GEOTECHNICAL SITE INVESTIGATION FOR AMMAN BUS RAPID TRANSIT (BRT) PROJECT–PRESS TUNNEL BRIDGE AMMAN-JORDAN

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PREPARED FOR
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AMMAN-JORDAN

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Arab Center For Engineering Studies
المركز العربي للدراسات الهندسية

Partners for Quality Construction

Messrs.: Steer Davies Gleave (SDG)
Amman-Jordan

Ref.: S16000152-Rev.1
Date: 14 November 2016

Subject: Geotechnical Site Investigation for the Proposed Amman Bus Rapid Transit (BRT) Project–Press Tunnel Bridge Amman-Jordan

Dear Sirs,

Arab Center for Engineering Studies (ACES) is pleased to submit this report for the proposed **Amman Bus Rapid Transit (BRT) Project–Press Tunnel Bridge** to be constructed along Queen Rania Al Abdullah Street at the Press Tunnel with approximate length of 650m. This investigation was carried out according to our proposal ref. no. PS16000225-Rev.0, dated 07 September 2016, and following the project specification as provided by the client representative (Engicon) via email on the 5th of September, 2016.

This report includes the results and findings of the field and laboratory investigations, geotechnical analyses and interpretation of the findings, conclusion and recommendation to aid in the design and construction of foundations of the proposed bridge, in addition to groundwork/site preparation.

In the event that additional information or clarifications are required, please contact our office at your convenience. We would like to take this opportunity to thank you for your confidence and look forward to be of service to you in the near future.

Sincerely yours,
Arab Center for Engineering Studies (ACES)

Thaer Wahshat

Dr. Thaer M. Wahshat, P.E.
ACES Jordan Manager

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1.0 INTRODUCTION

This report presents the results and findings of the site investigation conducted for the proposed bridge to be constructed along Queen Rania Al Abdullah Street at the press tunnel area between approximate Sta.0+180 and Sta.1+035. The proposed bridge is part of Amman Bus Rapid Transit (BRT) project. The location of the investigated area is presented in **Figure 1**.

1.1 Purpose of Study

The purpose of this study is to determine the surface and subsurface conditions at the project site along with the physical and mechanical properties of the ground materials in order to provide sufficient geotechnical parameters for design and construction of the proposed structure.

1.2 Scope of Work

In order to achieve the objectives of this investigation, the following activities were carried out:

1. Collecting available information and maps particular to the project site such as public services, site plans, land use maps, topographical and geological maps.
2. Conducting site visits to the project area in order to identify the geological features, outcrops, topography, surface drainage, surficial materials and general site conditions.
3. Drilling and sampling of five (5) boreholes.
4. Conducting the necessary and applicable laboratory tests.
5. Performing engineering analysis of findings.
6. Providing conclusions and recommendations for the design and construction of foundations for the proposed project.

2.0 PROJECT AND SITE DESCRIPTION

Based on the provided information by the client, the proposed project entails the construction of a bridge along the Queen Rania Al Abdullah Street as part of the under-construction Bus Rapid Transit (BRT) transportation system project. The proposed bridge will starts at the area near Al Ra'i Newspaper building and ends at the area near the Ministry of Agriculture, with approximate length of 650m. The bridge will consist of 2 abutments and 26 piers with the bridge center at the Press Tunnel area.

The construction work for the BRT is currently underway at Al Dawriyat intersection, and will continue along a route that runs through Queen Rania Al Abdullah Street passing the Jordan University Mosque intersection and the area between the University Hospital Bridge and Press tunnel area (area addressed in this investigation).

A site investigation was requested by the client along the proposed bridge alignment between approximate Sta.0+180 and Sta.1+035, in order to provide a general understanding of the underground condition that would assist in the design and construction of the proposed bridge.

A general site plan showing the proposed bridge alignment and drilled boreholes location is presented in **Figure 2**.

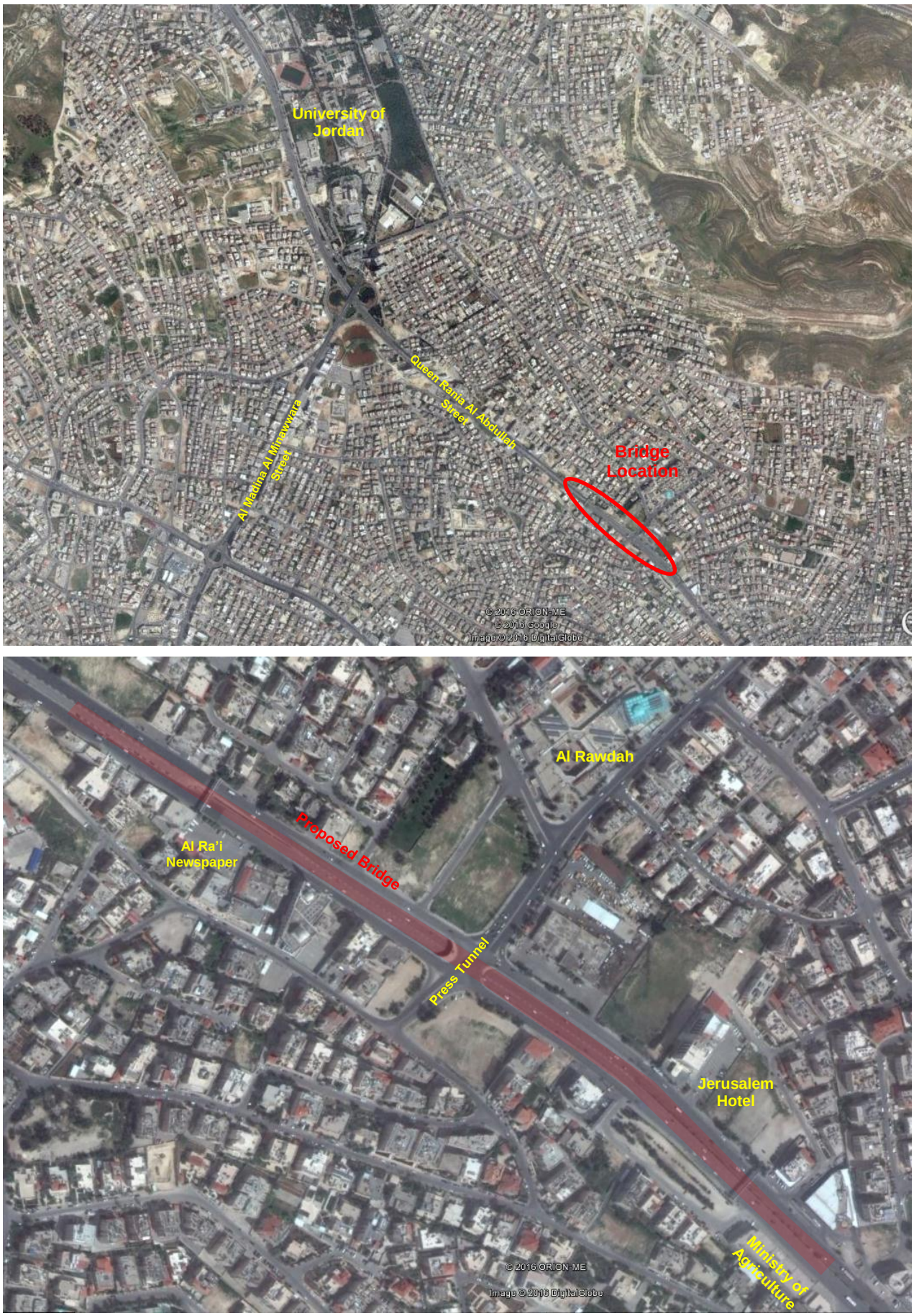


Figure 1: General Location Map

ACES	**Project:** BRT-Press Tunnel Bridge **Project No.:** S16000152 **Location:** Amman-Jordan **Client:** Steer Davies Gleave (SDG)	**Legend:** Bridge Alignment Boreholes	General Site Plan **Date:** November 2016 **Figure:** 2

3.0 GEOLOGY OF THE AREA

According to the available geological map of the project area (Amman, sheet no. 3153-I), the project site belong to the Upper Cretaceous Ajlun group represented by Wadi As Sir Formation. Fill and recent soil sediments cover these bedrocks at the investigated site with various thicknesses.

A geological map for the general project area is presented in **Figure 3**. A brief description of the geological units representing the project site is presented below (from the oldest to youngest):

3.1 Ajlun Group

3.1.1 Wadi As Sir Limestone Formation (WSL)

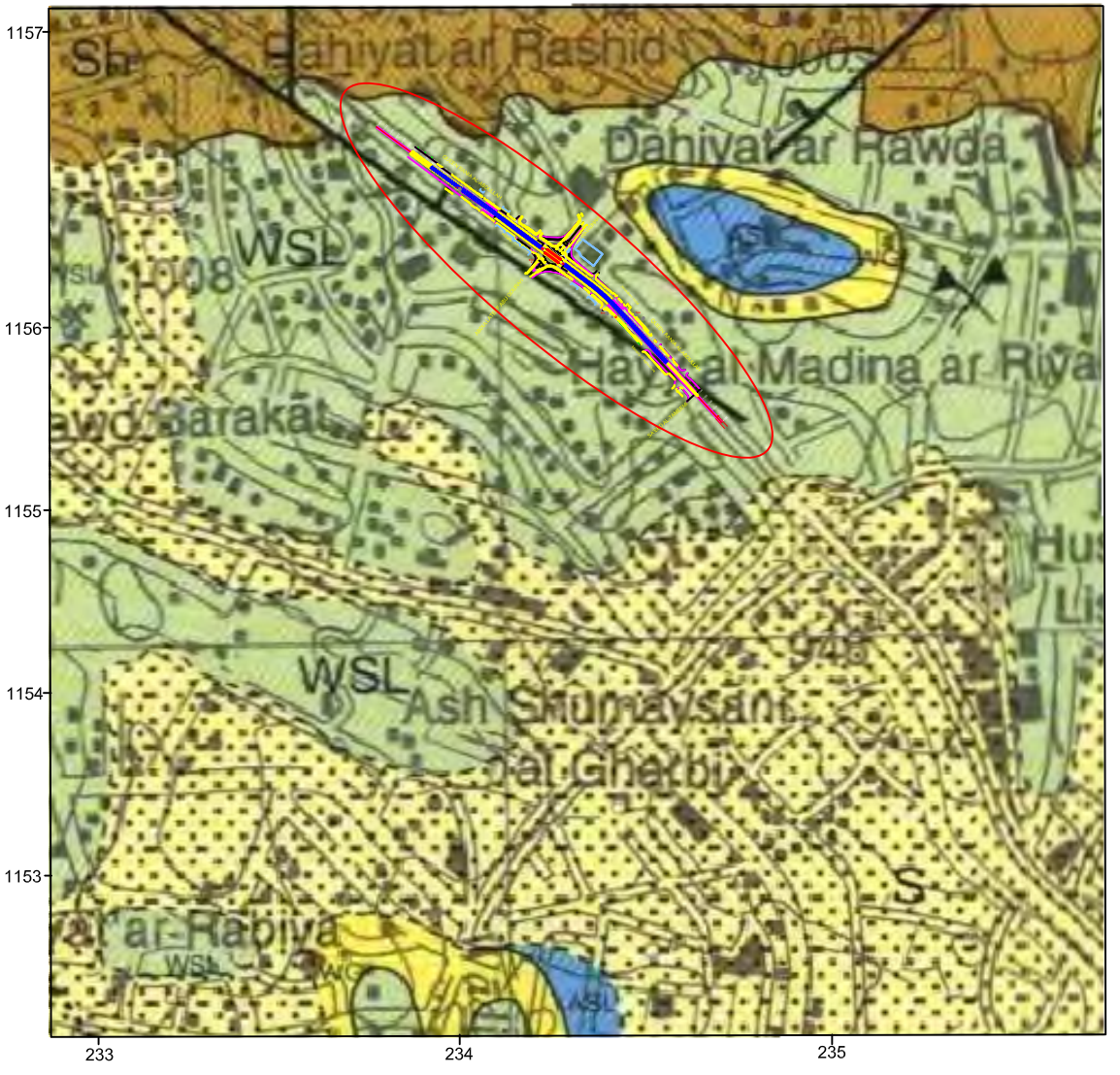
This formation consists of three units. The lower unit comprises dolomite, dolomitic limestone and locally recrystallized limestone and due to secondary iron oxides the bed of this unit is characterized by the red color. The middle unit consists of relatively soft marly limestone and limestone whereas the upper unit consists of thick bedded to massive limestone including fossiliferous beds. The formation forms a steep slopes and cliffs of limestone of grey-weathering colors intercalated with marly limestone and marl.

3.2 Superficial Deposits

Surficial deposits of red brown silty clay soil covers the project site with variable thicknesses.

4.0 SEISMICITY AND EARTHQUAKES

According to the Jordanian Seismic Code (published by the ministry of public works and housing in Oct., 2005); the project site lies within zone (2A); with a seismic zone factor of Z=0.15. The classification of the subsurface materials at the project site based on the average soil/rock properties in the top 30m is **S_B** (representing moderately weak rock). The related seismic coefficients for acceleration of **C_a=0.15** and seismic velocity of **C_v=0.15** is recommended in the design of the proposed structure.



Natural Resources Authority (NRA)
Geological Map of Amman
Sheet No. 3153-I
Not to Scale

Generalized Vertical Section

Formation		Group
S	Soil	
ASL	Amman Silicified Limestone	Belqa
WG	Wadi Umm Ghudrn	Belqa
WSL	Wadi As Sir Limestone	Ajlun
Sh	Shu'ayb	Ajlun

Legend

- Geological Boundary
- Geological Boundary inferred
- Anticlinal
- Sinclinal
- Fault
- Land Slip
- Dip measured

Project Name: BRT - Press Tunnel Bridge	**Legend:**		Geological Map
Project No.: S16000152	Project Site	Contour Line 135	
Location : Amman, Jordan	Grid System 338	Wadi	**Date:** November, 2016
Client: Steer Davies Gleave (SDG)	Formation Symbol **PI**	Water Well	**Figure:** 3

5.0 FIELD EXPLORATION AND IN-SITU TESTING

5.1 Boreholes Drilling

A total of five (5) boreholes were drilled at the project site at selected locations along the proposed bridge alignment to approximate depth of 20m below the existing ground surface between the period of October 10 and November 6, 2016. The number and depth of these boreholes were determined by the client representative (Engicon) and marked in the field by ACES engineers based on the site accessibility and as agreed upon with the client representative. The boreholes details are presented in **Table 1** and are also shown in the site plan-Figure 2.

Table 1: Boreholes Details

BH No.	Approximate Station	Elevation (m)	Coordinates		Depth (m)	Remarks
			Northing	Easting		
BH01	Sta.0+280	969.1	155879	234003	20	At the existing PRT section
BH02	Sta.0+470	964.5	155792	234178	20	At the road opposite to the Sta. (LHS)
BH03	Sta.0+820	955.7	155540	234404	20	At the road opposite to the Sta. (RHS)
BH04	Sta.0+870	953.6	155538	234483	20	At land plot opposite to the Sta. (LHS)
BH05	Sta.0+550	964.6	155694	234198	20	At land plot opposite to the Sta. (RHS)

* Boreholes elevations were provided by the client.

Borehole drilling was executed using rotary drilling method utilizing air flush as drilling media. Drilling was completed with the following rigs:

- Mobile drill 36-I" type rig mounted on Mercedes LB 811 (capacity 200m)
- Toho-2 rotary rig mounted on Mercedes truck with capacity of 800m.

The logs of the drilled boreholes are presented in **Appendix A**.

5.2 Sampling

5.2.1 Undisturbed Samples

Continuous core recovery was carried out in all drilled boreholes using rotary coring and utilizing double tube core barrel (T6-101- 79mm) with tungsten carbide (TC) core bit and air flush to obtain undisturbed core samples in the rock materials. However, due to the interbedded and relatively weak nature of encountered materials (Marly Limestone and Dolomitic Limestone interbedded with Marl and Marlstone) the core sampling yielded in relatively poor RQD in most cases. The recovery and RQD values versus depth for all cores are presented on logs of boreholes as well as the subsurface profiles (**Appendix A**). Coring of rock was performed in accordance to ASTM D 2113.

The recovered samples were examined, visually described by our geologists in accordance with appropriate standards, placed in proper sequence in wooden boxes, photographed and taken to our laboratories for testing. Photos of the retrieved core samples from all boreholes are presented in **Appendix J**.

5.2.2 Disturbed Samples

Disturbed but representative samples were obtained from all drilled boreholes (except BH02) using split spoon sampler with open driving shoe while conducting the standard penetration test (SPT) in the soil materials. Percussion drilling techniques (using 4.25" OD down-the-hole hammer) were used at intervals where no SPTs sampling points were carried out, from which disturbed samples were obtained during this process.

Recovered samples were examined, visually described by our geological engineer, preserved in watertight bags to maintain the moisture content, properly marked with borehole name, sample number and depth, and placed in proper sequence in marked wooden boxes.

5.3 In-situ Testing

Standard Penetration Test (SPT) was performed in all drilled boreholes (except for BH02) at regular interval of 1.5m in the top first meters in the soil materials, to obtain approximate dynamic resistance of the ground materials. The test was performed in accordance with ASTM D 1586-08a. The SPT equipment used in this project consisted of an auto-trip hammer (63.5kg weight) and 45cm long split tube (5.0cm diameter) with a hammer drop of 760mm.

