Appendix E
Geotechnical
Interpretation Report

BUSCONNECTS – BALLYMUN / FINGLAS CORRIDORS
GEOTECHNICAL INTERPRETATIVE REPORT
TABLE OF CONTENTS

1. INTRODUCTION AND DESKTOP REVIEW 1
1.1 OVERVIEW OF GEOTECHNICAL CONDITIONS ALONG THE PROJECT 1
2. SUMMARY OF GROUND INVESTIGATION CONTRACT 2
3. SUMMARY OF FACTUAL REPORT 3
4. OVERVIEW OF SOIL CLASSIFICATION 5
4.1 MADE GROUND 5
4.2 COHESIVE DEPOSITS 5
4.3 BEDROCK 5
5. SUMMARY OF GROUND INVESTIGATION INTERPRETATIVE REPORT 5
6. HIDROGEOLOGY 6
7. GEOTECHNICAL INPUT TO STRUCTURES 7
8. APPENDICES 9
8.1 GEOLOGICAL GEOTECHNICAL PROFILE
8.2 GROUND PARAMETERS
8.3 CHARACTERISTIC COMPRESSIVE RESISTANCE OF PILES
8.4 GEOTECHNICAL PARAMETERS FOR BALLYMUN 04 RETAINING WALL DESIGN

1. INTRODUCTION AND DESKTOP REVIEW

The existing site investigation information for the area has been taken from the Geological Survey of Ireland (GSi) website and the British Geological Survey (BGS) website, including the Quaternary and Bedrock Geology of Dublin and Depth of Bedrock digital maps.

The following selection of published papers has found to be of relevance to estimate the lithology and geotechnical properties:

- "Geotechnical properties of Dublin boulder clay". Authors: Long, Michael M and Menkiti, Christopher O. Sept 2007, Géotechnique 57 (7): 595-611. Published by the ICE.
- Ground Investigation Report of the National Pediatric Hospital Project, Dublin. Roughan & O'Donovan Consulting Engineers, January 2015.

1.1 Overview of geotechnical conditions along the Project.

Quaternary sediments cover up to 80% of the Dublin region. Quaternary thicknesses at the city area range from 5 to 20m. Maximum thicknesses are recorded along a Tertiary channel occurring on the north shore of the River Liffey valley, reaching 45m, and along a channel-like feature running along the south margin of the Dodder valley Quaternary sediments, with a thickness of 15 to 25 m.

The most commonly occurring Quaternary deposit in the area has been termed locally as the Dublin Boulder Clay. It is a glacial deposit derived from the Lower Carboniferous Limestone and it is classified by its two main members: the Black Boulder Clay (BkBC) and the Brown Boulder Clay (BrBC). The Brown Boulder Clay is less consolidated and since it overlies the Black Boulder Clay it has been interpreted as its weathered upper layer.

The Upper Brown Boulder Clay (UBrBC) is the outcome of the oxidation of the clay particles in the top 2m to 3m of the UBkBC, resulting in a change in colour from black to brown and a lower strength material. It is usually described as thick stiff to very stiff brown, slightly sandy clay, with rare silt / gravel lenses and some rootlets, particularly in the upper metre.

The Upper Black Dublin Boulder Clay (UBkBC) is a very stiff, dark grey, slightly sandy clay, with some gravel and cobbles. It is typically 4 m to 12 m thick.

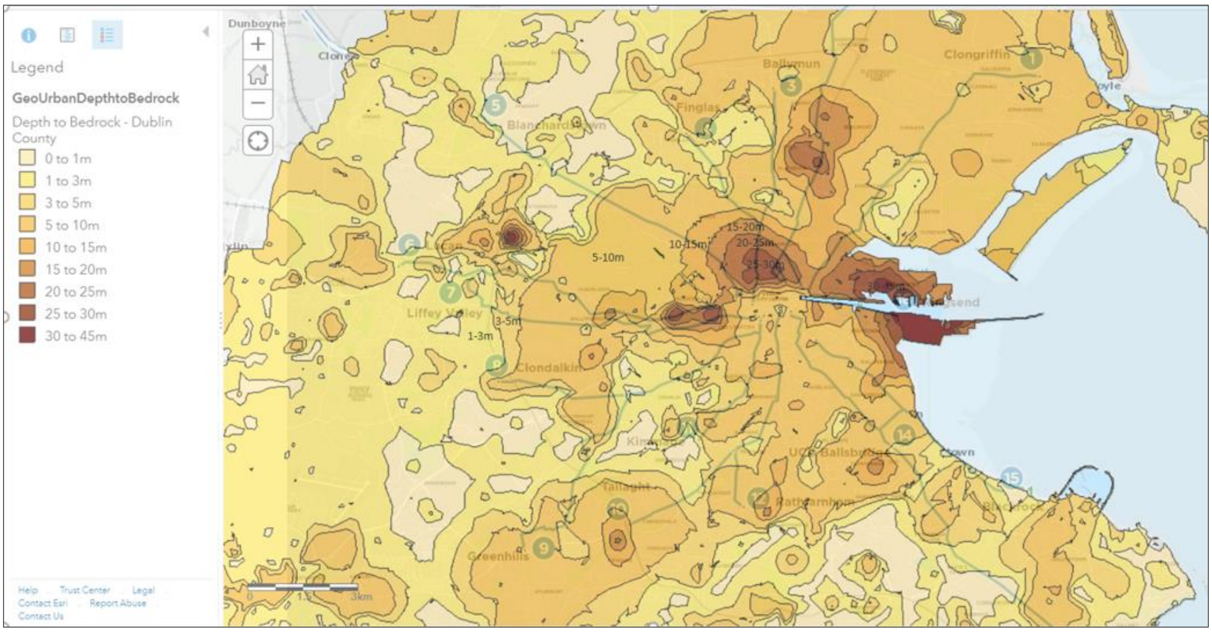
The Lower Brown Dublin Boulder Clay (LBrBC) exists as a 5 m to 9 m thick hard, brown, silty clay, with gravel, cobbles and boulders. It has previously been called the "sandy boulder clay" as it is similar to but siltier than the UBkBC above.

The Lower Black Dublin Boulder Clay (LBkBC) is a patchy layer of hard slightly sandy gravelly clay with an abundance of boulders. Its thickness does not exceed 4 m and is typically less than 2 m.

Note that not all four distinct formations of the Dublin Boulder Clay are always present. The upper two units though have been proven at all investigation sites across the city.

Bedrock close to the surface occurs mostly along the main riverbeds as well as the coastline and the higher ground areas of the Howth peninsula. The bedrock map of Ireland shows a wide variety of rock types which have originated at different periods of geological time. Underlaying the project area consists of Lower Carboniferous Limestone of the Lucan Formation (Calp), which is typically described as a dark grey to black fine grained limestone.

The following image from the Geological Survey Ireland website shows the expected depth to Bedrock.



Depth of Bedrock from the Geological Survey Ireland website

The water pressures correspond to hydrostatic conditions with a groundwater table about 2m below ground level.

- *Summary of Desktop Review.*

The following preliminary lithology and geotechnical properties has been assumed based on the Desktop Review:

Layer	Depth	Thickness	Undrained shear strength, c_u (kPa)
Made ground / Urban / Alluvium	0 to 1 m	1	0
Upper Brown Boulder Clay, UBrBC	1 to 3 m	2	80
Upper Black Boulder Clay, UBkBC	3 to 10 m	7	200
Lower Brown Boulder Clay, LBrBC	10 to 18 m	8	400
Lower Black Boulder Clay, LBkBC	18 to 22 m	4	600
Bedrock	>22 m	N/A	>600

The expected depth to bedrock has been included in Section 2.

2. SUMMARY OF GROUND INVESTIGATION CONTRACT

At the date of this document, there are two GI contracts underway. Lot 1, which includes projects C and D , and Lot 2, which covers A and B projects.

Proposed ground investigation works aim to assess the geology of the site and determine the ground properties and conditions to enable the design of Bus Connects Core Bus Corridors. The GI provides for boreholes, trial pits, dynamic probes, standpipes/piezometer installation and monitoring, in-situ testing, geotechnical and environmental laboratory testing and preparation of a factual report, all in accordance with the "*Specification and Related Documents for Ground Investigation in Ireland*".

At the Project D schemes (Ballymun/Finglas to City Centre, Kimmage to City Centre and Ringsend to City Centre), there are 21 proposed investigation points, consisting of Cable Percussion (CP) and Rotary Core (RC) boreholes as well as few windowless dynamic samples (WS) in restricted space areas. The location of these points can be found in the form of drawings in the "*BusConnects Detailed Ground Investigation – Stage 1 – LOT 1*", February 2020.

In situ tests mainly include standard penetration tests. Laboratory tests mainly include particle size distribution, Atterberg limits, density and moisture content to identify soils and direct shear strength, triaxial CU or UU and uniaxial compression to determine the strength of the soil/rock.

For more details see the "*BusConnects Detailed Ground Investigation – Stage 1 – LOT 1*", February 2020.

For the Ringsend to City Centre Core Bus Corridor Scheme, the following investigation points have been proposed:

Borehole Ref.	Expected Depth to Bedrock	Borehole Depth (m) – Cable Percussion	Borehole Depth (m) – Rotary Core
R3-CP01	15-20m	15	-
R3-CP02	15-20m	15	-
R3-CP03	15-20m	15	-
R3-CP04	15-20m	15	-
R3-CP05	15-20m	15	-
R3-CP06	15-20m	15	-
R3-CP07	15-20m	15	-
R3-CP08	15-20m	15	-
R3-CP09	20-25m	15	-
R3-CP10	20-25m	20	-
R3-CP11	20-25m	20	-
R3-CP12	20-25m	20	-
R3-CP13	20-25m	20	-
R3-CP14	20-25m	15	-

3. SUMMARY OF FACTUAL REPORT

The following factual report was issued as part of the Lot 1 GI:

Detailed Stage 1 Lot 1 Route 3. July 2021 Completed investigation points are as summarised below:

Structure	Borehole Ref.	Expected Depth to Bedrock	Borehole Depth (m) – Cable Percussion	Borehole Depth (m) – Rotary Core	Notes
Ballymun 01	R3-CP01	15-20m	-	-	Cancelled
	R3-CP02	15-20m	-	-	Cancelled
Ballymun 02	R3-CP03	15-20m	7.1	-	
Ballymun 02&03	R3-CP04	15-20m	-	-	Cancelled
	R3-CP05	15-20m	-	-	Cancelled
	R3-CP06	15-20m	-	-	Cancelled
Ballymun 03	R3-CP07	15-20m	6.0	-	

Structure	Borehole Ref.	Expected Depth to Bedrock	Borehole Depth (m) – Cable Percussion	Borehole Depth (m) – Rotary Core	Notes
	R3-CP08	15-20m	4.8	-	Changed to WS03 (Drive-in Windowless Sampler)
Ballymun 04	R3-CP09	20-25m	-	20	Changed to RC01
	R3-CP10	20-25m	-	20	Changed to RC02
	R3-CP11	20-25m	-	20	Changed to RC03
	R3-CP12	20-25m	1.5	-	Changed to WS01 (hand window sample)
	R3-CP13	20-25m	1.0	-	Changed to WS02 (hand window sample)
	R3-CP14	20-25m	9.0	-	

In addition, the following reports have been received to complete the GI performed for Lot1:

- GIR New Metro North (Glasnevin). March 2018. This includes 2 boreholes located among performed boreholes in Route 3.

- MetroLink Phase 4 GI. October 2020. This includes 2 boreholes and 3 inspection pits located among performed boreholes in Route 3.

The GI works undertaken comprise 3 No. Cable Percussion Boreholes to a maximum depth of 9.0m BGL, 3 No. Window Samples and 3 No. Rotary Core Boreholes to a maximum depth of 20.0m BGL; 58 SPT tests at 1 metre intervals alternating with disturbed samples, 2 No. Dynamic probeholes and 4 GWL recordings.

18 disturbed samples were taken at each change of soil consistency or between SPT tests and 1 undisturbed sample (UT100) where ground conditions permit. Geotechnical testing consisted of 19 moisture content, 8 Atterberg limits and 10 Particle Size Distribution. Soil strength testing consisted of 1 UU Triaxial Test, 2 Vane tests and 2 Shear Box.

Environmental & Chemical testing consisted of 23 Suite E samples and 2 PH and Organic matter content tests.

From Glasnevin and MetroLink Phase 4 GI works, 3No. Inspection Pit, 2 No. Cable Percussion Boreholes followed by Rotary Core Boreholes to a maximum depth of 40m BGL, 2 No. Rotary Core Boreholes to a maximum depth of 35.4m BGL; 40 SPT tests at 1 metre intervals alternating with disturbed samples and 6 GWL recordings.

40 disturbed samples were taken at each change of soil consistency or between SPT tests. Geotechnical testing consisting of 40 moisture content, 25 Atterberg limits and 24 Particle Size Distribution. Soil strength testing consisted of 9 CU Triaxial Tests, 3 CU Triaxial Tests with PWP and 2 Shear Box. Rock strength testing included 12 Unconfined Compressive Strength (UCS) testing, 13 Point Load Tests and 3 Brazilian Tests.

4. OVERVIEW OF SOIL CLASSIFICATION

4.1 Made ground

Made Ground deposits were encountered either from the surface or beneath the Topsoil/Surfacing and were present to depths of between 1.40m and 6.50m BGL.

Made ground deposits were described generally as either dark grey / brown, sandy gravelly Clay with occasional cobbles or greyish brown clayey sandy Gravel. In some investigation holes the made ground contained occasional fragments of concrete, ceramic, red brick metal, rubber and wood.

Soil classifies as CLAY of intermediate to high plasticity, with a plasticity index ranging between 17% and 40%.

The Particle Size Distribution tests confirm percentages of sands and gravels ranging between 10% and 42% and 24% and 47%, respectively.

PH and total organic carbon (TOC) were determined at boreholes R03-CP03 and C03-CP08, at 1m and 0.5m depth respectively. Organic matter content (OMC) was estimated from TOC. Average values of PH 7.8, TOC 2.7 % w/w C and OMC 4.6 % w/w were obtained.

Samples R03-WS02 and R03-CP14 showed high values (>6% w/w C) of total organic carbon at Suite E tests. Asbestos was detected at 0.5m depth at borehole R03-CP08.

4.2 Cohesive deposits

Cohesive deposits were encountered beneath the Made Ground and were described typically as brown sandy gravelly CLAY or grey / dark grey sandy gravelly CLAY with occasional cobbles and boulders.

The strength of the cohesive deposits typically increased with depth. In the majority of the exploratory holes, it was firm below 3.0m BGL, stiff below 5.0m BGL and very stiff below 7.0m BGL

The geotechnical testing carried out on recovered soil samples generally confirm the descriptions on the logs and classified the deposits as CLAY of low, with a plasticity index ranging between 14% and 17%.

The Particle Size Distribution tests confirm generally well-graded deposits with percentages of sands and gravels ranging between 14% and 31% and 20% and 56%, respectively, with average values of 22% of sand and 34% of gravel.

4.3 Bedrock

The rotary core boreholes recovered weak to medium strong thinly laminated to thickly bedded grey/dark grey fine-grained LIMESTONE locally interbedded with medium strong dark grey fine grained laminated MUDSTONE.

The depth to rock is of 18.5m BGL. RQD values are very poor but presumably because they belong to the upper weather zone.

5. SUMMARY OF GROUND INVESTIGATION INTERPRETATIVE REPORT

For Ballymun/Finglas to City Centre CBC scheme, the following lithology and soil strength properties has been assumed based on the GI findings:

Layer	Depth (m)	SPT	Undrained shear strength, c_u (kPa)
Topsoil	0 to 0.5 m	-	-
Made Ground: Gravel / Brown Clay (possibly UBrBC) / Grey Clay	0.5 to 4m	8	50
Stiff / Very stiff Grey or Dark Grey Boulder Clay (UBkBC)	4 to 12.5	20-50	250
Very stiff Brown Boulder Clay (LBrBC)	12.5 to 17.5	50	325
Gravel	14 to 18.5	50	325
Limestone	>18.5	-	-

- 2 Vane tests at Made Ground layer UBrBC, defined as brown slightly sandy slightly gravelly Clay have shown Peak shear strength values of about 20 KPa.

- 1 undrained triaxial UU test at UBrBC layer, defined as stiff brown slightly sandy gravelly Clay, has given a shear strength of about 80 KPa.

