Soil Investigations Report For To Construct Multi-Storey Building in Al-Mansour Al-Rowad Street

تقرير تحريات تربة لإنشاء بناية متعددة الطوابق في المنصور شارع الرواد

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List of Symbols

b.g.l.	Below ground level
C_c	Compression index
C_s	Swelling index
C_u	Undrained cohesion
C_v	Coefficient of consolidation
DS	Disturbed Sample
S.S	Standard Penetration test Samples
N.P	Non-Plastic
CH	Clayey soil with high plasticity
CL	Clayey soil with low plasticity
q_u	Unconfined Compressive Strength
e_o	Initial void ratio
Gs	Specific Gravity
LI	Liquidity index
LL	Liquid limit
Ø	Angle of internal friction
m_v	Coefficient of volume change
N	Number of blows in SPT test
PI	Plasticity index
PL	Plastic limit
SPT	Standard Penetration Test
UCS	Unconfined compressive strength
USCS	Unified Soil Classification System
w_c %	Natural moisture content
γ_t	Total unit weight
Org. %	Organic Matters Content
TSS %	Total Soluble Salts Content
SO3 %	Sulphate Content
Gyp. %	Gypsum Content

1 INTRODUCTION

1.1 AUTHORIZATION AND SCOPE

This report presents the results of the geotechnical investigation for the proposed, Construction of **to construct multi-storey building in Al-Mansour Al-Rowad Street**, in Baghdad Governorate, Iraq.

The site investigation was carried out on **28/6/2025**. The soil exploration and investigations described in this report consist of drilling boreholes, performing the field tests, obtaining representative samples, performing laboratory testing, and describing the subsoil stratification. Furthermore, this report includes evaluating the geotechnical parameters and subsurface conditions for the recommendations of suitable foundations for the items of the project.

The Purpose of Soil Investigation is

- To explore the sub-surface conditions and to provide the general relating to the project.
- To carry out the Standard Penetration Test (SPT) and determine the natural bearing capacity of the subsoil for the purpose of design.
- To obtain disturbed and undisturbed samples for carrying out the laboratory tests to determine the physical properties of the sub soil pertaining to the site for the purpose of design.
- Identify additional requirements for design to provide durability based on the chemical test results.
- Estimate the suitable types of foundations for the proposed structure.

1.2 SITE LOCATION

The proposed site of **to construct multi-storey building in Al-Mansour Al-Rowad Street** is located in **Baghdad** government.

1.3 NUMBER OF BOREHOLES AND LOCATIONS

The number and depth of the boreholes were decided by the client to cover the site as per the type and expected loads from the proposed structures. The report involves the subsurface conditions by drilling **two boreholes to a depth of 30 m to give the total depth of boring (60 m)**. The location, ground surface elevations of boreholes and the level of initial and final groundwater are included in Table 1.

Table (1): Boreholes and depth of drilling and water table level.

B.H. No.	Date of Boring	Depth (m)	Initial W.T. level, m	Final W.T. level, m	Borehole Location	
1	28/6/2025	30	4.50	3.00	N=33°19´03.1"	E=44°21´18.0"
2	28/6/2025	30	4.50	3.00	N=33°19´04.0"	E=44°21´18.8"
Total Depth		60 m				

2 FIELD INVESTIGATIONS

2.1 BORING AND METHOD OF DRILLING

The drilling was executed using solid stem auger method in accordance with standard of the American Society for Testing Materials (ASTM-D 1452 and D-5783). **On 28 June 2025, two boreholes were drilled at the site**.

The location of borehole was specified by the geotechnical engineer and engineering staff whom represent client to cover all proposed job site area. All samples were placed in labeled nylon bags and sent to the laboratory for further examination and testing.

2.2 RECOVERY OF THE SOIL SAMPLES

2.2.1 Undisturbed Samples

Undisturbed Samples (US) were obtained at some locations for cohesive soils.

2.2.2 Disturbed Samples

Disturbed Samples (DS) were the samples obtained from the SPT tests. The secured samples by the standard split spoon samplers used in the Standard Penetration Test (SPT) were also used as disturbed samples, which were performed for each test boring at different intervals depending on the stratification of the soil.

2.3 STANDARD PENETRATION TEST (SPT)

During drilling work, the consistency of the soil was measured at several depths by the Standard Penetration Test (SPT), which was conducted according to (ASTM D 1586). The test was performed in all types of soil, especially in sandy layers. The test involves recording the number of blows of 140 Ib (63.5 kg) standards hammer with a 30-inch (760 mm) drop to drive the 2-inch (50.8 mm) diameter standard split spoon sampler into the soil 12-inch (305 mm). Initially, the sampler is driven to 150 mm into the soil to be seated and to pass through disturbed soil at the bottom of the borehole.

Terzaghi and Peck (1967) correlated the (SPT) value with the relative density and angle of internal friction of granular soil, consistency and unconfined strength of cohesive soil, these correlations can be listed in Table (2) and (3).