SPT penetration resistance value (N-value) is the number of blows required to achieve a penetration of 300mm below an initial seating drive of 150mm. The test was terminated in some cases when the number of blows recorded during the penetration of 150mm reached 50 blows. Test results are shown on the boring logs as well as the subsurface profiles at the respective test depths and are summarized in **Section 6.3**. Several empirical correlations have been established to relate the SPT blow counts (N) with relative density and friction angle for granular materials, and with consistency and undrained shear strength for cohesive materials. The definition of SPT and useful SPT correlations for granular and cohesive soils are presented in the legend to boring logs (Appendix A). Represntative photographs of the SPT and retrieved samples are provided belwo.

6.0 SUBSURFACE CONDITIONS

6.1 Ground Materials

The geological description of the subsurface materials at the drilled boreholes with the approximate average depths at which they were encountered are provided on logs of boreholes in **Appendix A**, and are as follows:

- **Fill Layer**

Topsoil materials composed of brown silty clay with gravel and cobbles of limestone. This material was encountered at the surface of all drilled boreholes with approximate thicknesses ranging from 1.0m to 2.0m.

- **Buried Topsoil Materials**

Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone. This materials was encountered in all drilled boreholes underneath the fill materials with approximate thicknesses ranging from 1.0m to 1.5m.

- **Silty Clay Materials**

Brown to reddish brown, stiff to very stiff, Silty Clay, with some scattered gravel and cobbles of limestone. This material was encountered at the location of all drilled boreholes underneath the buried topsoil materials with approximate thicknesses ranging from 1.0m to 3.0m.

- **Interbedded Bedrock**

Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong Dolomitic Limestone, and thin bands of dark yellow, very weak to weak Marl and Marlstone. These materials were encountered at the location of BH01, BH02 and BH05 at approximate depths of 3.0m, 4.3m and 6.0m below the existing ground surface and extended to the bottom of these boreholes.

In addition, Interbedded materials composed of grayish creamy, fractured, moderately weak to moderately strong, DOLOMITIC LIMESTONE, interbedded with thin to thick bands of yellowish creamy, fractured, weak to moderately weak nodular to fossiliferous Marly Limestone, and thin

bands of very weak to weak Marl and Marlstone. These materials were encountered at the location of BH03 and BH04 at approximate depth of 5.0m below the existing ground surface and extended to the bottom of these boreholes.

Generalized subsurface profile for drilled boreholes projected on the bridge alignment is presented in **Figure 4**. In addition, interpolation between the drilled boreholes with crossing road profiles were made and were projected on the bridge profile as presented in **Figure 5**.

6.2 Standard Penetration Test (SPT) Results

Standard Penetration Test (SPT) was performed at regular intervals in the top first meters in all drilled boreholes except for BH02 in order to obtain approximate dynamic resistance of the ground materials. The test results are shown on the boring logs, as well as the subsurface profiles at the respective test depths, and are also summarized in **Table 2**, below.

The SPT N-values in the tested silty clay materials ranged from 26 to refusal indicating stiff to hard materials. The obtained N-values were corrected for overburden and used equipment as follows:

$$N_{1(60)} = C_N \times C_E \times N$$

Where:
$N_{1(60)}$= corrected number of blows obtained from standard penetration test.
C_N = correction due to overburden pressure; where $C_N = 9.78\sqrt{1/\sigma_N(KN/m^2)}$; $\sigma_N =$ effective overburden pressure. Note that most of subject references do not consider correction of SPT N-values due to overburden at depths shallower than 5m. Therefore C_N was considered 1 for the top 5m.
C_E : correction for SPT hammer energy and is calculated from the following relation:

$$C_E = E_m C_B C_S C_R$$

Where:

- E_m= hammer efficiency (%) of about 60 percent energy ratio (ERr/60).
- C_B =correction for borehole diameter (1.0 for borehole diameters of 60 – 120mm)
- C_S =sampler correction (1.0 for standard sampler)
- C_R =correction for rod length:
  1.00 for rod length >10m.
  0.95 for rod length 6-10m.
  0.85 for rod length 4-6m.
  0.75 for rod length 0-4m.

Accordingly, the results of the field and corrected SPT N-values are presented in **Table 2**.

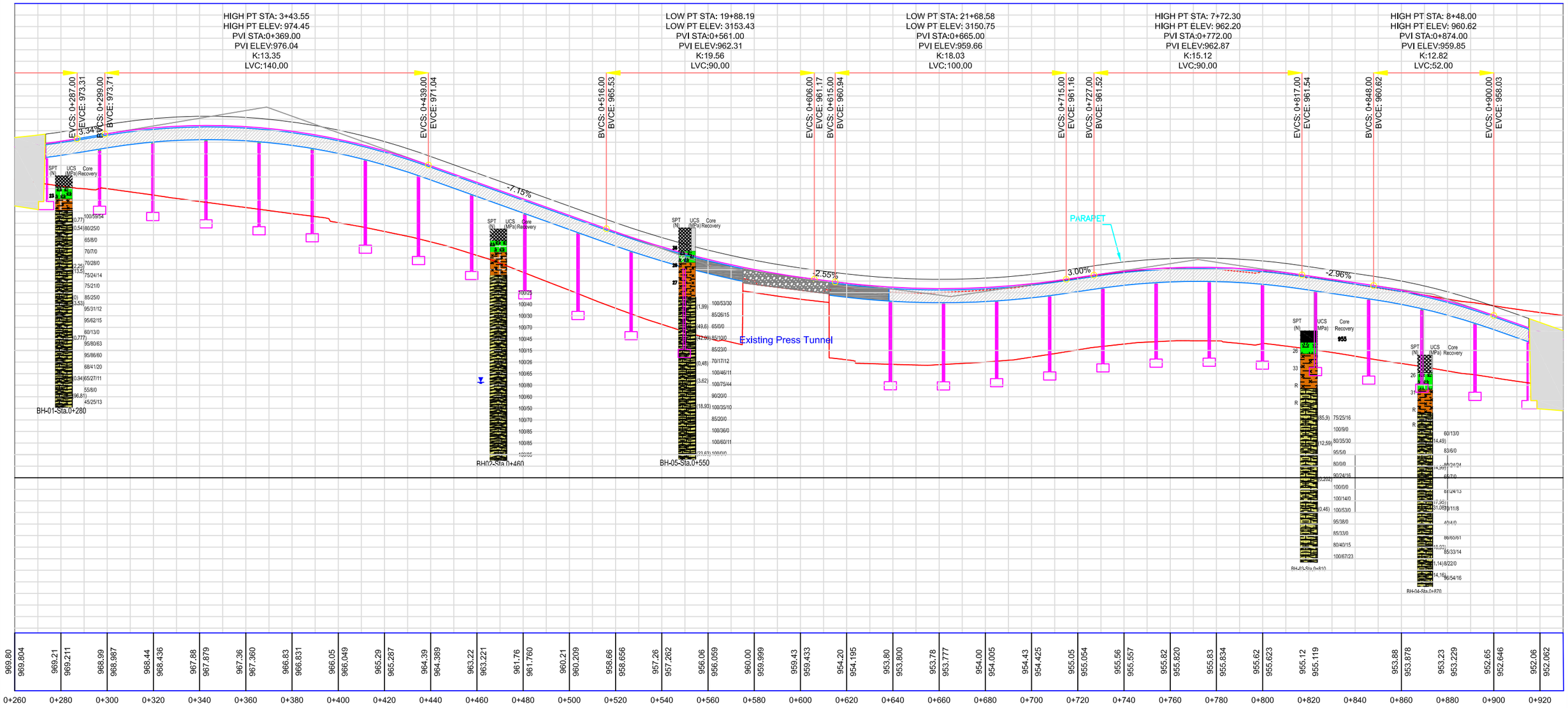
Table 2: SPT Test Results

BH No.	Depth (m)	Material	SPT blows			N-value	Overburden Correction C_N	Equipment Correction C_E	$N_{1(60)}$
			0-15cm	15-30cm	30-45cm				
BH01	1.5	Buried Topsoil	5	9	14	23	1.00	0.75	17
BH03	1.5	Buried Topsoil	9	12	14	26	1.00	0.75	20
	3	Silty Clay	12	15	18	33	1.00	0.75	25
	4.5	Silty Clay	6	50/9cm	-	R	1.00	0.85	-
	6	Interbedded	50/3cm	-	-	R	0.94	0.95	-
BH04	1.5	Buried Topsoil	6	10	16	26	1.00	0.75	20
	3	Silty Clay	11	13	18	31	1.00	0.75	23
	4.5	Silty Clay	15	50/7cm	-	R	1.00	0.85	-
	6	Interbedded	50/3cm	-	-	R	0.94	0.95	-
BH05	1.5	Fill	11	15	21	36	1.00	0.75	27
	3	Silty Clay	9	12	14	26	1.00	0.75	20
	4.5	Silty Clay	6	10	17	27	1.00	0.85	23

* Refusal represents blows >50/15cm

Generalized Subsurface Profile

Main Road PROFILE



Ground Water Table Core Recovery: TCR/SCR/RQD

Project Name: Bus Rapid Transit (BRT)–Press Tunnel Bridge

Project No.: S16000152

Location: Amman, Jordan

Client: Steer Davies Gleave (SDG)

Profile No.: Projected Drilled Boreholes Figure No.: 4

Fill Materials

Topsoil

Silt Clay

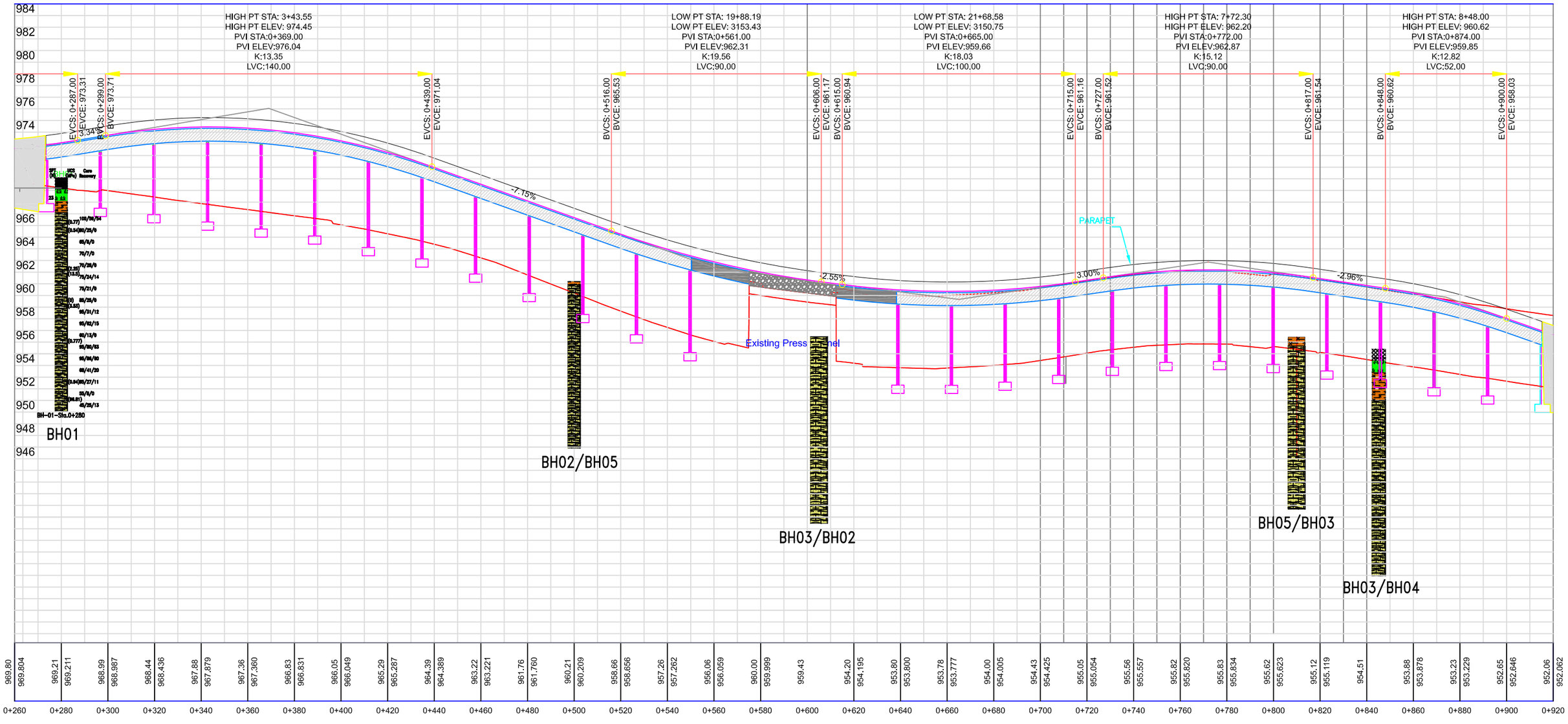
Interbedded

Boreholes Information

BH–No.	Depth (m)	Elev. (m)
BH–01–Sta.0+280	20	969.1
BH–02–Sta.0+470	20	964.5
BH–03–Sta.0+820	20	955.7
BH–04–Sta.0+870	20	953.6
BH–05–Sta.0+550	20	964.6

Generalized Subsurface Profile

Main Road PROFILE



Ground correlation was estimated based on the interpolated crossing the road profiles, and should be taken as approximate.

Project Name: Bus Rapid Transit (BRT)–Press Tunnel Bridge

Project No.: S16000152

Location: Amman, Jordan

Client: Steer Davies Gleave (SDG)

Profile No.: Crossing the Road Profiles Figure No.: 5

Fill Materials

Topsoil

Silt Clay

Interbedded

Crossing the Road Profile

Section	Station	Elev. (m)
BH01	Sta.0+280	968.2
BH03/BH04	Sta.0+845	954.4
BH03/BH02	Sta.0+605	954.4
BH02/BH05	Sta.0+500	960.2
BH05/BH03	Sta.0+810	955.4

6.3 Groundwater and Cavities

No groundwater was encountered in any of the drilled boreholes at the drilled depths during or at the completion of drilling activities. However, water accumulation was observed at the location of BH02 after 24 hours from drilling down to 11m below the existing ground surface. The source of the water is believed to be from a local spring in the area. The water level was remeasured after the completion of drilling activity on the 7th and 8th of October and was recorded at approximate depths of 13.25m and 13.27m, respectively.

No cavities were encountered in any of the boreholes at the drilled depths during or at the completion of drilling activities.

7.0 LABORATORY TESTING

7.1 List of Laboratory Tests

Laboratory tests were performed on representative samples obtained from the drilled boreholes in order to identify the physical and mechanical properties of the ground materials. The following laboratory tests were performed:

1. Classification and index tests: moisture content, particle size distribution and Atterberg limits.
2. Strength Tests: point load and unconfined/uniaxial compressive strength.

The tests were performed according to the relevant American Society for Testing and Materials (ASTM) Standards and/or British Standards (BS). **Table 3** presents the applicable standards along with some photographs for these tests.

Table 3: Standards for the Performed Lab. Tests

No.	Test	Illustration	Standard No.	Title of Standard
1.	**Classification and Index Tests**			
1.1	Moisture Content		D 2216-05	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
1.2	Particle Size		D 422-63-07	Standard Test Method for Particle-Size Analysis of Soils
1.3	Atterberg Limits		D 4318-10	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soil
1.4	Bulk Density		D 7263-09	Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens

Table 3 (Cont'd): Standards for the Performed Lab Tests

No.	Test	Illustration	ASTM No.	Title of Standard
2.	**Strength Test**			
2.1	Point Load		D 5731-08	Standard Method for Determination of the Point Load Strength Index of Rock
2.2	Uniaxial Compression		D 7012-10	Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core specimens under Varying States of Stress and Temperatures

7.2 Material Physical & Mechanical Properties

Laboratory tests results performed on selected samples retrieved from the drilled boreholes are as follows.

7.2.1 Classification and Index Tests

Classification and index tests were performed on selected samples retrieved from the boreholes including moisture content, grains size distribution (sieve and hydrometer) and atterberg limits. The results of these tests are as presented in **Table 4**, whereas the tests sheets are presented in **Appendix B**.

The sieve analysis test results were used for soil classification according to Unified Soil Classification System (USCS). Atterberg limits tests results were compared with Casagrande plasticity chart, to obtain the plasticity of the soils. The tables given in the legend to boring logs, Appendix A were used to describe the consistencies, relative density and strength of the soils.

Table 4: Laboratory Test Results

BH No.	Depth (m)	Material	MC (%)	Grain Size Distribution				Atterberg Limits			USCS
				G (%)	S (%)	M (%)	C (%)	LL (%)	PL (%)	PI (%)	
BH-01	2	Silty Clay	11	6	43.5	30.6	20	35	21	14	CL
BH-03	2	Silty Clay	14.4	0.8	6.4	44.6	48.2	51	29	22	MH
BH-03	3	Silty Clay	15.6	7.7	21.9	28.6	41.8	67	35	32	MH
BH-04	3	Silty Clay	6	30.7	18.6	20.9	29.8	55	27	28	CH
BH-05	2	Buried Topsoil	6.7	9.9	42.9	31.4	15.8	46	20	26	SC
BH-05	4	Silty Clay	12.9	1.3	6	50.8	41.9	65	30	35	CH

G: Gravel; S: Sand; M: Silt; C: Clay; LL: Liquid Limit; PL: Plastic Limit; PI: Plasticity Index

7.2.2 Strength Tests

Point load and unconfined compressive strength tests were conducted on recovered core samples from most of drilled boreholes. The point load test was performed in accordance with ASTM D5731-95 (Standard Test Methods for Point Load Strength Index of Rock) whereas the uniaxial compressive strength test was carried out in accordance with ATSM 7012-10 (Standard test Method of Compressive Strength of Intact Rock Core). The results of these tests at respective test depth are presented in **Table 5** and **Figure 6**, whereas the test sheets are presented in **Appendix B**.

