SITE INVESTIGATION AND GEOTECHNICAL EVALUATION OF THE HANGAR IN GHOUR AL-SAFI

July 2nd,2009

This publication was produced for review by the United States Agency for International Development. It was prepared by the Engineering Axis for Studies

SITE INVESTIGATION AND GEOTECHNICAL EVALUATION OF THE HANGAR IN GHOUR AL-SAFI

USAID JORDAN ECONOMIC DEVELOPMENT PROGRAM

CONTRACT NUMBER: 278-C-00-06-00332-00

DELOITTE CONSULTING LLP

USAID/ECONOMIC GROWTH OFFICE (EG)

JULY 2ND 2009

AUTHOR: ENGINEERING AZIS FOR STUDIES

TASK NO: 5C.14.04.27.08.01

Contents

1. INTRODUCTION:

This report presents the findings of the site investigation and geotechnical and concrete evaluation for the existing hangar.

The purposes of this investigation were to:

- Determine the surface and subsurface geotechnical conditions, the soil/rock properties at the mentioned site, bearing capacity, settlement, type and depth of foundations.
- Determine the depth and dimensions of the existing slab-on-grade foundation system.
- Assessment of the concrete strength and the condition of the existing foundation concrete.

Such information would assist the structural engineer in the evaluation of the existing foundations in order to implement the most safe and feasible design.

The following methodology was implemented for this investigation:

- Investigating the site and collecting of data including available geological maps and previous studies, if any.
- Taking of four concrete cores from the hangar slab-on-grade foundation system.
- Excavating of Two test pits to the level of the bottom of the foundation.
- Drilling of three boreholes to determine the stratigraphy and obtaining samples of the encountered materials for engineering analysis.
- Conducting laboratory tests on representative samples for the evaluation of the physical and mechanical properties of the subsurface materials.
- Performing engineering analysis for the field and laboratory findings and developing of conclusions and recommendations.

2. SITE AND HANGAR DESCRIPTION

The site of the existing hangar is located in Ghour Al Safi. Generally, the site is surrounded by a paved road from the west, by an existing building from the north and by unutilized areas from the remaining sides. The surficial ground consists of alluvial deposits materials.

The existing hangar has an area of about 700 m^2. By inspection, it was revealed that the existing concrete of the slab-on-grade foundation suffers from many cracks (block cracking shape) and few potholes. However, the existing hangar steel, as inspected, does not suffer from any visible deformations.

Figure No. 1 shows the general site plan including the location of the existing hangar, the drilled boreholes and excavated test pits.

3. SEISMICITY

In respect to Jordanian Seismic Code; the site lies within zone (3) **with a seismic zone factor** Z=0.30**. Considering the recommended foundations formations, the following seismic parameters are tabulated:**

Ground Materials	***Formation Classification***	***Seismic Factor for Acceleration, (Ca)***	***Seismic Factor for Velocity, (Cv)***
Alluvial Deposits	S_D	0.36	0.54

The above parameters shall be used in the structural design of the proposed project. The seismicity and earthquake map related to the site area is shown in Appendix B.

4. FIELD and Laboratory Works

4.1 Field Work

The field work included the following:

- **Drilling of three boreholes on June 28th, 2009. These borings were numbered BH1, BH2 and BH3, and drilled to depths of 8m, 10m and 8m, respectively, each below the existing ground surface. The drilling work was executed with "Halco rotary rig, mounted on Mercedes LB 1622" using air flush drilling method.**

- **Excavating of two test pits near side the foundation to determine the depth and dimensions of the existing foundations, and the foundation materials. Bulk samples were taken to our laboratories for testing.**

- **Taking of four concrete cores from the slab on hangar ground to evaluate the concrete strength. The cores were taken using rotary core cutting machine with diamond bits, they labeled and taken to our laboratories for inspection and testing.**

4.2 Sampling from Boreholes

Due to the intermixed and loose nature of the existing alluvial materials; the core barrel could not be used to obtain undisturbed samples and only disturbed and split spoon samples were obtained from these materials. The collected samples were inspected, labeled in a proper sequence, then contained in tight plastic bags and taken to (**EAS**) laboratories for testing. All drilling and sampling activities were supervised by specialist geotechnical staff.

4.3 Field Testing in Boreholes and Test Pits

4.3.1 Standard Penetration Test (SPT)

Standard Penetration Test (SPT) was performed at various depths to obtain approximate relative densities of the ground materials. The test was performed in accordance with:

- ASTM D 1586-99; "Penetration Test and Split Barrel Sampling of Soils".

The SPT number of blows versus depth is presented on logs of borings, Appendix A. The Standard Penetration Test is defined in the legend to borings logs, attached at the end of this report. Interpretation of the test results are also given in the legend.

4.3.2 Dynamic Cone Penetration Test (DCP)

Dynamic cone Penetration Test (DCP) was performed at the foundation level on the excavated test pits.

4.4. Visual Examination

Visual examination was carried out on the samples obtained from the boreholes. The examinations were performed following the procedures outlined in:

1- ASTM D 2488-00; “Practice for Description and Identification of Soils (Visual - Manual Procedure)”.