Table (2): Relation between N-values, Relative Density, and Angle of Internal Friction in Sand.

N-value	Relative Density	Angle of Internal Friction, Ø°
0-5	Very Loose	26-30
5-10	Loose	28-35
10-30	Medium	35-42
30-50	Dense	38-45
Over 50	Very Dense	> 45

Table (3): Relation between N-values, Consistency, and Unconfined Strength in Clay.

N-value	Consistency	Unconfined Compression Strength (q_u), kN/m^2	Undrained cohesion (c_u), kN/m^2
0-2	Very Soft	0-25	0-12
2-4	Soft	25-50	12-25
4-8	Medium	50-100	25-50
8-16	Stiff	100-200	50-100
16-30	Very Stiff	200-400	100-200
>30	Hard	>400	>200

3 LABORATORY TESTING

Laboratory tests were conducted on samples in the laboratory. A laboratory testing program was conducted to classify soil and to evaluate the physical, mechanical, and chemical properties of the sub-surface soil. The scope of the laboratory testing program is summarized in Table 4. It is worth mentioning herein that the testing program was decided and prepared according to the encountered soil at the site.

All the tests were conducted according to the current standards of the American society for testing and materials (ASTM), mentioned against each test. The results of these tests are shown in the record of tests sheet in table **Appendix (B)**.

Table 4: Summary of Laboratory Testing

Type	Test	Testing Standard
Classification Tests	Atterberg Limits (LL and PL)	ASTM D 4318
	Grain Size Analysis (Sieve & Hydrometer)	ASTM D 422
Physical Properties	Specific Gravity	ASTM D 854
	Natural Water Content	ASTM D 2216
	Unit Weight	BS1377:1990
Shear Strength	Unconfined Compression Test	ASTM D 2850
	Direct Shear Tests	ASTM D3080
Compressibility	One Dimensional Consolidation Test	ASTM D2435
Chemical Test	Sulphate Content	BS 1377: 1990 Part 3 and Earth Manual
	Organic Matter Content	
	Total Soluble Salts (TSS)	
	Gypsum Content	

4 SUBSOIL STRATIFICATION

4.1 SOIL PROFILE DESCRIPTION

The boreholes log of the soil are drawn in **Appendix (A)** ; where a study of the test boring data was coupled with the results of laboratory tests to provide a complete understanding of the subsoil conditions.

The test borings showed that the soil for **to construct multi-storey building in Al-Mansour Al-Rowad Street** are shown in **Appendix (A)** and the soil profile showed:

a- Form the surface to 1.0 m, it’s a filling material.

b- From (1.0 m – 9.0 m) the soil is classified to stiff to very stiff brown silty clay with sand.

c- From (9.0 m – 28.0 m) the soil is classified to medium to dense gray silty sand.

d- From (28.0 m – 30.0 m) the soil is classified to very dense gray silty sand.

4.2 UNDERGROUND WATER LEVEL

The groundwater regime is often not very well determined by ground investigation. Groundwater was encountered in all boreholes during drilling and it took a final level is (3.00) m.b.g.l is recorded after (24 hr) of boring. Groundwater table may be rise during the winter season or may drop if a dewatering in the vicinity is performed.

5 TESTS RESULTS AND ANALYSIS

5.1 Standard Penetration Tests

In the field, the magnitude of hammer efficiencies can vary from 30 to 90%.The standard practice now expresses the N-value to an average energy ratio of 60% Thus, correcting for field procedures and based on field observations, it appears reasonable to standardize the field penetration numbers a function of the input driving energy and its dissipation around the sampler into the surrounding soil as given below and its parameters are presented in Table 5.

$$N_{60} = N_{SPT} * C_E * C_R * C_B * C_S \quad \text{............... (1)}$$

$$C_E = E_H / 60 \quad \text{................ (2)}$$

The measured SPT N values can be corrected for effective overburden pressure, using the well known relationships proposed by Peck, Hanson & Thornburn, 1974

$$\boldsymbol{N_c = C_N * N} \quad \text{............... (3)}$$

$$\boldsymbol{C_N = 0.77 \log\left(\frac{2000}{\bar{P}_o}\right)} \quad \text{................ (4)}$$

$$(N_1)_{60} = N_{60} * C_N \quad \text{............... (5)}$$

Where:

N_{60}: Standard penetration number, corrected for field conditions for an efficiency of 60%.Cestari, 1996.

$(N_1)_{60}$: corrected of standard penetration number for the energy and overburden pressure (**Eq 5**).

N_{SPT}: is the measured SPT from the field.

C_E: Energy correction factor (**Eq 2**).

E_H: Hammer energy transfer ratio according to ASTM D-4633-8(**Table (5)**).

C_R: Rod length correction factor (**Table (5)**).