Table 5: Strength Test Results

Station	Point No.	Depth (m)	Material	Bulk Density (g/cm³)	Unconfined		Uniaxial	Point Load	
					UCS (kPa)	Su (kPa)	qu (MPa)	$Is_{(50)}$ (MPa)	Eq.qu* (MPa)
Sta.0+280	BH01	3.8	Interbedded	-	-	-	0.77	-	-
		4.5	Interbedded	1.847	-	-	-	0.03	0.54
		7.8	Interbedded	2.309	-	-	-	0.11	2.25
		8.2	Interbedded	-	-	-	13.5	-	-
		10.5	Interbedded	1.988	-	-	-	0	
		11	Interbedded	-	-	-	3.53	-	-
		14	Interbedded	-	777	388	-	-	-
		17.5	Interbedded	-	-	-	-	0.05	0.94
		19	Interbedded	-	-	-	96.81	-	-
Sta.0+460	BH02	5.5	Interbedded	-	-	-	-	0.52	10.66
		6	Interbedded	-	-	-	-	1.11	22.52
		8.5	Interbedded	-	-	-	31.59	-	-
		8.8	Interbedded	-	-	-	-	0.02	0.51
		10	Interbedded	-	-	-	-	0.05	0.93
		12.3	Interbedded	-	-	-	-	2.72	55.27
		16.7	Interbedded	-	-	-	4.61	-	-
		18.3	Interbedded	-	-	-	8.80	-	-
		19.3	Interbedded	-	-	-	3.09	-	-
Sta.0+810	BH03	7.5	Interbedded	1.991	-	-	-	4.09	85.9
		9.7	Interbedded	-	-	-	12.59	-	-
		12.8	Interbedded	-	202	101	-	-	-
		15.4	Interbedded	2.437	-	-	-	0.02	0.46
Sta.0+870	BH04	7.4	Interbedded	2.376	-	-	-	0.7	14.49
		9.7	Interbedded	-	-	-	14.99	-	-
		12.7	Interbedded	-	-	-	17.95	-	-
		13	Interbedded	-	-	-	31.08	-	-
		16.6	Interbedded	-	-	-	18.93	-	-
		18	Interbedded	2.228	-	-	-	0.05	1.14
		19	Interbedded	2.539	-	-	-	0.7	14.16
Sta.0+550	BH05	6.8	Interbedded	-	-	-	1.99	-	-
		8.5	Interbedded	2.34	-	-	-	2.34	49.6
		9.5	Interbedded	2.471	-	-	-	1.95	42.09
		11.7	Interbedded	2.29	-	-	-	0.02	0.48
		13.2	Interbedded	-	-	-	3.62	-	-
		15.4	Interbedded	2.452	-	-	-	0.94	18.93
		19.5	Interbedded	-	-	-	-	1.16	23.63

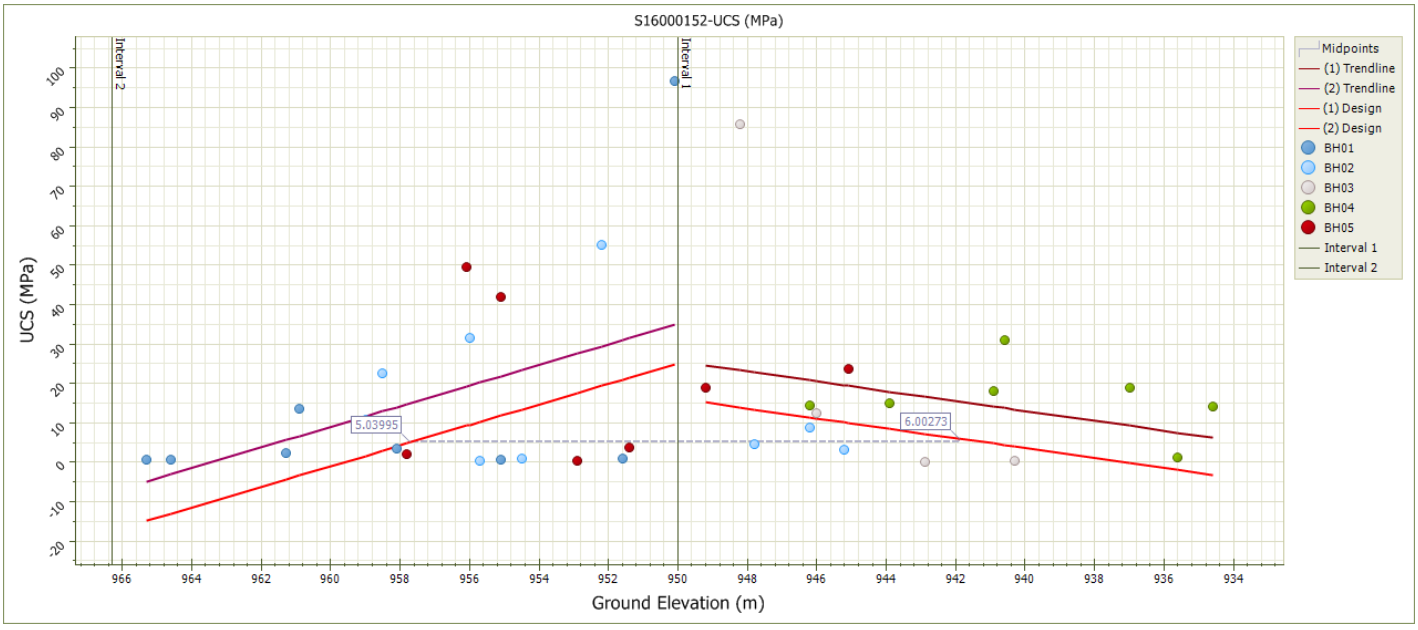


Figure 6: Graphical Presentation of Strength Test Results versus Depth

8.0 CONCLUSIONS AND RECOMMENDATIONS

According to field and laboratory investigation, surface and subsurface conditions and practical experience, it can be concluded that the foundations of the proposed structure can be satisfactorily supported by the ground at the investigated site provided that the following considerations and recommendations are followed.

8.1 Foundation Depth and Type

Generally, foundation depth should be chosen so as to allow for the combination of design requirements, suitable ground and minimum foundation depth below the finished design level (F.D.L) of ground surrounding the road/bridge (i.e. foundation ground cover) required for protection against environmental influences (especially moisture content changes).

Based on the encountered materials at the drilled boreholes the following are recommended:

- **Bridge Piers**; it is recommended to the lay the foundation of bridge piers on the Interbedded bedrock which was encountered at the existing street level in the crossing area between drilled BH02 and BH05 boreholes, and at approximate depth of 2m below the existing street level at BH01, and at approximate depth of 3.5m below the existing street level at the crossing area between BH03 and BH04; refer to Figure 5-interpolated crossing road profiles. Deeper excavation will be required at the crossing area between BH03 and BH04 until the recommended foundation ground (Interbedded) is reached. This foundation ground is suitable and may support the imposed loads on shallow foundation.

  The minimum recommended foundation depth for foundation laid on Interbedded bedrock should not be less than 1.2m below the finished design level surrounding the road. Furthermore, at areas where deeper excavation is required to reach the Interbedded layer, a minimum penetration of 0.5m in the Interbedded bedrock is recommended. A summary of the estimated depth to recommended foundation ground and recommended foundation depth based on interpolated crossing the road profiles (Figure 2) is presented in **Table 6**.

Table 6: Estimated Depth to Interbedded Foundation Ground and recommended Foundation depth

Section	Crossing the road profile	Elevation at the existing road (Tunnel)	Estimated depth of Bedrock (m)	Minimum Recommended depth of Foundation* (m)
BH01	Sta.0+280	968.2	2.2	2.6
BH 3/ BH 4	Sta. 0+845	954.4	3.5	4.0
BH 3/ BH 2	Sta. 0+605	954.4	at Existing street Level	1.2
BH 2/ BH 5	Sta.0+500	960.2	at Existing street Level	1.2
BH 5/ BH 3	Sta. 0+810	955.4	at Existing street Level	1.2

*Foundation depth below the existing street level was estimated based on the interpolated crossing the road profiles-Figure 5, and should be taken as approximate.

- **Bridge Abutments**; based on the nearest drilled boreholes at the location of the bridge abutments, it is recommended to lay the foundation of the bridge abutments (gravity abutment of ~90m to 110m base) on the Interbedded materials. However, based on the proposed design level and ground/street grading, foundation may bear on the Silty Clay materials especially at the area of the lower abutment at the bridge end part. Regardless, foundation should never be laid on the existing fill/topsoil materials, which was encountered at the surface of all drilled boreholes with approximate thicknesses ranging from 2m to 3m.

  The minimum recommended foundation depth for foundation laid on Silty Clay layer (If any; at the abutment location) should not be less than **3.0m** below the finished ground level surrounding the abutment.

8.1.1 Allowable Bearing Pressure

8.1.1.1 For Bedrock (Interbedded Layer)

The net allowable bearing pressure for the Interbedded layer can be estimated based on the point load and compressive strength tests results, considering that the bearing pressure of the rock is equal to the unconfined test result performed on the rock sample:

$$q_{net(all)} = \frac{q_{un}}{FS}$$

Where:
q_{netall}: net allowable bearing pressure (kPa).
q_{un}: compressive strength results.
FS: factor of safety which is varied from 5 (for the RQD > 75%) to 20 (for the RQD < 25%).

The strength test results (from point load and unconfined compressive strength tests) for tested samples from the Interbedded layer ranged from 0.77MPa to 97MPa. Considering RQD values in the range of 0 to 80%, a net allowable bearing pressure value of **300kPa** is recommended for the Interbedded layer.

8.1.1.2 For Soil Layer (Silty clay)

As discussed above, if the foundation of the abutment will be laid on silty clay materials, based on the actual site condition and provided that the recommended foundation depth is satisfied, the recommended net allowable bearing pressure for this layer is **180kPa**.

If the foundation will be laid on both Interbedded and Silty Clay layer, it is recommended to unify the bearing pressure value for the design of the abutment considering the lower value of 180kPa.

8.2 Foundation Settlement

The immediate (distortion) settlement of the encountered materials can be calculated using the following equation based on the theory of elasticity (Bowels, 1999):

$$S_e = \Delta\sigma(\alpha B')\frac{1-\mu^2}{E_s} I_s I_f$$

Where:

- S_e : elastic settlement of the footing (mm).
- $\Delta\sigma$: net applied pressure on the foundation (kPa).
- μ: poisson's ratio of the materials (μ assumed to be 0.3).
- B': least lateral dimension of contributing area (m), which equal to:
  B'=B/2 for center of foundation.
  B'= B for corner of foundation.
- α: number of corners contributing to settlement, which equal to:
  α=4 for the center.
  α=1 for the corner.

  I_f: Influence factor for footing, based on D/B and poisons ratio. I_f is conservatively taken as 1.
  I_s: shape factor (Steinbrenner, 1934), which depend on L/B and thickness of stratum (H).

  $I_s = I_1 + \frac{1-2\mu}{1-\mu} I_2$ (Flexible)

  $I_{sr} = 0.931 I_s$ (Rigid)

  I_1 & I_2: influence factors given by Steinbrenner for N = (H/B') and M = (L/B), where H is the thickness of the stratum.

E_s: is the elasticity modulus of the materials, which is estimated based on investigation results as well as our experience with similar materials. The considered E_s values for the foundation ground is as follows:

- Silty Clay Materials, 80MPa.
- Interbedded Materials, 1000MPa

Accordingly, the calculated immediate settlements for the foundation grounds are small and within tolerable limits and are likely to occur during construction and initial loading. The results of the estimated settlement are presented in **Table 6**.

Figure 7: Estimated Settlement for Foundation Grounds

Layer(s)	Elastic Modulus, E (MPa)	$q_{net(all)}$ (kPa)	Settlement (mm)
Silty Clay Layer	80	180	11.1
Interbedded Materials	1000	300	0.2

8.3 Excavation Methods

It is expected that the excavation will be carried out through fill/topsoil, silty clay and interbedded bedrock. Therefore, pneumatic equipment such as jackhammer will be needed in addition to the conventional excavation equipment such as loaders and dozers for excavation work at the site.

Table 7 summarizes the proper excavation methods that could be used for excavating the encountered materials at the project site.

Table 7: Excavation Methods

Excavation Method	Material	Remarks
Scrape	Fill/topsoil and Silty Clay materials	Conventional excavation equipment such as loaders and bulldozers. Jackhammers and rock breaker may also be required for excavation if any large boulders and rock fragments where encountered within these materials.
Rip	Interbedded Bedrocks	Pneumatic equipment such as jackhammers, rock breakers and rippers may use to breakout these rocks. The highly fractured and weathered nature of these bedrocks facilitates its ripping and scraping.

8.4 Excavation of Side Slopes

To minimize the stability problems in the temporary construction, it is recommended that the material at the site to be cut at a face inclination not steeper than the following:

- One horizontal to one vertical (1H: 1V) for the fill/topsoil and silty clay materials.
- One horizontal to Three vertical (1H: 3V) for interbedded materials.

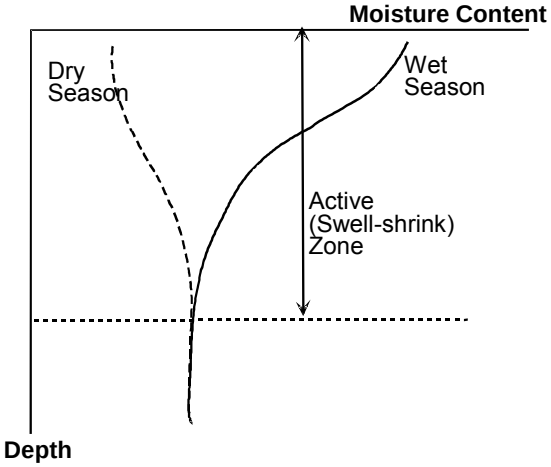
If these side slopes cannot be achieved due to insufficient lateral clearance or for any other reason, temporary lateral support (shoring) system and/or other support systems may be necessary and should be considered.

8.5 Drainage

It is recommended to protect the foundation ground and excavation from surface water both during and after construction by providing proper drainage and protection system and maintaining the sewer and water system of the structure continuously. The rain water and surface water (if any) which is collected from the rain water ducts and from ground surface should be directed away from the structure.

8.6 Swelling and Shrinkage

The soil materials encountered at the project site possessed low to very high expansiveness potential. This means that these materials are sensitive to moisture content changes and are subjected to volumetric changes with the change of their moisture content. Dry expansive soil tends to expand (swell) when given access to water or significant moisture change, whereas wet expansive soils have the tendency to shrink upon drying or reduction of moisture. These volumetric changes may be detrimental to pavements and structures (especially light weight structures). They could lead to the development of cracks in structure walls and ground floor slab. The amount of swell and the corresponding swell pressure of dry expansive soil upon wetting may exceed the working structure loads leading to sagging mode of deflections (expansion of outer structure bounds). This is the case of dry season construction. For wet season construction (construction on wet expansive soils), the soil tends to shrink upon drying during the summer leading to settlements of the outer parts of the structure. The active zone is determined based on the measured seasonal variations of moisture contents. This zone is defined as the depth at which the moisture contents are relatively constant throughout the year, as demonstrated in below sketch.



Demonstration of Active Zone with Seasonal Moisture Variation Depth

In general, the depth of the active zone generally ranges from 2.0 to 3.0 m. Active zone depths may exceed 3.0 m for soils with very high expansiveness/shrinkage potential.

Construction on soils with expansive nature should involve measures to reduce or prevent the swelling or shrinkage of the soil below structures, utilities or pavement. This can be accomplished either by treating the soil (with chemical agents), or control the moisture variations. Control of moisture variations can be accomplished as follow:

- Foundation excavation should not be exposed for long time either to the sun or to rain fall. After concreting the foundations, the excavations should be filled and compacted in layers of 20 to 25 cm thick in order to prevent water infiltration to the foundation ground. (A plastic tent or cover should be used for excavations and excavations sides that will be left open for long time).

- It is recommended that 1.5 to 2.0 m wide pavement sloping down and away from the building with a slope of 15 horizontal to 1 vertical (15H:1V) be constructed in order to protect the foundation from surface water. This pavement should be separated from the building by sealed vertical slip joint.
- Rain water falling on roofs should be ducted well away from the foundations.
- It is recommended to avoid planting deep root trees in order to minimize seasonal variation in moisture content of ground materials. The effect of trees can be noticed as trees reach a height approximately equal to their distance away from the building. Therefore, if any trees are to be planted at the area, they should by locate away from the building at a minimum distance that is equal to the expected maximum height of the tree in the future.
- Water supply and sewer pipes should be sufficiently flexible, or have flexible connections, to accommodate movements.
- If water or septic tanks are to be constructed at the site, care should be taken to prevent completely the seepage of water from these structures towards the foundations.
- It is recommended to protect the foundation ground and excavation from surface water both during and after construction by providing proper drainage and protection systems as well as maintaining the sewer and water system of the structure continuously. The rain water and surface water (if any) which is collected from the rain water ducts and from ground surface should be directed away from the proposed structure.
- It is recommended to study the landscaping of the site in relation to the proposed building and to provide efficient surface drainage of the garden so that any water runs off flows away from the building and the plot.
- Ground floor slab, pavements or any other yards should not be constructed directly on the silty clay materials. The expansive clay below these elements should be excavated to a depth not less than 0.6 m for this project and this depth shall be filled with suitable, compacted engineered fill materials.

8.7 Backfill Material and Compaction Criteria

8.7.1 Selected Backfill Materials

The materials to be used for backfilling purposes under bottom slab and behind underground walls (if any) shall be a soil or soil-rock mixture, which is free from organic matter or other deleterious substances. It shall not contain rocks or lumps over 15 cm in greatest dimension, and not more than 15 percent larger than 7 cm. The fine materials (passing sieve 200) shall not exceed 35 percent. The plasticity index for the backfill material shall not be more than 10 percent. It shall be spread in lifts not exceeding 25cm in uncompacted thickness, moisture conditioned to its optimum moisture content, and compacted to density not less than 95 percent of the maximum dry density as obtained by modified proctor compaction test (ASTM D 1557-09).

