

The Chalk was described following the procedure described in CIRIA C574 and generally conforms to the Group D classification.

Table 8.4: Classification of Chalk

Grade	Description
A	Discontinuities closed
B	Typical discontinuity aperture <3mm
C	Typical discontinuity aperture > 3mm
D	Structureless or remoulded melange

Chalk Grade D should be subdivided on the basis of engineering behaviour by the addition of the suffixes m. or c. as given in Table 8.5 below. Where the comminuted chalk matrix dominates, the material will behave as a cohesive, fine soil (Grade D_m), and where the clasts (intact chalk lumps) dominate, the material will behave as a granular, coarse soil (Grade D_c). The proportion of matrix to clasts at which this change in behaviour occurs varies, but approximate percentages are given in Table 8.5 as a guide.

Table 8.5: Subdivisions of Grade D chalk by engineering behaviour

Suffix	Engineering Behaviour	Dominant Element	Comminuted Chalk Matrix	Coarser Fragments
m	fine soil	soil matrix	>35% approx	<65%
c	coarse soil	soil clasts	<35% approx	>65%

In-situ Testing

Standard penetration tests were carried out throughout the UWC during the current and previous ground investigations (Table 8.6).

Table 8.6: Distribution of SPT N values in the Undifferentiated White Chalk

BH No.	Depth (mbgl)	SPT N Value	Recovered as CIRIA Grade	BH No.	Depth (mbgl)	SPT N Value	Recovered as CIRIA Grade
Ridge 2017							
BH201	5.00	9	Grade Dc	BH202	8.00	12	
	6.50	12			9.50	9	
	8.00	7					
	9.50	8					

Table 8.6 Contd.

RPS Investigation								
BH1	9.50	6	Grade Dc	BH2	9.50	23	Grade Dc	
	11.10	10			11.10	44		
	14.20	18			12.60	7		
	15.00	21			14.10	17		
	16.10	20			15.40	15		
	17.00	44			17.60	36		
BH3	9.00	16	Grade Dc	BH4	5.00	14	Grade Dc	
	10.50	26			6.00	16		
	12.00	30			7.50	8		
	13.50	21			9.00	9		
	14.40	42			10.50	12		
BH5	9.50	43	Grade Dc		12.00	29		BH6
	11.00	18		14.50	48			
	12.50	17		9.50	17	Grade Dc		
	14.00	11		11.10	22			
	15.50	27		12.70	8			
			14.10	29				
			15.00	26				
Structural Soils Investigation								
BH8	10.50	24	Grade Dc	BH9	13.50	15	Grade Dc	
	13.50	22			16.50	17		
	16.50	28			19.50	31		
	19.50	30						
BH10	10.50	20	Grade Dc					
	12.00	21						
	15.00	25						
	18.00	32						

Careful inspection of the all the SPT N-Values shows a scatter of results in the top 5m of the UWC after which there is an identifiable increase in N-value with depth. Therefore, for design purposes a characteristic N-value of 15 is considered appropriate for the upper 5.00m of the UWC.

Classification Testing

Intact Dry Density

During the earlier RPS investigation, six samples of UWC underwent laboratory testing to ascertain the intact dry density of the chalk clasts within the Grade D_c Chalk. The results, presented in Table 8.7, indicate that all the samples tested showed the intact dry density to be consistent with a medium density Chalk.

Table 8.7: Intact Dry Density of the UWC

Sample Location	Depth (mbgl)	Intact Dry Density (Mg/m ³)	CIRIA C574 Description
BH1	12.60-13.05	1.62	Medium
BH2	11.10-11.55	1.57	Medium
	12.60-13.60	1.56	Medium
BH5	12.00-13.00	1.69	Medium
BH6	11.70-11.55	1.65	Medium
	12.70-13.70	1.49	low/medium

Shear Strength Parameters

For most chalks, provided that they have not been weathered to the point that they have become disaggregated, mass strength is dominated by the behaviour of discontinuities and unlike other materials there is no reliable empirical relationship with SPT N value.