- 2 Shear Box tests at UBkBC layer, defined as slightly sandy slightly gravelly Clay, shown angles of peak shearing resistant between 32 and 36 degrees and effective cohesion between 5 and 15 kPa.

From Glasnevin project 9 triaxial CU tests. Layers of UBkBC and LBrBC shown values between 600 and 700 kPa. Also 1 triaxial CU from Thameslink project on LBrBC showing a value of 800 kPa.

From Metrolink 2 Shear Box tests, one at Made Ground layer showing an angle of peak shearing resistant of 29 degrees and effective cohesion of 6 kPa, and another at the bottom Gravel layer with an angle of peak shearing resistant of 34 degrees and no effective cohesion.

The geological geotechnical ground profile can be found at Appendix 1.

Ground parameters from in situ and lab tests are shown in Appendix 2.

6. HIDROGEOLOGY

Groundwater was noted during the investigation although the exploratory holes did not remain open for sufficiently long periods of time to establish the hydrogeological regime. However, standpipes were installed to allow the equilibrium groundwater level to be determined.

Groundwater levels recorded during the GI works are summarized below:

Date:	20/4/21	16/6/21
R3-CP01	-	-
R3-CP02	-	10.03
R3-CP03	-	-
R3-CP04	-	-
R3-CP05	-	-
R3-CP06	-	-
R3-CP07	1.29	1.27
R3-CP08	-	-
R3-CP09	-	-
R3-CP10	-	-
R3-CP11	-	-
R3-CP12	-	-
R3-CP13	-	-
R3-CP14	-	1.25

Date:	9/2/18	14/2/18
Glasnevin BH01	9.80	9.80
Glasnevin BH02A	10.10	11.25
Date:	**30/7/20**	**31/7/20**
Metrolink GBH01	8.97-9.06	-
Metrolink GBH02	-	10.47-11.2

7. GEOTECHNICAL INPUT TO STRUCTURES

The following table shows the expected depth to bedrock, based on the data from the Desktop Review, as well as the depth of the encountered bedrock in the GI undertaken.

Note that most of the boreholes were terminated at a shorter length, before encountering the bedrock strata. Therefore, the expected depth to bedrock could not be confirmed.

Structure	Permanent loads / Variable loads (KN)	Borehole Ref.	Expected Depth to Bedrock	Depth to encountered Bedrock	Depth to N_{SPT} values of Refusal	Piles estimated length (m)
Ballymun 01 D=0.5m	454 / 120	-	15-20m	-	-	9.5
Ballymun 02 D=0.5m	424 / 179	R3-CP03	15-20m	-	5m	8.5
Ballymun 03 D=0.5m	82 / 169	R3-CP07	15-20m	-	5m	5.5
		R3-WS03	15-20m	-	5m	5.5
Ballymun 04 D=0.8m	298 / 425	R3-RC01	20-25m	18.5m	9.5m	10.0
		R3-RC02	20-25m	18.5m	6.5m	7.0
		R3-RC03	20-25m	18.5m	8m	8.5
		R3-WS01	20-25m	-	-	-
		R3-WS02	20-25m	-	-	-
		R3-CP14	20-25m	-	5m	6.0
Ballymun 04 D=0.5m	298 / 425	R3-RC01	20-25m	18.5m	9.5m	14.5
		R3-RC02	20-25m	18.5m	6.5m	12.0
		R3-RC03	20-25m	18.5m	8m	12.0
		R3-WS01	20-25m	-	-	-
		R3-WS02	20-25m	-	-	-
		R3-CP14	20-25m	-	5m	11.0

A preliminary number of the characteristic compressive resistance of piles has been obtained following the alternative procedure in accordance with the Eurocode 7 and the Irish National Annex. This procedure makes use of the ground parameters (such as the undrained shear strength, c_u) to estimate the shaft and base compressive resistance of piles.

Cu values have been derived from SPT values obtained in each borehole following the SPT-Cu relationship proposed by Stroud and Butler (1975). Calcs can be found at Appendix 3.

For 0.5m diameter driven piles embedded in the Dublin boulder clay (except for Ballymun 04, where piles diameters are 0.8m), the estimated piles length that satisfies the ULS is as detailed in the table above.

At Ballymun 04 a retaining wall is proposed, for which the following geotechnical parameters derived from the ground investigation works can be used for the design

Route 3 Ballymun 04	**Depth (m)**	**Dry weight (KN/m^3)**	**Undrained shear strength, c_u (kPa)**	**Young's modulus E (MPa)**	**Undrained Young's modulus (MPa)**	**Friction angle φ' (º)**	**Cohesion c' (KPa)**	**Poisson's coefficient (-)**	**Earth pressure coefficient at rest K_0 (-)**	**Horizontal spring stiffness (KN/m^3)**
Made Ground	0 to 4.5m	-	50	25	-	28	0	0.3	1	3,500 – 5,000
Grey Boulder Clay (UBkBC)	4.5 to 12.5	22.5	250	80	100	30	0	0.2	1.3	17,000 – 20,000
Brown Boulder Clay (LBrBC)	12.5 to 17.5	-	325	-	120	35	0	0.2	1.3	20,000 – 25,000
Mudstone	17.5 to 19.5	-	325	-	-	-	-	-	-	-
Limestone	>19.5	25	500	800	1000	45	0	.	-	35,000 – 37,500

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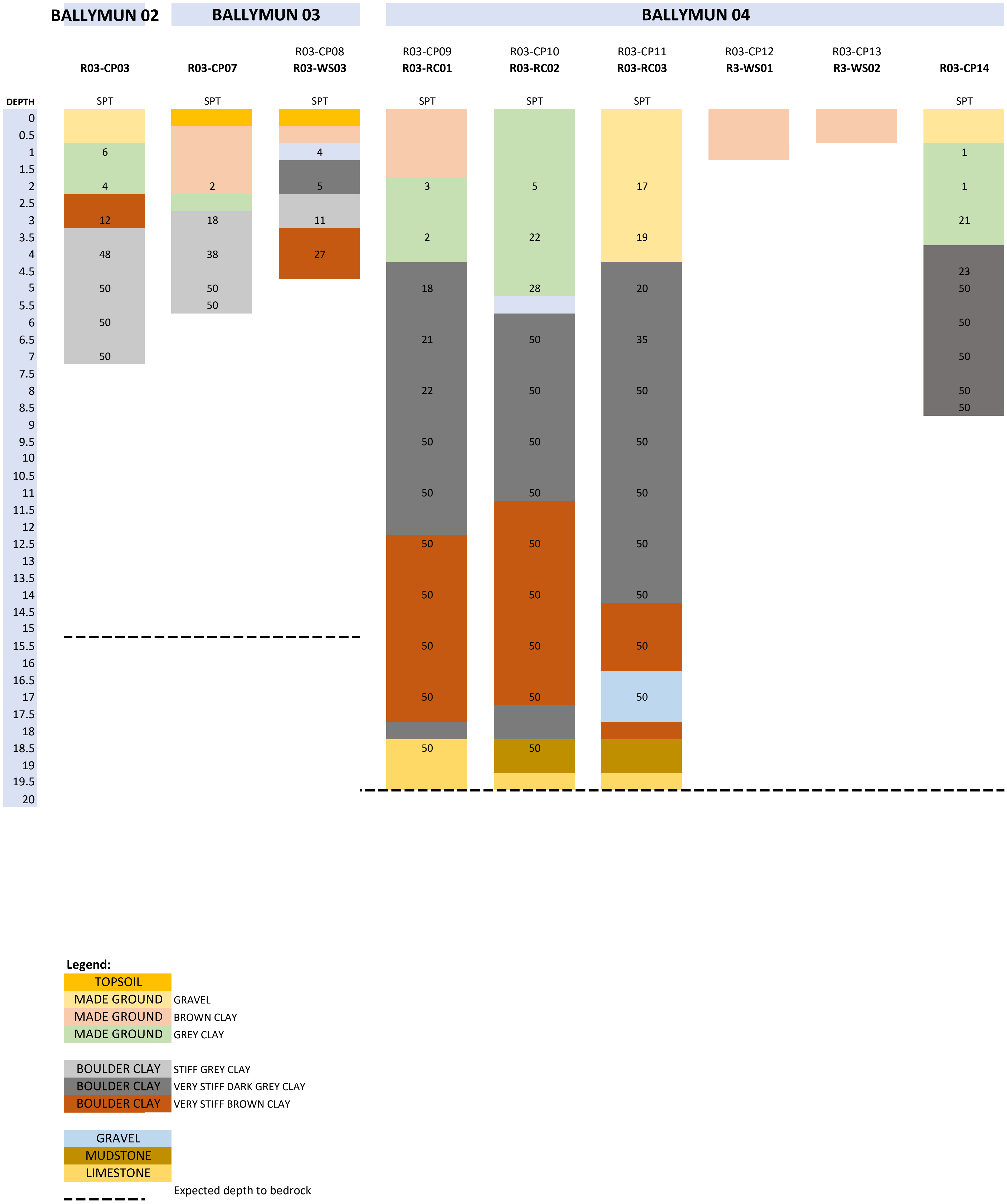
8. APPENDICES

8.1 Geological geotechnical profile

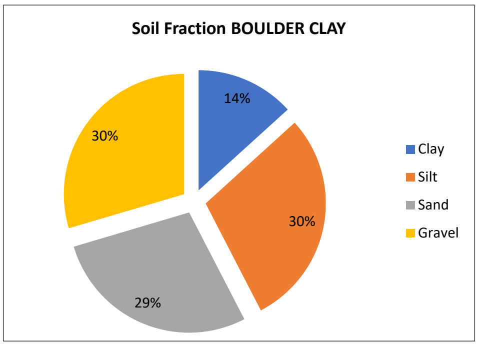


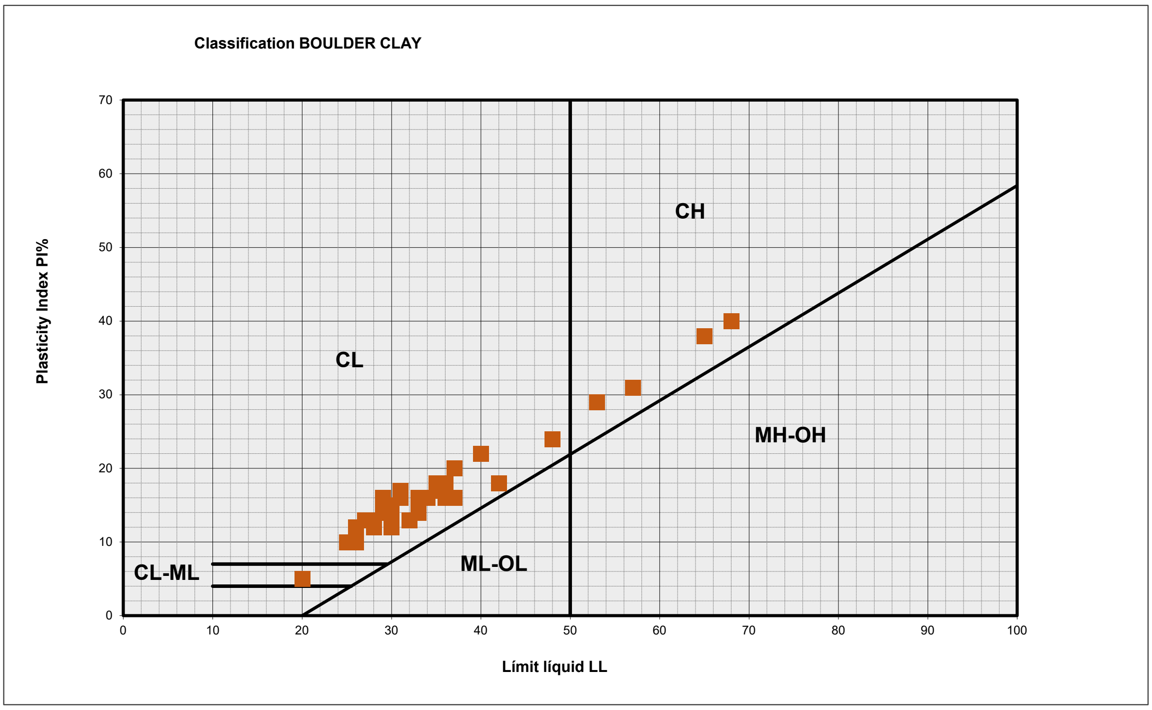
BALLYMUN 02
BALLYMUN 03
BALLYMUN 04
R03-CP03
R03-CP07
R03-CP08
R03-WS03
R03-CP09
R03-RC01
R03-CP10
R03-RC02
R03-CP11
R03-RC03
R03-CP12
R3-WS01
R03-CP13
R3-WS02
R03-CP14
DEPTH
SPT
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15 15.5 16 16.5 17 17.5 18 18.5 19 19.5 20
R03-CP03: 6 4 12 48 50 50 50
R03-CP07: 2 18 38 50 50
R03-CP08 / R03-WS03: 4 5 11 27
R03-CP09 / R03-RC01: 3 2 18 21 22 50 50 50 50 50 50 50
R03-CP10 / R03-RC02: 5 22 28 50 50 50 50 50 50 50 50 50
R03-CP11 / R03-RC03: 17 19 20 35 50 50 50 50 50 50 50
R03-CP14: 1 1 21 23 50 50 50 50 50
Legend:
TOPSOIL
MADE GROUND GRAVEL
MADE GROUND BROWN CLAY
MADE GROUND GREY CLAY
BOULDER CLAY STIFF GREY CLAY
BOULDER CLAY VERY STIFF DARK GREY CLAY
BOULDER CLAY VERY STIFF BROWN CLAY
GRAVEL
MUDSTONE
LIMESTONE
Expected depth to bedrock