8.7.1 General Treatment and Leveling Works

The materials to be used for backfilling purposes under the pavement layers for leveling and protection purposes shall comply with the clauses relevant to the embankment in the Specification for Highway and Bridge Construction, 1991, Issued by Ministry of Public Works And Housing In Jordan.

8.7.2 Retaining Walls (Filter Materials)

The backfill materials immediately behind the retaining walls (if any) shall consist of filter/drainage materials composed of clean coarse sand and gravel or crushed stone conforming to the following gradation requirements:

Sieve Size	Percentage Passing By Weight
2 1/2”	100
1 1/2”	80-100
3/4”	60-95
No. 4	35-65
No. 8	25-50
No. 30	5-25
No. 200	0-3

(Single size gravel may also be used as an alternative to the above filter materials).

These materials shall extend vertically from the bottom of the walls to a level of approximately 1m below the finished ground level behind the walls. The top 1m shall be backfilled with relatively impervious materials.

9.0 STANDARD OF CARE

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The conclusion and recommendation given in this report are based on the assumption that the surface/subsurface material and conditions do not deviate appreciably from those indicated in this report. If any variations or undesirable conditions are encountered during constructions, our offices should be notified in order to evaluate the effects of these conditions on the provided recommendations, and develop supplemental recommendations if necessary.

Additionally, the borings indicate the subsurface conditions at the locations, dates, and depths indicated and it is not warranted that they are strictly representative of the materials and conditions at other locations, times, and greater depths than indicated.

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Appendices

Appendix A: Log of Boring
Appendix B: Laboratory Test Results
Appendix C: Seismicity and Earthquake
Appendix D: Core Sample Photos

Appendix A
Logs of Boring

LEGEND FOR BORING LOGS

Symbols for Soil & Rock

Soil

- Cobbles & Boulders
- Gravel
- Sand
- Silt
- Clay

Others

- Made Ground / Fill
- Peat / Topsoil
- Concrete
- Asphalt
- Landslide / Debris Flow

Rock

Sedimentary

- Chalk
- Limestone
- Phosphate
- Coral
- Chert
- Conglomerate
- Breccia
- Sandstone
- Siltstone
- Mudstone / Claystone
- Shale
- Marlstone
- Coal
- Gypsum / Rocksalt

Igneous

- (C) Granite / Gabbro
- (M) Diorite / Andesite
- (F) Basalt / Rhyolite

Metamorphic (Foliated)

- (C) Gneiss
- (M) Schist
- (F) Slate

Metamorphic (Non Foliated)

- (C) Metaconglomerate
- (M) Marble
- (F) Hornfels

Note:

- Composite Soil types will be signed by combined symbols, e.g. Sandy Silt.

Abbreviations:

(C): Coarse Grained.
(M): Medium Grained.
(F): Fine Grained.

Soil & Rock - Consistency, Strength and Relative Density

Coarse Soils - Relative Density & Strength

(BS 5930:1999+A2:2010; EN ISO 14688-2:2004)

SPT N Value	Relative Density	Density Index I_D(%)	Angle of Internal Friction, (ϕ)*
0 - 4	Very Loose	0 to 15	< 29
4 - 10	Loose	15 to 35	29 to 30
10 - 30	Medium Dense	35 to 65	30 to 36
30 - 50	Dense	65 to 85	36 to 41
>50	Very Dense	85 to 100	> 41

* Reference: Peck, Hanson and Thornburn (1974).

Fine Soils - Consistency

(BS 5930:1999+A2:2010; EN ISO 14688-2:2004)

Consistency	Consistency Description	Consistency Index I_C
Very Soft	Finger easily pushed in up to 25mm. Exudes between fingers	< 0.25
Soft	Finger pushed in up to 10mm. Moulds by light finger pressure	0.25 to 0.50
Firm	Thumb makes impression easily. Cannot be moulded by fingers, rolls in the hand to a 3mm thick thread without breaking or crumbling	0.50 to 0.75
Stiff	Can be indented slightly by thumb. Crumbles in rolling a 3mm thick thread, but can then be remoulded into a lump	0.75 to 1.00
Very Stiff	Can be indented slightly by thumb nail. Cannot be moulded but crumbles under pressure	>1.00
Hard	Can be scratched by thumbnail	

Fine Soils - Undrained Shear Strength

(BS 5930:1999+A2:2010; EN ISO 14688-2:2004)

Undrained Shear Strength of Clays	Undrained Shear Strength C_U(kPa)
Extremely Low	< 10
Very Low	10 to 20
Low	20 to 40
Medium	40 to 75
High	75 to 150
Very High	150 to 300
Extremely High	> 300

Rock Strength

(BS 5930:1999+A2:2010)

Description	Field Definition	Unconfined Compressive Strength, UCS (MPa)
Extremely Weak	Can be indented by thumbnail. gravel sized lumps crush between finger and thumb.	0.6 - 1.0
Very Weak	Crumbles under firm blows with point of geological hammer. Can be peeled by a pocket knife.	1.0 - 5.0
Weak	Can be peeled by a pocket knife with difficulty. shallow indentations made be firm blow with the point of geological hammer.	5.0 - 25.0
Medium Strong	Cannot be scraped with pocket knife. Can be fractured with a single firm blow of geological hammer.	25.0 - 50.0
Strong	Requires more than one blow of geological hammer to fracture.	50.0 - 100.0
Very Strong	Requires many blows of geological hammer to fracture.	100.0 - 250.0
Extremely Strong	Can only chipped with geological hammer.	>250.0

Rock Quality

(ASTM 6032-08)

Rock Quality Designation RQD (%)	Rock Quality Description
0 - 25	Very Poor
25 - 50	Poor
50 - 70	Fair
70 - 90	Good
90 - 100	Excellent

Definitions

- SPT - Standard Penetration Test (N): Number of blows to drive the sampler to final 300mm of the total 450mm driving distance.
- TCR - Total Core Recovery (%): Ratio of length of core recovered to length drilled.
- SCR - Solid Core Recovery (%): Ratio of length of core recovered as solid full diameter core pieces to length drilled.
- RQD - Rock Quality Designation (%): ratio of length of core recovered in lengths greater than 100mm to length drilled.
- FI - Fracture Index: Number of fractures to length of core run per linear meter.
- I_D - Density Index: Ratio of difference between maximum void ratio and natural void ratio to difference between maximum and minimum void ratios.
- I_C - Consistency Index: Ratio of difference between liquid limit and natural water content to plasticity index.

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-01-Sta.0+28
Sheet 1 of 2

Total Depth (m): 20
Ground Level (m): 969.1
Coordinates: N= 155,879.00
E= 234,003.00

Drilling Method: Rotary Percussive
Boring Started: 23-10-2016
Boring Completed: 24-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
1	P	0 - 1.5										**FILL MATERIALS** Fill materials composed of crushed limestone and dolomitic limestone with silty clay and marl intercalations.	(1) 1	968.10	
2	SPT	1.5 - 1.95	5	9	14	23						**BURIED TOPSOIL MATERIALS** Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone.	(1) 2	967.10	
3	P	1.95 - 3										**SILTY CLAY** Brown to reddish brown, stiff to very stiff SILTY CLAY with some scattered gravel and cobbles of limestone.	(1) 3	966.10	
4	CS	3 - 4					100	59	54		0.77	**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE. *From 4.5-8.0m; Increase of nodular marly limestone.			
5	CS	4 - 5					80	25	0		0.54				
6	CS	5 - 6					65	8	0						
7	CS	6 - 7					70	7	0						
8	CS	7 - 8					70	28	0		2.25				
9	CS	8 - 9					75	24	14		13.5	*From 8.0-10.0m; Increase of dolomitic limestone.			
	CS	9 - 10					75	21	0						

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-01-Sta.0+28
Sheet 2 of 2

Total Depth (m): 20
Ground Level (m): 969.1
Coordinates: N= 155,879.00
E= 234,003.00

Drilling Method: Rotary Percussive
Boring Started: 23-10-2016
Boring Completed: 24-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
11	CS	10 - 11					85	25	0		0	**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE. *From 10.5-10.7m; marlstone band. *From 10.7-12.0m; Increase of marly limestone. *From 12.2-12.7m; Increase of marlstone and marl. *From 12.7-18.0m; Increase of marly limestone. *From 14.0-14.3m; marl band. *From 16.0-16.5m; Increase of marl and marlstone. *From 18.0-20.0m; Increase of dolomitic limestone and fossiliferous limestone.	(17)		
12	CS	11 - 12					95	31	12		3.53				
13	CS	12 - 13					95	62	15						
14	CS	13 - 14					60	13	0						
15	CS	14 - 15					95	80	63		0.777				
16	CS	15 - 16					95	86	60						
17	CS	16 - 17					68	41	20						
18	CS	17 - 18					65	27	11		0.94				
19	CS	18 - 19					55	8	0						
	CS	19 - 20					45	25	13		96.81	Bottom of Borehole	20	949.10	

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH02-Sta.0+46(
Sheet 1 of 2

Total Depth (m): 20
Ground Level (m): 964.5
Coordinates: N= 155,792.00
E= 234,178.00

Drilling Method: Rotary Percussive
Boring Started: 05-11-2016
Boring Completed: 06-11-2016
Rig: ACESDRILL-1A Driller: AN

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): 13.25

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
1	P	0 - 1										**FILL MATERIALS** Fill materials composed of crushed limestone and dolomitic limestone with silty clay and marl intercalations and some asphalt remains.	(1) 1	963.50	
2	P	1 - 2										**BURIED TOPSOIL MATERIALS** Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone.	(1) 2	962.50	
3	P	2 - 3										**SILTY CLAY** Brown to reddish brown, stiff to very stiff SILTY CLAY with some scattered gravel and cobbles of limestone. * From 3.0-4.0m; increase of gravel and cobbles.	(2) 4	960.50	
4	P	3 - 4													
5	P	4 - 5										**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE. * From 4.0-5.0m; highly fractured, highly weathered with silty clay fillings. * From 5.0-8.8m; increase of marly limestone.			
6	CS	5 - 6					100	25	0						
7	CS	6 - 7					100	40	20						
8	CS	7 - 8					100	30	0						
9	CS	8 - 9					100	70	60			* From 8.8m-11.7m; marlstone layer.			
10	CS	9 - 10					100	45	20						

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: RSK

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH02-Sta.0+46(
Sheet 2 of 2

Total Depth (m): 20
Ground Level (m): 964.5
Coordinates: N= 155,792.00
E= 234,178.00

Drilling Method: Rotary Percussive
Boring Started: 05-11-2016
Boring Completed: 06-11-2016
Rig: ACESDRILL-1A Driller: AN

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): 13.25

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
11	CS	10 - 11					100	15	10			**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE. * From 11.0-11.5m; saturated marl sample. * From 11.7-12.0m; increase of marl. * From 12.0-12.5m; increase of dolomitic limestone.	(16)		
12	CS	11 - 12					100	26	10						
13	CS	12 - 13					100	65	45						
14	CS	13 - 14					100	80	60						
15	CS	14 - 15					100	60	30			* From 14.0-14.4m; increase of marl.			
16	CS	15 - 16					100	50	30			* From 15.0-18.7m; increase of marl bands and marl filing the fractures.			
17	CS	16 - 17					100	70	40						
18	CS	17 - 18					100	85	75						
19	CS	18 - 19					100	85	80			* From 18.7-19.3m; marlstone layer.			
	CS	19 - 20					100	85	75			* From 19.7-20m; marlstone layer. Bottom of Borehole	20	944.50	

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF
Checked By: RSK

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-03-Sta.0+82
Sheet 1 of 2

Total Depth (m): 20
Ground Level (m): 955.7
Coordinates: N= 155,540.00
E= 234,404.00

Drilling Method: Rotary Percussive
Boring Started: 18-10-2016
Boring Completed: 19-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
1	P	0 - 1.5										**FILL MATERIALS** Fill materials composed of crushed limestone and dolomitic limestone with silty clay and marl intercalations.	(1) 1	954.70	
2	SPT	1.5 - 1.95	9	12	14	26						**BURIED TOPSOIL MATERIALS** Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone.	(1) 2	953.70	
3	P	1.95 - 3										**SILTY CLAY** Brown to reddish brown, stiff to very stiff SILTY CLAY with some scattered gravel and cobbles of limestone.			
4	SPT	3 - 3.45	12	15	18	33							(3)		
5	P	3.45 - 4.5										*From 4.0-5.0m; Increase of gravel.	5	950.70	
6	SPT	4.5 - 4.95	6	50/9cm	-	R									
7	P	4.95 - 6										**INTERBEDDED BEDROCK** Grayish creamy, fractured, moderately weak to moderately strong, DOLOMITIC LIMESTONE, interbedded with thin to thick bands of yellowish creamy, fractured, weak to moderately weak nodular to fossiliferous MARLY LIMESTONE, and thin bands of very weak to weak MARL and MARLSTONE. * From 5.0-12.0m; increase of dolomitic limestone. ** From 6.0-7.0m; Highly fractured.			
8	SPT	6 - 6.45	50/3cm	-	-	R									
9	P	6.45 - 7													
10	CS	7 - 8					75	25	16		85.9				
	CS	8 - 9					100	9	0						
	CS	9 - 10					80	35	30		12.59				

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-03-Sta.0+82
Sheet 2 of 2

Total Depth (m): 20
Ground Level (m): 955.7
Coordinates: N= 155,540.00
E= 234,404.00

Drilling Method: Rotary Percussive
Boring Started: 18-10-2016
Boring Completed: 19-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
11	CS	10 - 11					95	5	0			**INTERBEDDED BEDROCK** Grayish creamy, fractured, moderately weak to moderately strong, DOLOMITIC LIMESTONE, interbedded with thin to thick bands of yellowish creamy, fractured, weak to moderately weak nodular to fossiliferous MARLY LIMESTONE, and thin bands of very weak to weak MARL and MARLSTONE.			
	CS	11 - 12					80	0	0						
12	CS	12 - 13					90	24	16		0.202	*From 12.0-13.5m; Increase of marl and marlstone.	(15)		
13	CS	13 - 14					100	0	0			*From 13.5-16.0m; Increase of nodular marly limestone and marl filling the fractured.			
14	CS	14 - 15					100	14	0						
15	CS	15 - 16					100	53	0		0.46				
16	CS	16 - 17					95	38	0			*From 16.0-16.5m; Increase of dolomitic limestone. *From 16.5-20.0m; Increase of nodular marly limestone.			
17	CS	17 - 18					85	33	0						
18	CS	18 - 19					80	40	15						
19	CS	19 - 20					100	67	23						
												Bottom of Borehole	20	935.70	

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-04-Sta.0+87
Sheet 1 of 2

Total Depth (m): 20
Ground Level (m): 953.6
Coordinates: N= 155,538.00
E= 234,483.00

Drilling Method: Rotary Percussive
Boring Started: 10-10-2016
Boring Completed: 17-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
1	P	0 - 1.5										**FILL MATERIALS** Fill materials composed of crushed limestone and dolomitic limestone with silty clay and marl intercalations.	(1.5) 1.5	952.10	
2	SPT	1.5 - 1.95	6	10	16	26						**BURIED TOPSOIL MATERIALS** Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone.	(1.5) 3	950.60	
3	P	1.95 - 3													
4	SPT	3 - 3.45	11	13	18	31						**SILTY CLAY** Brown to reddish brown, stiff to very stiff SILTY CLAY with some scattered gravel and cobbles of limestone.	(2) 5	948.60	
5	P	3.45 - 4.5													
6	SPT	4.5 - 4.95	15	50/7cm	-	R									
7	P	4.95 - 6										**INTERBEDDED BEDROCK** Grayish creamy, fractured, moderately weak to meoderately strong, DOLOMITIC LIMESTONE, interbedded with thin to thick bands of yellowish creamy, fractured, weak to moderately weak nodular to fossiliferous MARLY LIMESTONE, and thin bands of very weak to weak MARL and MARLSTONE. *From 5.0-6.0m; Increase of highly fractured marly limestone. *From 6.0-12.0m; Increase of diagonaly to vertially jointed dolomatic limestone.			
8	SPT	6 - 6.03	50/3cm			R									
9	CS	6.03 - 7.5					60	13	0		14.49				
10	CS	7.5 - 9					83	6	0						
	CS	9 - 10					80	24	24		14.99				

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-04-Sta.0+870
Sheet 2 of 2

Total Depth (m): 20
Ground Level (m): 953.6
Coordinates: N= 155,538.00
E= 234,483.00

Drilling Method: Rotary Percussive
Boring Started: 10-10-2016
Boring Completed: 17-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
11	CS	10 - 11					65	7	0			**INTERBEDDED BEDROCK** Grayish creamy, fractured, moderately weak to meoderately strong, DOLOMITIC LIMESTONE, interbedded with thin to thick bands of yellowish creamy, fractured, weak to moderately weak nodular to fossiliferous MARLY LIMESTONE, and thin bands of very weak to weak MARL and MARLSTONE.			
12	CS	11 - 12.5					87	24	13			*From 12.0-15.0m; Increase of marly nodular limestone.	(15)		
13	CS	12.5 - 14					70	11	8		17.95 31.08				
14	CS	14 - 15					40	4	0						
15	CS	15 - 16.5					86	65	61			*From 15.0-17.0m; Increase of dolomitic limestone.			
16	CS	16.5 - 17.5					85	33	14		18.93	*From 17.0-20.0m; Increase of nodular marly limestone.			
17	CS	17.5 - 18.5					8	22	0		1.14	*From 17.7-18.5m; Increase of marlstone and marl.			
18	CS	18.5 - 20					96	54	16		14.16				
19												Bottom of Borehole	20	933.60	

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-05-Sta.0+55
Sheet 1 of 2

Total Depth (m): 20
Ground Level (m): 964.6
Coordinates: N= 155,694.00
E= 234,198.00

Drilling Method: Rotary Percussive
Boring Started: 20-10-2016
Boring Completed: 22-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
1	P	0 - 1.5										**FILL MATERIALS** Fill materials composed of crushed limestone and dolomitic limestone with silty clay and marl intercalations.	(2)		
2	SPT	1.5 - 1.95	11	15	21	36							2	962.60	
	P	1.95 - 3										**BURIED TOPSOIL MATERIALS** Buried topsoil materials composed of brown to reddish brown silty clay with some gravel and cobbles of limestone.	(1)		
3	SPT	3 - 3.45	9	12	14	26							3	961.60	
4	P	3.45 - 4.5										**SILTY CLAY** Brown to reddish brown, stiff to very stiff SILTY CLAY with some scattered gravel and cobbles of limestone.	(3)		
	SPT	4.5 - 4.95	6	10	17	27									
5	P	4.95 - 6											6	958.60	
6	CS	6 - 7					100	53	30		1.99	**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE. *From 6.0-7.3m; Increase of marlstone and marl. *From 7.3-9.0m; Increase of dolomitic limestone beds.			
7	CS	7 - 8					85	26	15						
8	CS	8 - 9					65	0	0		49.6				
9	CS	9 - 10					85	10	0		42.09	*From 9.0-11.7m; Increase of nodular marly limestone.			