C_B: Bore-hole diameter correction factor (**Table (5)**).

C_S: Liner (sample) correction factor (**Table (5)**).

C_N: Overburden pressure correction factor (**Eq 4**).

$\overline{P}_o$: is the effective overburden pressure (measured in kPa)

The measured SPT "N" values are presented **Appendix (A)** for the boreholes.

Table (5): Correction table for field procedure of SPT N-value

SPT Hammer Efficiencies (BNBC 2015 Table 6.D.4)		
Hammer Type	**Hammer Release Mechanism**	**Efficiency, E_H**
Automatic	Trip	0.70
Donut	Hand dropped	0.60
Donut	Cathead+2 turns	0.50
Safety	Cathead+2 turns	0.55-0.60
Drop/Pin	Hand dropped	0.45
Borehole, Sampler and Rod Correction Factors (BNBC 2015 Table 6.D.5)		
Factor	**Equipment Variables**	**Correction Factor**
Borehole Dia Factor, C_B	65 – 115 mm (2.5-4.5 in)	1.00
	150 mm (6 in)	1.05
	200 mm (8 in)	1.15
Sampler Correction, C_S	Standard sampler	1.00
	Sampler without liner (not recommended)	1.20
Rod Length Correction, C_R	3 – 4 m (10-13 ft)	0.75
	4 – 6 m (13-20 ft)	0.85
	6 – 10 m (20-30 ft)	0.95
	>10 m (>30 ft)	1.00

5.2 Soil Classification and Identification

Soil may be classified according to their texture, plasticity and SPT values.

- **Textural Classification**: Having determined the basic components of the soil, namely sand, silt and clay from **Appendix (B)**. The USCS classification was used to texturally classify the soil. Cohesive soil was found **brown silty clay with sand** which classified as (**CL**) and non-cohesive soil was found **gray silty sand** which classified as (**SM**) according to USCS classification.

- **Atterberg Limits**: Results of liquid limit, plastic limit and natural moisture content. And plasticity index are shown in **Appendix (B**), According to the Unified Soil Classification System, most the non-cohesive soils are sandy soil (SM). The liquidity index, LI, has been proposed as a measure of quantifying liquefaction problem. Values of LI $\geq$ 1 are indicative of a liquefaction or quick potential. As long as most the average calculated values of LI is less than one, so the samples have no liquefaction potential.
- **Standard Penetration Test (SPT**): in general the number of blows required for 30 cm penetration is increasing with depths, but for places with high percent of filling material (gravel or construction remains) the N values where very high and exceeded 50 blows.
- **Expansive soil**: In areas likely to have expansive soil, the building official shall require soil tests to determine where such soil do exist. Soils meeting all four of the following provisions shall be considered to be expansive, except that tests to show compliance with Items 1, 2 and 3 shall not be required if the test prescribed in Item 4 is conducted:

  1- Plasticity index (PI) of 15 or greater, determined in accordance with ASTM D4318.

  2- More than 10 percent of the soil particles pass a No.200 sieve (75 um), determined in accordance with ASTM D422.

  3- More than 10 percent of the soil particles are less than 5 micrometers in size, determined in accordance with ASTM D422.

  4- Expansion index greater than 20, determined in accordance with ASTM D4829.

According to the correlations recommended by Terzaghi and Peck (1967) shown in Table (5-1), the cohesive soil for the lower layer considered as very stiff soil and for sand is dense to very dense soil:

Table (5-1) correlation of SPT to Relative density, Terzaghi and Peck (1967)

A. For granular soils

SPT N- values	Relative Density
0 - 4	Very loose
4 - 10	Loose
10 –30	Medium
30 - 50	Dense
More than 50	Very dense

B. For cohesive soils

SPT N- values	Consistency
Less than 2	Very soft
2 –4	Soft
4 – 8	Medium
8 – 15	Stiff
15 – 30	Very stiff
More than 30	hard

5.3 Chemical Tests for Soil

Soil samples were analyzed for sulphate and organic content. Soil samples were taken from the boreholes at varying depths. The results are summarized in **Appendix (B**). Examining the tests results, it can be seen that the range of:

1- The sulphate (SO3) in most of soil samples tested is range between (0.16 – 1.43 %) for soil. According to article 4.2 of (ACI 318, 2011) exposure condition is classified as Severe Exposure (S2).

2- The range of organic contents of the soil samples between (0.12 – 1.12 %). According to the International Organization for Standardization in ISO 14688-1 (2002) and ISO 14688-2 (2004), the soil is classified as very low organic content.

3- Also, due to presence of salts content in some places, protection of the foundation by three layers of bitumen martial is highly recommended.