However, when considering foundation design and in particular allowable bearing pressure it is the yield strength, q_y that is more important as exceeding this value will lead to unacceptable settlements.

For Grade D_c Chalk, CIRIA C574 suggest a suitable yield strength of 250kN/m².

8.4. Aggressive Ground Soil Chemistry

Chemical testing was carried out on seven samples of the encountered materials in accordance with Box C10, BRE Special Digest 1. The results are summarised in Table 8.8.

Table 8.8 Summary of the Results of Chemical Testing for Concrete Classification

Test	BH201	BH201	BH201	BH201	BH202	BH202	BH202
	0.40m	2.10	4.00	6.00	1.00	5.00	9.00
	Made Ground	RTD	RTD	Chalk	Made Ground	RTD	Chalk
pH	7.45	7.53	7.51	7.50	7.45	7.48	7.50
Soluble Sulphate (g/l)	0.32	0.32	0.26	0.34	0.36	0.34	0.27

Tables C1 and C2 of BRE SD1 gives a Design Sulphate Classification of DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) Class of AC-1 assuming mobile groundwater conditions above the groundwater table.

8.5. Characteristic Geotechnical Parameters

Based on the laboratory test results, in-situ testing and subsequent analysis a range of characteristic geotechnical parameters, which should be used in the subsequent geotechnical and foundation design calculations are presented in Table 8.9.

Table 8.9: Characteristic Geotechnical Parameters

Stratum	Parameter		Source	Value
Topsoil / Made Ground	Not used in Foundation Design			
River Terrace Deposits	Unit Weight γ_k (kN/m ³)		BS8002	18kN/m ³
	Shear Strength	c_k (kN/m ²)	BS8002 (2015)	0kN/m ²
		ϕ_k (°)		36°
Undifferentiated Chalk Formation	Dry Density (Mg/m ³)		Laboratory Testing	1.64Mg/m ³
	Bulk Density (Mg/m ³)		Laboratory Testing	2.10Mg/m ³
	Undrained Shear Strength	c_{uk} (kN/m ²)	CIRIA C574	90kN/m ²
		ϕ_{uk} (°)		0°
	Drained Shear Strength	c'_k (kN/m ²)	CIRIA C574	0kN/m ²
		ϕ'_k (°)		31°
	Yield Strength	q_{yk} (kN/m ²)	CIRIA C574	250kN/m ²
	Secant Modulus	Short term E_s (MN/m ²)	CIRIA C574	200MN/m ²
		Long Term E_s (MN/m ²)		75MN/m ²

9. FOUNDATION AND GROUND ENGINEERING

9.1. Introduction

The geotechnical assessment below relates to the details of the proposed development. It is understood that the development comprises the construction of commercial and industrial buildings and associated access ways and hardstanding.

Two cable percussive boreholes and five windowless sample boreholes were undertaken across the site during the current ground investigation. The data collected during this ground investigation has been augmented with the findings of two previous ground investigations where appropriate. The ground conditions encountered are presented in Table 4.1 and in brief comprise Topsoil / Made Ground overlying a discontinuous cover of Alluvium in turn overlying River Terrace Deposits with Undifferentiated White Chalk forming the basal unit in all boreholes.

9.2. Groundwater

Groundwater was encountered during the ground investigation works and recorded during return monitoring visits associated with the previous ground investigations (Table 9.1).