2- BS 5930: 1999; “Code of Practice for Site Investigation”.

4.5 Laboratory Work

As part of the adopted methodology; laboratory testing program was performed on representative samples for the evaluation of the physical and mechanical properties of the subsurface materials and the existing concrete strength. Tests were conducted according to the following standards:

1- ASTM D 2216 – 98; “Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass”.

2- ASTM D 4318 – 00; “Liquid Limit, Plastic Limit, and Plasticity Index of Soils”.

3- STM D 422 – 63 (1998); “Particle Size Analysis of Soils”; Sieve analysis.

4- AASHTO T 24-97; “Obtaining and Testing Drilled Cores and Sawed Beams of Concrete”.

5- AASHTO T 231-97; “Capping Cylindrical Concrete Specimens”.

Tests results for samples from boreholes, test pits and concrete cores are summarized in Tables No. 1 through No. 3.

Table No.1 Boreholes Laboratory Test Results

BH No	***Depth (m)***	***M.C (%)***	***Bu lk Density (G/CM3)***	***Dry Density (g/Cm3)***	***Atterberg Limits***			***Grain Size Distribution***				***Qu (Kg/cm2)***
					LL	***PL***	***PI***	***Gravel (%)***	***Sand (%)***	***Silt (%)***	***Clay (%)***	
BH1	0.0-1.0	2.1										
	1.0-2.5	3.5			--	--	N.P	53	41	4	2	
	3.0-4.5	6.0										
	4.5-6.0	5.6										
	6.0-7.0	7.4										
	7.0-8.-	8.2										
BH1	0.0-1.5	3.8			--	--	N.P					
	1.5-3.0	4.9										
	3.0-4.5	5.2										
	4.5-6.0	6.7										
	6.0-7.0	8.0										
	8.5-10.0	7.8										
BH3	0.0-1.5	3.1										
	1.5-3.0	5.0										
	3.0-4.5	6.7										
	5.5-7.0	6.1										
	7.0-8.0	6.3										

M.C: Moisture Content *LL: Liquid Limit* *qu: Unconfined Compressive Strength*
PI: Plasticity Index *PL: Plastic Limit*

Table No.2 Test Pits Laboratory Tests Results

Test Pit No.	Depth (M)	M.C(%)	Bulk Density (G/cm 3	Dry Density (G/Cm3)	Atterberg Limits			Grain Size Distribution				Qu(Kg/cm2)
					LL	PL	PI	Gravel (%)	Sand (%)	Silt (%)	Clay(%)	
TP1	0.0-0.7	1.6										
	0.7	2.7			--	--	N.P	61	32	5	3	
TP2	0.0-0.6	2.1										
	0.6	3.0			--	--	N.P	48	46	4	2	

M.C: Moisture Content *LL: Liquid Limit* *qu. Unconfined Compressive Strength*
PI: Plasticity Index *PL: Plastic Limit*

Table No.3 concrete Cores Tests Results

Core No.	Location	Core Density (gm/cm^3)	Length Dia. Ratio (L/ D)	Core Strength N/mm^ 2)	Correction Factor	Corrected Core Strength (N/mm^ 2)	Estimated Cube Strength (N/mm^ 2)
1	Foundation Slab	2.292	1.00	18.7	0.87	16.3	21.1
2		2.359	1.20	26.6	0.92	24.5	28.8
3		2.342	1.01	19.8	0.87	17.3	22.5
4		2.311	1.27	22.7	0.93	21.2	24.9

5. DESCRIPTION And PROPERTIES OF FORMATIONS

5.1 Subsurface Stratigraphy

The investigation program has revealed that the surface and subsurface ground materials across the study area consist of:

Loose to Medium dense, varicolored, sub rounded to rounded, **alluvial deposits** composed of gravels, sand and fines of silt and clay. These materials we found at the ground surface and extended to the end of borings

Further details and information regarding the encountered materials and strata thicknesses are presented in the logs of borings, Appendix A.

The strata continuity was interpolated by imaginary lines connecting the encountered thicknesses of the similar ground strata in the drilled boreholes, as presented in the Generalized Subsurface Profile AA' in Figure No. 2. However, these lines are made for illustration purposes and may not represent the actual field conditions.

5.2 Description of Materials at the Test Pits:

- Loose to Medium dense, varicolored, sub rounded to rounded, ALLUVIAL DEPOSITS composed of gravels and and fined of silt and caly. These materials were found at the ground surface and extended to the end of borings

