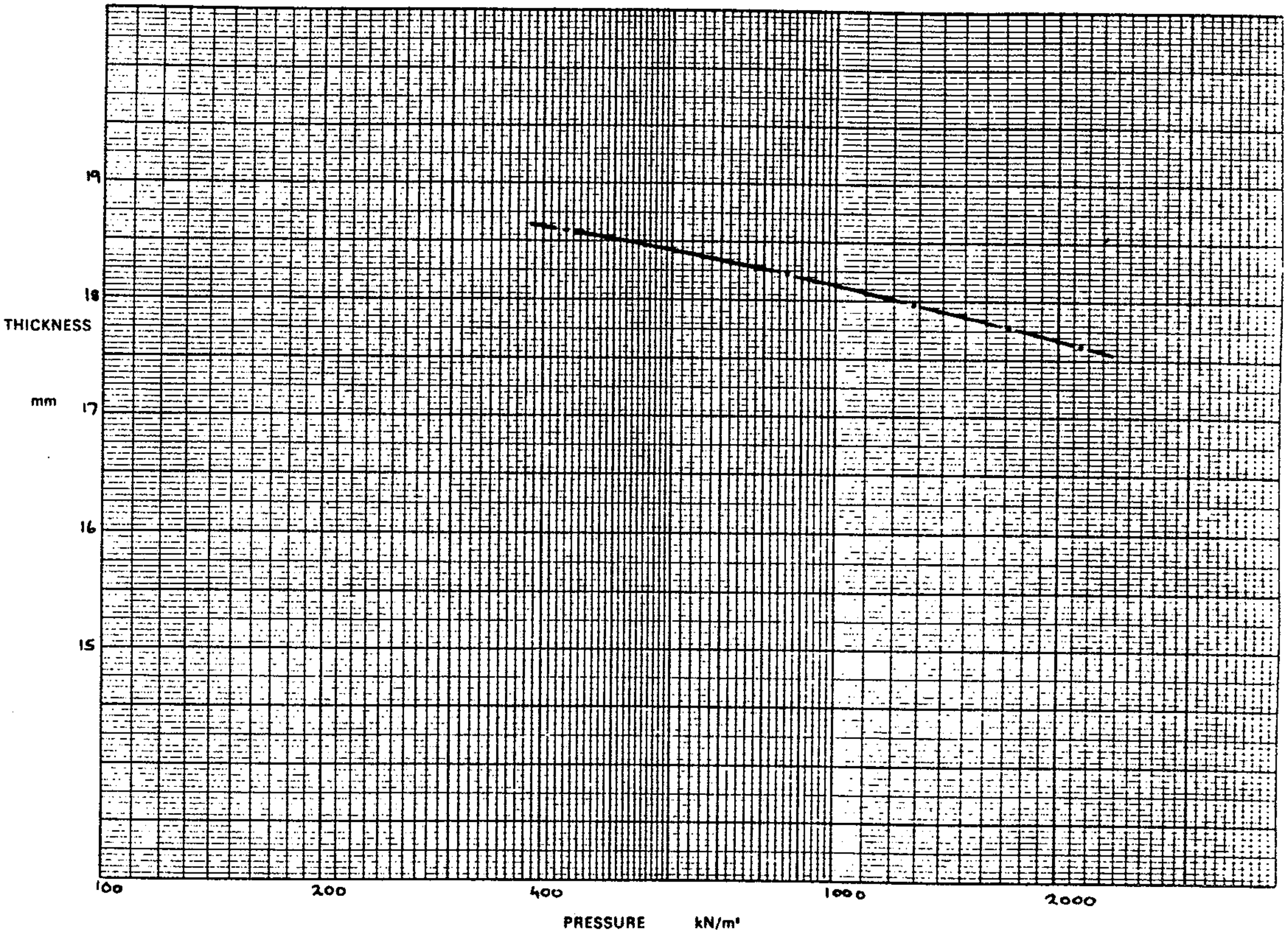
Borehole No.	Sample No.	Depth m
2	0022	27.00 - 27.45

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
22·4	1900	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
430		
	45	2·35
855		
	35	0·70
1285		
	25	0·65
1710		
	15	0·60
2140		



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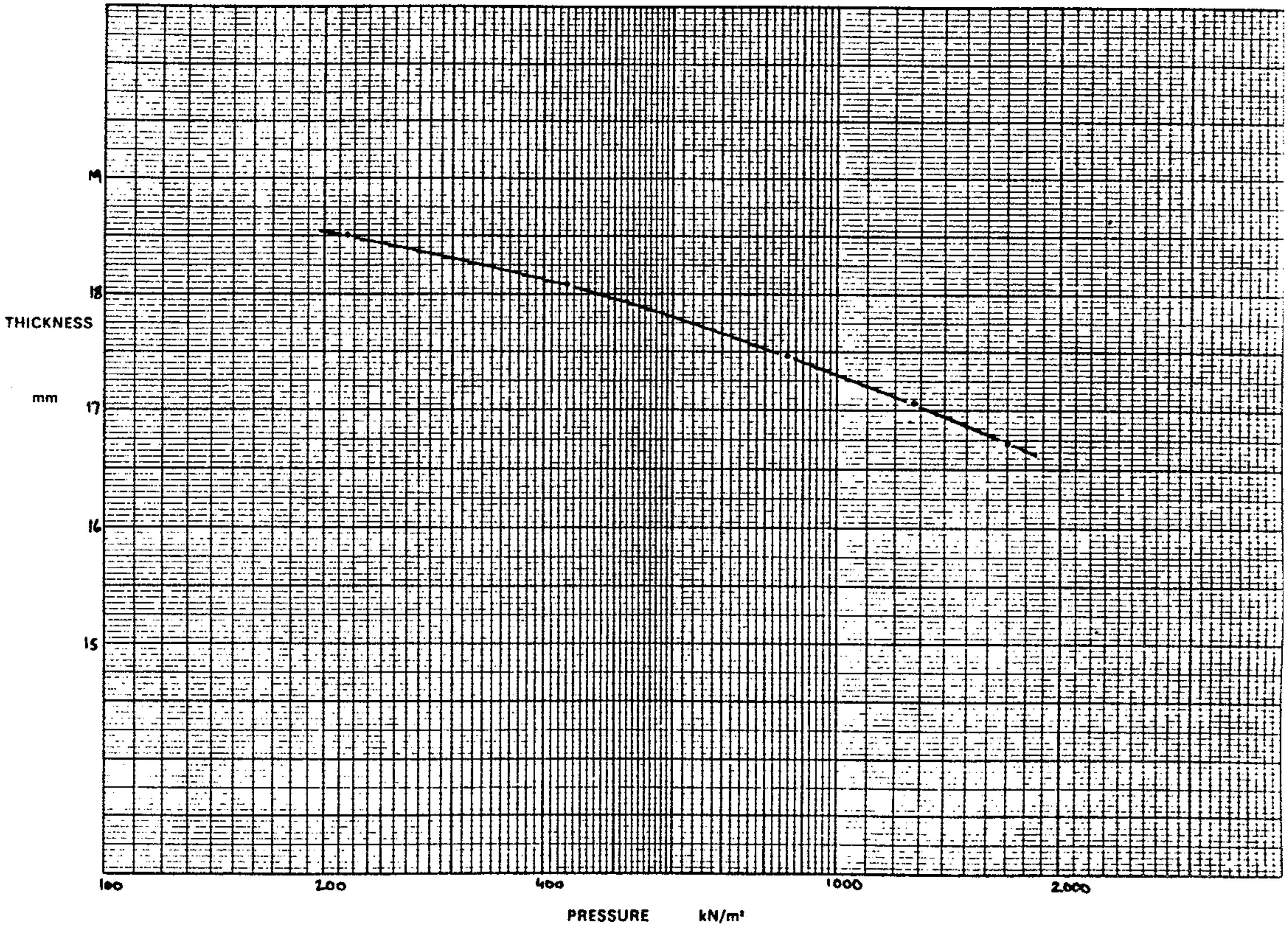
Borehole No.	Sample No.	Depth m
3	0838	11.40 - 11.85