Table 9.1: Groundwater strikes and Monitoring Levels

Ground Investigation	BH Location	Groundwater Strike Depth (mbgl)	Standing Groundwater Depth (mbgl)	Return Monitoring Depth (mbgl)	Stratum (Standing)
Ridge 2017	BH201	1.80	-		RTD
	BH202	1.80	-		
	WS201	1.70	-		
	WS202	1.80	-		
	WS203	1.70	-		
	WS204	1.80	-		
	WS205	1.80	-		
RPS 2007	BH1	1.90	1.84	1.79 ⁽¹⁾	RTD
	BH2	2.30	1.66	1.72	
	BH3	2.20	2.10	1.77	
	BH4	1.80	1.50	1.95	Alluvium
	BH5	2.40	1.35	2.16	
Structural Soils 2013	Groundwater strikes not recorded				

^{1.} Monitoring date 08/08/2007

Groundwater strike data for the Ridge 2017 and the RPS 2007 ground investigation indicates the groundwater to be present within the RTD. In BHs 4 & 5 it appears that the groundwater is confined by the fine-grained Alluvium and rose to a standing water depth of 1.35mbgl within the Alluvium.

9.3. Shallow Foundations

A bearing resistance for foundations constructed within the RTD has been presented in the Structural Soils Report. It is assumed that this is a “presumed” value as no calculations are presented, which is a requirement of EC7. Therefore, for completeness the ultimate limit state bearing resistance of the RTD has been calculated for both a strip and pad foundation constructed on the RTD at a minimum depth of 1.00mbgl.

In reality the depth to the RTD varies across the site and due to variations in the depth factor of the ULS calculations the ULS bearing resistance will also vary. However, for simplicity the ULS value presented will be appropriate for all foundation depths.

9.3.1. Ultimate Limit State Bearing Resistance

The ground model and characteristic material properties used in the ULS analysis are presented in Table 9.2.

Table 9.2: Ground Model used in the ULS Bearing Resistance Calculations

Ground Model	Stratum	Thickness		Shear Strength Parameters			
		From (mbgl)	To (mbgl)	Total		Effective	
				c_{uk} (kN/m ²)	ϕ_{uk} (°)	c'_k (kN/m ²)	ϕ'_k (°)
GM1	Made Ground	GL	1.00 minimum	Not used			
	RTD	1.00	5.00	0	36	0	36

The UK has implemented Design Approach 1 (DA1) of BS EN1997-1:2004 (Eurocode 7: Geotechnical Design), which requires two design combinations to be satisfied:

Combination 1 (C1): A1 “+” M1 “+” R1

Combination 2 (C2): A2 “+” M2 “+” R1

Where A, M and R refer to groups of partial factors relating to actions, materials and resistance respectively.

Table 9.3: Partial Factors Applied to the Bearing Resistance Analysis

	Combination 1			Combination 2		
	A1	M1	R1	A2	M2	R2
Tangent of the Angle of Shearing Resistance ($\tan \phi$)		1.00			1.25	
Cohesion Intercept (c')		1.00			1.25	
Undrained Cohesion c_u		1.00			1.40	
Permanent Action	1.35					
Variable Action	1.50					
Resistance						1.00

The summary of the bearing checks is presented in Table 9.4 and the geotechnical calculation sheets are located in Appendix 7.

Table 9.4: Summary of ULS Bearing Resistance Checks

GM	Foundation Type	Foundation Dimensions	Minimum Depth (mbgl)	DA1 Combination	ULS Bearing Resistance (kN/m^2)
1	Strip	0.60m wide	1.00	1	450
				2	210
	Pad	2.00m x 2.00m	1.00	1	800
				2	350

These calculations indicate that combination 2 presents the most critical case. The results given represent the ultimate limit state that is the maximum load that can be supported by the soil without failure occurring within the soil mass.

The bearing resistances calculated indicate a ULS of 210kN/m^2 for a 0.60m wide strip foundation and 350kN/m^2 for a 2.0 x 2.0 pad foundation both at a minimum depth of 1.00mbgl.

9.3.2. Serviceability Limit State

Eurocode 7 states that calculations of settlement must always be carried out on footings on soft clays - and should be carried out on footings on firm to stiff clays when the risk is anything other than negligible. Therefore, verification of serviceability limit is not required for foundations placed on Gravel.

However, it is appropriate to state that provided the foundation load do not exceed the ULS bearing resistances presented within Table 9.4 settlements should remain manageable.