6 Geotechnical Analysis

The proposed site is of **to construct multi-storey building in Al-Mansour Al-Rowad Street**. However, the top ground conditions at the site generally comprise of **filling material**. This section will consider the following items:

- Shallow Foundations
- Pile foundations
- Seismic Activity
- Dewatering

6.1 Shallow Foundations

6.1.1 Allowable Bearing Capacity

It is important to mention that the allowable bearing capacity of the soil depends on the proposed foundation type. Consequently, there are changeable and different values for bearing capacity when the type of proposed foundation to use is changed. However, depending on the SPT and the soil Lab results, the following bearing capacities are recommended with depth.

Regarding to the site tests (SPT) and the Lab tests, the shear strength parameter is adopting to evaluate the allowable bearing capacity (BC) for shallow foundations using Terzaghi formula and the modification suggested by Meyerhof (1963) with factor of safety equals (2.5). Terzaghi equations and the modification suggested by Meyerhof (1963) for the ultimate Bearing Capacity (BC) for shallow foundations

$q_{ult} = CN_c + qN_q + 0.5B\gamma N_\gamma$ continuous footing ………….. (6)

$q_{ult} = 1.3CN_c + qN_q + 0.4B\gamma N_\gamma$ square footing …………. (7)

$q_{ult} = 1.3CN_c + qN_q + 0.3B\gamma N_\gamma$ round footing ………….. (8)

$q_{ult} = CN_cS_cd_c + qN_qS_qd_q + 0.5B\gamma N_\gamma S_\gamma d_\gamma$ Meyerhof ……..……. (9)

Where N_c, N_q, N_γ Bearing capacity factors

S_C, S_q, S_γ Shape factors

d_c, d_q, d_γ Depth factors

$S_C = 1 + N_q b / N_c L$ ………… (10)

$S_q = 1 + \frac{B}{L} \tan\emptyset$ ………… (11)

$S_\gamma = 1 - 0.4\frac{B}{L}$ ………… (12)

$d_c = 1 + 0.4\frac{D_f}{B}$ ………… (13)

$d_q = 1 + \tan\emptyset(1 - \sin\emptyset)^2 \frac{D}{B}$ ………… (14)

6.2 PILE FOUNDATIONS

The use of precast, Franki or bored pile is considered appropriate for supporting the relatively heavier structural loadings; when the applied pressure exceeds that allowable bearing capacity of the supporting soil. The ultimate pile capacity (Q_u) consists of side friction of adhesion (Q_s) and end bearing (Q_b). It is worth to mention herein that the side friction in cohesive soil is greater than end bearing. Moreover pile capacity would be increase when pile installed or resting on sandy soil. Also, pile capacity can be found using the result of SPT test. From the above explanation pile capacity is calculated as follows:

$Q_{alt} = Q_S + Q_b$ …………. (15)

$Q_{all} = \frac{Q_{alt}}{FS}$ ………….. (16)

Where:

Q_{all}: Working pile capacity or allowable working load of the pile.
FS: Factor of safety (taken as 2.5).

When precast piles are used, the group action should be considered in the design of pile group. The estimated working loads for different pile length of the common used precast concrete driven piles with square shape of (0.285*0.285) as listed in Table 6.2 below. It may be suitable to state herein that the densest and the highest stiffness of the soil layer can be occupied at a depth more or equal to (20 m.b.g.l.) This depth would give the great end bearing for pile capacity calculation. It is necessary to take into considerations that if pile foundation is considered in the design of footings, pile loading test should be done on site to determine the actual allowable working load and allowable settlement.

Table (6.2): Estimated Pile Capacity

Pile Type and Dimensions	Pile length (m)	Working load (Ton)
Precast Concrete Pile (0.285 x 0.285) m	12	40
Bored Pile (0.6 m)	10	100
	15	140
	20	170
	25	200
	30	240
Bored Pile (0.8 m)	10	120
	15	180
	20	220
	25	270
	30	310
Bored Pile (1.0 m)	10	160
	15	240
	20	300
	25	340
	30	400
Franki Pile (0.52 m)	10 - 12	100

6.3 Seismic Activity

The seismic classification for the site can be evaluated based either on the weighted average of the shear wave velocity (Vs), undrained shear strength (cu), or standard penetration resistance (SPT). According to the available information, seismic classification for the site is evaluated based on SPT values. According to the ASCE, 2017 code, the project is located within site **class D** as shown in Table 6.3.

In this report we recommend using ASCE, 2017, the soil type is listed in Table (6.3) and the relationship between seismic zone factors with seismic intensity listed in Table (6.4).

Table 6.3: Soil classification for seismic analysis (ASCE7, 2017)

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50 blows/ft	>2,000 lb/ft^2
D. Stiff soil	600 to 1,200 ft/s	15 to 50 blows/ft	1,000 to 2,000 lb/ft^2
E. Soft clay soil	<600 ft/s	<15 blows/ft	<1,000 lb/ft^2
	Any profile with more than 10 ft of soil that has the following characteristics: — Plasticity index $PI > 20$, — Moisture content $w \geq 40\%$, — Undrained shear strength $\bar{s}_u < 500$ lb/ft^2		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

Note: For SI: 1 ft=0.3048 m; 1 ft/s=0.3048 m/s; 1 lb/ft^2=0.0479 kN/m^2.