Description:

Brown/orange mottled fissured clay.

Natural Water Content %	Bulk Density kg/m³	
29.3	1950	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
215		
	110	2.70
430		
	80	1.20
855		
	55	0.60
1285		
	45	0.55
1710		



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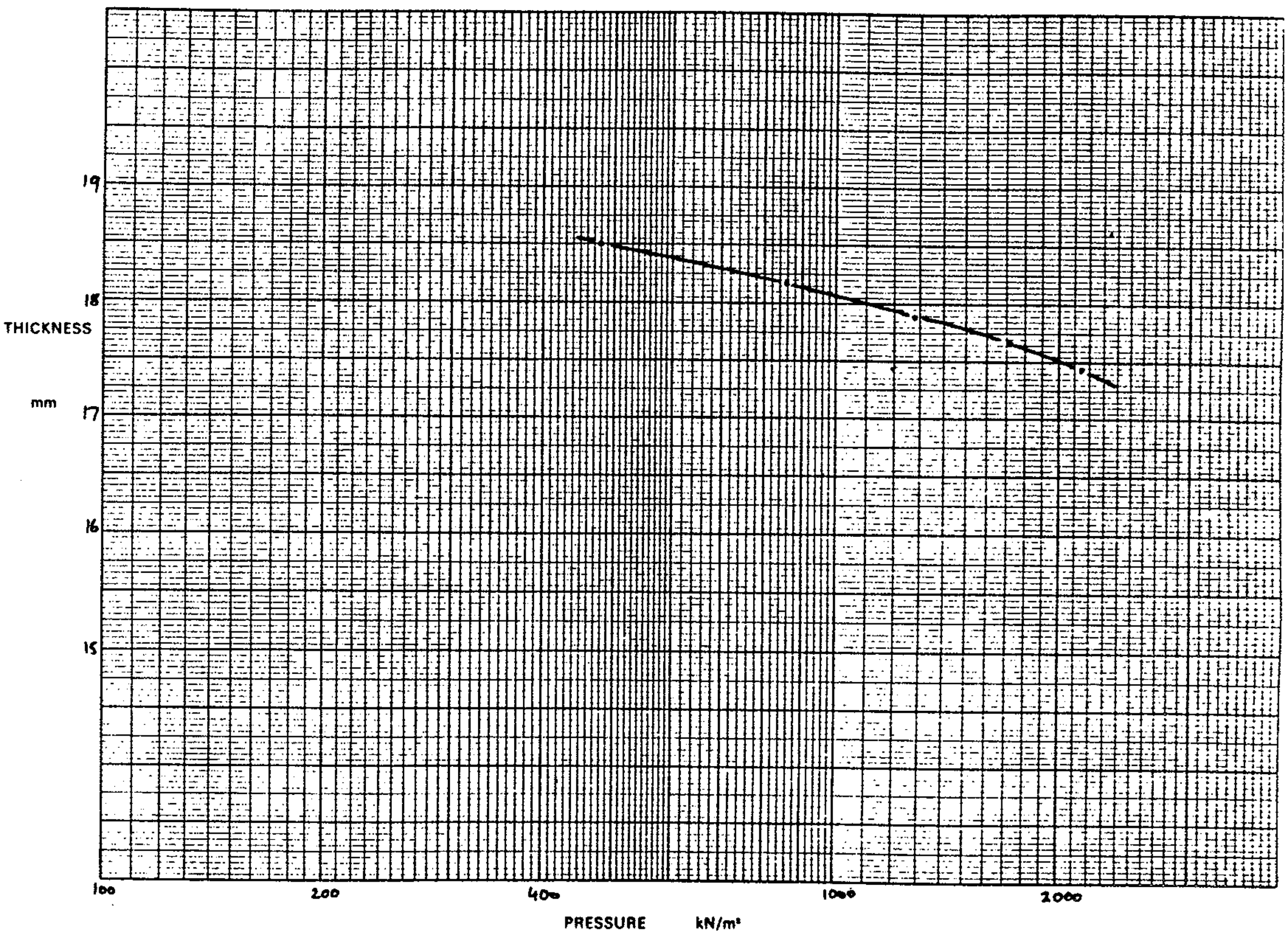
Borehole No.	Sample No.	Depth m
3	0850	20.50 - 20.95

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
25.7	1950	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
480		
	50	1.70
855		
	35	0.70
1285		
	30	0.60
1710		
	30	0.55
2140		