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Borehole Log

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge
Project No: S16000152
Location: Amman, Jordan
Client/Owner: Steer Davies Gleave (SDG)

Borehole No. BH-05-Sta.0+55
Sheet 2 of 2

Total Depth (m): 20
Ground Level (m): 964.6
Coordinates: N= 155,694.00
E= 234,198.00

Drilling Method: Rotary Percussive
Boring Started: 20-10-2016
Boring Completed: 22-10-2016
Rig: Toho 2 Driller: Ahmad Amerah

Drilling Medium: Air Flush
Boring Dia. (mm): 101.3
Core Dia. (mm): 79.0
Casing Dia. (mm): -
Casing Depth (m): -
Water Depth (m): Nill

Scale (m)	Samples: Type and Number	Samples: Depth (m)	SPT Records: Field Records 0-15 (cm)	15-30 (cm)	30-45 (cm)	N Blows	Core Recovery: TCR (%)	SCR (%)	RQD (%)	FI	UCS (MPa)	Description of Strata	Depth (Thickness) (m)	Reduced Level (m)	Legend
11	CS	10 - 11					85	23	0			**INTERBEDDED BEDROCK** Creamy to yellowish creamy, fractured, weak to moderately weak, nodular to fossiliferous MARLY LIMESTONE, interbedded with thin layers of grayish creamy, fractured, moderately weak to moderately strong DOLOMITIC LIMESTONE, and thin bands of dark yellow, very weak to weak MARL and MARLSTONE.			
	CS	11 - 12					70	17	12		0.48	*From 11.7-12.0m; Increase of marl and marlstone. *From 12.0-14.0m; Increase of marly limestone.			
12	CS	12 - 13					100	46	11						
13	CS	13 - 14					100	75	44		3.62		(14)		
14	CS	14 - 15					90	20	0			*From 14.5-15.0m; Increase of dolomitic limestone.			
15	CS	15 - 16					100	35	10		18.93	*From 15.0-20.0m; Increase of nodular marly limestone with thin beds of marl filling the fractures.			
16	CS	16 - 17					85	20	0						
17	CS	17 - 18					100	36	0			*From 16.7-17.0m; Increase of dolomitic limestone. *From 18.0-20.0m; Increase of fossiliferous limestone.			
18	CS	18 - 19					100	60	11						
19	CS	19 - 20					100	0	0		23.63				
												Bottom of Borehole	20	944.60	

Undisturbed Sample Key:
- CS: Core Sample
- DB: Drive Barrel
- SH: Shelby Tube

Disturbed Sample Key:
- P:Percussion
- SPT:Standard Penetration Test
- AU:Auger

Abbreviations:
- Ground Water Table
- TCR: Total Core Recovery
- SCR: Solid Core Recovery
- RQD: Rock Quality Designation
- FI: Fracture Index
- UCS:Unconfined Comp. Strength

Remarks:
* The samples were described in accordance with appropriate standards (BS 5930; ASTM D2488).

Logged By: AAF

Checked By: HKR

Appendix B
Laboratory Tests Results

Summary of Laboratory Tests Results

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Sample Identification				MC (%)	SG	Density		Atterberg Limits				Particle Size Analysis				Classification		Unconfined Soil		Uniaxial Rock		Point Strength Index		Compaction		CBR	
Point No.	Depth (m)	Type of Sample	Description			BD (g/cm^3)	DD (g/cm^3)	LL (%)	PL (%)	PI (%)	Plasticity	G (%)	S (%)	M (%)	C (%)	USCS	AASHTO	UCS (kPa)	Su (kPa)	qu (MPa)	Es (MPa)	$I_{S(50)}$ (MPa)	Eq.qu (MPa)	MDD (g/cm^3)	OWC (%)	@0.1	@0.2
BH-01-Sta.0+282	2.00	Disturbed	SANDY LEAN CLAY (CL)	11.0	-	-	-	35	21	14	Intermediate	6.0	43.5	30.6	20.0	CL	A-6 (4)	-	-	-	-	-	-	-	-	-	-
BH-01-Sta.0+283	3.08	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.77	-	-	-	-	-	-	-
BH-01-Sta.0+284	4.05	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.54	-	-	-	-
BH-01-Sta.0+285	5.08	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11	2.25	-	-	-	-
BH-01-Sta.0+286	6.02	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.50	-	-	-	-	-	-	-
BH-01-Sta.0+287	7.05	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	-	-	-	-
BH-01-Sta.0+288	8.00	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.53	-	-	-	-	-	-	-
BH-01-Sta.0+289	9.00	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	777	388	-	-	-	-	-	-	-	-
BH-01-Sta.0+290	7.50	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.94	-	-	-	-
BH-01-Sta.0+291	9.00	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	96.81	-	-	-	-	-	-	-
BH02-Sta.0+465	5.50	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.52	10.66	-	-	-	-
BH02-Sta.0+466	6.00	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.11	22.52	-	-	-	-
BH02-Sta.0+468	8.50	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31.59	-	-	-	-	-	-	-
BH02-Sta.0+468	8.80	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.51	-	-	-	-
BH02-Sta.0+469	0.00	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.93	-	-	-	-
BH02-Sta.0+471	2.30	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.72	55.27	-	-	-	-

Abbreviation:

MC: Moisture Content, SG: Specific Gravity, BD: Bulk Density, DD: Dry Density, LL: Liquid Limit, PL: Plastic Limit, PI: Plasticity Index, G:Gravel, S: Sand, M: Silt, C: Clay, USCS: Unified Soil Classification System, AASHTO: American Association of State Highway and Transportation Officials, UCS: Unconfined Compressive Strength, SU: Undrained Shear Strength, qu: Compressive Strength, Es: Elastic Modulus, Is(50): Corrected Strength Index, Eq.qu: Equivalent Compressive Strength, MDD: Maximum Dry Density, OWC: Optimum Water Content, CBR: California Bearing Ratio.

Summary of Laboratory Tests Results

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Sample Identification				MC (%)	SG	Density		Atterberg Limits				Particle Size Analysis				Classification		Unconfined Soil		Uniaxial Rock		Point Strength Index		Compaction		CBR	
Point No.	Depth (m)	Type of Sample	Description			BD (g/cm^3)	DD (g/cm^3)	LL (%)	PL (%)	PI (%)	Plasticity	G (%)	S (%)	M (%)	C (%)	USCS	AASHTO	UCS (kPa)	Su (kPa)	qu (MPa)	Es (MPa)	$I_{S(50)}$ (MPa)	Eq.qu (MPa)	MDD (g/cm^3)	OWC (%)	@0.1	@0.2
		Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH02-Sta.0+460	6.7	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.61	-	-	-	-	-	-	-
BH02-Sta.0+460	8.3	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.80	-	-	-	-	-	-	-
BH02-Sta.0+460	9.3	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.09	-	-	-	-	-	-	-
BH-03-Sta.0+820	2.0	Disturbed	ELASTIC SILT (MH)	14.4	-	-	-	51	29	22	High	0.8	6.4	44.6	48.2	MH	A-7-6 (24)	-	-	-	-	-	-	-	-	-	-
BH-03-Sta.0+820	3.0	Disturbed	ELASTIC SILT with SAND (MH)	15.6	-	-	-	67	35	32	High	7.7	21.9	28.6	41.8	MH	A-7-5 (24)	-	-	-	-	-	-	-	-	-	-
BH-03-Sta.0+820	5.5	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.09	85.90	-	-	-	-
BH-03-Sta.0+820	9.7	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.59	-	-	-	-	-	-	-
BH-03-Sta.0+820	12.8	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	202	101	-	-	-	-	-	-	-	-
BH-03-Sta.0+820	16.4	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.46	-	-	-	-
BH-03-Sta.0+820	18.3	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.75	117.22	-	-	-	-
BH-04-Sta.0+870	2.0	Disturbed	GRAVELLY FAT CLAY with SAND (CH)	6.0	-	-	-	55	27	28	High	30.7	18.6	20.9	29.8	CH	A-7-6 (11)	-	-	-	-	-	-	-	-	-	-
BH-04-Sta.0+870	4.4	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70	14.49	-	-	-	-
BH-04-Sta.0+870	9.7	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.99	-	-	-	-	-	-	-
BH-04-Sta.0+870	12.7	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.95	-	-	-	-	-	-	-
BH-04-Sta.0+870	16.0	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31.08	-	-	-	-	-	-	-

Abbreviation:

MC: Moisture Content, SG: Specific Gravity, BD: Bulk Density, DD: Dry Density, LL: Liquid Limit, PL: Plastic Limit, PI: Plasticity Index, G:Gravel, S: Sand, M: Silt, C: Clay, USCS: Unified Soil Classification System, AASHTO: American Association of State Highway and Transportation Officials, UCS: Unconfined Compressive Strength, SU: Undrained Shear Strength, qu: Compressive Strength, Es: Elastic Modulus, Is(50): Corrected Strength Index, Eq.qu: Equivalent Compressive Strength, MDD: Maximum Dry Density, OWC: Optimum Water Content, CBR: California Bearing Ratio.

Summary of Laboratory Tests Results

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Sample Identification				MC (%)	SG	Density		Atterberg Limits				Particle Size Analysis				Classification		Unconfined Soil		Uniaxial Rock		Point Strength Index		Compaction		CBR	
Point No.	Depth (m)	Type of Sample	Description			BD (g/cm^3)	DD (g/cm^3)	LL (%)	PL (%)	PI (%)	Plasticity	G (%)	S (%)	M (%)	C (%)	USCS	AASHTO	UCS (kPa)	Su (kPa)	qu (MPa)	Es (MPa)	$I_{S(50)}$ (MPa)	Eq.qu (MPa)	MDD (g/cm^3)	OWC (%)	@0.1	@0.2
BH-04-Sta.0+870	16.6	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.93	-	-	-	-	-	-	-
BH-04-Sta.0+870	18.0	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	1.14	-	-	-	-
BH-04-Sta.0+870	19.0	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70	14.16	-	-	-	-
BH-05-Sta.0+550	2.0	Disturbed	CLAYEY SAND (SC)	6.7	-	-	-	46	20	26	Intermediate	9.9	42.9	31.4	15.8	SC	A-7-6 (8)	-	-	-	-	-	-	-	-	-	-
BH-05-Sta.0+550	4.0	Disturbed	FAT CLAY (CH)	12.9	-	-	-	65	30	35	High	1.3	6.0	50.8	41.9	CH	A-7-5 (38)	-	-	-	-	-	-	-	-	-	-
BH-05-Sta.0+550	6.8	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.99	-	-	-	-	-	-	-
BH-05-Sta.0+550	8.5	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.34	49.60	-	-	-	-
BH-05-Sta.0+550	9.5	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.95	42.09	-	-	-	-
BH-05-Sta.0+550	10.7	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.48	-	-	-	-
BH-05-Sta.0+550	13.2	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.62	-	-	-	-	-	-	-
BH-05-Sta.0+550	15.4	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.94	18.93	-	-	-	-
BH-05-Sta.0+550	19.5	Core Sample	Interbedded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.16	23.63	-	-	-	-

Abbreviation:

MC: Moisture Content, SG: Specific Gravity, BD: Bulk Density, DD: Dry Density, LL: Liquid Limit, PL: Plastic Limit, PI: Plasticity Index, G:Gravel, S: Sand, M: Silt, C: Clay, USCS: Unified Soil Classification System, AASHTO: American Association of State Highway and Transportation Officials, UCS: Unconfined Compressive Strength, SU: Undrained Shear Strength, qu: Compressive Strength, Es: Elastic Modulus, Is(50): Corrected Strength Index, Eq.qu: Equivalent Compressive Strength, MDD: Maximum Dry Density, OWC: Optimum Water Content, CBR: California Bearing Ratio.

Water (Moisture) Content

ASTM D2216 - 10

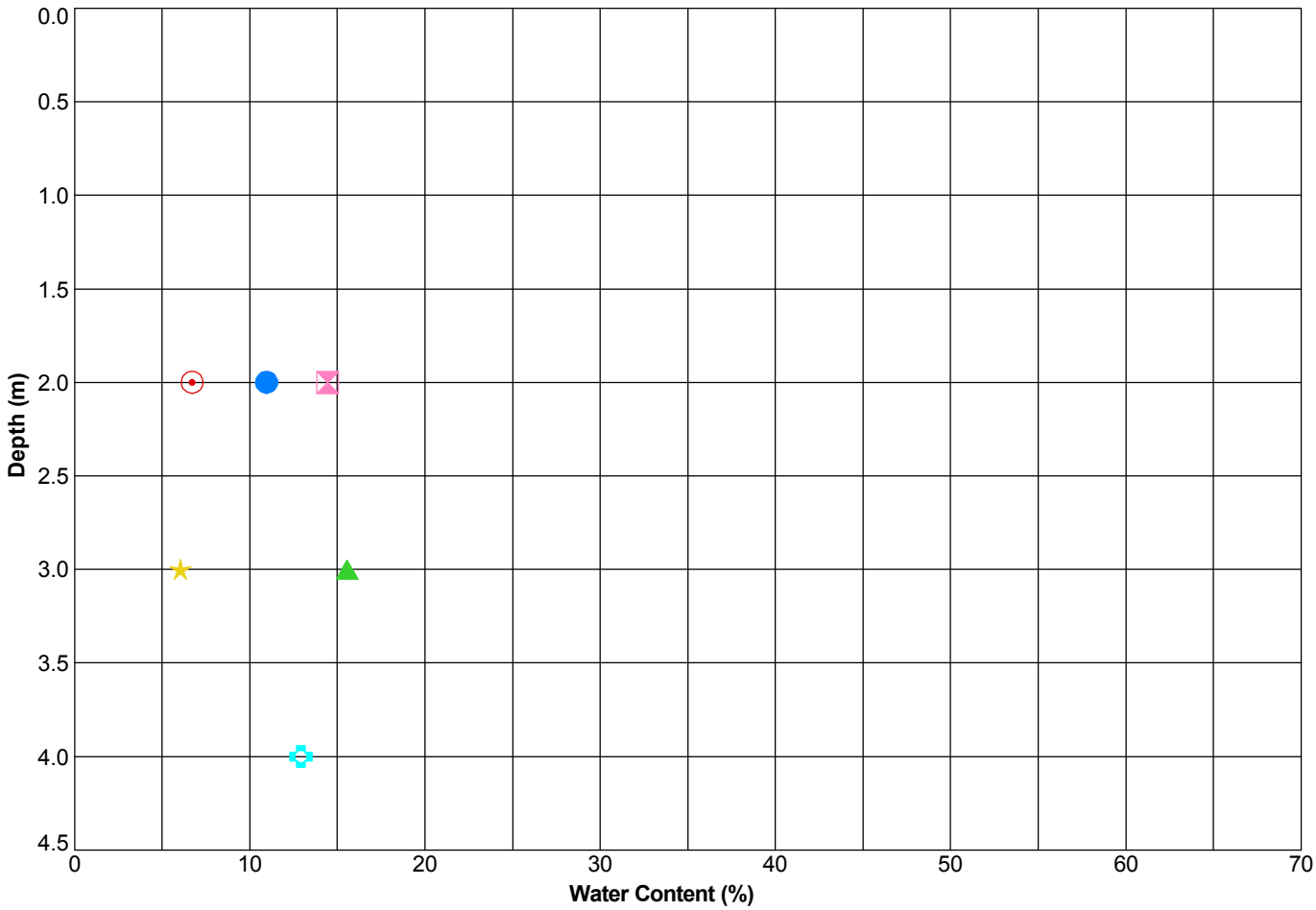
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 06-11-2016

Sym.	Point No.	Depth (m)	Type of Sample	Description	Drying Temperature (°C)	Water Content (%)
●	BH-01-Sta.0+280	2.0	Disturbed	SANDY LEAN CLAY (CL)	110 ± 5°C	11.0
⋈	BH-03-Sta.0+820	2.0	Disturbed	ELASTIC SILT (MH)	110 ± 5°C	14.4
▲	BH-03-Sta.0+820	3.0	Disturbed	ELASTIC SILT with SAND (MH)	110 ± 5°C	15.6
★	BH-04-Sta.0+870	3.0	Disturbed	GRAVELLY FAT CLAY with SAND (CH)	110 ± 5°C	6.0
⊙	BH-05-Sta.0+550	2.0	Disturbed	CLAYEY SAND (SC)	110 ± 5°C	6.7
◈	BH-05-Sta.0+550	4.0	Disturbed	FAT CLAY (CH)	110 ± 5°C	12.9