Table 6.4: Seismic zone factor with seismic intensity UBC code.

Zone	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

6.4 Dewatering

The site investigation data shows that final groundwater is found (3.00) m.b.g.l. It may also be affected by seasonal variations. For the safe excavation below this level, de-watering may be required. Groundwater control measures could take the form of local de-watering by the construction of perimeter drains and sump pumping.

6.5 Design Parameters

The soil parameters summarized in Table 6.5 are recommended for the design of foundations.

Table 6.5 Recommended Values of the Design Parameters

Date of Boring		**28/6/2025**
Allowable bearing capacity for shallow footing at (1.0 - 1.5) m , kPa		**70 – 75**
Allowable bearing capacity for shallow footing at (2.0 – 2.5) m , kPa		**85 - 95**
Allowable bearing capacity for shallow footing at (3.0 – 3.5) m , kPa		**105 - 115**
Subgrade Modulus, kN/m^3	**Depth: 1.0 -1.5 m**	**7000 – 7500**
	Depth: 2.0 -2.5 m	**8500 – 9500**
	Depth: 3.0 -3.5 m	**10500 - 11500**
The minimum depth of footings below the undisturbed ground surface, IBC 2003		**305 mm**
Initial water table Level , m		**4.50**
Final water table Level is recorded after 24 hr after boring , m		**3.00**
Factor of safety for bearing capacity		**2.5**
Density of clayey soil kN/m^3		**18.93 – 19.52**
Density of sandy soil kN/m^3		**17.74 – 18.58**
Cohesion, (C, kPa)	**Depth: 2.0 m**	**60.1**
	Depth: 4.5 m	**69.5**
Friction angle (Ø°)	**Depth: 12.0 m**	**32.0**
	Depth: 14.0 m	**33.8**
	Depth: 20.0 m	**35.8**
	Depth: 22.0 m	**36.7**
	Depth: 28.0 m	**40.2**
	Depth: 30.0 m	**42.4**
Specific Gravity, Gs		**2.66 – 2.73**
Chemical tests		**Appendix (B)**
Pile capacity		**Table (6.2) page 15**
The zone for seismic		**3**
Soil type for seismic analysis (according to ASCE7 2017)		**D**
Shear velocity m/sec		**180 -350**
Zone factor, Z		**0.30**

7 Recommendations

Geotechnical investigations have been carried out for of **to construct multi-storey building in Al-Mansour Al-Rowad Street**. A total drilling of two boreholes were drilled at the site. Laboratory tests have been undertaken to determine grading, shear strength parameters, chemical tests for soils (sulphate, organic content, total soluble salts and gypsum). From the field observation and test results the following conclusions and recommendations are gathered:

7.1 Soil Profile and Classification

In general the test borings showed:

a- Form the surface to 1.0 m, it's a filling material.

b- From (1.0 m – 9.0 m) the soil is classified to stiff to very stiff brown silty clay with sand.

c- From (9.0 m – 28.0 m) the soil is classified to medium to dense gray silty sand.

d- From (28.0 m – 30.0 m) the soil is classified to very dense gray silty sand.

7.2 Water Table Location and Dewatering and Excavation

The final Groundwater levels have been recorded after (24 hr.) of the boring depth is (3.00) m. Dewatering is required in the case of foundations under the groundwater level. The water table should be pumped out using adequate trenches and sumps, filter on the intake should also be used to prevent pumping the fine particles out of the soil. If the site has nearby buildings or any excavation shall be carried out in such not to damage the base materials due to uncontrolled hydraulic gradient may be need to use sheet pile, retaining wall or other retaining technique to protect nearby structure and it is up to the engineer designed to assess this situation and indicate the need.

7.3 Preparing of the Site

The site shall be cleaned, leveled and all concrete casting, subbase materials, debris, bricks, organic matter, salts, unsuitable soils and deleterious materials shall be removed and disposed out of the site.

7.4 Allowable Bearing Capacity

Depending on the bearing pressure, shallow foundations (raft foundation) with a suitable rigidity could be considered appropriate for the light structures with loads less than bearing capacity of soil. The allowable bearing capacity is (70 - 75) kPa at a depth of (1.0 – 1.5) m below natural ground level. More details of allowable bearing capacity with depth can be seen Table (6.5) page (17).

7.5 Preparation and Replacement under Foundation

1. The preparation of shallow foundation requires to remove of undesirable material below the footing up to (100 cm) and replaced with 2 –layer of bolder (each layer is 25.0 cm) and 2-layer of well compacted subbase (each layer is 25.0 cm). The subbase (Type B) must be well compacted according to the standard specification to 95% relative density. The prepration of natural soil prior to placement of compacted filling materials (bolders and subbase layers) should be compacted to the standard specification to 90% relative density.