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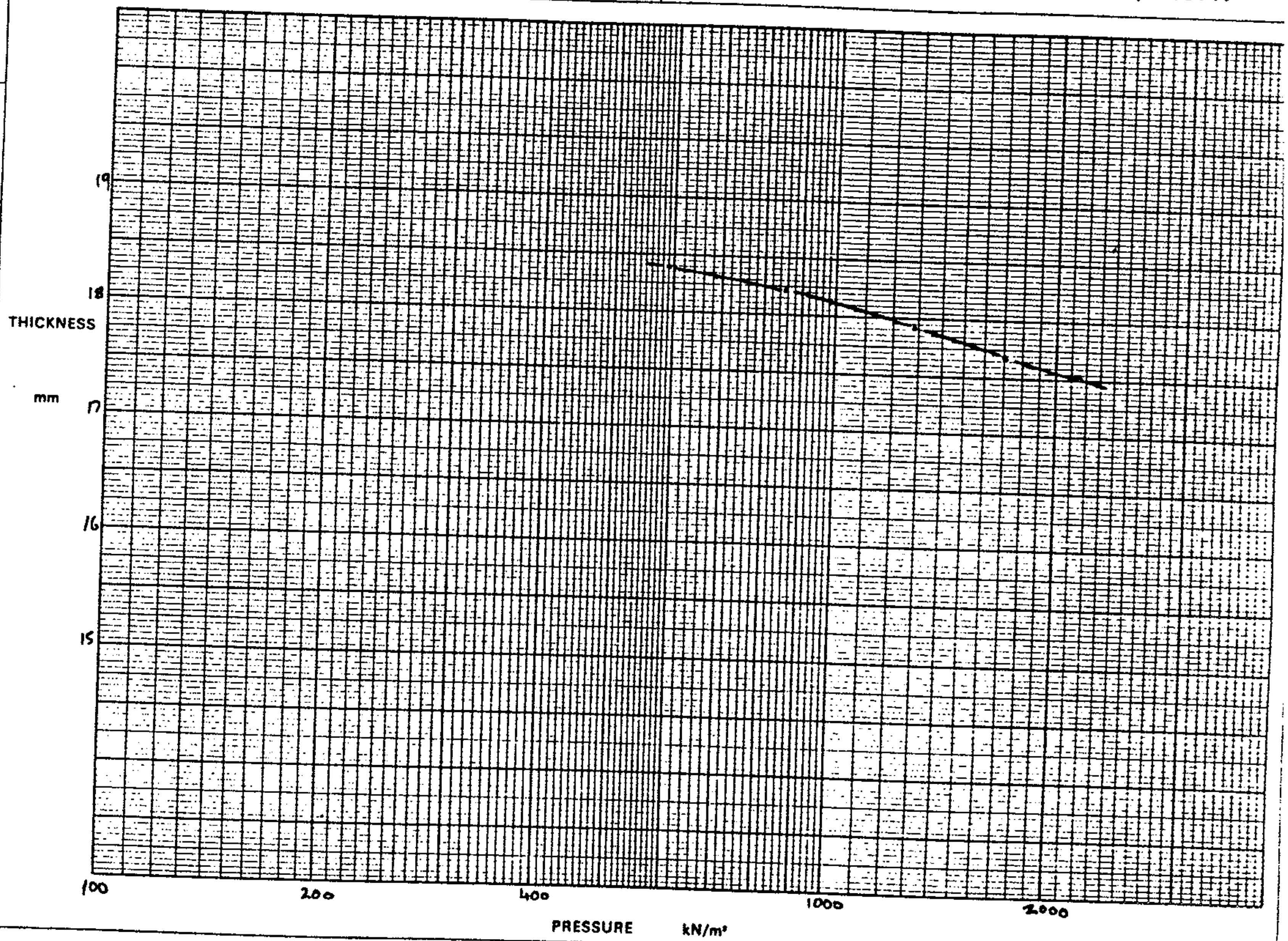
Borehole No.	Sample No.	Depth m
3	0856	25.00 - 25.45

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
26.9	1950	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
590		
	40	1.60
855		
	35	0.80
1285		
	30	0.45
1710		
	20	0.40
2140		



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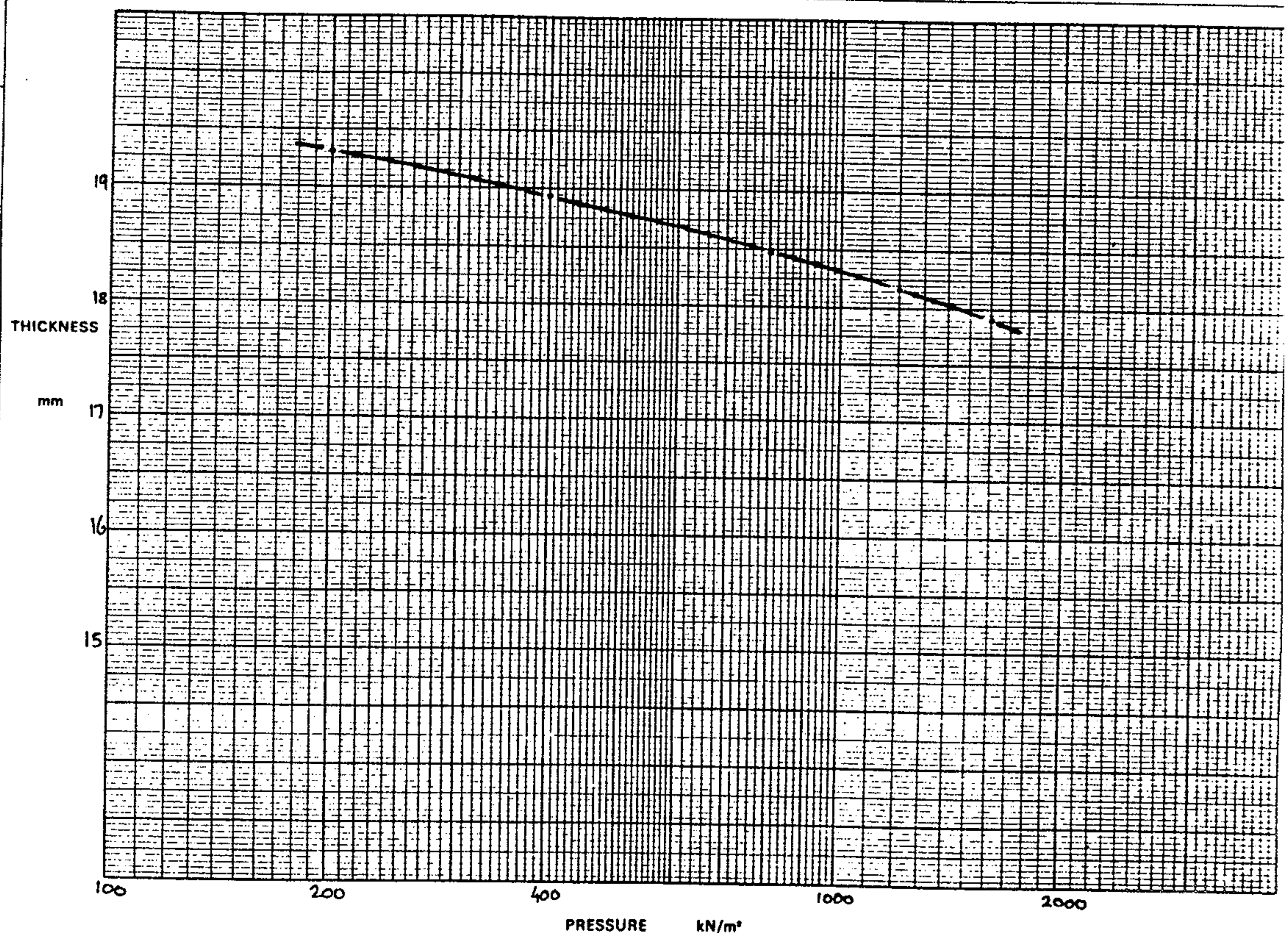
Borehole No.	Sample No.	Depth m
4	0932	11.40 - 11.85

Description:

Brown/orange mottled fissured clay.