8.2 Ground parameters

SOIL CLASSIFICATION

Borehole	Soil description	Sample type	Top depth (m)	Moisture Content %	Particle density Mg/m^3	Bulk density Mg/m^3	Liquid limit %	Plastic limit %	Plasticity Index %	Passing 0.425mm %	Classification		Particle size distribution - Soil Fraction: Clay	Silt	Sand	Gravel	Cobbles	Total
Glasnevin BH01	-	CB	2.1	9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	Dark grey slightly sandy gravelly silty CLAY	CB	3.6	10.1	-	-	34	18	16	33.1	CL	-	8%	15%	18%	58%	0%	100%
Glasnevin BH01	-	CB	5.1	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	Dark grey slightly sandy slightly gravelly silty CLAY	CB	6.6	7.8	-	-	-	-	-	-	-	-	10%	25%	32%	33%	0%	100%
Glasnevin BH01	-	CB	8.1	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	Dark grey silty very sandy fine to coarse GRAVEL	C	8.8	6.2	-	-	20	15	5	34	CL-ML	-	4%	17%	35%	44%	0%	100%
Glasnevin BH01	-	CB	9.6	29.7	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	-	CB	11.1	16.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	Dark grey slightly sandy gravelly silty CLAY	C	11.9	11	-	-	36	18	18	55.8	CL	-	17%	29%	15%	39%	0%	100%
Glasnevin BH01	-	CB	12.6	8.8	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	-	CB	14.1	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	-	CB	15.6	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH01	Dark gery/brown slightly gravelly slightly sandy slity CLAY	C	16.4	9.6	-	-	33	17	16	72.3	CL	-	17%	30%	35%	18%	0%	100%
Glasnevin BH02A	-	CB	2.4	12.3	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH02A	Dark grey slightly gravelly slightly sandy silty CLAY.	C	4.7	8.1	-	-	30	18	12	60.6	CL	-	14%	31%	31%	24%	0%	100%
Glasnevin BH02A	-	CB	6.9	8	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH02A	Dark grey slightly sandy slightly gravelly silty CLAY	C	10.95	9.3	-	-	36	19	17	57.8	CL	-	14%	30%	25%	31%	0%	100%
Glasnevin BH02A	Dark grey slightly sandy slightly gravelly silty CLAY	C	16.5	9.3	-	-	35	17	18	55.8	CL	-	14%	30%	22%	34%	0%	100%
Glasnevin BH02A	-	CB	17.4	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH02A	-	CB	20.4	10	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH02A	Dark grey slightly sandy slightly gravelly silty CLAY	C	22	9.8	-	-	37	17	20	67.1	CL	-	15%	35%	25%	25%	0%	100%
Glasnevin BH02A	-	CB	23.4	9.9	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
Glasnevin BH02A	Dark grey slightly gravelly slightly sandy silty CLAY	C	25.2	12.3	-	-	40	18	22	78.9	CL	-	19%	41%	25%	14%	0%	100%
Metrolink GBH01	Greyish brown sandy gravelly silty CLAY	B	1.2	12	-	-	33	19	14	69	CL	Low Plasticity CL	15%	33%	30%	22%	0%	100%
Metrolink GBH01	Greyish brown sandy gravelly silty CLAY	B	2	12	-	-	32	19	13	63	CL	Low Plasticity CL	17%	31%	30%	23%	0%	101%
Metrolink GBH01	Greyish brown sandy gravelly CLAY	B	4	12	-	-	26	15	11	64	CL	Low Plasticity CL	17%	35%	32%	17%	0%	101%
Metrolink GBH01	Greyish brown sandy gravelly CLAY	B	6.6	7.7	-	-	26	15	11	62	CL	Low Plasticity CL	10%	33%	39%	19%	0%	101%
Metrolink GBH01	Greyish brown sandy gravelly CLAY	B	9.4	19	-	-	27	14	13	44	CL	Low Plasticity CL	8%	20%	51%	21%	0%	100%
Metrolink GBH01	-	C	12	8.1	-	-	26	16	10	57	CL	Low Plasticity CL	17%	34%	36%	13%	0%	100%
Metrolink GBH01	-	B	16.6	7	-	-	-	-	-	-	-		-	4%	23%	54%	20%	101%
Metrolink GBH01	-	B	17.2	8.2	-	-	25	15	10	58	CL	Low Plasticity CL	17%	35%	36%	13%	0%	101%
Metrolink GBH02	Greyish brown sandy gravelly silty CLAY	B	2	16	-	-	48	24	24	70	CI	Low Plasticity CL	14%	33%	30%	23%	0%	100%
Metrolink GBH02	Greyish brown sandy gravelly silty CLAY	B	4	11	-	-	29	14	15	60	CL	Low Plasticity CL	16%	34%	30%	20%	0%	100%
Metrolink GBH02	Greyish brown sandy gravelly CLAY	B	6	8.1	-	-	25	15	10	58	CL	Low Plasticity CL	13%	34%	32%	21%	0%	100%
Metrolink GBH02	Grey very gravelly very sandy CLAY	C	9.6	10	-	-	30	16	14	51	CL	Low Plasticity CL	15%	21%	29%	35%	0%	100%
Metrolink GBH02	Greyish brown sandy gravelly CLAY	B	14	10	-	-	30	15	15	72	CL	Low Plasticity CL	-	-	-	-	-	0%
Metrolink GBH02	Greyish brown sandy gravelly CLAY	B	16	10	-	-	28	15	13	63	CL	Low Plasticity CL	12%	25%	45%	19%	0%	101%
Metrolink GBH21	Greyish brown sandy gravelly silty CLAY	B	1.2	8.5	-	-	26	15	11	50	CL	Low Plasticity CL	10%	40%	38%	13%	0%	101%
Metrolink GBH22	Greyish brown sandy gravelly silty CLAY	B	1.2	8.7	-	-	26	14	12	46	CL	Low Plasticity CL	13%	34%	35%	19%	0%	101%
Metrolink GBH28	Greyish brown sandy gravelly silty CLAY	B	1.2	8	-	-	28	16	12	55	CL	Low Plasticity CL	10%	33%	40%	18%	0%	101%
R03-CP03	Dark brown mottled grey sandy slightly gravelly CLAY	B	2	17	-	-	-	-	-	-	-	-	-	34%	42%	24%	0%	100%
R03-CP03	Brown slightly sandy slightly gravelly CLAY	B	3	19	-	-	-	-	-	-	-	-	-	46%	25%	29%	0%	100%
R03-CP03	Dark brown mottled grey slightly sandy slightly gravelly CLAY	B	5	12	2.64	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP03	Dark brown mottled grey slightly sandy slightly gravelly CLAY	B	6	12	-	-	29	15	14	64	CL	Low Plasticity CL	-	49%	31%	20%	0%	100%
R03-CP07	Brown slightly sandy gravelly CLAY	B	1.5	23	-	-	35	18	17	43	CI	Intermediate Plasticity CI	-	29%	24%	47%	0%	100%
R03-CP07	Brown slightly sandy gravelly CLAY	B	3	16	2.6	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP07	Brown mottled grey slightly sandy slightly gravelly CLAY with many cobbles.	B	5	12	-	-	29	15	14	31	CL	Low Plasticity CL	-	24%	14%	27%	35%	100%
R03-CP07	Brown slightly sandy gravelly CLAY	B	6	14	2.7	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP08	Brown slightly sandy slightly gravelly CLAY	B	2.2	31	2.64	-	68	28	40	65	CH	High Plasticity CH	27%	33%	10%	30%	0%	100%
R03-CP08	Stiff brown slightly sandy gravelly CLAY	U	3.5	9.4	2.62	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP08	Brown slightly sandy very gravelly CLAY	B	4	11	-	-	31	15	16	50	CL	Low Plasticity CL	17%	23%	23%	37%	0%	100%
R03-CP14	MADE GROUND dark grey very gravelly clayey sand of ash.	B	2	38	2.03	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP14	Dark grey gravelly slightly sandy CLAY with some organic material	B	3	49	-	-	65	27	38	51	CH	High Plasticity CH	15%	27%	23%	35%	0%	100%
R03-CP14	Dark grey very gravelly very sandy CLAY.	B	4	15	2.59	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP14	Dark grey sandy very clayey GRAVEL	B	5	10	-	-	29	13	16	36	CL	Low Plasticity CL	11%	17%	16%	56%	0%	100%
R03-CP14	Dark grey very gravelly very sandy CLAY.	B	6	11	2.61	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP14	Dark grey gravelly slightly sandy CLAY	B	7	14	-	-	31	14	17	51	CL	Low Plasticity CL	16%	25%	22%	37%	0%	100%
R03-CP14	Dark grey very gravelly very sandy CLAY.	B	8	13	2.6	-	-	-	-	-	-	-	-	-	-	-	-	0%
R03-CP14	Brown slightly sandy gravelly CLAY	B	9	13		-	-	-	-	-	-	-	-	-	-	-	-	0%
R11-CP01	Grey brown slightly sandy slightly gravelly silty CLAY	B	2	15.6	-	-	42	24	18	59	CL	-	13%	32%	24%	31%	0%	100%
R11-CP01	Grey brown slightly sandy slightly gravelly silty CLAY	B	2.5	14.2	-	-	-	-	-	-	-	-	-	45%	24%	32%	0%	100%
R11-CP01	Grey brown slightly sandy slightly gravelly silty CLAY	B	4	15.9	-	-	37	21	16	59	CL	-	0%	31%	28%	28%	0%	87%
R11-CP01	Dark grey slightly gravelly slightly sandy silty CLAY	B	5.5	13.5	-	-	-	-	-	-	-	-	-	45%	28%	27%	0%	100%
R11-CP01	Dark grey slightly sandy slightly gravelly silty CLAY	B	6	13.6	-	-	30	18	12	54.5	CL	-	13%	27%	26%	34%	0%	100%
R11-CP01	Dark grey slightly sandy slightly gravelly silty CLAY	B	7.5	13.3	-	-	34	18	16	58.2	CL	-	14%	30%	28%	28%	0%	100%
R11-CP01	Dark grey slightly sandy slightly gravelly silty CLAY	B	8	14.3	-	-	-	-	-	-	-	-	-	41%	25%	34%	0%	100%
R11-CP03	MADE GROUND brownish grey very gravelly very sandy CLAY	B	2	23	-	-	36	20	16	49	CI	Intermediate Plasticity CI	-	-	-	-	-	0%
R11-CP03	Grey very sandy clayey GRAVEL	B	3	15	2.67	-	-	-	-	-	-	-	-	-	-	-	-	0%
R11-CP03	-	B	4.48	0.3	-	2.71	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP01	Brown slightly clayey silty very sandy GRAVEL	B	1.2	11	2.61	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP01	Brown silty very sandy GRAVEL	B	2	4.7	-	-	-	NP	-		-	-	-	17%	30%	40%	13%	100%
R16-CP02	Brown very gravelly SAND	B	1	13	2.64	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP02	Brown silty very sandy GRAVEL	B	2	9.7	-	-	-	NP	-	-	-	-	-	6%	25%	69%	0%	100%
R16-CP02	Brown & grey silty SAND	U100	6.5	19	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP02	Brown mottled grey slightly sandy slightly gravelly CLAY with some organic material	U100	7.5	41	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP02	Brown slightly silty very sandy GRAVEL	B	8	3.5	2.62	-	-	NP	-	-	-	-	-	2%	29%	69%	0%	100%
R16-CP04	Brown silty very sandy GRAVEL with many cobbles	B	1	-	2.68	-	-	-	-	-	-	-	-	9%	22%	35%	34%	100%
R16-CP04	Brown slightly clayey silty very gravelly SAND	B	3	-	2.62	-	-	-	-	-	-	-	-	16%	53%	31%	0%	100%
R16-CP04	Brown slightly clayey silty very gravelly SAND	B	4	14	2.65	2.06	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP04	Brown silty very gravelly SAND	B	5	-	2.66	-	-	-	-	-	-	-	-	9%	58%	33%	0%	100%
R16-CP04	Brown silty gravelly SAND	B	6	6.4	2.65	1.7	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP04	Brown & grey silty SAND	U100	6.5	19	2.58	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP04	Brown mottled grey slightly sandy slightly gravelly CLAY with some organic material	B	7	47	-	-	57	26	31	90	CH	High plasticity CH	-	84%	11%	5%	0%	100%
R16-CP04	Brown mottled grey slightly sandy slightly gravelly CLAY with some organic material	U100	7.5	41	2.52	-	-	-	-	-	-	-	-	-	-	-	-	0%
R16-CP04	Brown mottled grey slightly sandy slightly gravelly CLAY with some organic material	B	8	46	-	-	53	24	29	93	CH	High plasticity CH	-	83%	15%	2%	0%	100%
R16-CP04	Brownish grey silty sandy GRAVEL with cobbles	B	12	-	2.69	-	-	-	-	-	-	-	-	5%	18%	67%	10%	100%


Soil Fraction BOULDER CLAY
14%
30%
29%
30%
Clay
Silt
Sand
Gravel

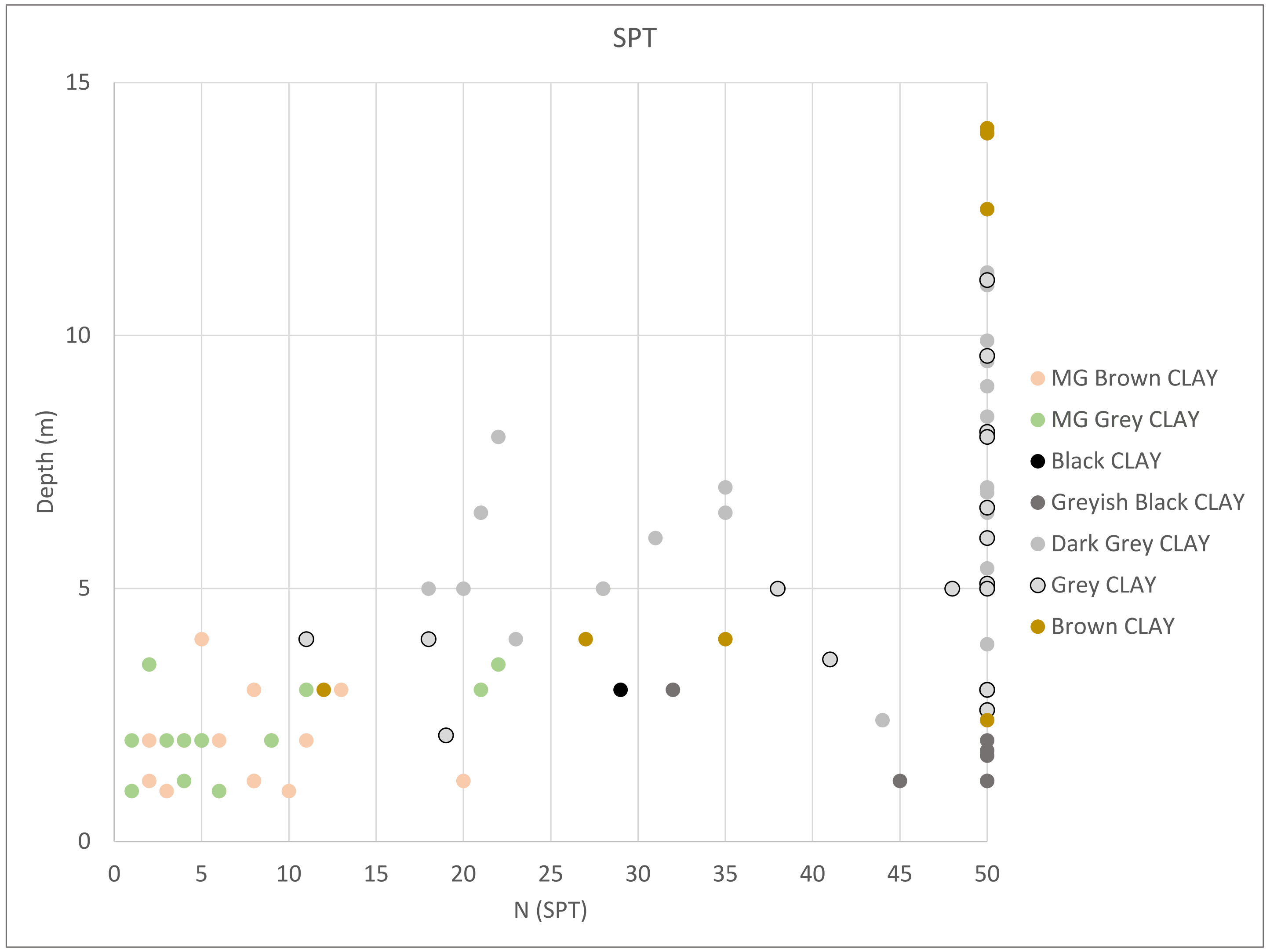

Classification BOULDER CLAY
Plasticity Index PI%
Límit liquid LL
CH
CL
MH-OH
ML-OL
CL-ML
0
10
20
30
40
50
60
70
80
90
100