2. It is recommended to fill the zone around the foundation with a well compactable materials of low permeability such as a clean soil. The clean soil should satisfied the standard specification to 90% relative density and the value of CBR not less than 4 %.

7.6 Chemical Tests and Precautions

From a review of the chemical test results and according to the requirement for concrete exposed to chemical attack, the following precautions and recommendations are highlighted:

1- The sulphate (SO3) in most of soil samples tested is range between (0.16 – 1.43) % for soil. According to article 4.2 of (ACI 318, 2011) exposure condition is classified as Severe Exposure (S2).

2- The range of organic contents of the soil samples between (0.12 – 1.12)%. According to the International Organization for Standardization in ISO 14688-1 (2002) and ISO 14688-2 (2004), the soil is classified as very low organic content.

3- Also, due to presence of salts content in some places, protection of the foundation by three layers of bitumen martial is highly recommended.

7.7 Type of Cement

1- Cement type V sulphate resisting should be used in all concrete works that will be contacted with soil.

2- Minimum cement content and maximum free water (W/C) ratio should be within the requirement of specifications.

3- Vibrators must be used in order to densify the fresh concrete.

4- All concrete work in contact with soil should be coated with bituminous material, with the use of sulphate resisting Portland cement.

7.8 Pile Size and Capacity

1. For bearing pressure of structures greater than that of soil, pile foundation can be used to bear the extra pressure or to reduce the expected settlement. Capacity of piles, Pile length and types was listed in Table (6.2) page (15).

2. If the pile used, pile loading test must be checked for the experimental pile by test the pile near the site to determine the ultimate and allowable pile capacity according to the ASTM D1143.

7.9 Soil Type for Seismic Analysis

The soil profile type can be classification according to the ASCE 2017 depend on the SPT value and undrained shear strength (Cu) according to available information, seismic classification for the site is evaluated based on SPT values. According to the ASCE 2017 code the site is located within site **class D** as shown in Table 7.1.

Table 7.1 Soil classification for Seismic Analysis ASCE 2017.

Soil Profile Type	Soil Profile Description	Wave Shear Velocity m/sec	Undrained Shear Strength Cu, KPa	N_{avg}
D	Stiff	180-360	50-100	15-50

Seismic Coefficients Fa and Fv for soil can be listed Table 7.2.

Table 7.2a: Seismic Coefficients Fa, site coefficient for the short period response.

Site Class	Mapped spectral response acceleration at short periods				
	Ss≤0.25g	Ss=0.5g	Ss=0.75g	Ss=1.0g	Ss≥1.25g
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	-				

Table 7.2b: Seismic Coefficients Fv, site coefficient for the long period response.

Site Class	Mapped spectral response acceleration at short periods				
	Ss≤0.1g	Ss=0.2g	Ss=0.3g	Ss=0.4g	Ss≥0.5g
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	-				

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APPENDIX A

BOREHOLE LOGS

BORE HOLE LOG

Description Of Strata	Legend	W.T.	$N_{measured}$	$(N_1)_{60}$	Depth, m
Filling Material					1.0
Stiff to very stiff brown silty clay with sand			16	12	1.5
		3.00 m	19	14	3.0
			24	18	4.5
			25	19	6.0
			28	22	7.5
Medium to dense gray silty sand			38	30	9.0
			39	28	12.5
			44	31	14.0
			49	33	16.0
			52	34	18.0
			56	35	20.0
			64	39	22.0
			69	40	24.0
			85	48	26.0
Very dense gray silty sand			94	52	28.0
			100	53	30.0

Boring contractor

Project Name: t**o construct multi-storey building in Al-Mansour Al-Rowad Street**.

Bore hole No.:1

Date 28/6/2025

Borehole location: (GPS):
N=33°19´03.1" E=44°21´18.0""
bore hole elevation: 30 m

Ground Surface elevation , m : NGL
Casing: No casing
D(mm):
L(mm):
Hammer:

S.P.T.
(OD) (mm) (50)
weight of hammer (Kg) (63.5)
Drop of hammer (mm) (760)

Initial Water was encountered at depth 4.50 m from the NGL.
Finial Water was encountered at depth 3.00 m from the NGL.

Fig. (1.1a) Borehole Log for BH.No.1.

BORE HOLE LOG

Description Of Strata	Legend	W.T.	$N_{measured}$	$(N_1)_{60}$	Depth, m
Filling Material					1.0
Stiff brown silty clay with sand			11	8	1.5
		3.00 m	16	12	3.0
					4.5
			11	8	6.0
			17	13	7.5
			20	16	9.0
Medium to dense gray silty sand			23	17	12.0
			30	21	14.0
			32	22	16.0
			38	25	18.0
			43	27	20.0
			50	30	22.0
			53	31	24.0
			68	38	26.0
Very dense gray silty sand			91	50	28.0
			94	50	30.0

Boring contractor

Project Name: t**o construct multi-storey building in Al-Mansour Al-Rowad Street**.