Natural Water Content %	Bulk Density kg/m³	
26·2	1930	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
200		
	95	3·30
400		
	65	1·30
800		
	45	0·75
1200		
	35	0·60
1600		



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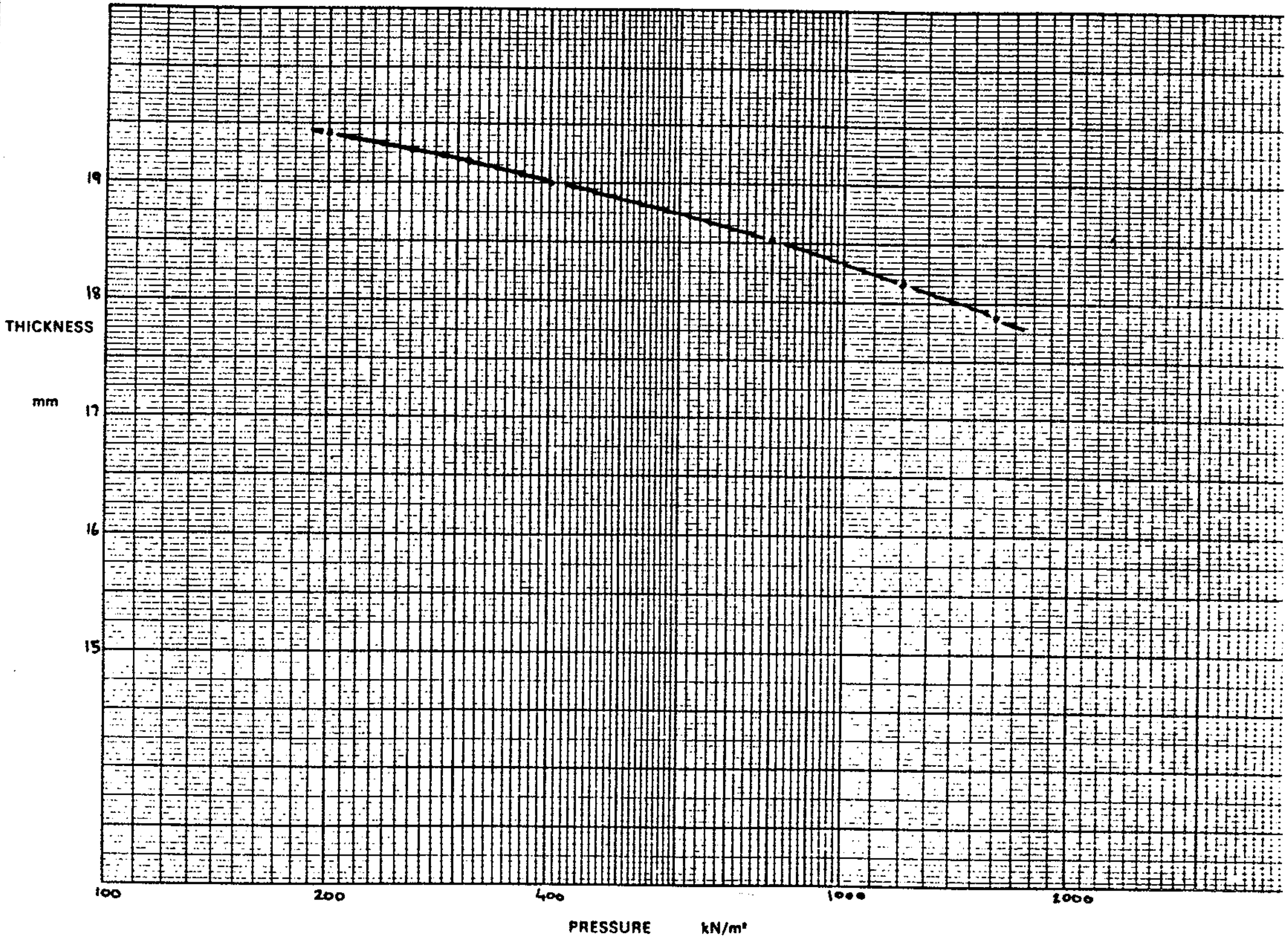
Borehole No.	Sample No.	Depth m
4	0935	13.40 - 13.85

Description:
Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³
26.6	1990

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
200		
	105	4.00
400		
	65	1.55
800		
	50	0.75
1200		
	35	0.65
1600		



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REPORT No.: 2187/TSR

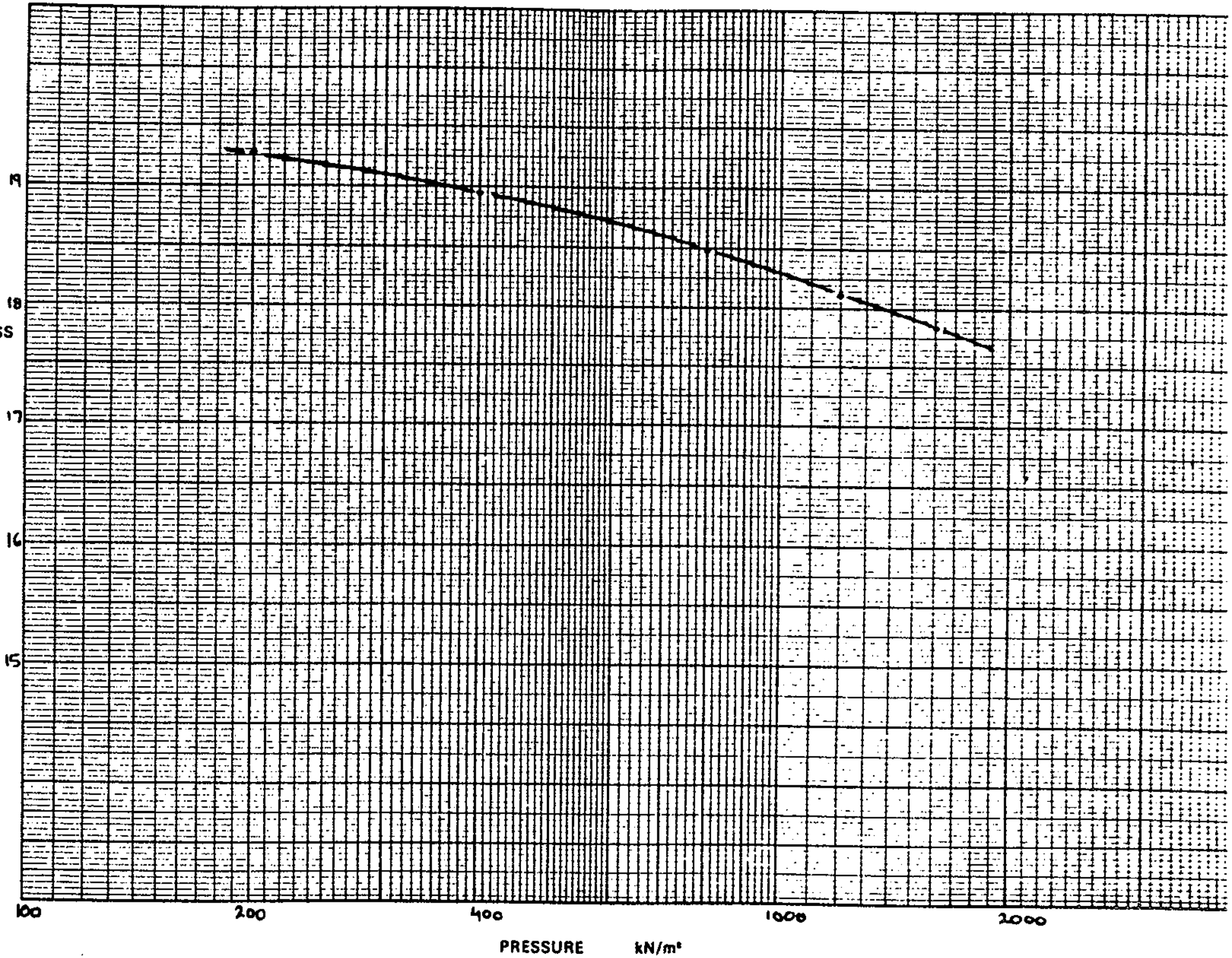
Borehole No.	Sample No.	Depth m
4	0937	15.00 - 15.45