SOIL STRENGTH

Test	BH	Top depth (m)	Soil	N_{SPT}	Correlation factor	Cu (KPa)
	R11-CP04	1	MADE GROUND: Brown slightly sandy slightly gravelly silty CLAY. Gravel is anugular to sub rounded fine to coarse with occasional fragments of brick and concrete.	10		65
	R11-CP04	2	Medium dense greyish brown sandy sub angular to rounded fine to coarse GRAVEL	27		175.5
	R11-CP04	2.6	Firm brownish grey slightly sandy gravelly CLAY. Gravel is angular to sub rounded fine to coarse	50		325
	R11-CP01	1.2	MADE GROUND: Greyish brown slightly sandy gravelly Clay with occasional sub-angular to sub-rounded cobbles, red brick and mortar fragments.	2		13
	R11-CP01	2	MADE GROUND: Greyish brown slightly sandy gravelly Clay with occasional sub-angular to sub-rounded cobbles, red brick and mortar fragments.	4		26
	R11-CP01	3	MADE GROUND: Greyish brown slightly sandy gravelly Clay with occasional sub-angular to sub-rounded cobbles, red brick and mortar fragments.	13		84.5
	R11-CP01	4	Very stiff brown slightly sandy slightly gravelly CLAY with occasional sand lenses.	35		227.5
	R11-CP01	5	Very stiff dark grey slightly sandy gravelly CLAY with rare sub-rounded cobbles.	28		182
	R11-CP01	6	Very stiff dark grey slightly sandy gravelly CLAY with rare sub-rounded cobbles.	31		201.5
	R11-CP01	7	Very stiff dark grey slightly sandy gravelly CLAY with rare sub-rounded cobbles.	35		227.5
	R11-CP01	8	Very stiff dark grey slightly sandy gravelly CLAY with rare sub-rounded cobbles.	50		325
	R11-CP03	1	MADE GROUND: Dark brown slightly sandy gravelly Clay with occasional angular to subrounded cobbles and occasional fragments of glass, metal, red brick and wood (creosote like odour)	3		19.5
	R11-CP03	2	MADE GROUND: Grey slightly sandy slightly gravelly Clay with occasional angular to subangular cobbles and occasional fragments of red brick and wood	9		58.5
	R11-CP03	3	MADE GROUND: Grey slightly sandy slightly gravelly Clay with occasional angular to subangular cobbles and occasional fragments of red brick and wood	50		325
	R16-CP01	1.2	MADE GROUND: Brown slightly sandy gravelly Clay with some subangular to rounded cobbles, occasional boulders and occasional fragments of red brick	8		52
	R16-CP01	2	MADE GROUND: Brown slightly sandy gravelly Clay with some subangular to rounded cobbles, occasional boulders and occasional fragments of red brick	9		58.5
	R16-CP01	3	MADE GROUND: Brown slightly sandy gravelly Clay with some subangular to rounded cobbles, occasional boulders and occasional fragments of red brick	8		52
	R16-CP01	4	MADE GROUND: Brown slightly sandy gravelly Clay with some subangular to rounded cobbles, occasional boulders and occasional fragments of red brick	5		32.5
	R16-CP01	5	MADE GROUND: Brown slightly sandy gravelly Clay with some subangular to rounded cobbles, occasional boulders and occasional fragments of red brick	50		325
	R16-CP02	2	MADE GROUND: Brown slightly sandy gravelly Clay with occasional angular to subrounded cobbles and occasional fragments of concrete and red brick	6		39
	R16-CP02	5.3	MADE GROUND: Brown sandy clayey angular to rounded fine to coarse GRAVEL with occasional fragments of red brick (driller's notes)	17		110.5
	R16-CP02	6	Dense grey slightly clayey very sandy subangular to rounded fine to coarse GRAVEL with some subangular to rounded cobbles	50		325
	R16-CP02	8	Dense grey slightly clayey very sandy subangular to rounded fine to coarse GRAVEL with some subangular to rounded cobbles	50		325
	R16-CP03	1	MADE GROUND: Brown silty gravelly Sand withoccasional cobbles and boulders, and occasional fragments of concrete, plastic, wood and red brick	6		39
	R16-CP03	2	POSSIBLE MADE GROUND: Brown slightly gravelly clayey SAND.	5		32.5
	R16-CP03	3	Soft dark grey slighlty sandy very gravelly CLAY with occasional sub angular to sub rounded cobbles. Gravel is subrounded to rounded fine to coarse	11		71.5
	R16-CP03	4	Very loose grey very sandy subangular to rounded fine to coarse GRAVEL.	5		32.5
	R16-CP03	5	Very loose grey very sandy subangular to rounded fine to coarse GRAVEL.	8		52
	R16-CP03	7	Very soft grey slightly sandy silty CLAY with occasional shell fragments and orgnic matter.	5		32.5
	R16-CP03	8	Very soft grey slightly sandy silty CLAY with occasional shell fragments and orgnic matter.	5		32.5
	R16-CP03	9	Very soft grey slightly sandy silty CLAY with occasional shell fragments and orgnic matter.	3		19.5
	R16-CP03	10	Very soft grey slightly sandy silty CLAY with occasional shell fragments and orgnic matter.	3		19.5
	R16-CP03	11	Very soft grey slightly sandy silty CLAY with occasional shell fragments and orgnic matter.	50		325
	R16-CP03	12	Dense grey sandy subrounded to rounded fine to coarse GRAVEL with some subangular to rounded cobbles.	50		325
	R16-CP04	2	MADE GROUND: Brown slightly gravelly sandy CLAY with some cobbles and occasional fragments of red brick	11		71.5
	R16-CP04	3	MADE GROUND: Greyish brown clayey gravelly fine to coarse SAND. Gravel is subangular to rounded fine to coarse	5		32.5
	R16-CP04	4	MADE GROUND: Greyish brown clayey gravelly fine to coarse SAND. Gravel is subangular to rounded fine to coarse	3		19.5
	R16-CP04	5	Very loose dark grey clayey gravelly fine to coarse SAND. Gravel is subrounded to rounded fine to coarse	2		13
	R16-CP04	6	Very loose grey very gravelly fine to coarse SAND. Gravel is subrounded to rounded fine to coarse	2		13
	R16-CP04	7	Very soft grey slightly sandy silty CLAY with occasional shell fragments	3		19.5
	R16-CP04	8	Very soft grey slightly sandy silty CLAY with occasional shell fragments	2		13
	R16-CP04	9	Very soft grey slightly sandy silty CLAY with occasional shell fragments	4		26
	R16-CP04	10	Very soft grey slightly sandy silty CLAY with occasional shell fragments	2		13
	R16-CP04	11	Very soft grey slightly sandy silty CLAY with occasional shell fragments	3		19.5
	R16-CP04	12	Dense grey slightly clayey very sandy subrounded to rounded fine to coarse GRAVEL with some subangular to rounded cobbles	50		325
	R16-CP04	13	Dense grey slightly clayey very sandy subrounded to rounded fine to coarse GRAVEL with some subangular to rounded cobbles	50		325
	Glasnevin BH01	2.1	Stiff grey sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is fine to coarse subangular to subrounded	19		123.5
	Glasnevin BH01	3.6	Very stiff grey sandy gravelly CLAY with occasional subangular to subrounded cobbles and boulders. Gravel is fine to coarse subangular to subrounded	41		266.5
	Glasnevin BH01	5.1	Driller notes gravelly CLAY - Recovery consists subangular to subrounded cobbles and boulders of Limestone	50		325
	Glasnevin BH01	6.6	Very stiff grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded.	50		325
	Glasnevin BH01	8.1	Very stiff grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded.	50		325
	Glasnevin BH01	9.6	Very stiff grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded.	50		325
	Glasnevin BH01	11.1	Very stiff grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded.	50		325
	Glasnevin BH01	14.1	Very stiff brown grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded	50		325
	Glasnevin BH01	15.6	Very stiff brown grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded	50		325
	Glasnevin BH01	17.1	Very stiff brown grey slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravels fine to coarse subangular to subrounded	50		325
	Glasnevin BH02A	2.4	Gravelly band. Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	44		286
	Glasnevin BH02A	3.9	Gravelly band. Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	5.4	Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	6.9	Gravelly band. Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	8.4	Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	9.9	Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	11.25	Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	15.9	Very stiff dark grey slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse.	50		325
	Glasnevin BH02A	17.4	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	18.7	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	2.4	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	21.9	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	23.4	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	24.9	Very stiff brown slightly sandy gravelly CLAY. Gravel subangular to subrounded fine to coarse	50		325
	Glasnevin BH02A	26.4	Dense grey fine to coarse angular to subangular GRAVEL with some angular to subrounded cobbles. Fines may have washed out	50		325
SPT	Metrolink GBH01	1.2	Sand is fine to coarse. Gravel is subangular fine to coarse of mixed lithologies. Cobbles and boulders are subrounded to subangular of mixed lithologies.	8	6.5	52
	Metrolink GBH01	3	Stiff becoming very stiff black slightly sandy slightly gravelly silty CLAY.Sand is fine to coarse. Gravel is subangular to subrounded fine tomedium of mixed lithologies.	29		188.5
	Metrolink GBH01	5	Very stiff brownish grey sandy slightly gravelly silty CLAY. Sand is fineto coarse. Gravel is subangular fine to medium of limestone.	50		325
	Metrolink GBH01	8	Very stiff brownish grey sandy slightly gravelly silty CLAY. Sand is fineto coarse. Gravel is subangular fine to medium of limestone.	50		325
	Metrolink GBH01	11	Greyish brown slightly silty gravelly fine to coarse SAND. Gravel issubangular fine to coarse of limestone and sandstone.	50		325
	Metrolink GBH01	14	Grey and brown slightly sandy subangular ne to coarse GRAVEL of limestone and sandstone with low cobble content.Sand is ne to coarse. Cobbles are subangular of limestone.	50		325
	Metrolink GBH02	1.2	MADE GROUND: Stiff greyish brown slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to medium of mixed lithologies.	20		130
	Metrolink GBH02	3	Very stiff greyish black slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to medium of mixed lithologies.	32		208
	Metrolink GBH02	5	Firm becoming stiff brownish grey slightly sandy slightly gravelly silty CLAY. Sand is ne to coarse. Gravel is subangular ne to medium of predominantly limestone.	50		325
	Metrolink GBH21	1.2	Very stiff greyish black slightly gravelly sandy silty CLAY. Sand is fine to coarse. Gravel is subangular fine to medium of mixed lithologies.	50		325
	Metrolink GBH21	1.7	Very stiff greyish black slightly gravelly sandy silty CLAY. Sand is fine to coarse. Gravel is subangular fine to medium of mixed lithologies.	50		325
	Metrolink GBH22	1.2	Very stiff greyish black slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is subrounded fine to medium of mixed lithologies.	50		325
	Metrolink GBH22	1.8	Very stiff greyish black slightly sandy slightly gravelly silty CLAY. Sand is fine to coarse. Gravel is subrounded fine to medium of mixed lithologies.	50		325
	Metrolink GBH28	1.2	Very stiff greyish black slightly gravelly sandy silty CLAY. Sand is fine to coarse. Gravel is subangular fine to medium of mixed lithologies.	45		292.5
	Metrolink GBH28	2	Very stiff greyish black slightly gravelly sandy silty CLAY. Sand is fine to coarse. Gravel is subangular fine to medium of mixed lithologies.	50		325
	R3-CP08	1.2	MADE GROUND: Brownish grey sandy clayey angular to subrounded fine to coarse Gravel with occasional fragments of ceramic, rubber and red brick	4		26
	R3-CP08	2	MADE GROUND: Brownish grey sandy clayey angular to subrounded fine to coarse Gravel with occasional fragments of ceramic, rubber and red brick	5		32.5
	R3-CP08	3	Firm brownish grey slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine to coarse	11		71.5
	R3-CP08	4	Stiff greyish brown slightly sandy gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	27		175.5
	R03-CP03	1	MADE GROUND: Grey slightly sandy gravelly Clay with occasional angular to subangular cobbles and occasional fragments of red brick	6		39
	R03-CP03	2	MADE GROUND: Grey slightly sandy gravelly Clay with occasional angular to subangular cobbles and occasional fragments of red brick	4		26
	R03-CP03	3	Firm brown slightly sandy slightly gravelly CLAY. Gravel is subangular to subrounded fine to coarse	12		78
	R03-CP03	4	Very stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	48		312
	R03-CP03	5	Very stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP07	2	MADE GROUND: Greyish brown slightly sandy slightly gravelly Clay with occasional rootlets and occasional fragments of red brick	2		13
	R03-CP07	3	Stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	18		117
	R03-CP07	4	Very stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	38		247
	R03-CP07	5	Very stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP07	6	Very stiff grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP14	1	MADE GROUND: Dark grey slightly sandy gravelly Clay with occasional angular to subangular cobbles and occasional fragments of brick, metal and wood	1		6.5
	R03-CP14	2	MADE GROUND: Dark grey slightly sandy gravelly Clay with occasional angular to subangular cobbles and occasional fragments of brick, metal and wood	1		6.5
	R03-CP14	3	MADE GROUND: Dark grey slightly sandy gravelly Clay with occasional angular to subangular cobbles and occasional fragments of brick, metal and wood	21		136.5
	R03-CP14	4	Stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	23		149.5
	R03-CP14	5	Very stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP14	6	Very stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP14	7	Very stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP14	8	Very stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-CP14	9	Very stiff dark grey slightly sandy slightly gravelly CLAY with occasional subangular to subrounded cobbles. Gravel is subangular to subrounded fine to coarse	50		325
	R03-RC01	2	MADE GROUND: Dark grey slightly sandy gravelly Clay with red brick fragments.	3		19.5
	R03-RC01	3.5	MADE GROUND: Dark grey slightly sandy gravelly Clay with red brick fragments.	2		13
	R03-RC01	5	Stiff dark grey slightly sandy gravelly CLAY with occasional cobbles. (Drillers notes: Boulder Clay)	18		117
	R03-RC01	6.5	Stiff dark grey slightly sandy gravelly CLAY with occasional cobbles. (Drillers notes: Boulder Clay)	21		136.5
	R03-RC01	8	Stiff dark grey slightly sandy gravelly CLAY with occasional cobbles. (Drillers notes: Boulder Clay)	22		143
	R03-RC01	9.5	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC01	11	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC01	12.5	Boulder Clay. Very stiff brown slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC01	14	Very stiff brown slightly sandy slightly gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-RC01	15.5	Very stiff brown slightly sandy slightly gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-RC01	17	Very stiff brown slightly sandy slightly gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-RC01	18.5	Very stiff dark brownish grey slightly sandy slightly gravelly CLAY.	50		325
	R03-RC02	2	MADE GROUND: Dark grey sandy gravelly Clay with occasional cobbles.	5		32.5
	R03-RC02	3.5	MADE GROUND: Dark grey sandy gravelly Clay with occasional cobbles.	22		143
	R03-RC02	5	MADE GROUND: Dark grey sandy gravelly Clay with occasional cobbles.	28		182
	R03-RC02	6.5	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	8	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	9.5	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	11	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	12.5	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	14	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	15.5	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	17	Boulder Clay. Very stiff dark grey slightly sandy gravelly CLAY with occasional cobbles.	50		325
	R03-RC02	18.5	MUDSTONE	50		325
	R03-CP03	2	MADE GROUND: Concrete fragments, red brick fragments and angular fine to coarse Gravel	17		110.5
	R03-CP03	3.5	MADE GROUND: Concrete fragments, red brick fragments and angular fine to coarse Gravel	19		123.5
	R03-CP03	5	Stiff dark grey slightly sandy gravelly CLAY with sub angular to sub rounded occasional cobbles.	20		130
	R03-CP03	6.5	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	35		227.5
	R03-CP03	8	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	9.5	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	11	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	12.5	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	14	Very stiff dark grey slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	15.5	Very stiff brown slightly sandy gravelly CLAY with occasional sub angular to sub rounded cobbles.	50		325
	R03-CP03	17	Grey slightly clayey sandy fine to coarse sub-angular to sub-rounded GRAVEL.	50		325

NOTE: $Cu=f1 \cdot N_{SPT}$. Correlation factor f1 according to Stroud and Butler (1975), taking a plasticity index PI=16%.

N_{SPT} Values - Average values					
Brown	Grey	Brown	Grey	Dark Grey	Greyish Black
10	9	35	50	28	32
2	(50)	50	19	31	50
4	11	50	41	35	50
13	4	50	50	50	50
3	5	50	50	44	50
8	6	50	50	50	45
9	4	50	50	50	50
8	1	50	50	50	46.71
5	1	50	50	50	
25	21	50	50	50	
6	3	27	50	50	
6	2	(12)	11	50	
11	5	50	48	23	
8	22	50	50	50	
20	28	50	18	50	
2	8.71	50	38	50	
8.75		50	50	50	
		47.63	50	50	
			50	18	
			43.42	21	
				22	
				26	
				50	
				50	
				50	
				50	
				50	
				50	
				50	
				50	
				50	
				50	
				20	
				35	
				50	
				50	
				50	
				50	
				50	
				43.67	



Soil		Average N_{SPT}	PI %	f1	Cu = f1· N_{SPT} (KPa)
Made ground	Brown	8	16	6.5	**52**
	Grey	9	16	6.5	**59**
Very stiff CLAY	Brown	45	16	6.5	**293**
	Grey	45	16	6.5	**293**
	Dark Grey	45	17	6.5	**293**
	Greyish Black	45	16	6.5	**293**

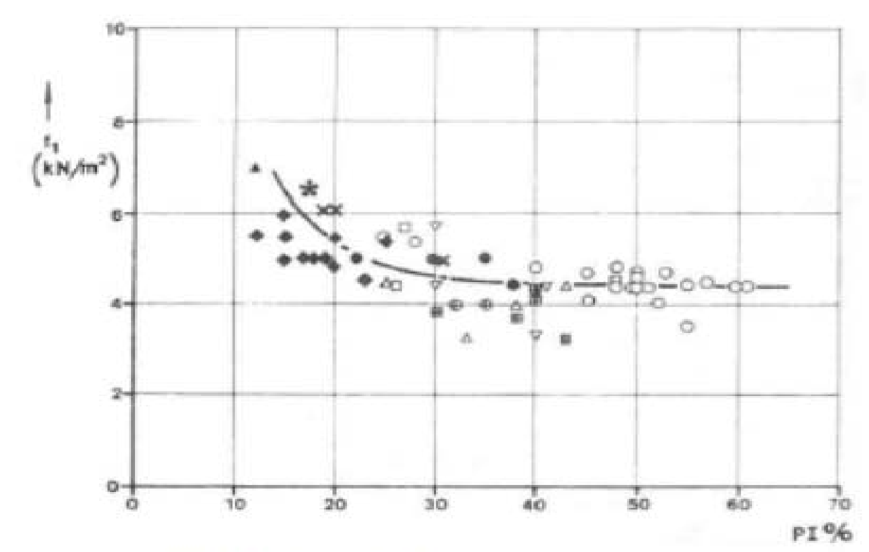


Fig.A.8.4 f_1 vs. PI from *Stroud and Butler*

SOIL STRENGTH

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Peak shear strength KPa
Vane Test	R16-CP01	Brown slightly clayey very sandy GRAVEL	B	3.00	-	>146
	R16-CP02	Dark brown very gravelly SAND	B	3.00	-	>146
	R16-CP02	Brown & grey silty SAND	U100	6.50	19.00	13.00
	R16-CP02	Brown mottled grey slightly sandy slightly gravelly CLAY with some organ	U100	7.50	41.00	11.00
	R03-CP03	Dark brown mottled grey sandy slightly gravelly CLAY	B	2.00	17.00	19.00
	R03-CP03	Brown slightly sandy slightly gravelly CLAY	B	3.00	19.00	20.00