9.3.3. Other Shallow Foundation Considerations

Before a shallow foundation solution is selected the following points should be considered.

Foundations will need to be constructed entirely in the RTD which, based on the ground investigation, may require excavations to 1.80mbgl within the Made Ground which is unlikely to remain stable for any period of time.

Based on the groundwater monitoring and strike danger there is a risk that groundwater may be encountered during the foundation excavations which is likely to cause collapse of the excavations. Therefore, widespread dewatering may be required to ensure their integrity prior to the placement of foundation concrete.

For these reasons it is recommended that consideration is given to the use of a piled foundation.

9.4. Piled Foundations

The ground model used in the pile design is presented in Table 9.5. The Made Ground will not be considered in the pile calculations.

Table 9.5: Details of the Ground Model Assessed in the Pile Calculations

Ground Model	Stratum	Thickness (m)	Notes
GM1	Topsoil / Made Ground	2.00	Not included in pile calculations
	RTD	3.00	Minimum thickness
		6.00	Maximum thickness
	CIRIA Grade Dc Chalk	>13.50 proven	Depth of Chalk will be increased if greater pile length required.

The pile design has been carried out following the procedure detailed in CIRIA C578 using the partial factors recommended in the UK National Annex to EC7.

9.4.1. Pile Calculations

The ultimate bearing capacity of the axially loaded piles have been determined using the following relationships:

River Terrace Deposits

Characteristic Shaft Resistance

$$R_{sk} = \frac{\bar{K}_s \bar{P}_d \tan \delta A_s}{\gamma_{rd}}$$

Where $K_s = 1.5$
 $\delta = 0.66 \phi_k$

Undifferentiated White Chalk

Characteristic End Bearing

$$R_{Bk} = \frac{200N}{\gamma_{rd}}$$

Where N is the SPT N value

Characteristic Shaft Resistance

$$R_{sk} = \frac{0.8 \bar{\sigma}'_v}{\gamma_{rd}}$$

Where σ'_v is the average effective overburden pressure along the pile shaft excluding any Made Ground or fill

9.4.2. Design Approach

The pile design has been carried out by applying partial factors to the calculated resistances in accordance with the UK National Annex to BS EN 1997. The design approach and combination of partial factors and their values are presented in Table 9.6.

Table 9.6: Design Approach and Partial Factors used in Pile Design

Bored Pile								
Combination	Design Action Load	γ_G	Material Factors	All Partial Factors	Design Resistance	γ_b	γ_s	γ_{Rd}
1	A1	1.35	M1	1.00	R1	1.00	1.00	1.4
2	A2	1.00	M1	1.00	R4	2.00	1.60	1.4

Higher carrying capacities are often achieved by driven piles, however, as the use of driven piles can cause environmental issues (noise and vibration) the initial axial resistance calculations have been carried out on bored piles.

The results of the axially loaded pile determination were carried out using two different design approaches as detailed above but only the lowest calculated values (DA1 C2) are presented in Table 9.7.

Table 9.7: Design Pile Resistances – Bored Pile

Pile Dia. (m)	Pile Length (m) ¹	Com.	Design Pile Resistance (kN)				
			Topsoil/MG	Skin Friction (R _{sd})		End Bearing (R _{bd})	Design Axial Pile Resistance (kN)
				RTD	Chalk	Chalk	
0.40	8.00	C2	No input to Axial Resistance	16	68	188	195
	11.00			70	113	188	265
0.50	8.00	C2		20	85	295	285
	11.00			87	141	295	370
0.60	8.00	C2		24	102	424	390
	11.00			104	170	424	500

¹ Pile lengths vary due to thickness of RTD. All piles towed into the UWC by a minimum of 3.00 Groundwater worst-case at 1.00mbgl.