Description:

Grey fissured clay.

Natural Water Content %	Bulk Density kg/m³	
25·7	1990	

Pressure kN/m²	Coefficient of Compressibility mm²/kN	Coefficient of Consolidation m²/year
200		
	85	4·50
400		
	65	1·20
800		
	50	1·05
1200		
	40	0·65
1600		



CONSOLIDATION

SULPHATES IN SOILS & GROUNDWATERS — CLASSIFICATION & RECOMMENDATIONS

Compiled from Building Research Digest No. 250, June 1981 Concrete in Sulphate-Bearing Soils and Groundwaters and other publications, with the permission of the Controller of Her Majesty's Stationery Office.

This Table applies to concrete placed in near-neutral groundwaters of pH 6-9, containing naturally occuring sulphates but not contaminants such as ammonium salts. Concrete should not be affected by alkaline conditions (pH >9). Ordinary Portland cement would not be recommended in acidic conditions (pH <6). Sulphate resisting Portland cement is slightly more acid-resistant but no experience of large scale use in these conditions is currently available.

Class	Concentrations of sulphates expressed as SO_3			Type of cement	Requirements for dense fully compacted concrete made with aggregates meeting the requirements of BS 882 or 1047	
	In soil		In groundwater			
	Total SO_3	Water : soil extract (2:1)		Ordinary Portland Cement Rapid Hardening Portland Cement Sulphate Resisting Portland Cement Portland Blastfurnace Cement	Minimum cement content[1] Kg/m³	Maximum free water/cement[1] ratio
	%	g/l	g/l			
1	Less than 0·2	Less than 1·0	Less than 0·3	OPC RHPC Cement/Slag Cement/pfa PBFC — Plain Concrete[2]	250	0·70
				Reinforced concrete	300	0·60
2	0·2 to 0·5	1·0 to 1·9	0·3 to 1·2	OPC or OPC /Slag or RHPC/Slag RHPC PBFC OPC /pfa or RHPC/pfa	330	0·50
				OPC /Slag with 10-30% Cement RHPC/Slag with 10-30% Cement OPC /pfa with 60-75% Cement RHPC/pfa with 60-75% Cement	310	0·55
				SRPC	290	0·55
3	0·5 to 1·0	1·9 to 3·1	1·2 to 2·5	OPC /Slag with 10-30% Cement RHPC/Slag with 10-30% Cement OPC /pfa with 60-75% Cement RHPC/pfa with 60-75% Cement	380	0·45
				SRPC	330	0·50
4	1·0 to 2·0	3·1 to 5·6	2·5 to 5·0	SRPC	370	0·45
5	Over 2	Over 5·6	Over 5·0	SRPC + protective coating[2]	370	0·45

(1) Inclusive of content of pfa or slag. These cement contents relate to 20 mm nominal maximum size aggregate in order to maintain the cement content of the mortar fraction at similar values, the minimum cement contents given should be increased by 50 kg/m³ for 10mm nominal maximum size aggregate and may be decreased by 40 kg/m³ for 40 mm nominal maximum size aggregate.

(2) When using strip foundations and trench filll for low-rise buildings in Class 1 sulphate conditions further relaxation in the cement content and water/cement ratio is permissible.

(3) Ground granulated blastfurness slag. A new BS is in preparation.

(4) Selected or classified pulverised-fuel ash to BS 3892. A new BS superseding BS 3892 is in preparation.

(5) Per cent by weight of slag/cement mixture.

(6) Per cent by weight of pfa/cement mixture.

(7) See BS CP 102:1973: Protection of buildings against water from the ground.

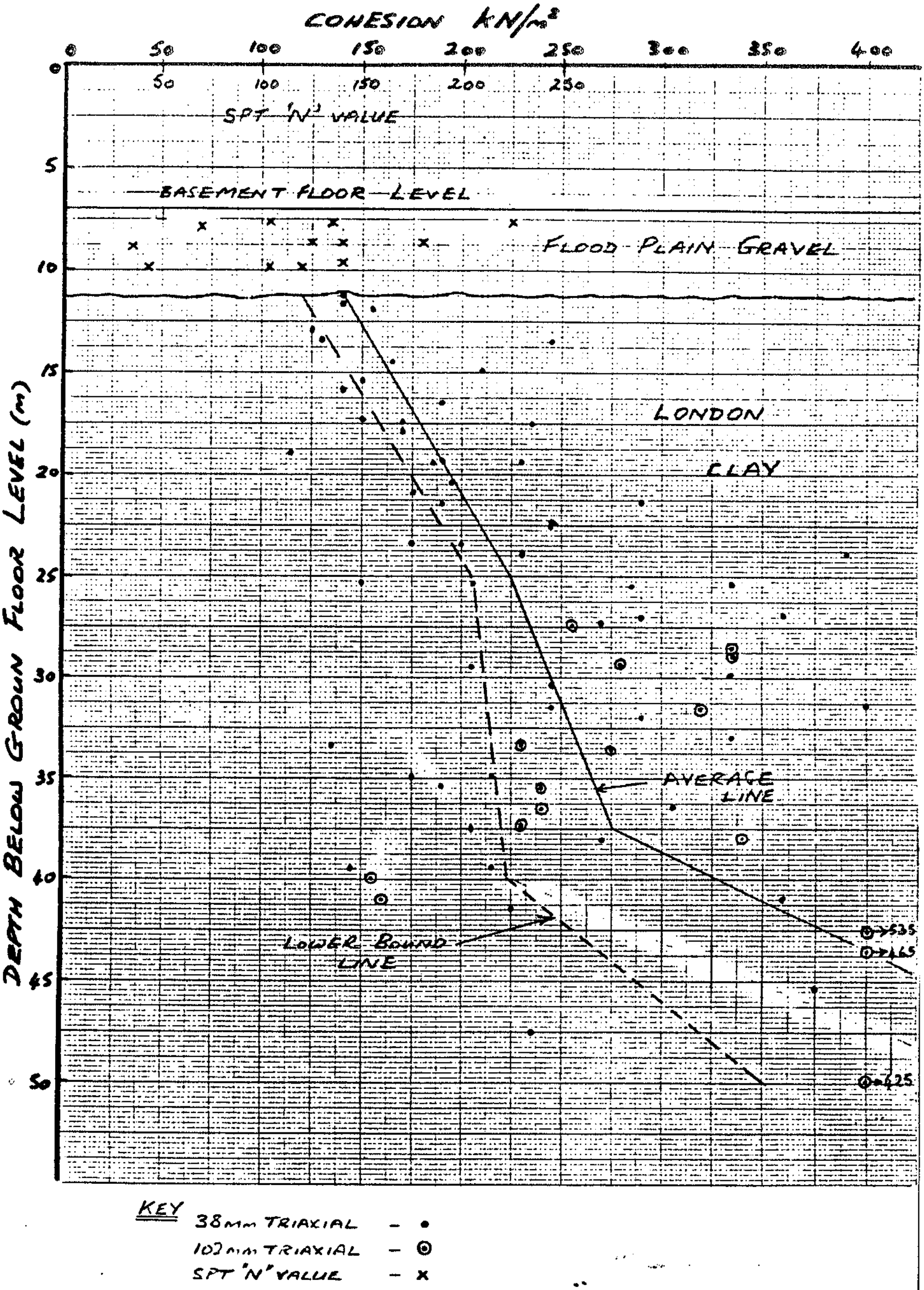
NOTES :