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Bulk density Mg/m^3	Cu KPa	Load failure (deviator) kPa	Failure Mode	Strain %	Effective angle of friction (º)	Effective cohesion kPa
Triaxial CU	Glasnevin BH01	Stiff dark grey silty very sandy fine to coarse GRAVEL	C	8.80	7.70	2.40	180.30	360.60	brittle	4.29	-	-
	Glasnevin BH01	Dark grey slightly sandy gravelly silty CLAY.	C	11.90	24.80	2.02	32.40	64.90	plastic	13.24	-	-
	Glasnevin BH01	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY	C	14.65	8.50	2.35	682.00	1364.00	plastic	8.85	-	-
	Glasnevin BH02A	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY	C	4.70	8.10	2.39	516.60	1033.30	brittle	4.98	-	-
	Glasnevin BH02A	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY	C	10.95	9.20	2.32	475.90	951.80	brittle	4.63	-	-
	Glasnevin BH02A	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY	C	16.50	8.30	2.40	662.80	1325.50	brittle	5.61	-	-
	Glasnevin BH02A	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY.	C	22.00	9.80	2.32	670.80	1341.70	brittle	3.66	-	-
	Glasnevin BH02A	Extremely stiff dark grey slightly sandy slightly gravelly silty CLAY	C	25.20	8.70	2.25	503.00	1006.00	brittle	7.56	-	-
	Metrolink GBH01	Greyish brown sandy gravelly silty CLAY	-	12.00	8.50	2.37	827.00	1654.00	brittle	12.50	-	-
Triaxial CU with PWP	Glasnevin BH02A	Stiff dark grey slightly sandy slightly gravelly silty CLAY	-	6.00	8.20	2.37	-	-	-	-	0.00	38.10
	Glasnevin BH02A	Stiff dark brown slightly sandy slightly gravelly silty CLAY	-	18.50	8.70	2.38	-	-	-	-	0.00	37.00
	Metrolink GBH02	Stiff brownish grey sandy gravelly silty CLAY	-	9.60	10.00	2.26	-	-	-	-	27.70	86.49
Triaxial UU	R03-CP08	Stiff brown slightly sandy gravelly CLAY	U	3.50	9.40	2.20	82.00	163.00	plastic	18.50	-	-

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Bulk density Mg/m^3	Peak Shear Stress KPa	Displacement at peak shear stress mm	Angle of shearing resistence	Effective cohesion KPa
Shear Box	R16-CP02	Gravel	B	7.00	-	-	-	-	-	-
	R16-CP02	Gravel	B	9.00	-	-	-	-	-	-
	R16-CP04	Brown slightly clayey silty very gravelly SAND	B	4.00	14.00	2.06	50-101-196	3-3-4	44.00	4.00
	R16-CP04	Brown silty gravelly SAND	B	6.00	6.40	1.70	46-49-147	4-4-6	34.00	13.00
	Metrolink BH01	Brown gravelly sandy CLAY	B	2.00	13.00	1.93	16-29-50	9.31-7.81-8.71	29.00	6.00
	Metrolink BH01	Gravel	B	17.20	20.00	1.96	124-231-459	2.4-9.6-6.61	34.00	0.00
	R03-CP03	Dark brown mottled grey slightly sandy slightly gravelly CLAY	B	5.00	12.00	2.24	45-79-138	5-5-4	32.00	15.00
	R03-CP14	Brown slightly sandy gravelly CLAY	B	9.00	13.00	2.32	39-80-150	4.51-4.8-8.1	36.00	5.00

ROCK CLASSIFICATION

Borehole	Top depth (m)	Soil	TCR	SCR	RQD	FI	Rock mass quality
R03-RC01	18.5	Limestone	96	80	33	13	poor
R03-RC02	18.5	Mudstone	83	26	16	NI	very poor
	19.5	Limestone	83	26	16	8	very poor
R03-RC03	18.5	Mudstone	100	52	16	14	very poor
R11-CP01	8	Limestone	51	35	27	7/NI	poor
	9.45		100	74	23	14	poor
	11		100	95	95	1	fair
R11-CP03	4.4	Limestone	100	63	50	8	fair
	5		100	85	58	26/6	fair

ROCK STRENGTH

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Bulk density Mg/m^3	UCS MPa	Load failure (KN)	Failure Mode
UCS	R11-CP03	Limestone	C	4.48	0.30	2.71	49.50	154.40	brittle
	R11-CP01A	Limestone	C	11.00	3.20	2.65	31.30	100.60	brittle
	Glasnevin BH01	Limestone	-	20.90	1.80	2.72	66.20	500.30	axial splitting
	Glasnevin BH01	Limestone	-	28.25	1.10	2.70	79.10	608.60	axial splitting
	Glasnevin BH01	Limestone	-	29.60	0.80	2.65	82.50	653.40	axial splitting
	Glasnevin BH01	Limestone	-	30.70	2.70	2.73	22.50	172.30	axial splitting
	Glasnevin BH02A	Limestone	-	32.10	1.70	2.70	79.90	640.40	axial splitting
	Glasnevin BH02A	Limestone	-	33.10	2.40	2.70	92.40	743.00	axial splitting
	Glasnevin BH02A	Limestone	-	33.90	2.10	2.68	66.40	530.10	axial splitting
	Metrolink BH01	Limestone	C	19.75	0.10	-	-	-	-
	Metrolink BH01	Limestone	-	22.50	1.10	2.64	39.70	320.80	-
	Metrolink BH01	Limestone	C	36.30	0.50	2.68	26.70	215.80	-
	Metrolink BH02	Limestone	C	23.00	0.70	2.73	39.10	315.40	-
	Metrolink BH02	Limestone	C	33.40	0.20	2.70	43.20	348.30	-

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Bulk density Mg/m^3	PLT	Point Load index	Load failure (KN)	Failure Mode	Conversion factor	UCS MPa
Point Load Test	Glasnevin BH01	Limestone	-	21.20	0.60	-	1.99	2.72	19.89	-	14.70	29.25
	Glasnevin BH01	Limestone	-	26.40	0.30	-	3.00	4.03	27.69	-	14.70	44.10
	Glasnevin BH01	Limestone	-	28.10	0.60	-	1.42	1.94	14.22	-	14.70	20.87
	Glasnevin BH01	Limestone	-	28.50	0.50	-	1.43	1.83	10.75	-	14.70	21.02
	Glasnevin BH01	Limestone	-	29.50	0.20	-	2.12	2.90	21.23	-	14.70	31.16
	Glasnevin BH01	Limestone	-	29.90	0.50	-	1.17	1.59	11.66	-	14.70	17.20
	Glasnevin BH01	Limestone	-	30.60	2.70	-	1.14	1.48	9.01	-	14.70	16.76
	Glasnevin BH01	Limestone	-	30.95	3.00	-	0.28	0.38	2.81	-	14.70	4.12
	Glasnevin BH02A	Limestone	-	30.80	2.00	-	1.79	2.42	17.17	-	14.70	26.31
	Glasnevin BH02A	Limestone	-	32.00	3.00	-	0.29	0.39	2.93	-	14.70	4.26
	Glasnevin BH02A	Limestone	-	33.60	2.60	-	1.18	1.34	5.22	-	14.70	17.35
	Glasnevin BH02A	Limestone	-	34.35	3.40	-	0.46	0.51	1.76	-	14.70	6.76
	Glasnevin BH02A	Limestone	-	34.60	1.60	-	2.35	3.25	24.94	-	14.70	34.55

Test	Borehole	Soil	Sample type	Top depth (m)	Moisture Content %	Bulk density Mg/m^3	Max Tensile Strenght MPa	BTS	Load failure (KN)	Failure Mode	Conversion factor	UCS MPa
Brazil test	Glasnevin BH01	Limestone	-	20.75	1.00	2.63	3.17	3.17	95.10	Satisfactory	13.70	43.47
	Glasnevin BH01	Limestone	-	26.20	1.60	2.68	7.44	7.44	116.50	Satisfactory	13.70	101.98
	Glasnevin BH02A	Limestone	-	32.90	2.10	2.62	5.15	5.15	83.70	Satisfactory	13.70	70.53

8.3 Characteristic compressive resistance of piles

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 01**
Details	**No Borehole. Route 3 representative section.**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Topsoil	0.5	0	-0.5	0
Made Ground	3.5	-0.5	-4	50
Grey Boulder Clay	8.5	-4	-12.5	250
Brown Boulder Clay	5	-12.5	-17.5	325
Gravel	1	-17.5	-18.5	325
	0			
	0			
	0			
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	9.50	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	454	kN
Variable Load	Q_k	120	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

Rc,d	809 kN
Fc,d	793 kN

Rc,d>Ec,d OK

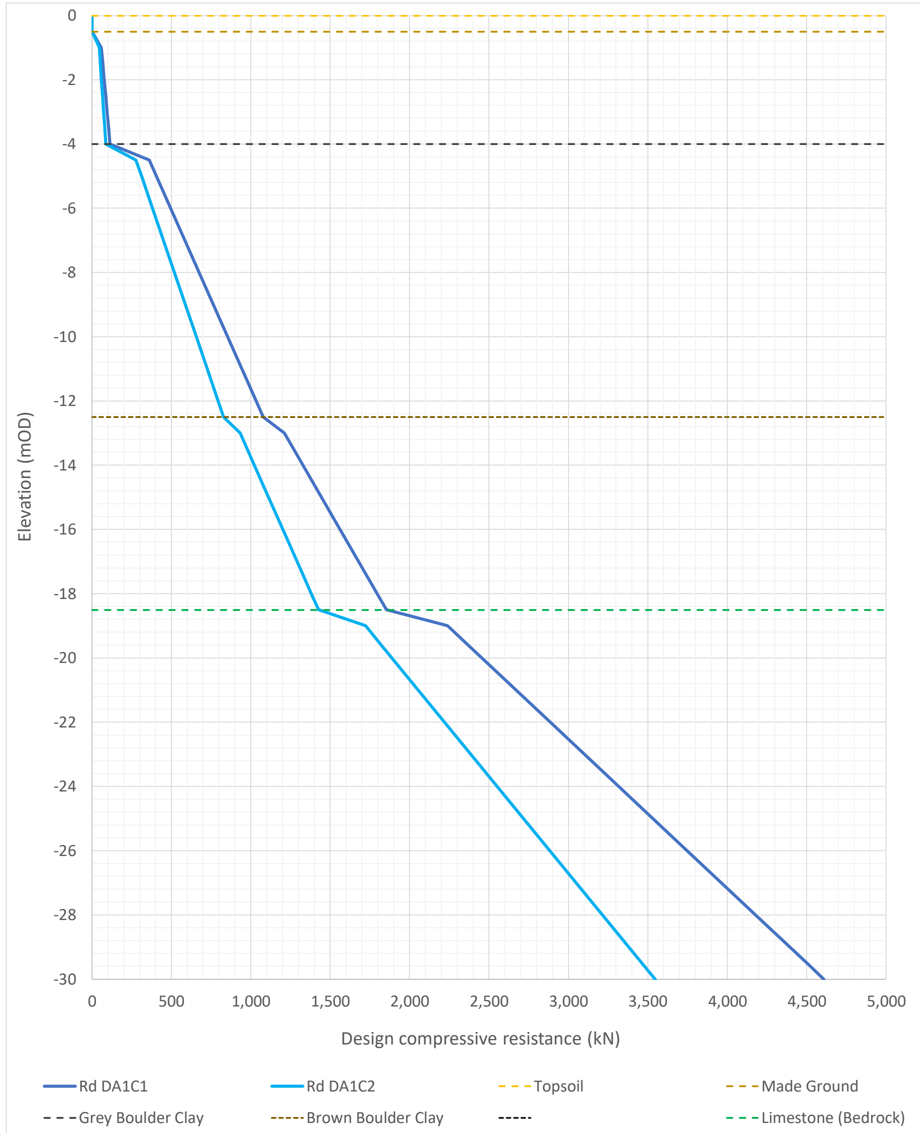
EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	622 kN
Fc,d	610 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 02**
Details	**Borehole R3-CP03**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	**0**	**mOD**
α	**0.4**	**-**
Nc	**9**	**-**

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Gravel	1	0	-1	0
Made Ground Gravelly Clay	1	-1	-2	39
Brown Clay	1	-2	-3	26
Grey Boulder Clay	1	-3	-4	78
Grey Boulder Clay	1	-4	-5	312
Grey Boulder Clay	10	-5	-15	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	5	-15	-20	600

FOUNDATION

Foundation level	**0**	**mOD**
ϕ_{pile}	**0.50**	**m**
Piles length	**8.50**	**m**
As	**1.57**	**m^2/m**
Ab	**0.20**	**m^2**

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	424	kN
Variable Load	Q_k	179	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

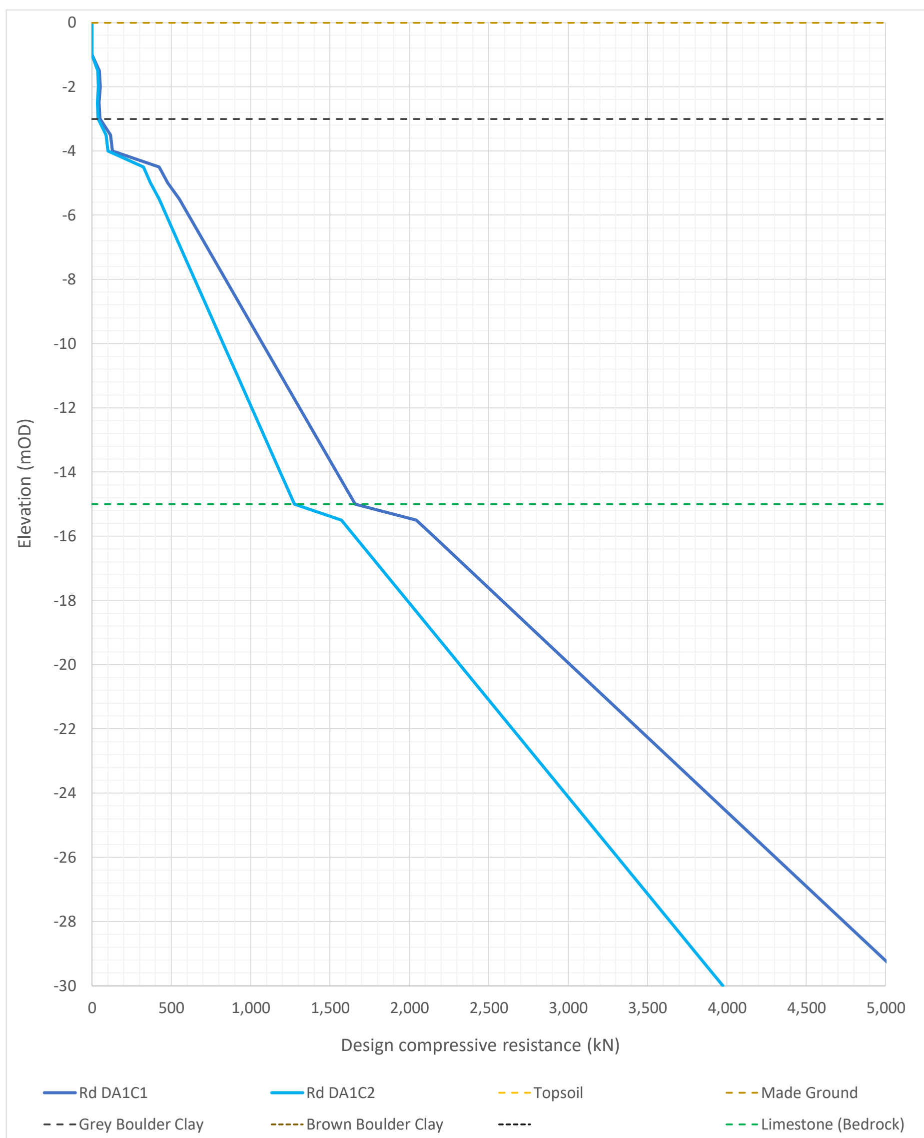
Rc,d	900 kN
Fc,d	841 kN

Rc,d>Ec,d OK

Rc,d	692 kN
Fc,d	657 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 03
Details	Borehole R3-CP07