Bore hole No.:2

Date 28/6/2025

Borehole location: (GPS):
N=33°19´04.0" E=44°21´18.8""
bore hole elevation: 30 m

Ground Surface elevation , m : NGL
Casing: No casing
D(mm):
L(mm):
Hammer:

S.P.T.
(OD) (mm) (50)
weight of hammer (Kg) (63.5)
Drop of hammer (mm) (760)

Initial Water was encountered at depth 4.50 m from the NGL.
Finial Water was encountered at depth 3.00 m from the NGL.

Fig. (1.1b) Borehole Log for BH.No.2.

APPENDIX B

LABORATORY TEST RESULTS

Results of Physical, Mechanical and Chemical Tests.

Borehole No. : 1

Total Depth: 30.0 m

Project Name: to construct multi-storey building in Al-Mansour Al-Rowad Street.

Sample			Index properties				Moisture content	Total Density	Shear Test				Gs	Grain size analysis			Consolidation tests			Chemicals tests			
									Unconfined Comp. strength		Direct shear												
No.	Depth	Type	L.L	P.L	P.I	USCS			q_u	C	C	Ø°		Grav.	Sand	Passing No.200	e	Cc	Cr	SO_3	T.S.S	Gyp.	Org.
	(m)		%	%	%		%	kN/m³	kPa	kPa	kP			%	%	%				%	%	%	%
1	1.5	SS	44	24	20	CL	19.78							0.0	1.8	98.2				1.20	3.77	2.58	0.95
2	2.0	US	42	22	20	CL		18.93	120.2	60.1			2.73	0.0	5.6	94.4	0.73	0.223	0.021				
3	3.0	SS	41	22	19	CL	23.65							0.0	5.0	95.0							
4	4.5	SS	39	21	18	CL								0.0	7.6	92.4							
5	6.0	SS	37	19	18	CL	21.05							0.0	6.9	93.1				0.73	2.29	1.57	0.65
6	7.5	SS	36	19	17	CL		19.50						0.0	9.4	90.6							
7	9.0	SS				SM	19.85							0.0	75.6	24.4							
8	12.5	SS				SM								0.0	74.8	25.2							
9	14.0	SS				SM	17.66				2.8	33.8		0.0	76.9	23.1							
10	16.0	SS				SM		17.74						0.0	79.5	20.5				0.40	1.26	0.86	0.33
11	18.0	SS				SM	18.14						2.68	0.0	77.1	22.9							
12	20.0	SS		NP		SM								0.0	79.7	20.3							
13	22.0	SS				SM	19.05				1.3	36.7		0.0	80.0	20.0							
14	24.0	SS				SM		18.33						0.0	80.1	19.9				0.25	0.79	0.54	0.21
15	26.0	SS				SM	17.77							0.0	78.4	21.6							
16	28.0	SS				SM							2.66	0.0	79.9	20.1							
17	30.0	SS				SM	15.41				0.4	42.4		0.0	81.3	18.7				0.16	0.50	0.34	0.12

SS: Standard Penetration Test Sample US: Undisturbed Sample NP: Non Plastic

Project Name: to construct multi-storey building in Al-Mansour Al-Rowad Street.