(i) The main safeguard is to obtain a dense, impermeable concrete.

(ii) For cast in-situ piles and heavily reinforced foundations, the over-riding consideration is to ensure complete compaction. Thus an admixture to improve workability or to reduce the water cement ratio may be beneficial in producing a denser concrete. Admixtures containing calcium chlorides are not recommended where sulphate ground conditions are present.

CHEMICAL ANALYSES

Borehole No.	Depth m	Description	Concentration of Sulphates Soil 2:1 gm/litre	Concentration of Sulphates Water pts. per 100,000	pH	Class
1	11.35	Brown/orange fissured clay	0.89			1
	(11.90)	WATER		0.22	8.2	1
2	16.00	Grey fissured slightly silty clay	0.31			1
3	11.20	Brown/orange fissured clay	0.24			1
	15.50	Grey fissured clay	0.58			1
4	20.00	Grey fissured clay	0.17			1
	30.00	Grey fissured clay with fine sand partings	0.38			1
	(10.45)	WATER		0.10	8.5	1



COHESION/PENETRATION DEPTH GRAPH	CONTRACT: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4. REPORT NO.: 2187/TSR

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TABLE 1

IMMEDIATE SETTLEMENT BENEATH CENTROID

B (m)	Z (m)	Z^1 (m)	Z/B	μ^1	Z^1/B	μ^1	$\mu_1-\mu^1$	Eu kN/m²	Settlement (mm)
22	0	4	0	0	0.18	0.13	0.13	1×10^5	1.0
	4	10	0.18	0.13	0.45	0.28	0.15	6.4×10^4	1.8
	10	13	0.45	0.28	0.59	0.35	0.07	7.4×10^4	0.7
Sewer Level	13	20	0.59	0.35	0.91	0.45	0.10	8.6×10^4	0.9
	20	30	0.91	0.45	1.36	0.53	0.08	1.0×10^5	0.6
	30	40	1.36	0.53	1.81	0.60	0.07	1.48×10^5	0.4