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Sandy Clay	2	0	-2	0
Made Ground Gravelly Clay	1	-2	-3	13
Grey Boulder Clay	1	-3	-4	117
Grey Boulder Clay	1	-4	-5	247
Grey Boulder Clay	10	-5	-15	325
	0			
	0			
	0			
	0			
	0			
Limestone (Bedrock)	5	-15	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	5.50	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	82	kN
Variable Load	Q_k	169	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

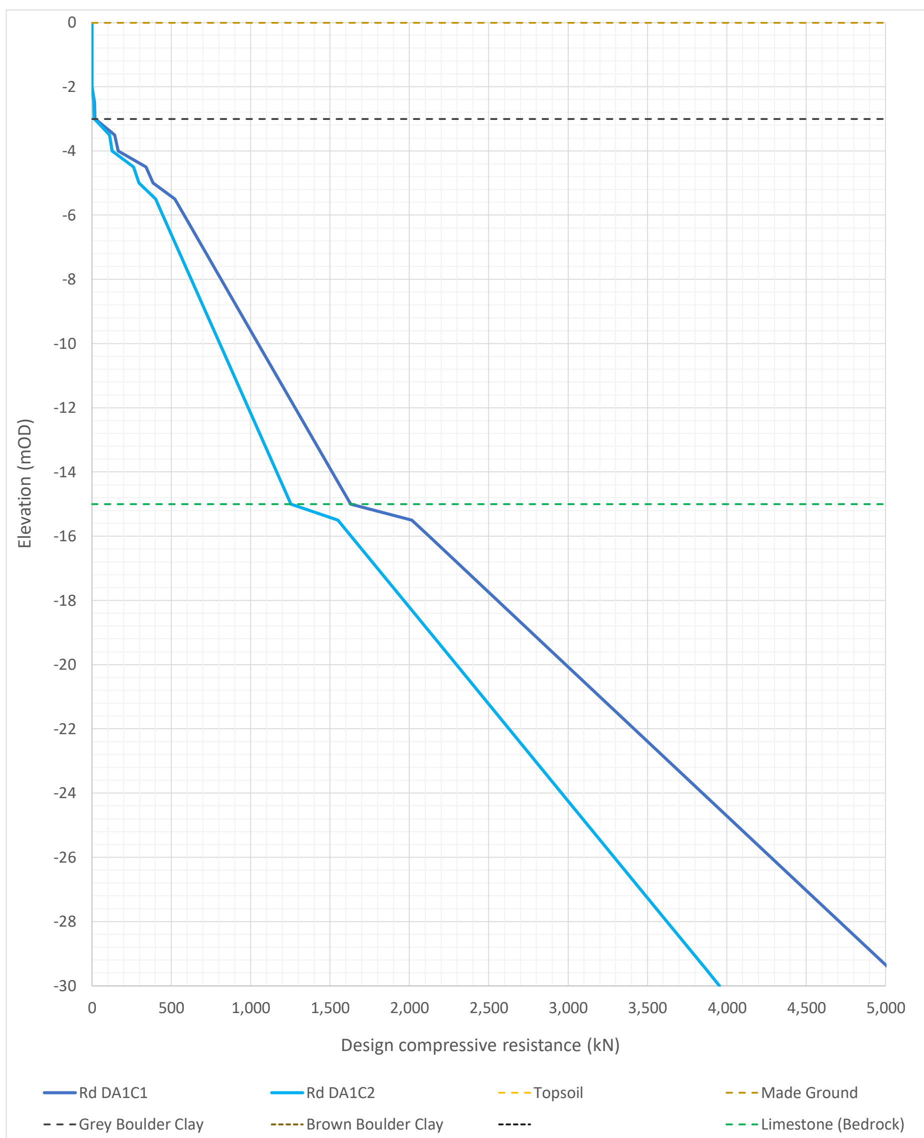
Rc,d	522 kN
Fc,d	364 kN

Rc,d>Ec,d OK

Rc,d	401 kN
Fc,d	302 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 03
Details	Borehole R3-WS03

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Sandy Clay	1.2	0	-1.2	0
Made Ground Gravel	0.8	-1.2	-2	26
Grey Boulder Clay	1	-2	-3	32.5
Grey Boulder Clay	1	-3	-4	71.5
Brown Boulder Clay	1	-4	-5	175.5
Brown Boulder Clay	10	-5	-15	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	5	-15	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	5.50	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	82	kN
Variable Load	Q_k	169	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

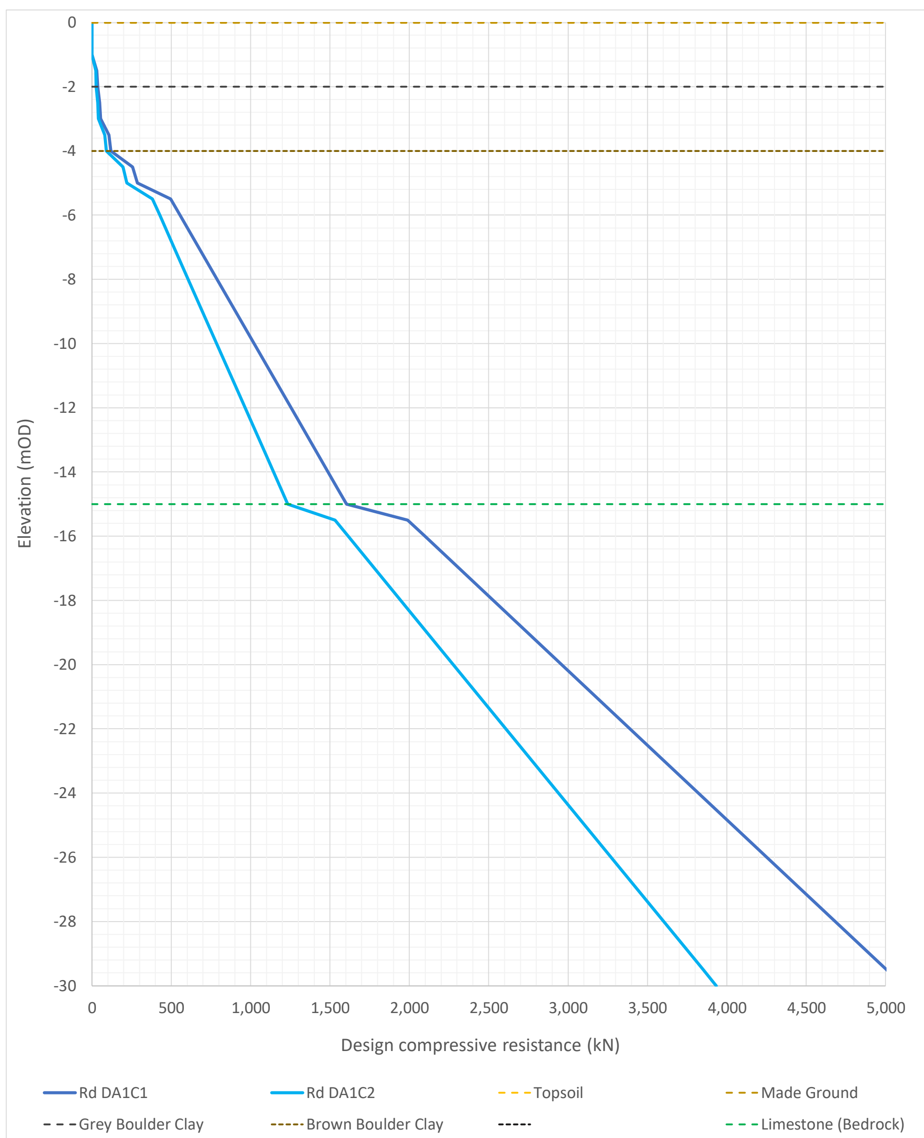
Rc,d	496 kN
Fc,d	364 kN

Rc,d>Ec,d OK

Rc,d	382 kN
Fc,d	302 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 04**
Details	**Borehole R3-RC01**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Clay	2	0	-2	0
Made Ground Gravelly Clay	1.5	-2	-3.5	19.5
Grey Boulder Clay	1.5	-3.5	-5	13
Grey Boulder Clay	1.5	-5	-6.5	117
Grey Boulder Clay	1.5	-6.5	-8	136.5
Grey Boulder Clay	1.5	-8	-9.5	143
Grey Boulder Clay	3	-9.5	-12.5	325
Brown Boulder Clay	6	-12.5	-18.5	325
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.80	m
Piles length	10.00	m
As	2.51	m^2/m
Ab	0.50	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

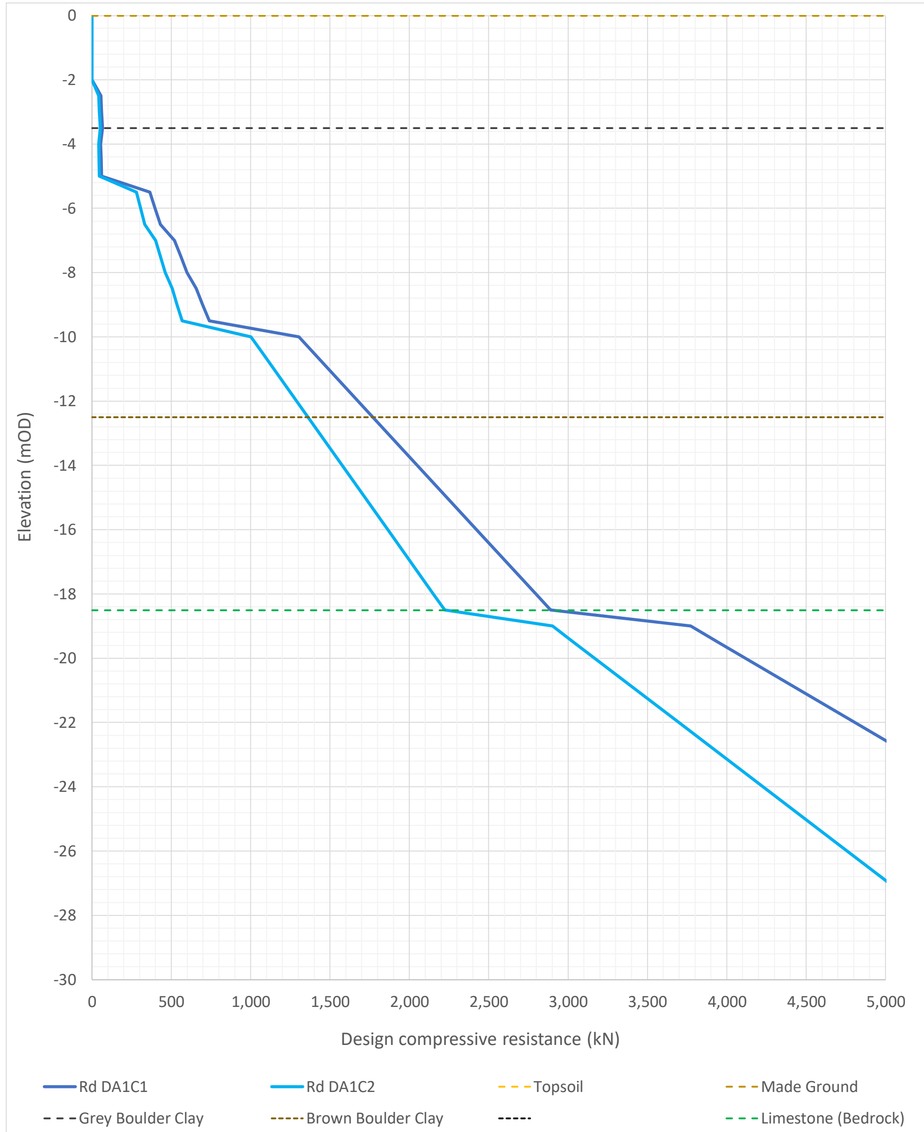
Rc,d	1303 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

Rc,d	1002 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 04
Details	Borehole R3-RC02

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Clay Gravelly Clay	2	0	-2	0
Made Ground Gravelly Clay	1.5	-2	-3.5	32.5
Made Ground Gravelly Clay	1.5	-3.5	-5	143
Made Ground Gravelly Clay	1.5	-5	-6.5	182
Grey Boulder Clay	5	-6.5	-11.5	325
Brown Boulder Clay	7	-11.5	-18.5	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.80	m
Piles length	7.00	m
As	2.51	m^2/m
Ab	0.50	m^2

Actions			
Favourable Permanent Load	$G_{k, fav}$	0	kN
Unfavourable Permanent Load	$G_{k, unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

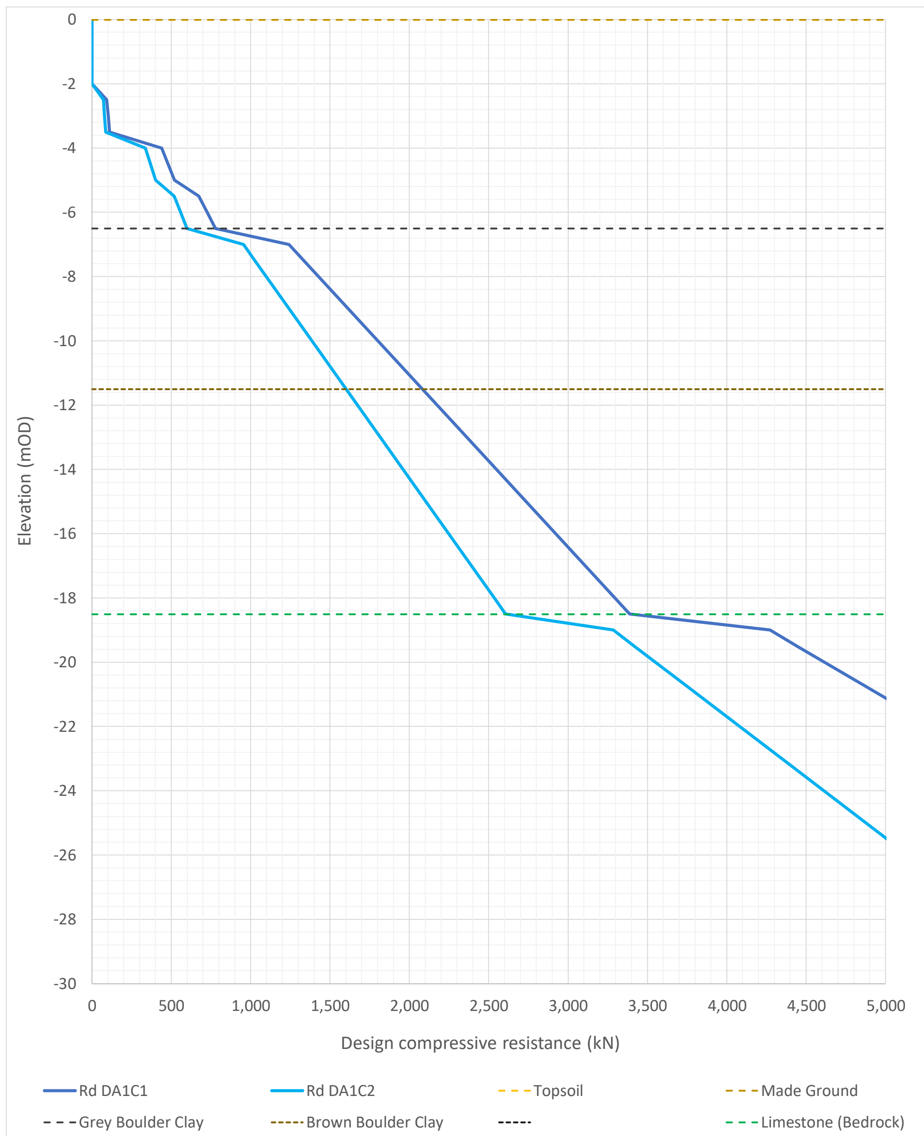
Rc,d	1242 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