With the variation in the thickness of the RTD it is difficult to give definite axial carrying capacities. The most conservative approach is to disregard the RTD completely and use the embedment in to the UWC only. Table 9.8 indicates the effect of increasing the depth of embedment on the pile axial carrying capacity of a bored pile

Table 9.8: Design Pile Resistances - Depth of Embedment

Pile Dia. (m)	Pile Toe Embedment into UWC (m)	Com.	Design Pile Resistance (kN)		
			Skin Friction (R_{sd})	End Bearing (R_{bd})	Design Axial Pile Resistance (kN)
0.40	3.00	C2	68	188	180
	4.00		106	188	210
	5.00		151	188	240
0.50	3.00	C2	85	295	270
	4.00		132	295	305
	5.00		188	295	345
0.60	3.00	C2	102	424	375
	4.00		158	424	415
	5.00		226	424	465

No increase in characteristic end bearing resistance is predicted in the top 5.00m of the UWC as no increase in SPT N value was identified in this region of the stratum. Increasing the depth of embedment to greater than 5.00m in to the UWC will lead to greater increases in both characteristic end bearing and characteristic shaft resistances.

It must be remembered that the carrying capacity of a pile group is generally less than the sum of the individual piles. Therefore, it is recommended that a pile group analysis is carried out if load bearing piles are placed closer than 1.5 x pile diameter.

9.5. Other Engineering Considerations

9.5.1. Floor Slabs

Given the granular nature of the Made Ground, ground bearing floor slabs are considered appropriate subject to careful inspection and proof-rolling of the founding stratum. If any soft spots or deleterious materials are identified they should be removed and replaced with a carefully recompacted granular engineering fill.

9.5.2. Californian Bearing Ratio

Five Californian Bearing Ratio assessments were carried out using a TRRL probe. A precis of the results is presented in Table 9.8; whilst the calculation sheets are presented in Appendix 8.

Table 9.8: Results of the CBR Assessment

CBR Test No.	Test Depth (mmbgl)	CBR%	Test Depth (mmbgl)	CBR%	Test Depth (mmbgl)	CBR%
TRL101	57	61	400	55	600	-
TRL 102	71	82	400	-	600	-
TRL 103	90	11	400	29	600	8
TRL 104	79	36	400	-	600	-
TRL 105	84	24	400	18	600	-

The results demonstrate the effect of coarse gravel and other obstructions on the calculated CBRs. However, there is sufficient data to recommend a preliminary design CBR 10%. It is recommended that further CBR testing is carried out on the prepared subgrade prior to the construction of any access ways or hardstanding.

9.5.3. Dissolution Features and their Treatment

The susceptibility of the calcium carbonate in the chalk to dissolution by water containing carbon dioxide can cause dissolution features within the chalk which can pose a hazard to foundations.

Although it is unlikely that the Chalk will be exposed on site given the thickness of the RTD, arisings from pile bores might give early warning of the presence of solution features which may reduce the carrying capacity of the pile and necessitate an increased pile length.

In areas where dissolution features are expected, soakaways should be avoided so as not to induce erosion and thereby trigger a collapse. Water pipes and foul and surface water drains should be constructed with flexible pipes and joints.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1. Contamination

The following source of contamination was identified:

- Ground gas from Made Ground and natural strata
- Potential for asbestos containing materials to be encountered during development
- Minor residual hydrocarbon contamination in Made Ground
- Potential migration of ground gas from off site landfills

The risk of impact to identified receptors from the identified sources is generally considered to be **very low to low/moderate** with the primary risk drivers being the potential for asbestos containing material in the Made Ground (not currently identified) and ground gas. There is also a potential risk to proposed PE water supply pipes.

Asbestos containing material or fibres have not been identified in the soils on site during the Ridge or previous investigations. However, it is recommended that the contractor remains vigilant throughout the development works for asbestos containing materials in soil. If suspected asbestos containing material are encountered, the risks posed by these materials should be assessed by a specialist.

TPH has been identified in near surface Made Ground samples at concentrations that may present a risk to proposed PE water supply pipes. It is therefore recommended that the chemical analysis results from this investigation and the previous investigations are provided to the designer of these pipes so an appropriate material can be selected for the pipes.