Equivalent rectangle = 22 m x 35 m

Immediate settlement $= \dfrac{q.\ B.\ (\mu_1-\mu^1)}{Eu}$

where q = net foundation pressure = 35 kN/m²

B = foundation width (equivalent) = 22 m

Centroid = 5.4 mm

Edge = 0.5 x 5.4 = 2.7 mm

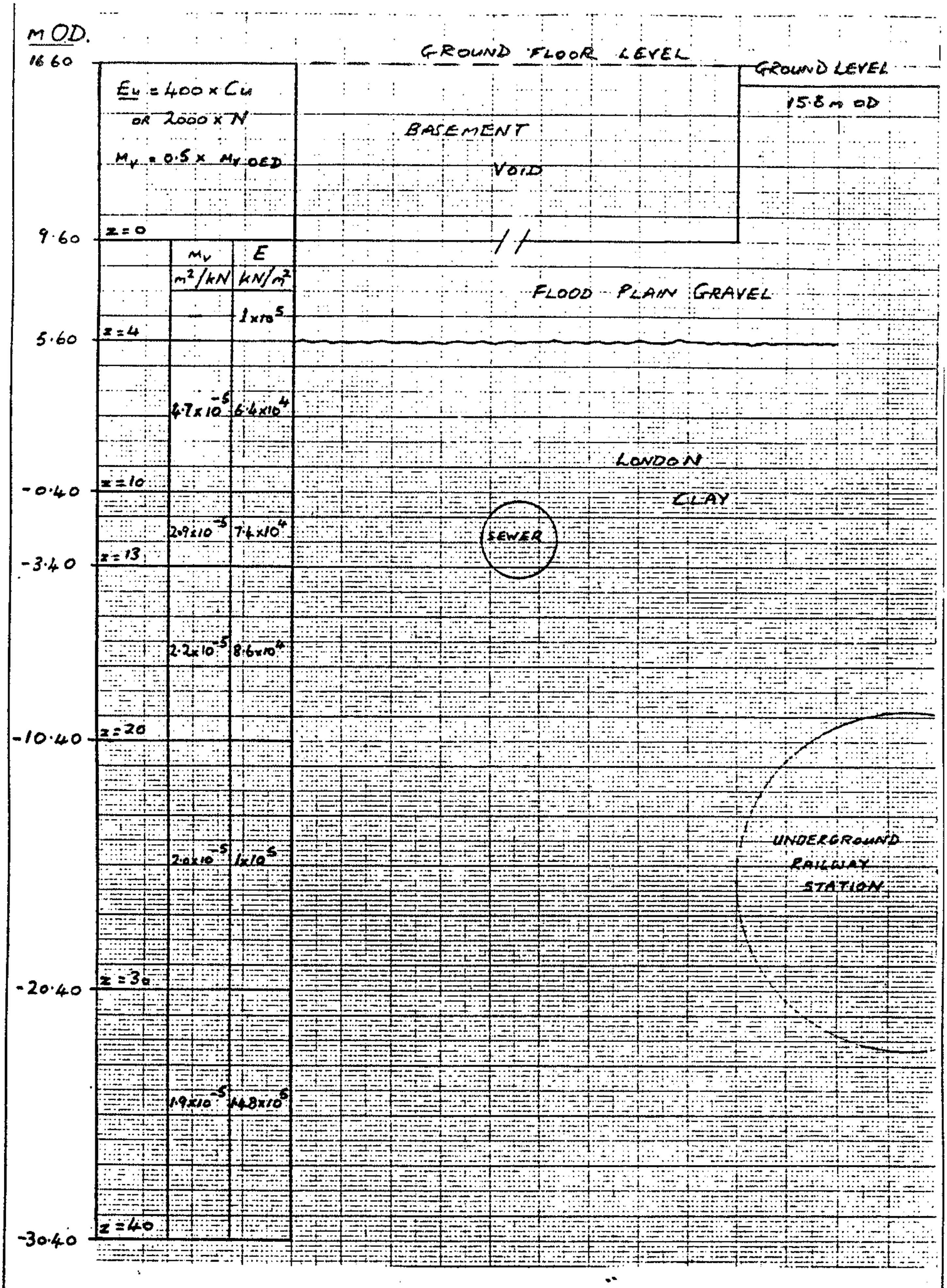
Corner = 0.25 x 5.4 = 1.4 mm

TABLE 2

CONSOLIDATION SETTLEMENTS

Z (m)	M_v (m^2/kN)	H (mm)	LOCATION ON PLAN					
			1	2	3	4 and 6	5	7
0-4	Ignore	-	-	-	-	-	-	-
4-10	4.7×10^{-5}	6,000	8.7	6.1	6.9	5.2	3.8	6.1
10-13	2.9×10^{-5}	3,000	2.2	1.3	1.5	0.9	0.4	1.3
13-20	2.2×10^{-5}	7,000	3.0	2.1	2.3	1.3	0.7	2.0
20-30	2.0×10^{-5}	10,000	2.4	2.0	2.1	1.4	0.9	2.0
30-40	1.9×10^{-5}	10,000	< 1.9	< 1.6	< 1.6	< 1.2	<0.8	< 1.6
TOTALS			18.2	13.1	14.4	10.0	6.6	13.0
BELOW SEWER			-	-	6.0	3.9	2.4	5.6

Net foundation pressure = 35 kN/m²



SECTION FOR SETTLEMENT ANALYSES	CONTRACT: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4. REPORT NO.: 2187/TSR

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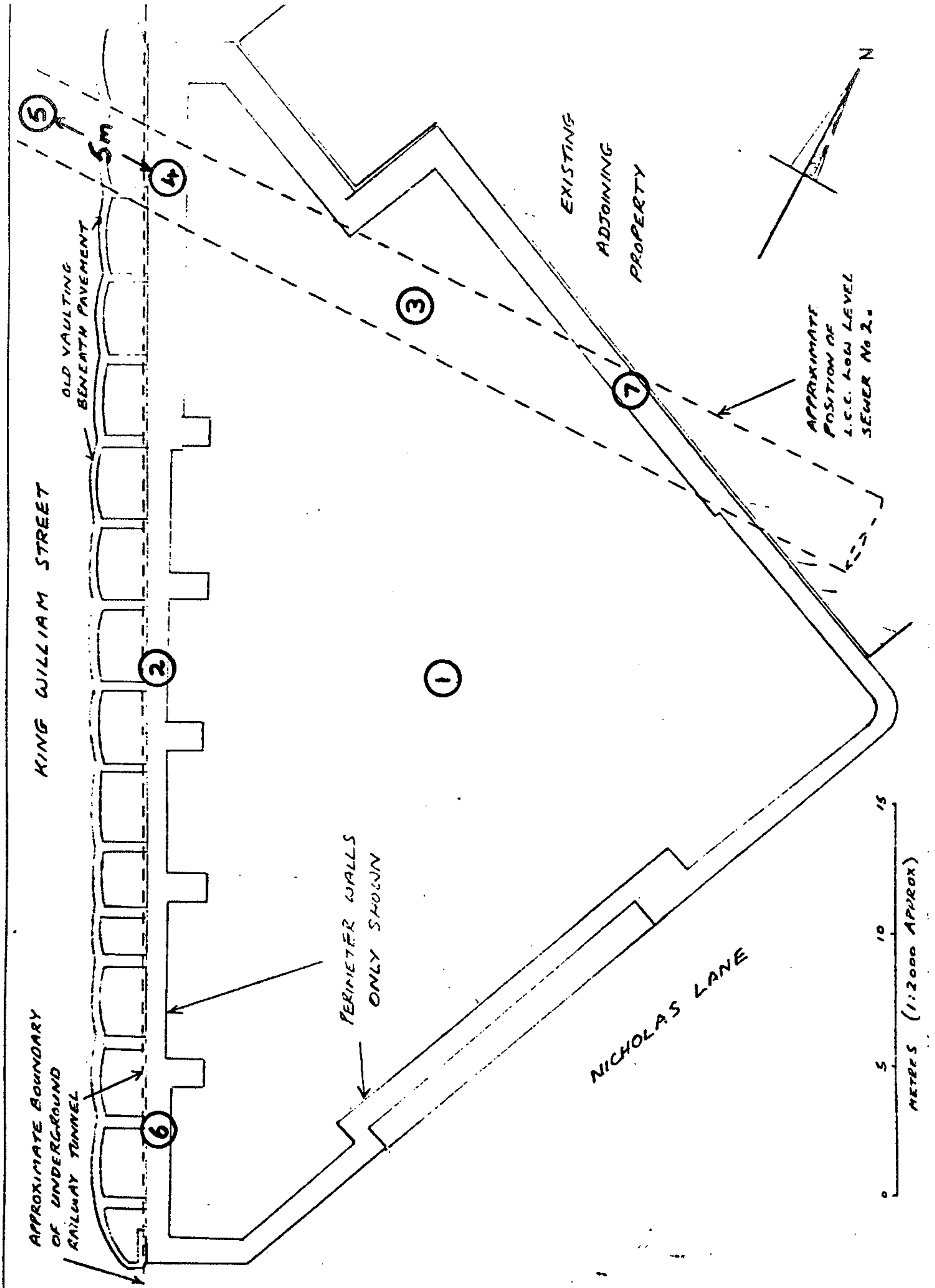