Rc,d	955 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 04
Details	Borehole R3-RC03

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground	2	0	-2	0
Made Ground Gravel	1.5	-2	-3.5	110.5
Made Ground Gravel	1.5	-3.5	-5	123.5
Grey Boulder Clay	1.5	-5	-6.5	130
Grey Boulder Clay	1.5	-6.5	-8	227.5
Grey Boulder Clay	6.5	-8	-14.5	325
Brown Boulder Clay	4	-14.5	-18.5	325
	0			
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.80	m
Piles length	8.50	m
As	2.51	m^2/m
Ab	0.50	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

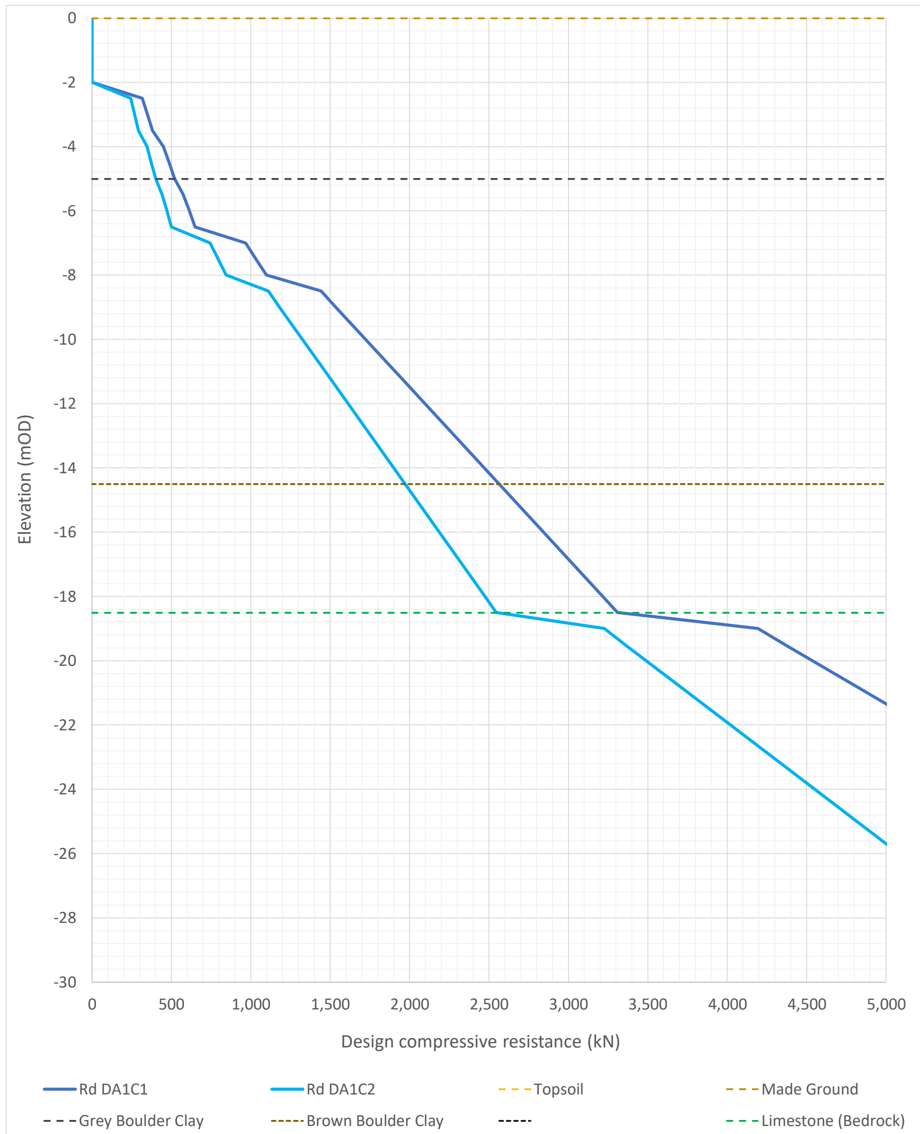
Rc,d	1443 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

Rc,d	1110 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 04
Details	Borehole R3-CP14

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Gravel	1	0	-1	0
Made Ground Gravelly Clay	1	-1	-2	6.5
Made Ground Gravelly Clay	1	-2	-3	6.5
Made Ground Gravelly Clay	1	-3	-4	136.5
Grey Boulder Clay	1	-4	-5	149.5
Grey Boulder Clay	10	-5	-15	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	5	-15	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.80	m
Piles length	6.00	m
As	2.51	m^2/m
Ab	0.50	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

Rc,d	1199 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

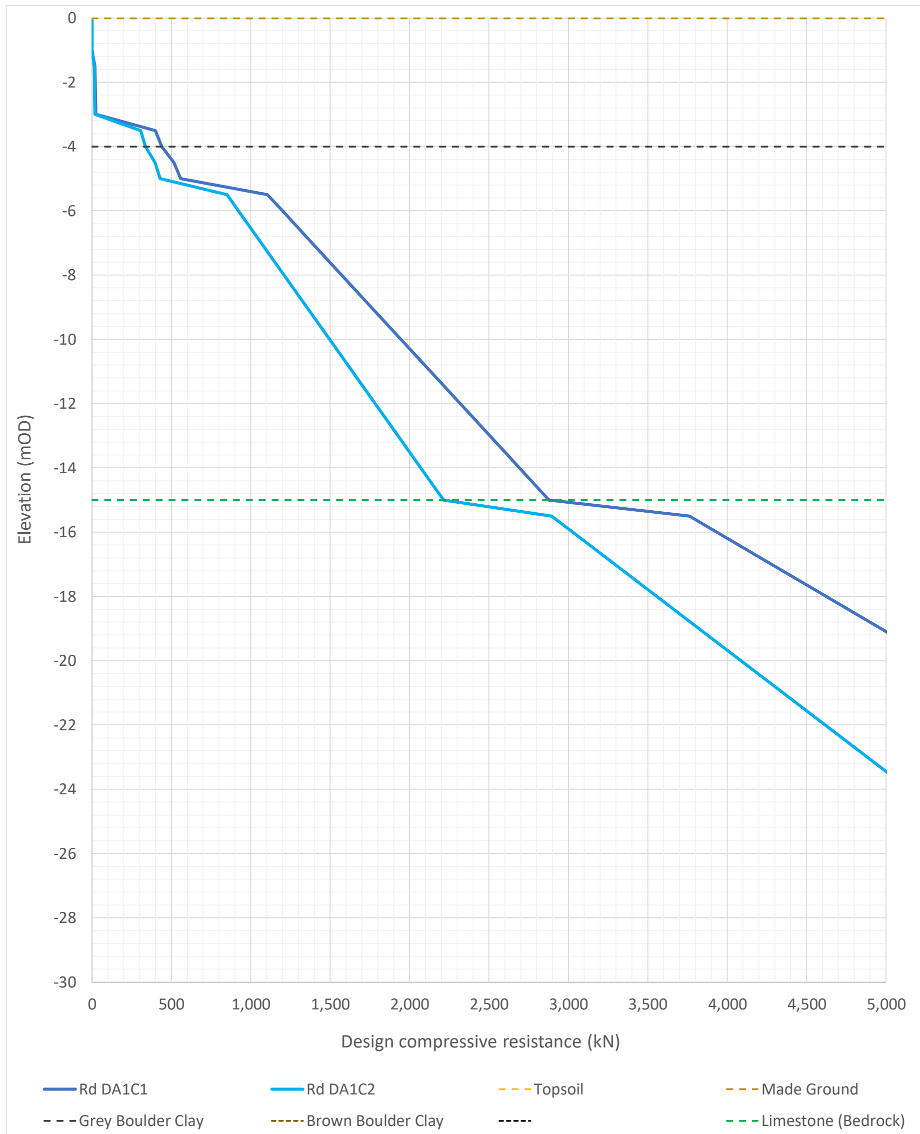
EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	922 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 04**
Details	**Borehole R3-RC01**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Clay	2	0	-2	0
Made Ground Gravelly Clay	1.5	-2	-3.5	19.5
Grey Boulder Clay	1.5	-3.5	-5	13
Grey Boulder Clay	1.5	-5	-6.5	117
Grey Boulder Clay	1.5	-6.5	-8	136.5
Grey Boulder Clay	1.5	-8	-9.5	143
Grey Boulder Clay	3	-9.5	-12.5	325
Brown Boulder Clay	6	-12.5	-18.5	325
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	14.50	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k, fav}$	0	kN
Unfavourable Permanent Load	$G_{k, unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1	
A1+M1+R1	
Design ground properties (M)	
Undrained shear strength γ_{Cu}	1.00
Design resistances (R)	
Partial factor for base resistance γ_b	1.00
Partial factor for shaft resistance γ_s	1.00
Model factor γ_m	1.75
Design actions (A)	
Permanent load factor (fav) γ_G	1.00
Permanent load factor (unfav) γ_G	1.35
Variable load factor γ_Q	1.50
Partial factor on the effects of action γ_F	1.00

Rc,d	1143 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

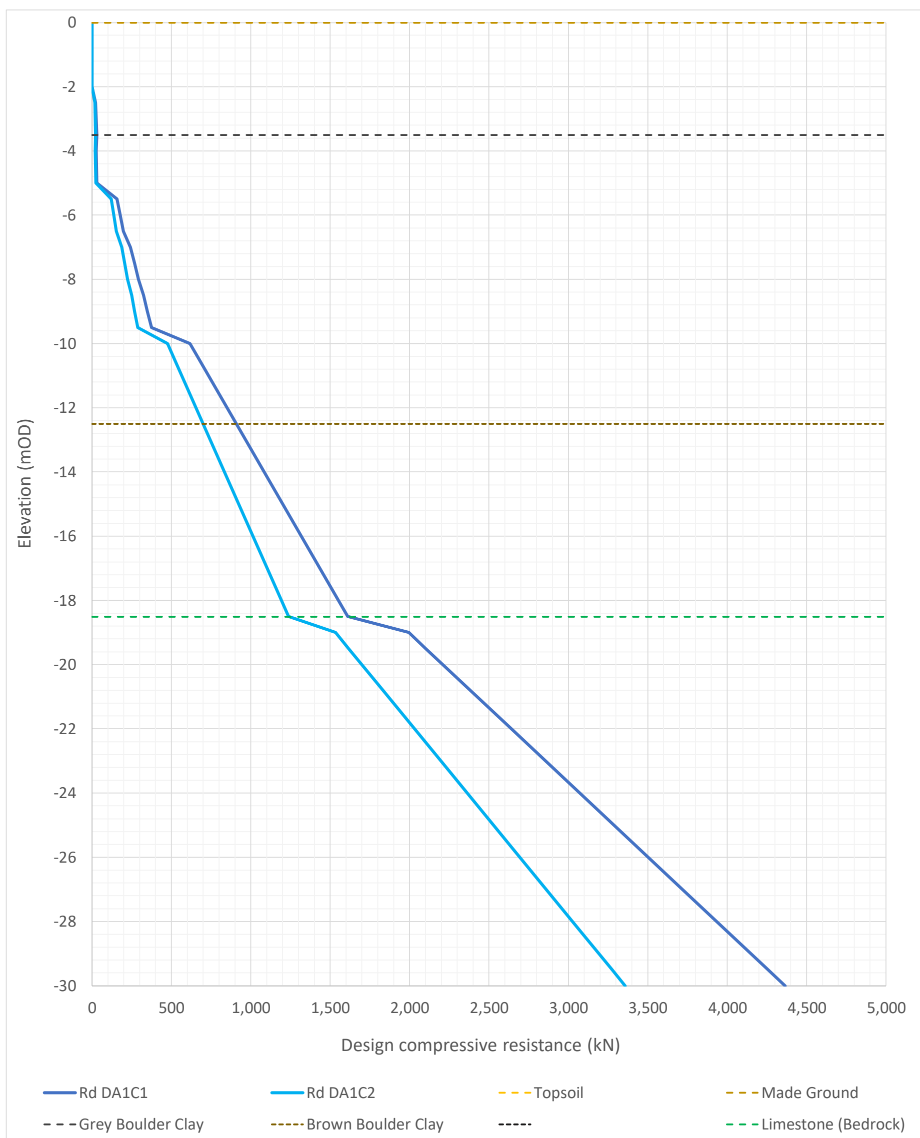
EC7 - DA1 C2	
A2+M1+R4	
Design ground properties (M)	
Undrained shear strength γ_{Cu}	1.00
Design resistances (R)	
Partial factor for base resistance γ_b	1.30
Partial factor for shaft resistance γ_s	1.30
Model factor γ_m	1.75
Design actions (A)	
Permanent load factor (fav) γ_G	1.00
Permanent load factor (unfav) γ_G	1.00
Variable load factor γ_Q	1.30
Partial factor on the effects of action γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	879 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 04**
Details	**Borehole R3-RC02**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Clay Gravelly Clay	2	0	-2	0
Made Ground Gravelly Clay	1.5	-2	-3.5	32.5
Made Ground Gravelly Clay	1.5	-3.5	-5	143
Made Ground Gravelly Clay	1.5	-5	-6.5	182
Grey Boulder Clay	5	-6.5	-11.5	325
Brown Boulder Clay	7	-11.5	-18.5	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	12.00	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

Rc,d	1163 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

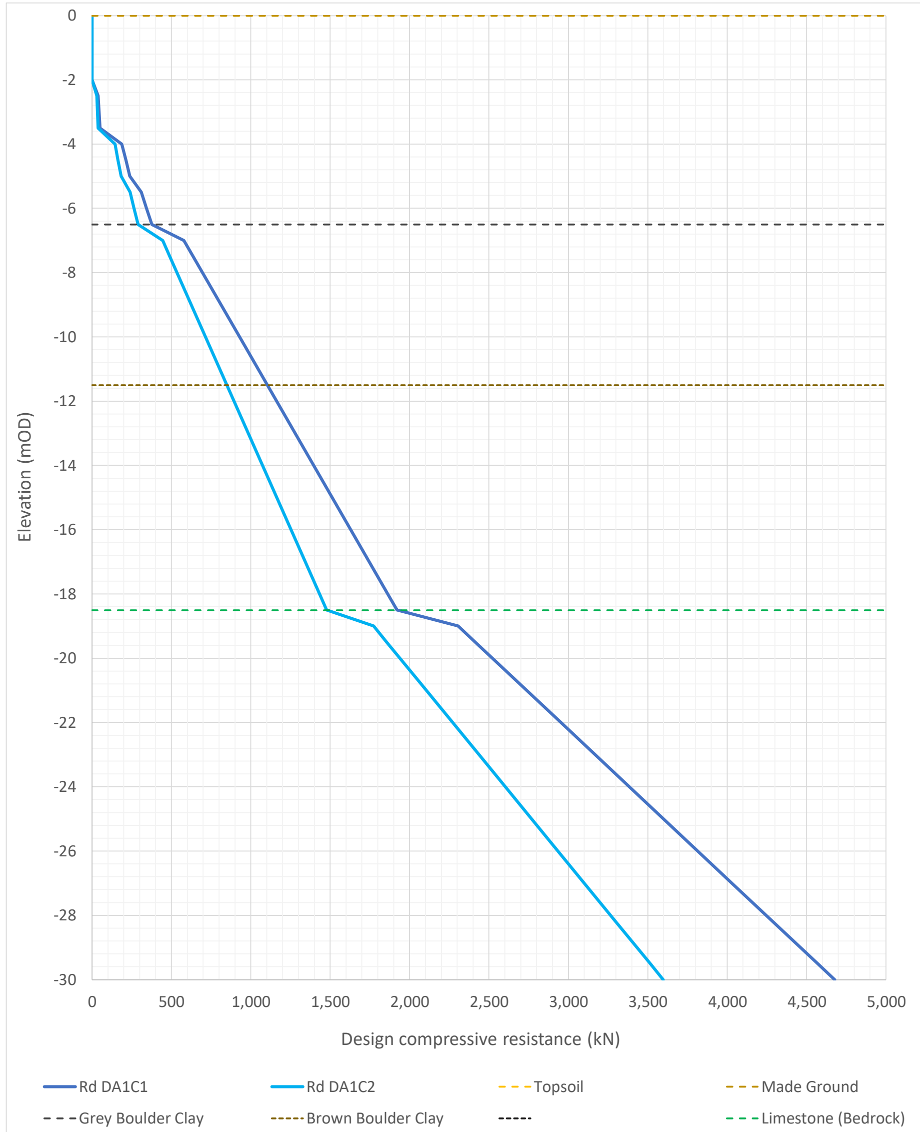
EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	894 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	**RD5862 Dublin BusConnect**
Structure	**Ballymun 04**
Details	**Borehole R3-RC03**