The site has been assessed as having a Characteristic Situation 2 ground gas regime, requiring ground gas protection measures. The details of the ground gas protection measures required will be dependent on the design of the proposed buildings, in line with the guidance in BS8485.

The local authority should be informed if any sources of contamination are identified during the development that have not been assessed in this report. These sources should then be assessed and dealt with appropriately, with the agreement of the Local Authority.

These conclusions are subject to agreement with the regulatory authorities, be it the Local Authority for human health related issues or the Environment Agency for environmental issues.

10.2. Geotechnical

The ground investigation revealed Made Ground overlying a discontinuous layer of fine-grained Alluvium in turn overlying River Terrace Deposits with Undifferentiated White Chalk forming the basal unit of the ground investigation.

Groundwater was encountered during the current ground investigation at between 1.70 and 1.80mbgl and at 1.35mbgl during a monitoring round carried out as part of a previous ground investigation. These shallow groundwater levels and potential seasonal fluctuations will place them close to the depth required for the construction of a shallow foundation which will need to be below the Made Ground within the RTD.

ULS bearing resistance calculations have been carried out for both a shallow strip and pad foundation constructed at a minimum depth of 1.00m below ground level within the RTD. The results indicate a ULS bearing resistance of 210kN/m² for a strip foundation and 350kNm/m² for a 2.00m x 2.00m pad foundation. Following the guidance presented in EC7 Serviceability Limit State settlement analyses are not required on foundations constructed within granular materials; however, provided foundation bearing pressures do not exceed the ULS bearing resistances presented in Table 9.4 settlements should remain within manageable limits.

Deep excavations to a depth of up to 1.80m will be required to ensure the foundations are placed within the RTD. The foundation excavations are unlikely to be stable for any length of time within the granular Made Ground. Furthermore, if groundwater is encountered during these excavations collapse of excavations should be expected.

For the above reasons it is recommended that consideration is given to a piled foundation solution. The current and previous ground investigations have shown the surface of the chalk to be undulating such that the thickness of the RTD varies unpredictably across the site making it difficult to create an appropriate ground model to use in the pile design. Initially two different models were used to demonstrate the effect on axial carrying capacity of the thickness of RTD (Table 9.7). Subsequently the conservative approach of using only the axial resistance generated by the embedment of the pile into the UWC was calculated (Table 9.8). Although the second approach appears conservative it proves a more robust design and given the shaft resistance generated in the RTD (Table 9.7) does not represent a huge over design.

10.2.1. Other Geotechnical Considerations

As a result of the presence of coarse-grained material, Californian Bearing Ratio determinations carried out in the top 0.80m of the site have returned a range of CBR values between 8 and 82%. Based on all the data a preliminary design value of 10% is recommended. Further CBR testing should be undertaken at the top of the prepared subgrade prior to the commencement of any access way or hardstanding construction.

10.2.2. Concrete Aggressivity

Chemical tests carried out on strata encountered during the ground investigation and indicate that both the Made Ground and the natural strata are consistent with Design Sulphate Class DS- 1. Based on the assumed mobile groundwater conditions above the groundwater table an ACEC classification of AC-1 should be adopted for concrete placed on the site.

FIGURE 1 – SITE LOCATION PLAN



-	13/10	FINAL	AP	RP
REF	DATE	REVISION	DRAWN	CHECKED

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PROJECT
HARTS FARM WAY
HAVANT

RIDGE

PARTNERSHIP HOUSE
MOORSIDE ROAD
WINCHESTER
HAMPSHIRE, SO23 7RX
Also at Reading, Bristol, London and Leicester

CLIENT
SALMON

DRAWING

5004378 - FIGURE 1

SCALE
NTS @ A4

DATE
13/10/2017

DRAWN BY
AP

CHECKED BY
RP

REV

SITE LOCATION

FIGURE 2 – INVESTIGATION LOCATION PLAN