Tested By: MZ

Analyzed By: RSK

Density (Unit Weight)

ASTM D7263 - 09

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Point No.	Depth (m)	Type of Sample	Description	Test Method	Water Content (%)	Bulk Density (g/cm^3)	Dry Density (g/cm^3)
BH-01-Sta.0+284	0.5	Core Sample	Interbedded	Method A	-	1.847	-
BH-01-Sta.0+287	7.8	Core Sample	Interbedded	Method A	-	2.309	-
BH-01-Sta.0+280	0.5	Core Sample	Interbedded	Method A	-	1.988	-
BH-03-Sta.0+827	7.5	Core Sample	Interbedded	Method A	-	1.991	-
BH-03-Sta.0+825	5.4	Core Sample	Interbedded	Method A	-	2.437	-
BH-04-Sta.0+877	7.4	Core Sample	Interbedded	Method A	-	2.376	-
BH-04-Sta.0+878	8.0	Core Sample	Interbedded	Method A	-	2.228	-
BH-04-Sta.0+879	9.0	Core Sample	Interbedded	Method A	-	2.539	-
BH-05-Sta.0+558	8.5	Core Sample	Interbedded	Method A	-	2.340	-
BH-05-Sta.0+559	9.5	Core Sample	Interbedded	Method A	-	2.471	-
BH-05-Sta.0+550	1.7	Core Sample	Interbedded	Method A	-	2.290	-
BH-05-Sta.0+556	5.4	Core Sample	Interbedded	Method A	-	2.452	-

Tested By: MZ

Analyzed By: RSK

Particle Size Analysis

ASTM D422 - 63 (Reapproved 2007)

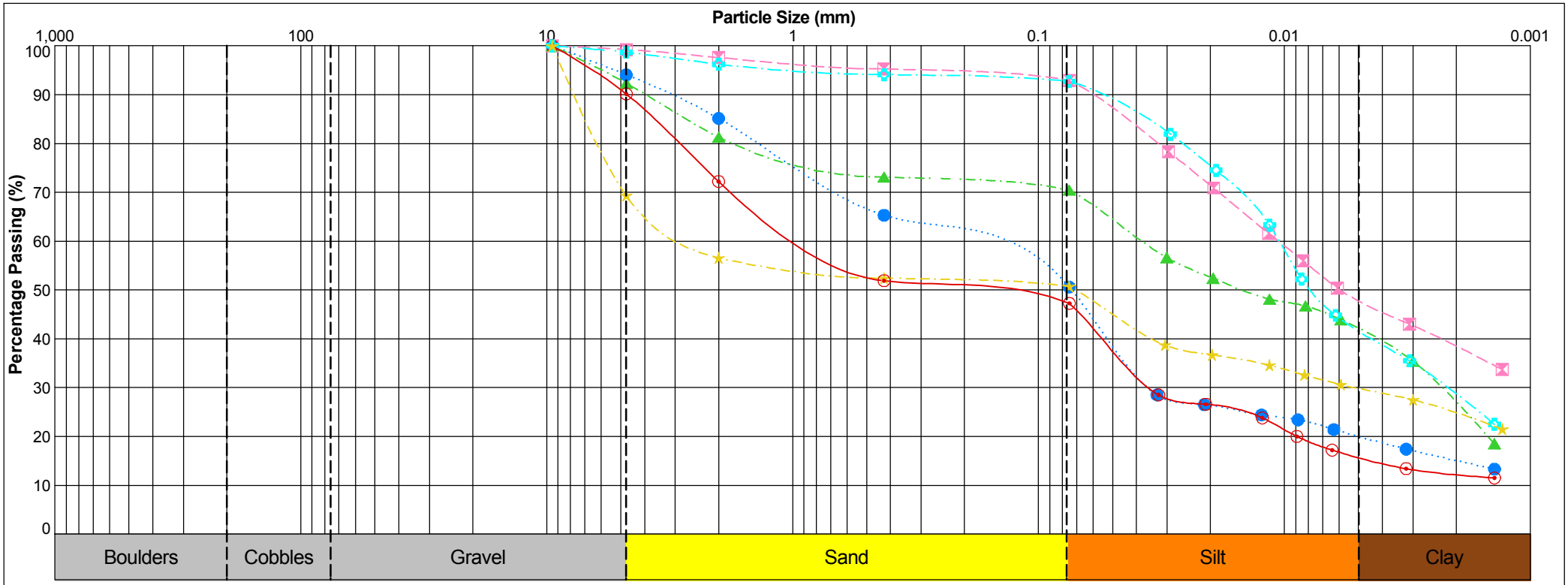
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 06-11-2016

Symbol	Point No.	Depth (m)	Description	% Gravel	% Sand	% Silt	% Clay	D_{10}(mm)	D_{30}(mm)	D_{50}(mm)	D_{60}(mm)	D_{100}(mm)	Cc	Cu
●	BH-01-Sta.0+280	2.0	SANDY LEAN CLAY (CL)	6.0	43.5	30.6 - 20.0		-	0.035	0.073	0.228	9.50	-	-
⊠	BH-03-Sta.0+820	2.0	ELASTIC SILT (MH)	0.8	6.4	44.6 - 48.2		-	-	0.006	0.011	9.50	-	-
▲	BH-03-Sta.0+820	3.0	ELASTIC SILT with SAND (MH)	7.7	21.9	28.6 - 41.8		-	0.002	0.015	0.038	9.50	-	-
★	BH-04-Sta.0+870	3.0	GRAVELLY FAT CLAY with SAND (CH)	30.7	18.6	20.9 - 29.8		-	0.005	0.071	2.527	9.50	-	-
⊙	BH-05-Sta.0+550	2.0	CLAYEY SAND (SC)	9.9	42.9	31.4 - 15.8		-	0.035	0.209	0.789	9.50	-	-
✿	BH-05-Sta.0+550	4.0	FAT CLAY (CH)	1.3	6.0	50.8 - 41.9		-	0.002	0.008	0.011	9.50	-	-



Tested By: MZ

Analyzed By: RSK

Atterberg Limits

ASTM D4318 - 10

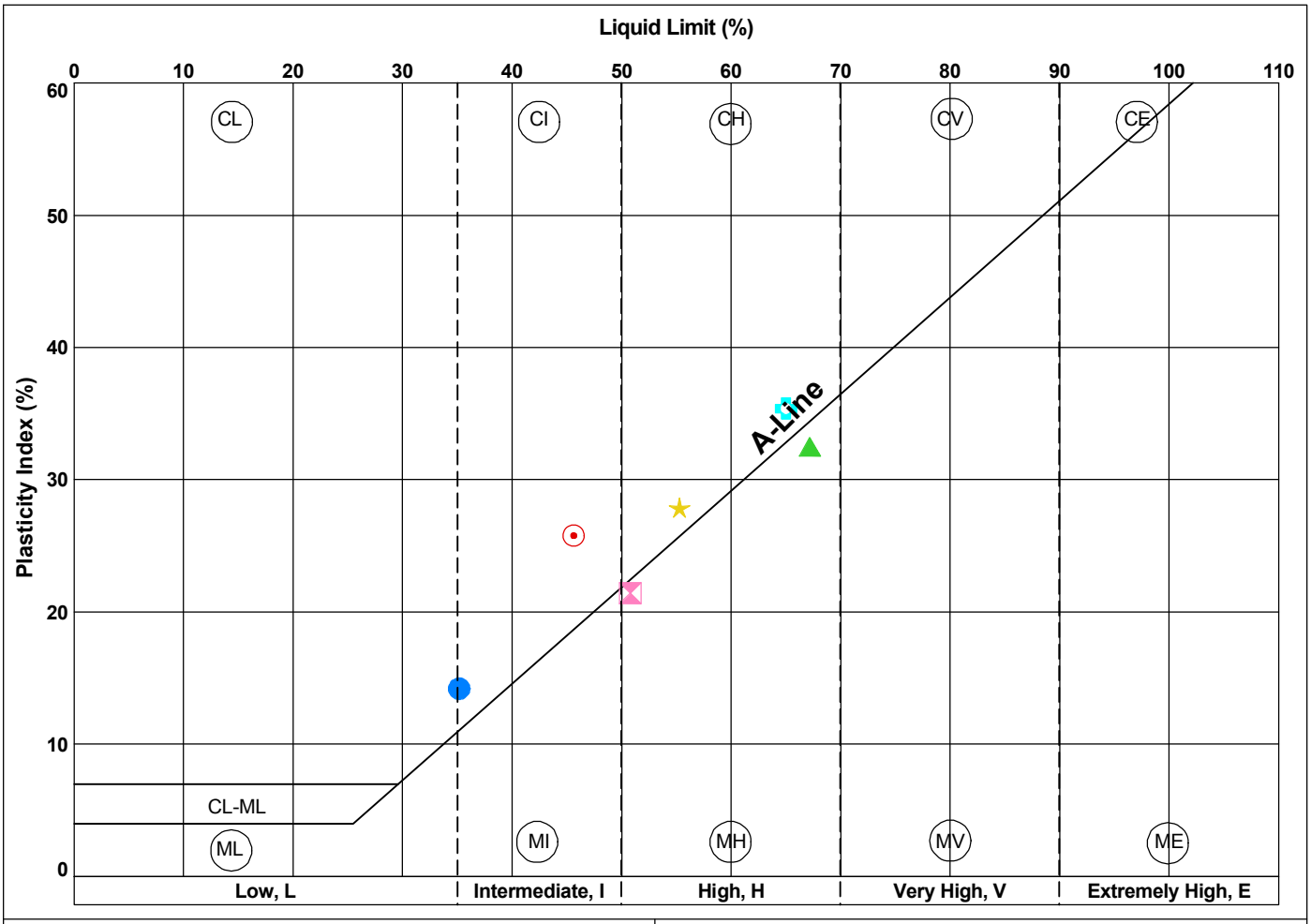
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 06-11-2016

Sym.	Point No.	Depth (m)	Description	% Passing Sieve No.40	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Plasticity
●	BH-01-Sta.0+280	2.0	SANDY LEAN CLAY (CL)	65.28	35	21	14	Intermediate
⊠	BH-03-Sta.0+820	2.0	ELASTIC SILT (MH)	95.27	51	29	22	High
▲	BH-03-Sta.0+820	3.0	ELASTIC SILT with SAND (MH)	73.13	67	35	32	High
★	BH-04-Sta.0+870	3.0	GRAVELLY FAT CLAY with SAND (CH)	52.41	55	27	28	High
⊙	BH-05-Sta.0+550	2.0	CLAYEY SAND (SC)	51.90	46	20	26	Intermediate
◈	BH-05-Sta.0+550	4.0	FAT CLAY (CH)	94.11	65	30	35	High



Tested By: MZ

Analyzed By: RSK

Unconfined Compressive Strength of Cohesive Soil

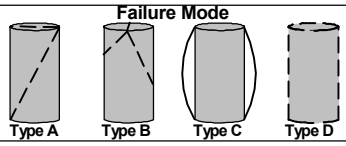
ASTM D2166M - 13

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

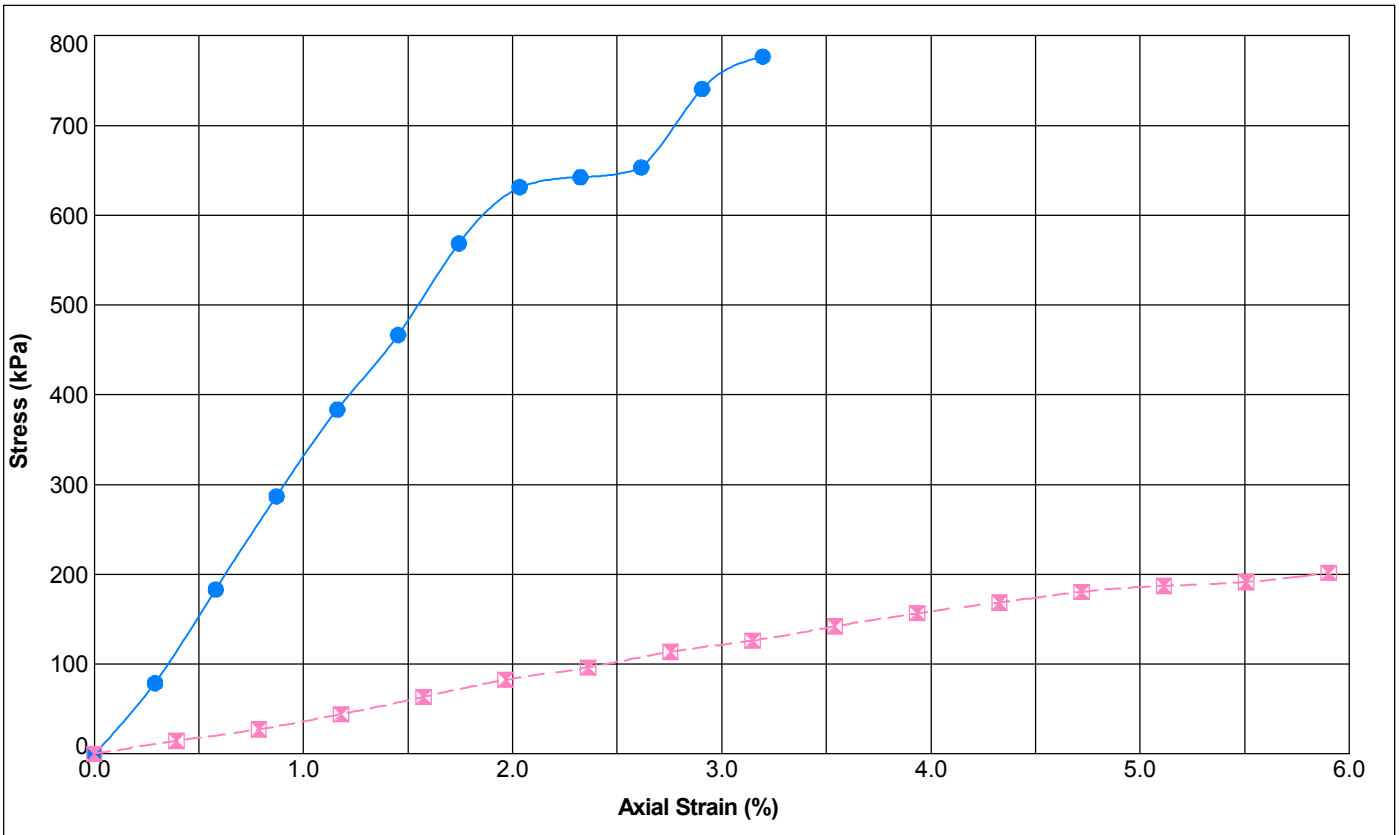
Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Symbol	●	⊠		
Point No.	BH-01-Sta.0+280	BH-03-Sta.0+820		
Depth (m)	14.0	12.8		
Type of Sample	Core Sample	Core Sample		
Description	Interbedded	Interbedded		
Height of Specimen (mm)	172.1	127.1		
Diameter of Specimen (mm)	78.1	78.1		
Height/Diameter Ratio	2.2	1.6		
As Received Water Content (%)	0.00	0.00		
Bulk Density (g/cm^3)	2.04	2.07		
Dry Density (g/cm^3)	2.04	2.07		
Degree of Saturation (%)	0.00	0.00		
Rate of Loading (mm/min)	0.01	0.01		
Strain at Failure (%)*	3.2	5.9		
Compressive Strength (kPa)*	777	202		
Undrained Shear Strength (kPa)	388	101		
Failure Mode 	-	-		

* According to ASTM 2166, the compressive strength value is the maximum stress or the compressive stress at 15% axial strain, whichever is secured first.