KEY PLAN FOR SETTLEMENT ANALYSES	CONTRACT: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4. REPORT NO.: 2187/TSR

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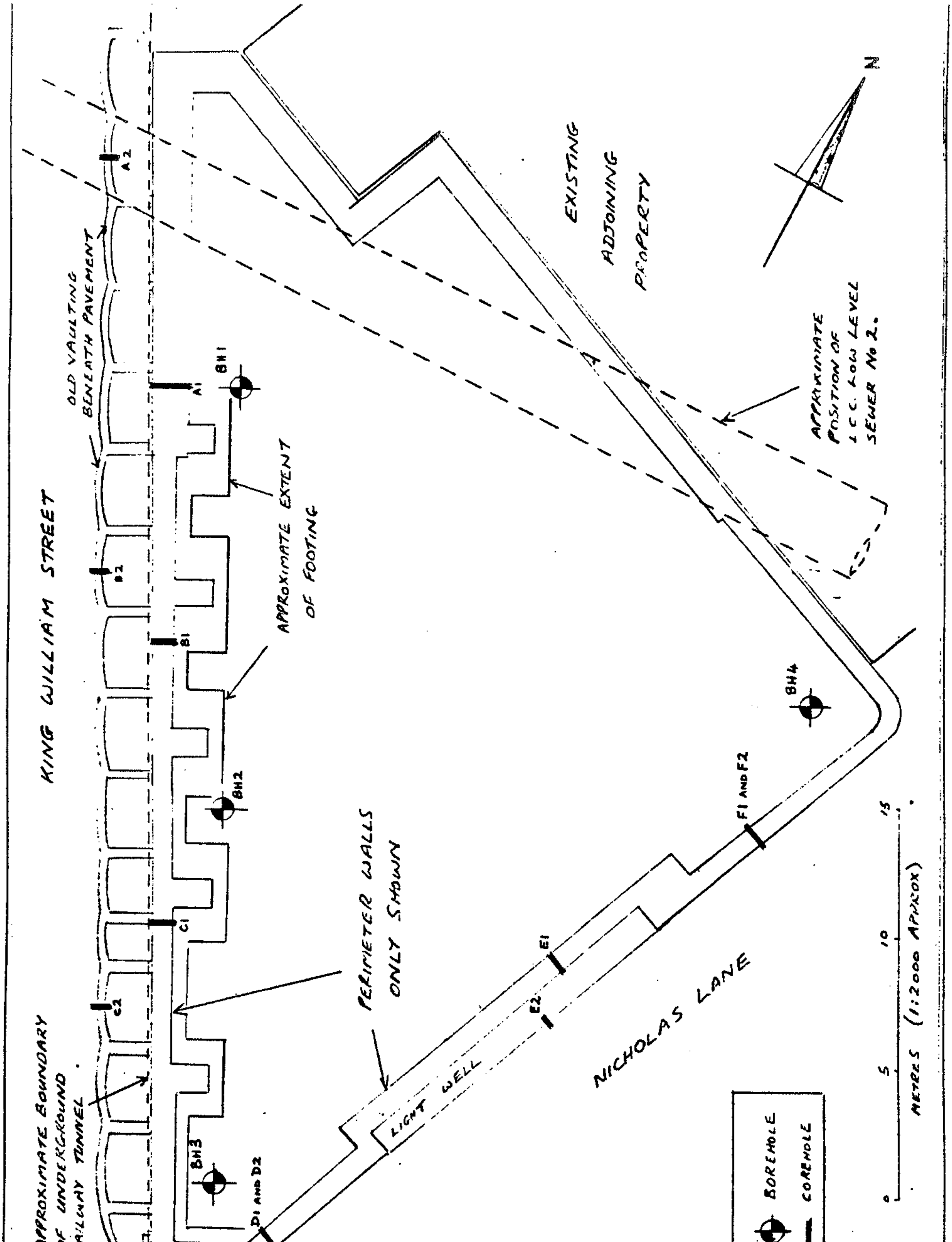

SITE PLAN	CONTRACT: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4. REPORT NO.: 2187/TSR

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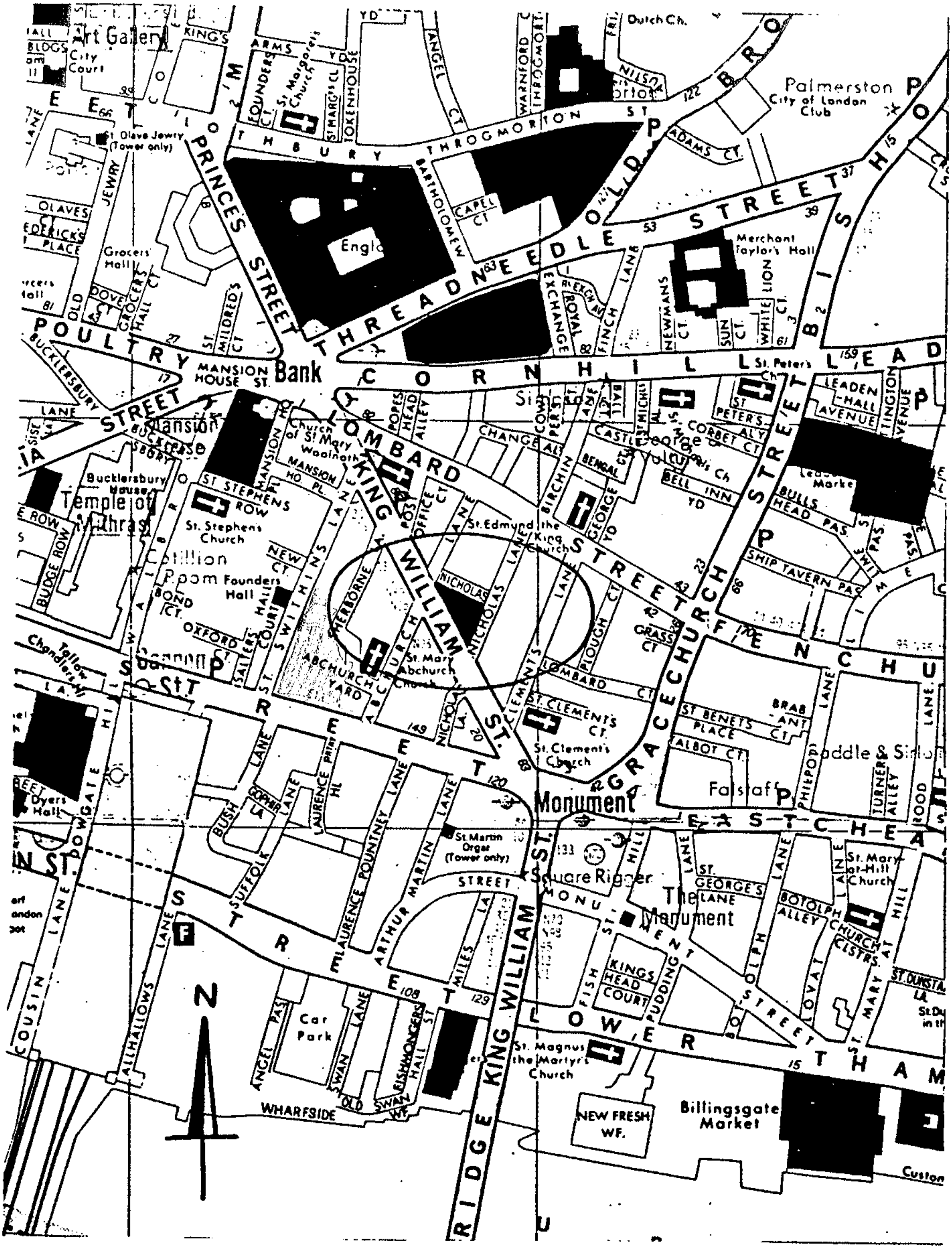

LOCATION PLAN	CONTRACT: KING WILLIAM STREET/NICHOLAS LANE, LONDON, E.C.4.	
	REPORT NO.: 2187/TSR	

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