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	**0**	**mOD**
α	**0.4**	**-**
Nc	**9**	**-**

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground	2	0	-2	0
Made Ground Gravel	1.5	-2	-3.5	110.5
Made Ground Gravel	1.5	-3.5	-5	123.5
Grey Boulder Clay	1.5	-5	-6.5	130
Grey Boulder Clay	1.5	-6.5	-8	227.5
Grey Boulder Clay	6.5	-8	-14.5	325
Brown Boulder Clay	4	-14.5	-18.5	325
	0			
	0			
	0			
Limestone (Bedrock)	1.5	-18.5	-20	600

FOUNDATION

Foundation level	**0**	**mOD**
ϕ_{pile}	**0.50**	**m**
Piles length	**12.00**	**m**
As	**1.57**	**m^2/m**
Ab	**0.20**	**m^2**

Actions			
Favourable Permanent Load	**$G_{k,fav}$**	**0**	**kN**
Unfavourable Permanent Load	**$G_{k,unfav}$**	**298**	**kN**
Variable Load	**Q_k**	**425**	**kN**

EC7 - DA1 C1		
A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

Rc,d	1113 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

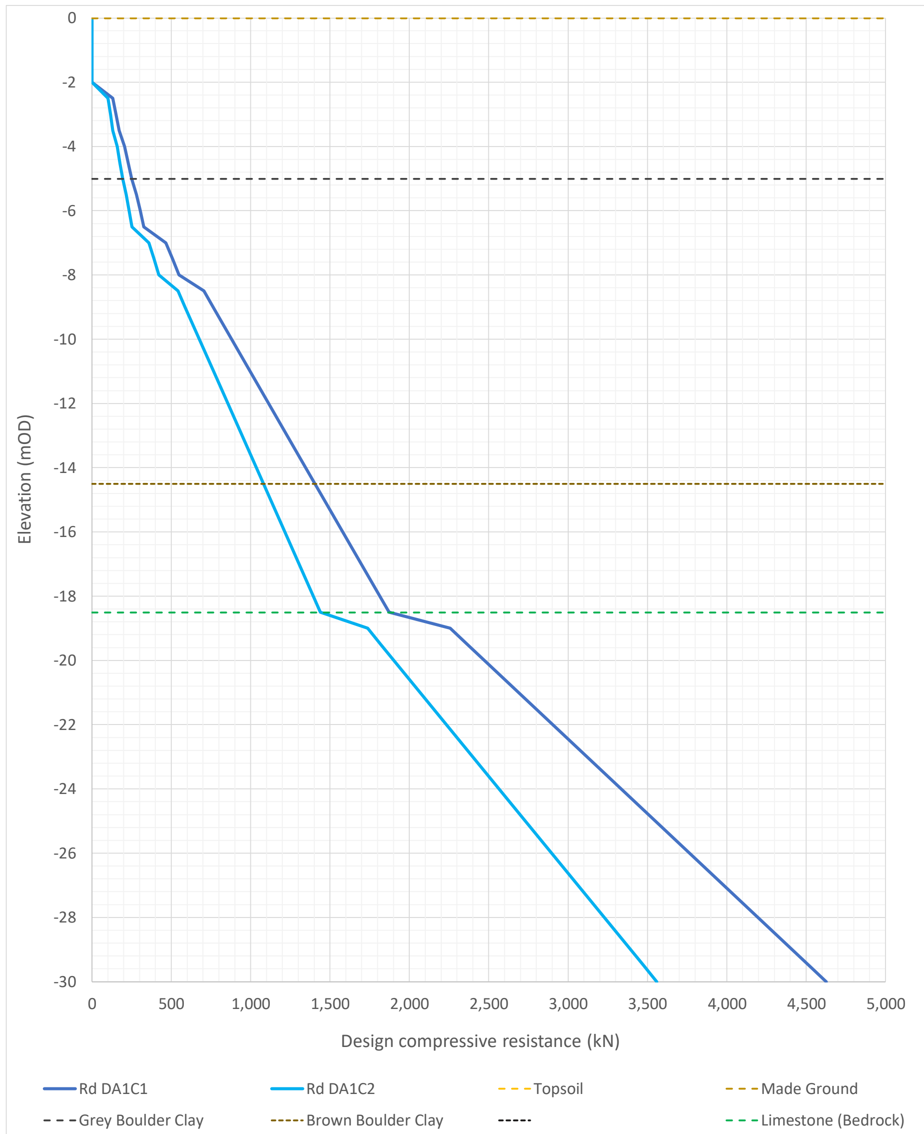
EC7 - DA1 C2		
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	857 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES

According to Eurocode 7 by calculation from ground parameters and Irish National Annex

(Valid for piles spaced at 3 diameters center to center or greater)

Project	RD5862 Dublin BusConnect
Structure	Ballymun 04
Details	Borehole R3-CP14

FORMULATION

Design compressive resistance of a pile, Rc,d:

$$R_{c,d} = R_{s,d} + R_{b,d} \geq F_{c,d}$$

where:

Fc,d: design value of the effects of actions (compression)

$$F_{c,d} = \frac{F_{c,k}}{\gamma_F}$$

γ_F: partial factor on actions or effects of actions

Rs,d: Design value of shaft resistance

$$R_{s,d} = \frac{R_{s,k}}{\gamma_s \cdot \gamma_m}$$

Rb,d: design value of base resistance

$$R_{b,d} = \frac{R_{b,k}}{\gamma_b \cdot \gamma_m}$$

γ_s: partial factor for shaft resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_b: partial factor for base resistance derived from National Annex. It depends on the type of piles (driven, bored or CFA).

γ_m: model factor

Rs,k: characteristic shaft resistance

$$R_{s,k} = \sum_i A_{s,i} \cdot q_{si,k} = \alpha \cdot c_u \cdot A_{si,k}$$

Rb,k: characteristic base resistance

$$R_{b,k} = A_b \cdot q_{b,k} = N_c \cdot c_u \cdot A_b$$

where:

α: adhesion factor (from 1 or higher for very soft clays to 0.2 for very stiff clays.

c_u: Undrained shear strength

Asi,k: area of the pile shaft (for the stratum under consideration)

Nc: bearing capacity factor (Nc=9 provided thate the pile has been driven at least to a depth of 5 diameters into the bearing stratum)

Ab,k: area of the pile base

INPUT DATA

SOIL

Ground Level	0	mOD
α	0.4	-
Nc	9	-

Lithology	Thickness	From (m)	To (m)	*Cu(kPa)
Made Ground Gravel	1	0	-1	0
Made Ground Gravelly Clay	1	-1	-2	6.5
Made Ground Gravelly Clay	1	-2	-3	6.5
Made Ground Gravelly Clay	1	-3	-4	136.5
Grey Boulder Clay	1	-4	-5	149.5
Grey Boulder Clay	10	-5	-15	325
	0			
	0			
	0			
	0			
Limestone (Bedrock)	5	-15	-20	600

FOUNDATION

Foundation level	0	mOD
ϕ_{pile}	0.50	m
Piles length	11.00	m
As	1.57	m^2/m
Ab	0.20	m^2

Actions			
Favourable Permanent Load	$G_{k,fav}$	0	kN
Unfavourable Permanent Load	$G_{k,unfav}$	298	kN
Variable Load	Q_k	425	kN

EC7 - DA1 C1

A1+M1+R1		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.00
Partial factor for shaft resistance	γ_s	1.00
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.35
Variable load factor	γ_Q	1.50
Partial factor on the effects of action	γ_F	1.00

Rc,d	1136 kN
Fc,d	1040 kN

Rc,d>Ec,d OK

EC7 - DA1 C2

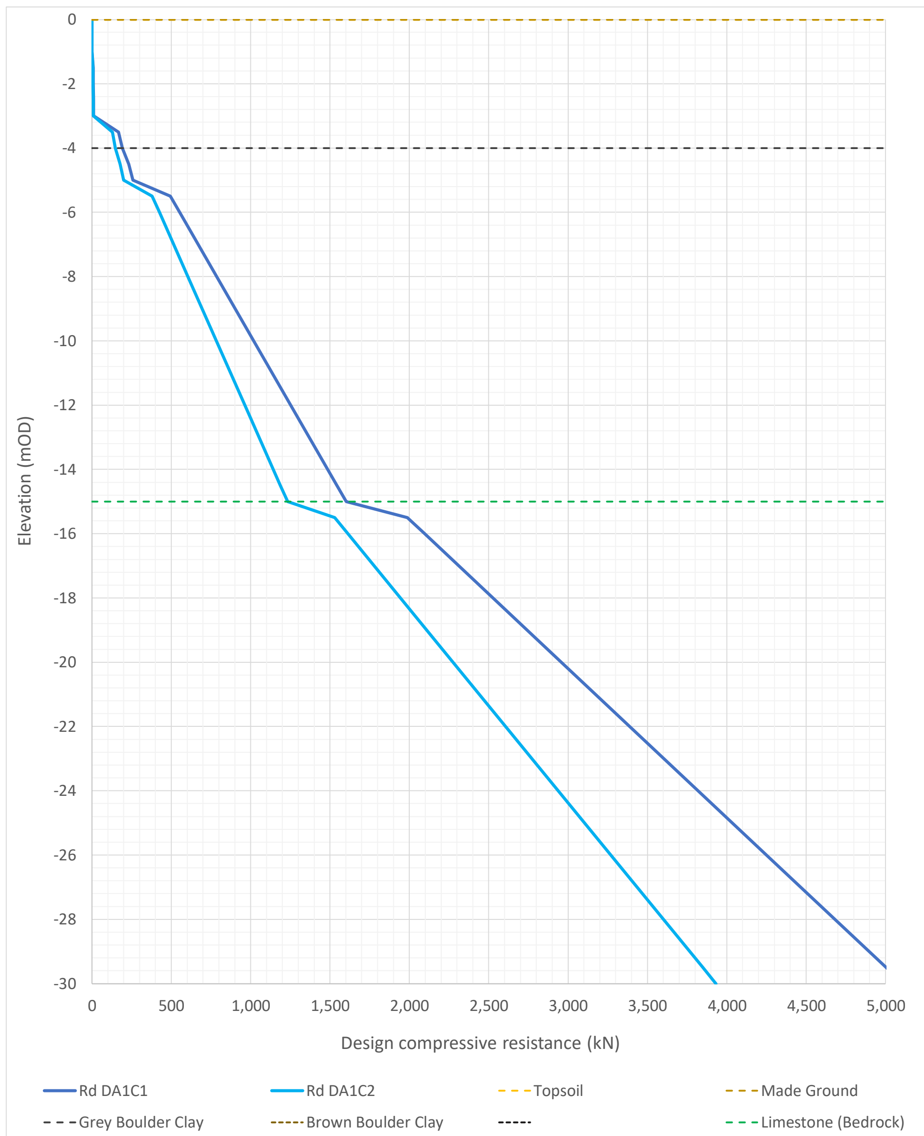
A2+M1+R4		
Design ground properties (M)		
Undrained shear strength	γ_{Cu}	1.00
Design resistances (R)		
Partial factor for base resistance	γ_b	1.30
Partial factor for shaft resistance	γ_s	1.30
Model factor	γ_m	1.75
Design actions (A)		
Permanent load factor (fav)	γ_G	1.00
Permanent load factor (unfav)	γ_G	1.00
Variable load factor	γ_Q	1.30
Partial factor on the effects of action	γ_F	1.00

NOTE: Set M2 is only used to calculate unfavourable design actions on piles e.g. to negative skin friction.

Rc,d	874 kN
Fc,d	851 kN

Rc,d>Ec,d OK

DESIGN COMPRESSION RESISTANCE OF PILES. TOTAL STRESSES



8.4 Geotechnical parameters for Ballymun 04 retaining wall design

Ballymun 04. Soil parameters. Retaining wall design.

1MPa = 1000 KPa

Depth (m)		Soil	Bulk density	Cu (KPa)	Young's modulus E (MPa)	Undrained Young's modulus Eu (MPa)	Poisson's Coeficient υ (-)	Eu = 3E/2(1+υ)	Fristion angle fi (º)	Cohesion c' (KPa)	Coefficient earth pressure at rest K_0	Horizontal spring stiffness Kh
Top	Bottom		KN/m^3	KN/m^2	MN/m^2	MN/m^2				KN/m^2	-	KN/m^3
0	4.5	Made Ground	-	50	25	-	0.3	31.25	28	0	1	3.500 - 5.000
4.5	12.5	BC Grey	22.5	250	80	100	0.2	100	30	0	1.3	17.000 - 20.000
12.5	17.5	BC Brown	-	325	-	120	0.2		35	0	1.3	20.000 - 25.000
17.5	19.5	Mudstone	-	325	-	-	-		-	0	-	25.000 - 35.000
19.5	-	Limestone	25	500	800	1000	-		45	0	-	35.000 - 37.500

Concrete		30,000

Ballymun 04. Horizontal Spring Stiffness Kh (KN/m^3)

Vesic (1961); $Kh = [(0.65 \cdot Es)/(D(1-\upsilon s^2))] \cdot [(Es \cdot D^{4)} / (Eh \cdot I)]^{1/12}$

Kh [kN/m^3] circular	**3595**	**3595**	**3595**	**3595**	**3595**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**12559**	**11785**	**11121**	**10543**	**10035**	**9584**	**9180**
Kh [kN/m^3] rectangular	**2787**	**2787**	**2787**	**2787**	**2787**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9736**	**9064**	**8492**	**7997**	**7564**	**7183**	**6844**
Depth [m]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
E soil [kN/m^2]	30000	30000	30000	30000	30000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
υs	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
E concrete [kN/m^2]	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000	30000000
Pile diameter (m)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
I [m^4] =pi R^4 /4	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619	0.02010619
I [m^4] =1/12 b h^3	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.42666667	0.46933333	0.512	0.55466667	0.59733333	0.64	0.68266667
D [m]	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	11	12	13	14	15	16

R. Ortiz COAM (1982), based on Terzagui, for rigid clays; Kh = f ·0.2/D where f depends on Cu

Kh [kN/m^3]	**5000**	**5000**	**5000**	**5000**	**5000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**	**20000**
Depth [m]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cu [kPa]	50	50	50	50	50	250	250	250	250	250	250	250	250	250	325	325	325	325	325	325	500	500
Factor f (Kp/cm^3)	2.5	2.5	2.5	2.5	2.5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
D [m]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

NAVFAC 7.2-235; Kh = 35 to 70 Cu (t/m^3)

Kh_max [kN/m^3]	**3500**	**3500**	**3500**	**3500**	**3500**	**17500**	**17500**	**17500**	**17500**	**17500**	**17500**	**17500**	**17500**	**17500**	**22750**	**22750**	**22750**	**22750**	**22750**	**22750**	**35000**	**35000**
Kh_min [kN/m^3]	**1750**	**1750**	**1750**	**1750**	**1750**	**8750**	**8750**	**8750**	**8750**	**8750**	**8750**	**8750**	**8750**	**8750**	**11375**	**11375**	**11375**	**11375**	**11375**	**11375**	**17500**	**17500**
Kh_ave [kN/m^3]	**2625**	**2625**	**2625**	**2625**	**2625**	**13125**	**13125**	**13125**	**13125**	**13125**	**13125**	**13125**	**13125**	**13125**	**17062.5**	**17062.5**	**17062.5**	**17062.5**	**17062.5**	**17062.5**	**26250**	**26250**
Depth [m]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cu [t/m2]	5	5	5	5	5	25	25	25	25	25	25	25	25	25	32.5	32.5	32.5	32.5	32.5	32.5	50	50

Guía de cimentaciones de obras de carretera GCOC / MFOM (2002) - piles within clays; Kh = 75·Cu·ΔL

Kh [kN/m^3]	**3750**	**3750**	**3750**	**3750**	**3750**	**18750**	**18750**	**18750**	**18750**	**18750**	**18750**	**18750**	**18750**	**18750**	**24375**	**24375**	**24375**	**24375**	**24375**	**24375**	**37500**	**37500**
Depth [m]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cu [kPa]	50	50	50	50	50	250	250	250	250	250	250	250	250	250	325	325	325	325	325	325	500	500
ΔL [m]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1