Tested By: MZ

Analyzed By: RSK

Uniaxial Compressive Strength of Intact Rock Core Samples

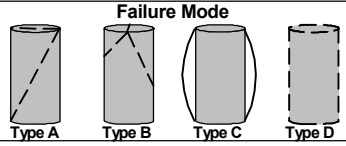
ASTM D7012 - 14 (Method C)

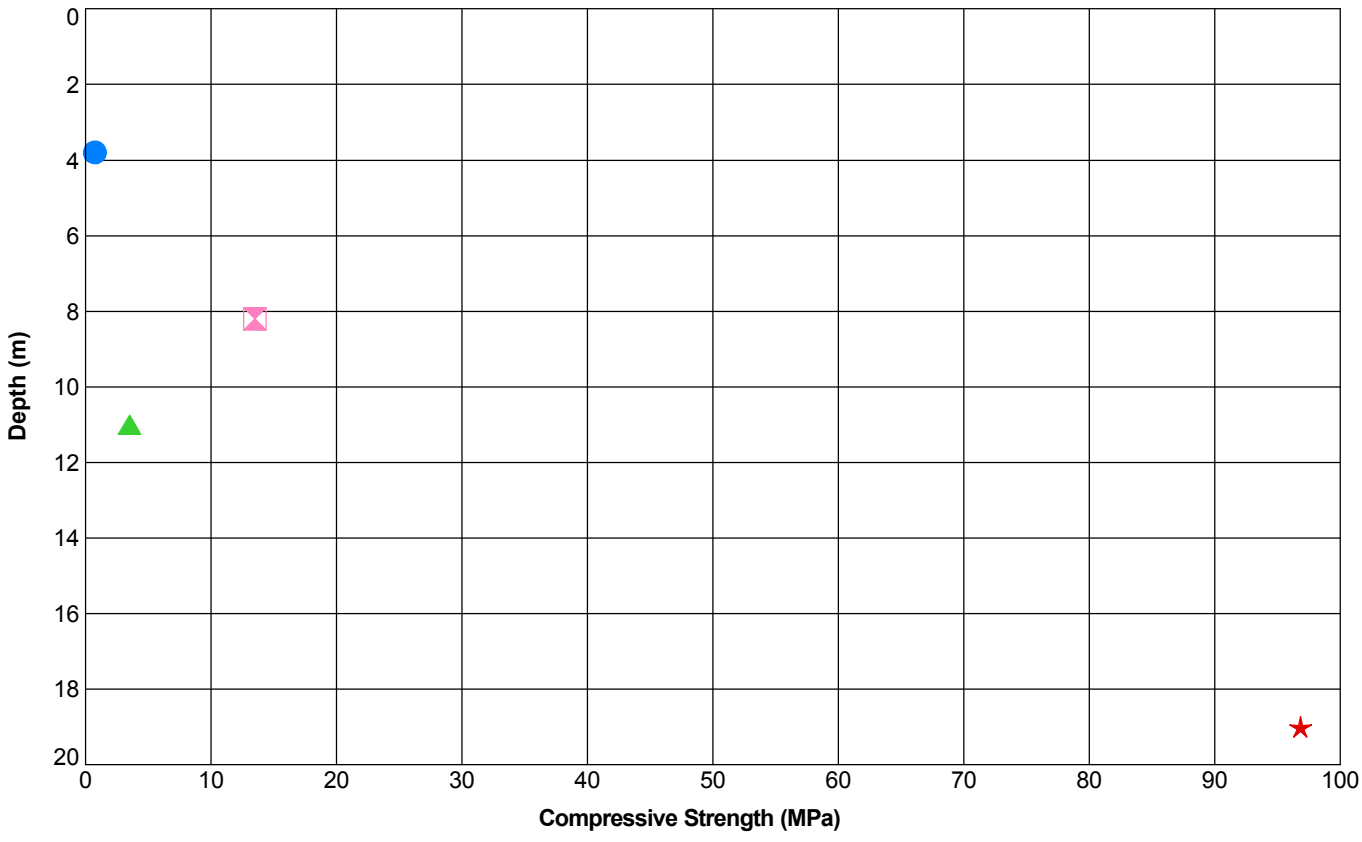
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Symbol	●	⊠	▲	★
Point No.	BH-01-Sta.0+280	BH-01-Sta.0+280	BH-01-Sta.0+280	BH-01-Sta.0+280
Depth (m)	3.8	8.2	11.0	19.0
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded
Height of Specimen (mm)	138.5	119.1	105.1	110.0
Diameter of Specimen (mm)	76.1	77.5	76.0	77.1
Height/Diameter Ratio	1.8	1.5	1.4	1.4
As Received Water Content (%)				
Bulk Density (g/cm^3)	1.92	2.34	2.27	2.60
Dry Density (g/cm^3)				
Temperature (^{o}C)	20.0	20.0	20.0	20.0
Load Direction	Axial	Axial	Axial	Axial
Rate of Loading (mm/min)	0.01	0.01	0.01	0.01
Compressive Strength (MPa)	0.77	13.50	3.53	96.81
Failure Mode 	-	-	-	-



Tested By: MZ

Analyzed By: RSK

Uniaxial Compressive Strength of Intact Rock Core Samples

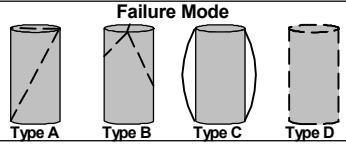
ASTM D7012 - 14 (Method C)

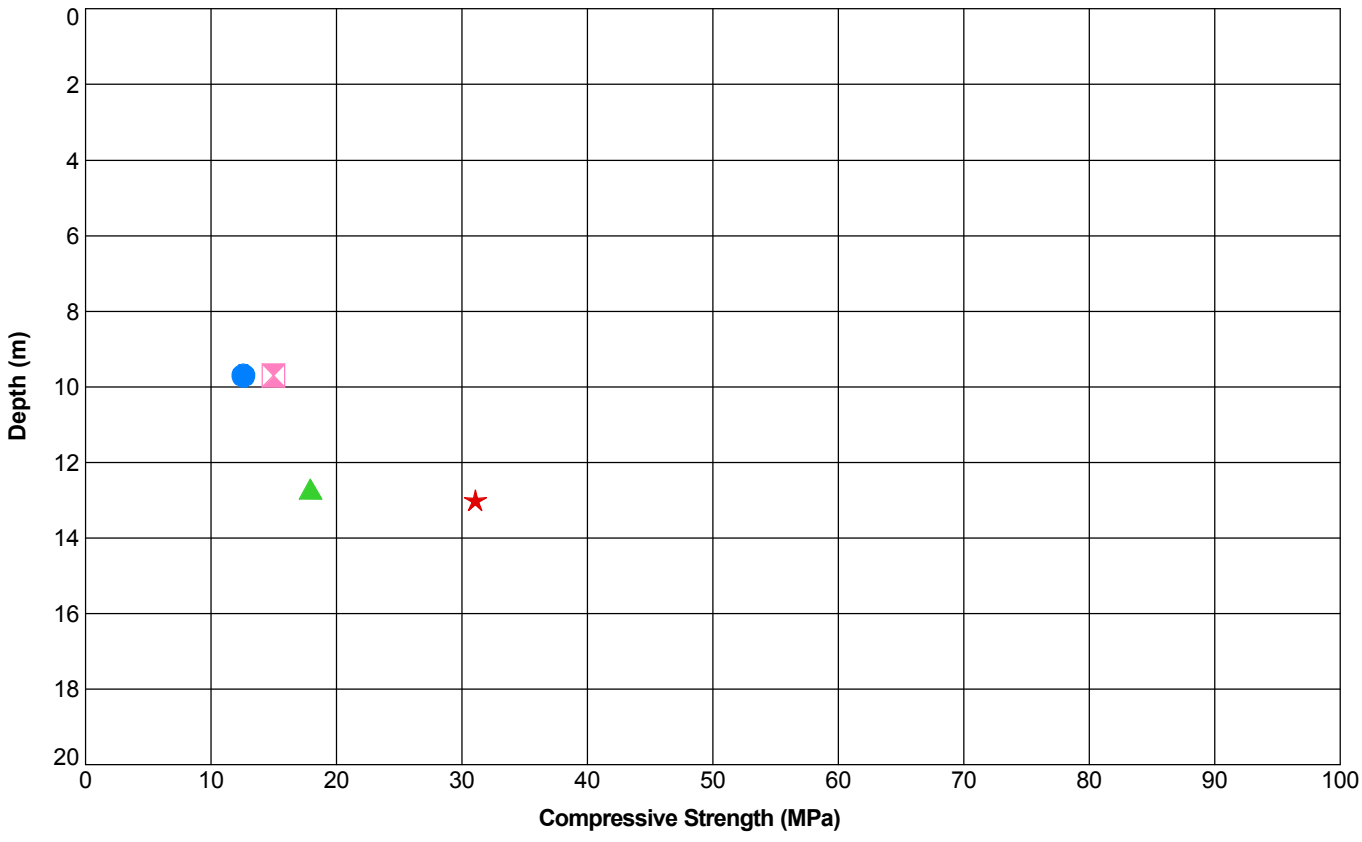
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Symbol	●	⊠	▲	★
Point No.	BH-03-Sta.0+820	BH-04-Sta.0+870	BH-04-Sta.0+870	BH-04-Sta.0+870
Depth (m)	9.7	9.7	12.7	13.0
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded
Height of Specimen (mm)	181.9	177.5	113.5	111.1
Diameter of Specimen (mm)	77.1	77.1	77.1	77.1
Height/Diameter Ratio	2.4	2.3	1.5	1.4
As Received Water Content (%)				
Bulk Density (g/cm^3)	2.41	2.50	2.21	2.39
Dry Density (g/cm^3)				
Temperature (^{o}C)	20.0	20.0	20.0	20.0
Load Direction	Axial	Axial	Axial	Axial
Rate of Loading (mm/min)	0.01	0.01	0.01	0.01
Compressive Strength (MPa)	12.59	14.99	17.95	31.08
Failure Mode 	-	-	-	-



Tested By: MZ

Analyzed By: RSK

Uniaxial Compressive Strength of Intact Rock Core Samples

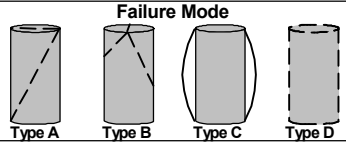
ASTM D7012 - 14 (Method C)

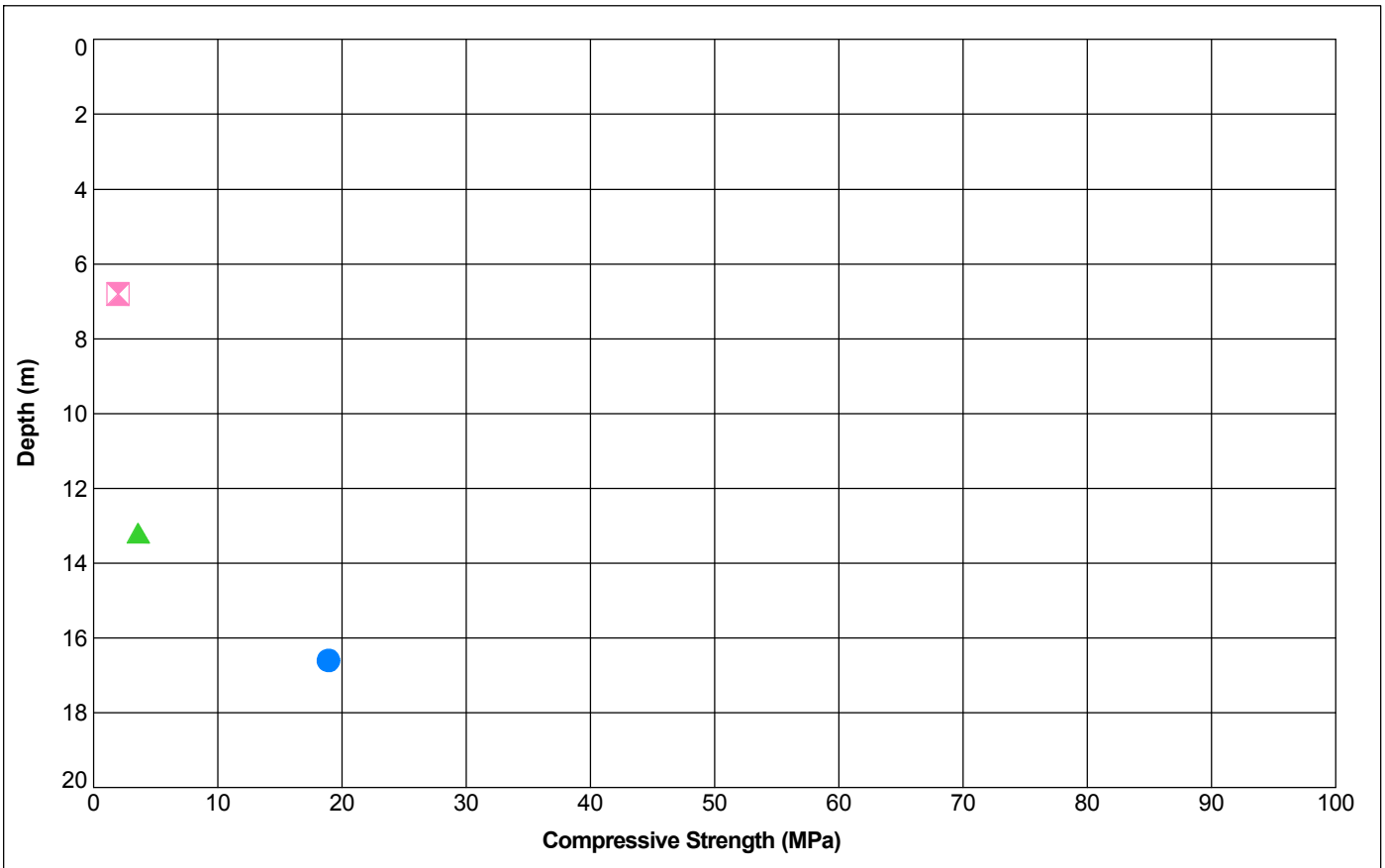
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Symbol	●	⊠	▲	
Point No.	BH-04-Sta.0+870	BH-05-Sta.0+550	BH-05-Sta.0+550	
Depth (m)	16.6	6.8	13.2	
Type of Sample	Core Sample	Core Sample	Core Sample	
Lithological Description	Interbedded	Interbedded	Interbedded	
Height of Specimen (mm)	115.0	143.1	141.9	
Diameter of Specimen (mm)	77.1	77.1	77.1	
Height/Diameter Ratio	1.5	1.9	1.8	
As Received Water Content (%)				
Bulk Density (g/cm^3)	2.11	1.67	2.28	
Dry Density (g/cm^3)				
Temperature (^{o}C)	20.0	20.0	20.0	
Load Direction	Axial	Axial	Axial	
Rate of Loading (mm/min)	0.01	0.01	0.01	
Compressive Strength (MPa)	18.93	1.99	3.62	
Failure Mode 	-	-	-	



Tested By: MZ

Analyzed By: RSK

Uniaxial Compressive Strength of Intact Rock Core Samples

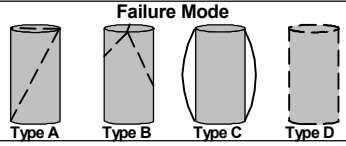
ASTM D7012 - 14 (Method C)

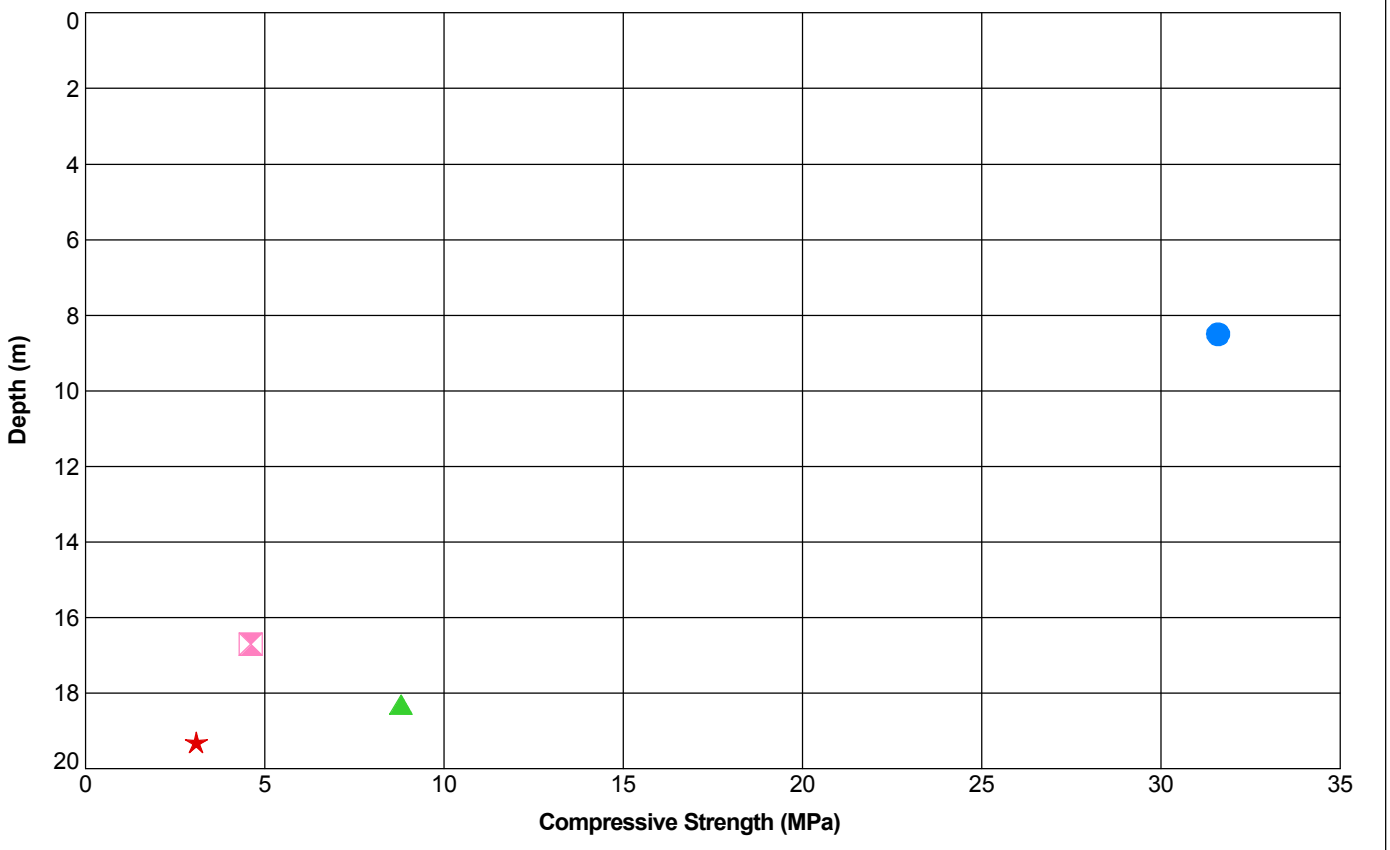
Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 13-11-2016