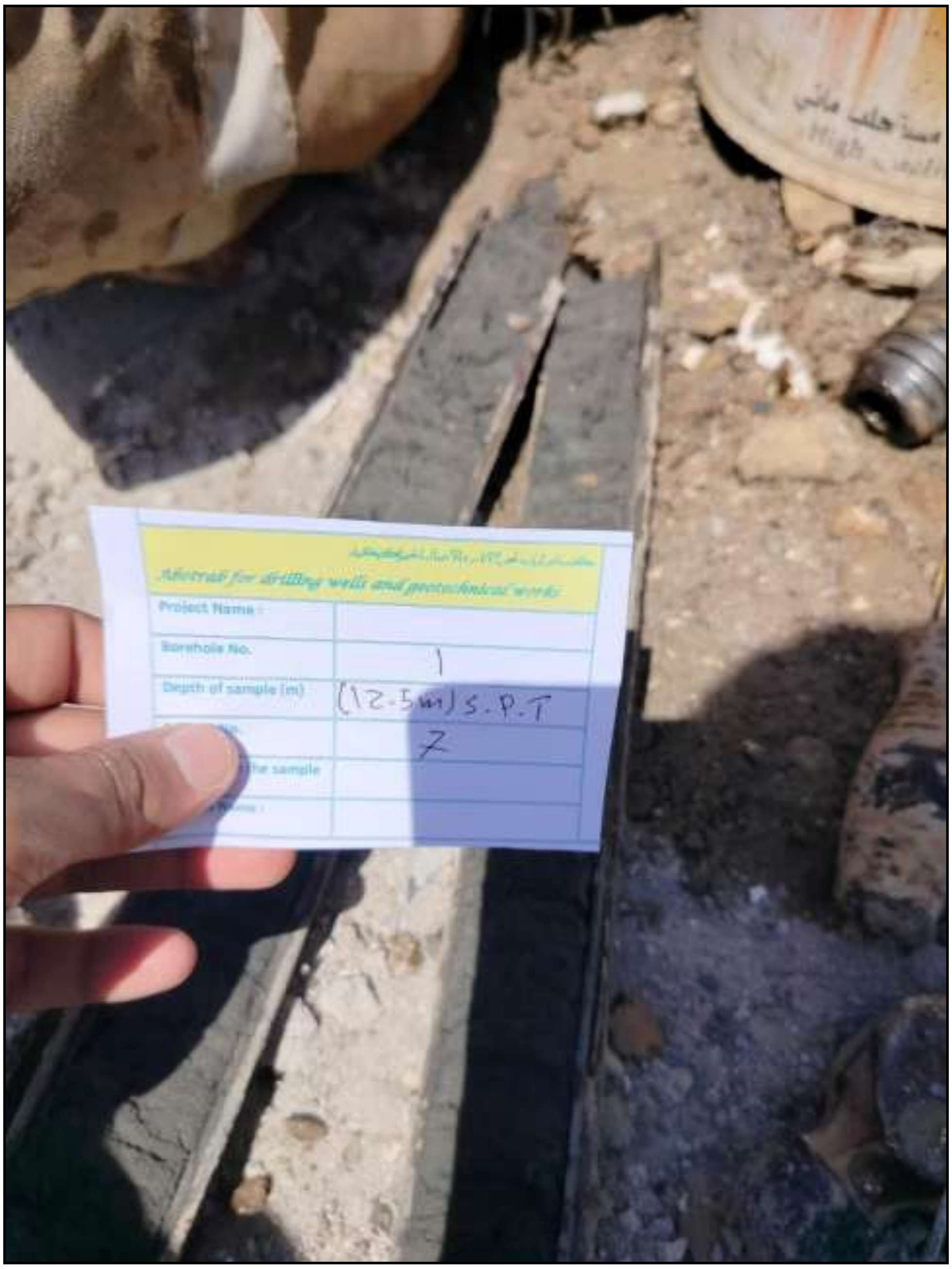
Borehole No. : 2
Total Depth: 30.0 m

Sample			Index properties				Moisture content	Total Density	Shear Test				Gs	Grain size analysis			Consolidation tests			Chemicals tests			
									Unconfined Comp. strength		Direct shear												
No.	Depth	Type	L.L	P.L	P.I	USCS			q_u	C	C	Ø°		Grav.	Sand	Passing No.200	e	Cc	Cr	SO_3	T.S.S	Gyp.	Org.
	(m)		%	%	%		%	kN/m³	kPa	kPa	kP			%	%	%				%	%	%	%
1	1.5	SS	42	23	19	CL	20.36							0.0	5.6	94.4				1.43	4.49	3.07	1.12
2	3.0	SS	40	22	18	CL	22.85							0.0	4.1	95.9							
3	4.5	US	41	23	18	CL		19.52	139.0	69.5			2.72	0.0	6.7	93.3	0.71	0.202	0.019				
4	6.0	SS	39	22	17	CL	24.14							0.0	3.0	97.0				1.06	3.33	2.28	0.86
5	7.5	SS	37	20	17	CL								0.0	7.9	92.1							
6	9.0	SS				SM	20.36							0.0	73.3	26.7							
7	12.0	SS				SM					3.4	32.0		0.0	72.0	28.0							
8	14.0	SS				SM	19.00							0.0	74.3	25.7				0.75	2.36	1.61	0.66
9	16.0	SS				SM		17.93					2.69	0.0	79.7	20.3							
10	18.0	SS				SM	17.74							0.0	79.2	20.8							
11	20.0	SS		NP		SM					1.8	35.8		0.0	81.0	19.0							
12	22.0	SS				SM	18.85							0.0	78.6	21.4				0.43	1.35	0.92	0.35
13	24.0	SS				SM								0.0	77.7	22.3							
14	26.0	SS				SM	17.25						2.67	0.0	79.5	20.5							
15	28.0	SS				SM		18.58			0.7	40.2		0.0	82.8	17.2							
16	30.0	SS				SM	16.03							0.0	83.5	16.5				0.22	0.69	0.47	0.20

SS: Standard Penetration Test Sample   US: Undisturbed Sample   NP: Non Plastic

APPENDIX C

PICTURES OF FIELD WORKS


Abstract for drilling wells and geotechnical works
Project Name :
Borehole No.
1
Depth of sample (m)
(12.5m) S.P.T
7
the sample