Symbol	●	⊠	▲	★
Point No.	BH02-Sta.0+460	BH02-Sta.0+460	BH02-Sta.0+460	BH02-Sta.0+460
Depth (m)	8.5	16.7	18.3	19.3
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded
Height of Specimen (mm)	127.6	129.4	155.1	169.0
Diameter of Specimen (mm)	78.4	78.3	78.4	78.3
Height/Diameter Ratio	1.6	1.7	2.0	2.2
As Received Water Content (%)				
Bulk Density (g/cm^3)	2.61	2.20	2.32	2.09
Dry Density (g/cm^3)				
Temperature (^{o}C)	20.0	20.0	20.0	20.0
Load Direction	Axial	Axial	Axial	Axial
Rate of Loading (mm/min)	0.01	0.01	0.01	0.01
Compressive Strength (MPa)	31.59	4.61	8.80	3.09
Failure Mode 	-	-	-	-



Tested By: AZ

Analyzed By: RSK

Point Load Strength Index

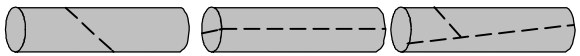
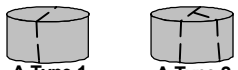
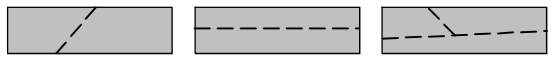
ASTM D5731 - 08

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Point No.	BH-01-Sta.0+280	BH-01-Sta.0+280	BH-01-Sta.0+280	BH-01-Sta.0+280	BH-03-Sta.0+820	BH-03-Sta.0+820	BH-03-Sta.0+820	BH-04-Sta.0+870
Depth (m)	4.5	7.8	10.5	17.5	7.5	15.4	18.3	7.4
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded
Diameter of Specimen (mm)	76.00	78.20	52.00	75.00	77.00	77.10	77.50	78.00
Height of Specimen (mm)	90.10	61.00		131.00	111.50	76.10	111.00	102.10
As Received Water Content (%)	-	-	-	-	-	-	-	-
Bulk Density (g/cm^3)	1.85	2.31	1.99	-	1.99	2.44	-	2.38
Dry Density (g/cm^3)	-	-	-	-	-	-	-	-
Type of Test	Diametrical	Diametrical	Axial	Diametrical	Diametrical	Diametrical	Diametrical	Diametrical
Initial Platen Separation, D (mm)	70.0	75.0	46.0	73.0	73.0	74.0	74.0	72.0
Final Platen Separation, D' (mm)	64.0	71.0	38.0	70.0	62.0	71.0	70.0	69.0
Failure Load, P (kN)	0.100	0.500	0.000	0.200	16.200	0.100	25.300	3.000
Uncorrected Strength Index, I_S (MPa)	0.02	0.09	0.00	0.04	3.58	0.02	4.88	0.60
Corrected Strength Index, $I_{S(50)}$ (MPa)	0.03	0.11	0.00	0.05	4.09	0.02	5.75	0.70
Strength Conversion Factor, K	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Equivalent Compressive Strength (MPa)	0.54	2.25	0.00	0.94	85.90	0.46	117.22	14.49
Type of Failure Mode	-	-	-	-	-	-	-	-
Typical Failure Mode	Diametrical Failure Mode			Axial Failure Mode		Block Failure Mode		
								
	D-Type 1	D-Type 2	D-Type 3	A-Type 1	A-Type 2	B-Type 1	B-Type 2	B-Type 3

Tested By: MZ

Analyzed By: RSK

Point Load Strength Index

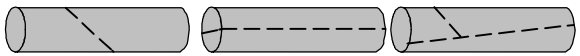
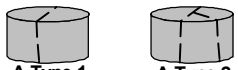
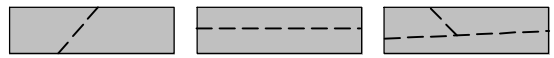
ASTM D5731 - 08

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 05-11-2016

Point No.	BH-04-Sta.0+870	BH-04-Sta.0+870	BH-05-Sta.0+550	BH-05-Sta.0+550	BH-05-Sta.0+550	BH-05-Sta.0+550	BH-05-Sta.0+550	
Depth (m)	18.0	19.0	8.5	9.5	11.7	15.4	19.5	
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample	
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded	
Diameter of Specimen (mm)	62.10	77.50	50.50	69.00	77.00	78.00	77.00	
Height of Specimen (mm)	78.00	89.90		61.00	94.50	115.20	118.10	
As Received Water Content (%)	-	-	-	-	-	-	-	
Bulk Density (g/cm^3)	2.23	2.54	2.34	2.47	2.29	2.45	-	
Dry Density (g/cm^3)	-	-	-	-	-	-	-	
Type of Test	Lump	Diametrical	Axial	Lump	Diametrical	Diametrical	Diametrical	
Initial Platen Separation, D (mm)	52.0	73.0	50.0	67.0	73.0	75.0	74.0	
Final Platen Separation, D' (mm)	48.0	72.0	45.0	53.0	68.0	71.0	70.0	
Failure Load, P (kN)	0.200	3.100	9.000	7.100	0.100	4.200	5.100	
Uncorrected Strength Index, I_S (MPa)	0.05	0.59	2.07	1.75	0.02	0.79	0.98	
Corrected Strength Index, $I_{S(50)}$ (MPa)	0.05	0.70	2.34	1.95	0.02	0.94	1.16	
Strength Conversion Factor, K	24.0	24.0	24.0	24.0	24.0	24.0	24.0	
Equivalent Compressive Strength (MPa)	1.14	14.16	49.60	42.09	0.48	18.93	23.63	
Type of Failure Mode	-	-	-	-	-	-	-	
Typical Failure Mode	Diametrical Failure Mode			Axial Failure Mode		Block Failure Mode		
	 D-Type 1	D-Type 2	D-Type 3	 A-Type 1	A-Type 2	 B-Type 1	B-Type 2	B-Type 3

Tested By: MZ

Analyzed By: RSK

Point Load Strength Index

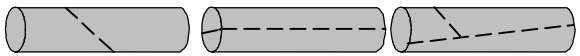
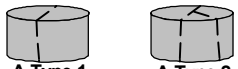
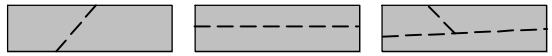
ASTM D5731 - 08

Project Name: Bus Rapid Transit (BRT)-Press Tunnel Bridge

Project No.: S16000152

Client/Owner: Steer Davies Gleave (SDG)

Test Date: 12-11-2016

Point No.	BH02-Sta.0+460	BH02-Sta.0+460	BH02-Sta.0+460	BH02-Sta.0+460	BH02-Sta.0+460			
Depth (m)	5.5	6.0	8.8	10.0	12.3			
Type of Sample	Core Sample	Core Sample	Core Sample	Core Sample	Core Sample			
Lithological Description	Interbedded	Interbedded	Interbedded	Interbedded	Interbedded			
Diameter of Specimen (mm)	78.90	76.90	78.90	78.00	78.20			
Height of Specimen (mm)	104.00	126.10	127.10	115.00	101.00			
As Received Water Content (%)	-	-	-	-	-			
Bulk Density (g/cm^3)	-	-	-	-	-			
Dry Density (g/cm^3)	-	-	-	-	-			
Type of Test	Diametrical	Diametrical	Diametrical	Diametrical	Diametrical			
Initial Platen Separation, D (mm)	74.0	74.0	73.0	74.0	74.0			
Final Platen Separation, D' (mm)	70.0	72.0	64.0	70.0	71.0			
Failure Load, P (kN)	2.300	5.000	0.100	0.200	12.100			
Uncorrected Strength Index, I_S (MPa)	0.44	0.94	0.02	0.04	2.30			
Corrected Strength Index, $I_{S(50)}$ (MPa)	0.52	1.11	0.02	0.05	2.72			
Strength Conversion Factor, K	24.0	24.0	24.0	24.0	24.0			
Equivalent Compressive Strength (MPa)	10.66	22.52	0.51	0.93	55.27			
Type of Failure Mode	-	-	-	-	-			
Typical Failure Mode	Diametrical Failure Mode			Axial Failure Mode		Block Failure Mode		
								
	D-Type 1	D-Type 2	D-Type 3	A-Type 1	A-Type 2	B-Type 1	B-Type 2	B-Type 3

Tested By: AZ

Analyzed By: RSK

Appendix C
Seismicity & Earthquake

SEISMICITY AND EARTHQUAKES

(Jordan Code for Seismic Factors-Building Code)
Soil Profile (Types and Description)

Soil Profile Description	Soil Profile Type
Strong-Very Strong Rock	S_A
Mod-Weak to Mod-Strong Rock	S_B
Very Dense Soil / Hard Soil / Soft Rock	S_C
Very Stiff Soil / Dense Soil	S_D
Firm to Stiff Soil / Loose to Medium Dense Soil	S_E
Very loose / Very Soft Soil	S_F

SEISMIC ZONE FACTOR (Z)

Zone	1	2A	2B	3
Factor (Z)	0.075	0.15	0.20	0.30

* Zone defined based on Seismic Zoning Map (P-3 of Appendix)

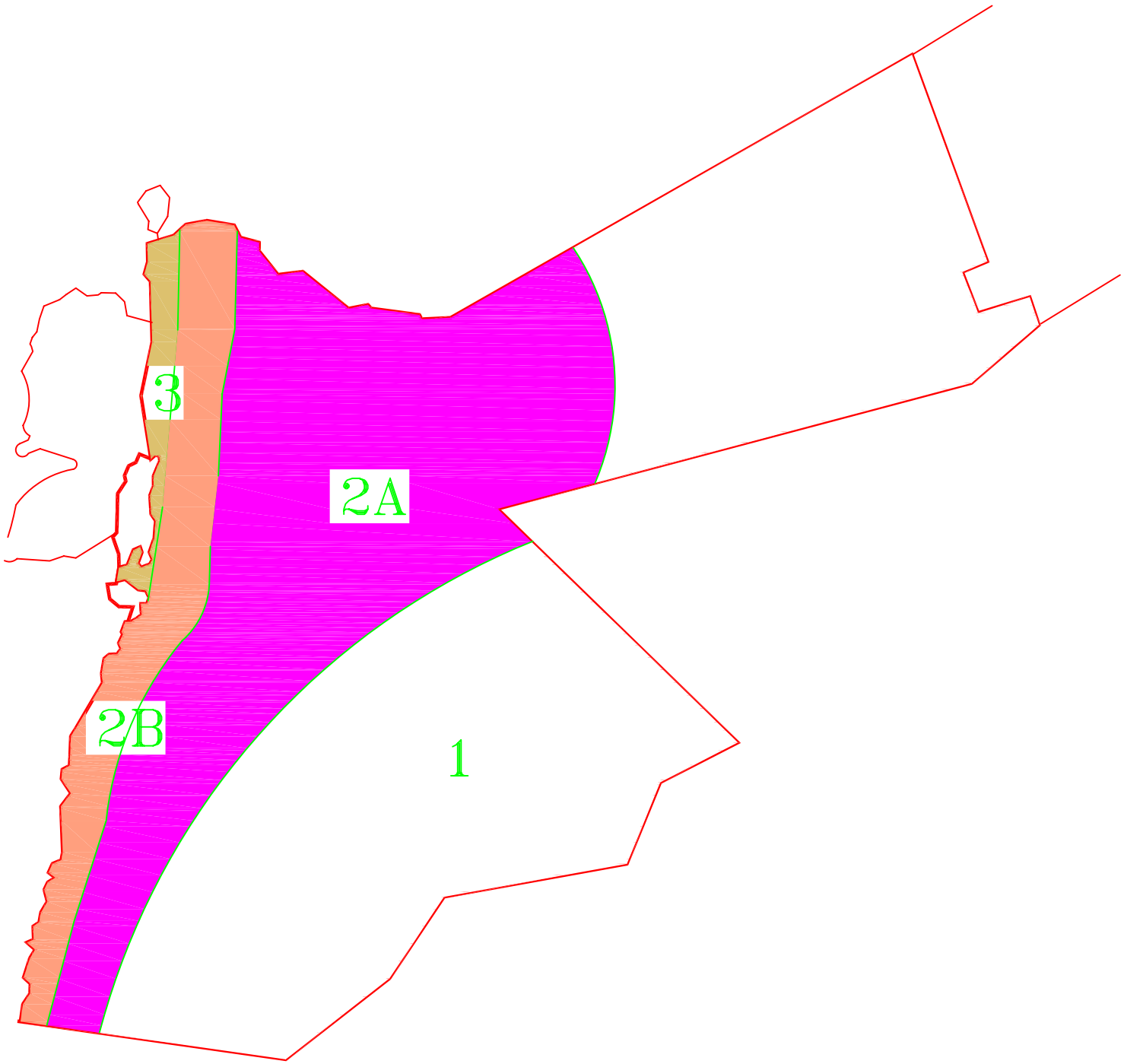
SEISMIC COEFFICIENT (Ca)

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR (z)			
	Z = 0.075	**Z = 0.15**	**Z = 0.20**	**Z = 0.3**
S_A	0.06	0.12	0.16	0.24
S_B	0.08	0.15	0.20	0.30
S_C	0.09	0.18	0.24	0.33
S_D	0.12	0.22	0.28	0.36
S_E	0.19	0.30	0.34	0.36
S_F	**Require Site Seismic Response Study**			

SEISMIC COEFFICIENT (Cv)

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR (z)			
	Z = 0.075	**Z = 0.15**	**Z = 0.20**	**Z = 0.3**
S_A	0.06	0.12	0.16	0.24
S_B	0.08	0.15	0.20	0.30
S_C	0.13	0.25	0.32	0.45
S_D	0.18	0.32	0.40	0.54
S_E	0.26	0.50	0.64	0.84
S_F	**Require Site Seismic Response Study**			

SEISMICITY AND EARTQUAKES MAP



ARAB CENTER FOR ENGINEERING STUDIES

Appendix D
Core Samples Photos

BH-01

Depth 3.0m-8.0m

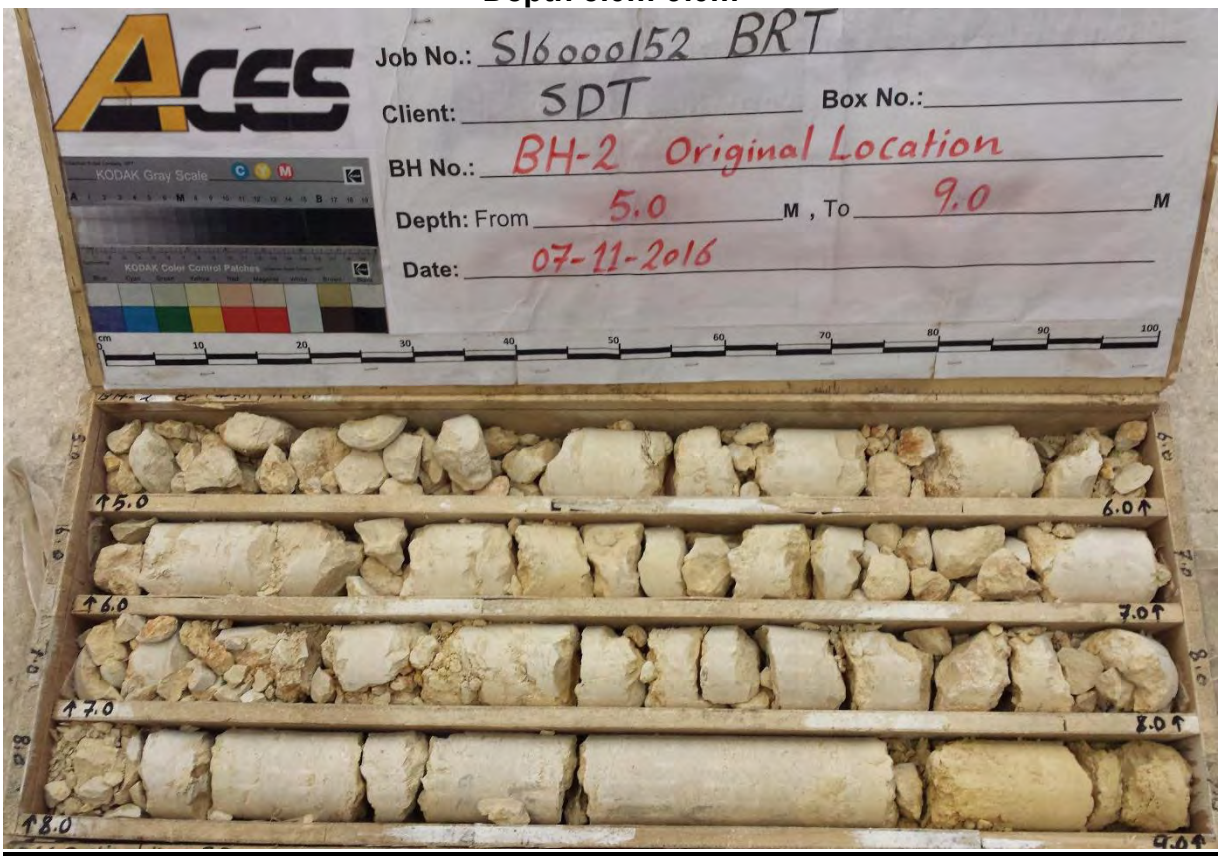
Depth 8.0m-12.0m

BH-01

Depth 16.0m-20.0m

BH-02

Depth 5.0m-9.0m



Depth 9.0m-14.0m

BH-02

Depth 14.0m-18.0m

Depth 14.0m-18.0m

BH-03

Depth 7.0m-120.0m

Depth 12.0m-17.0m

BH-03
Depth 17.0m-20.0m

BH-04

Depth 6.0m-10.0m

Depth 10.0m-14.0m

BH-04

Depth 14.0m-18.0m

BH-05
Depth 60m-9.0m

BH-05
Depth 9.0m-13.0m

BH-05

Depth 13.0m-17.0m

Depth 17.0m-120.0m