5.3 Geotechnical Properties

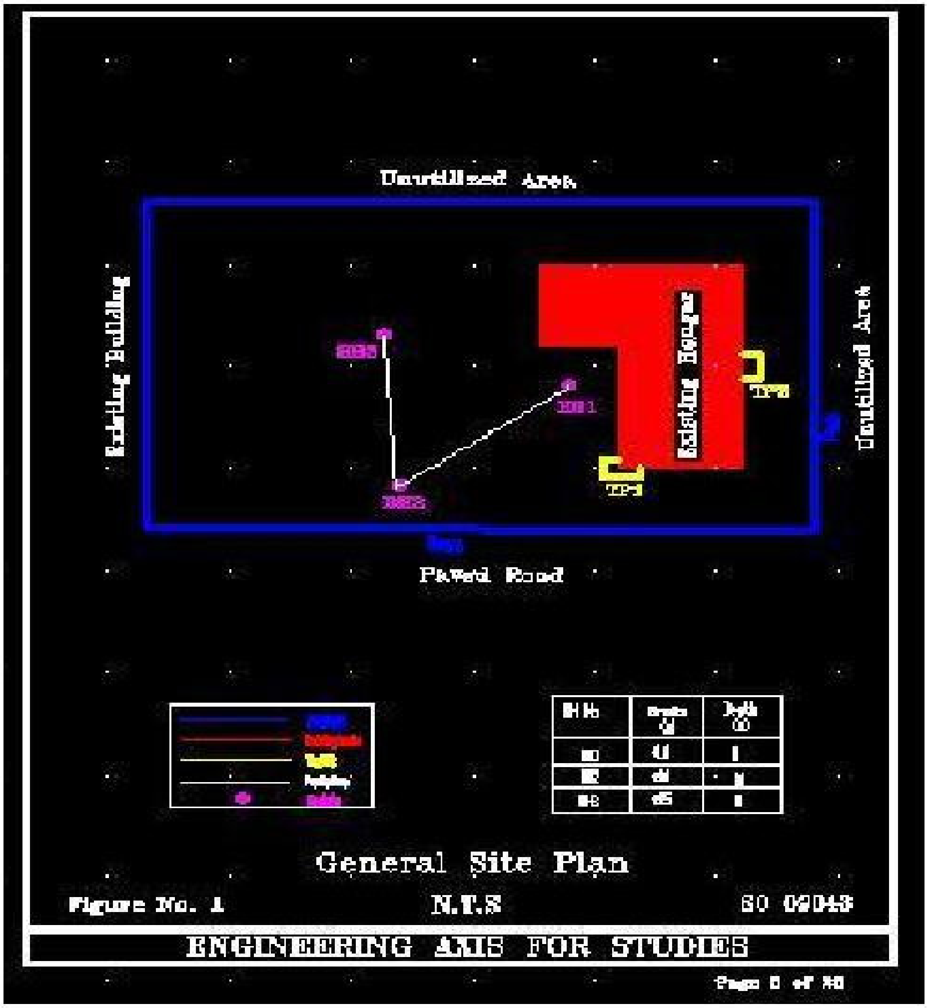
A Summary of tests results including a general evaluation of some geotechnical properties for the surface and subsurface materials is indicated in Table No.2

Table No. 4: Subsurface Materials Types and Properties

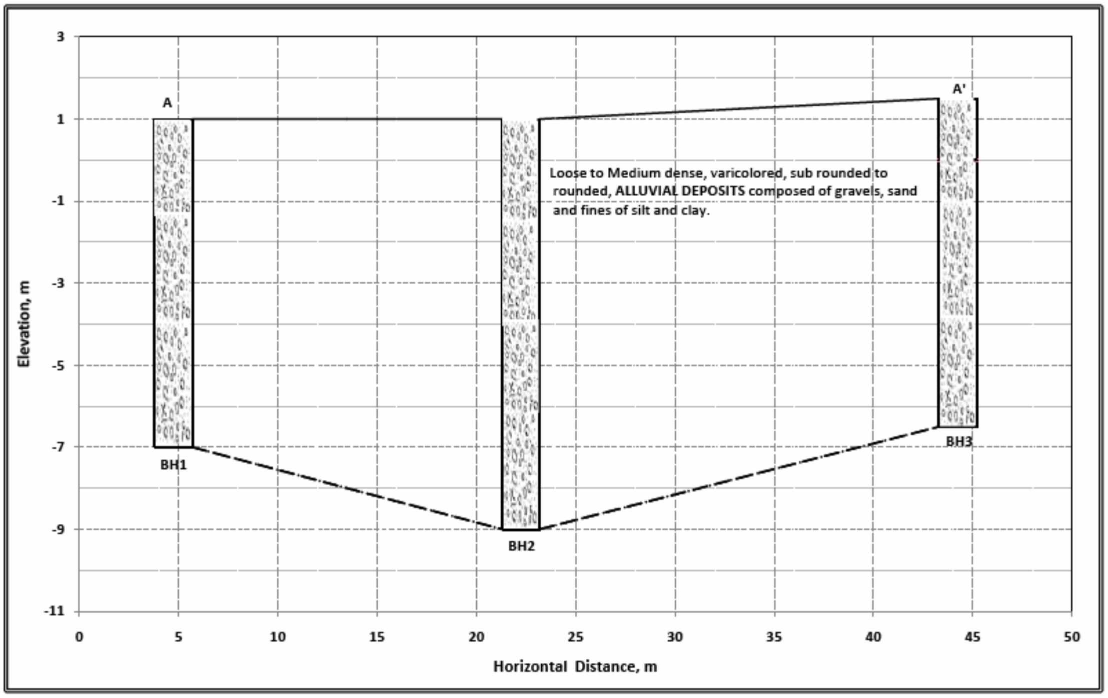
Approximate Depths (M)	***Materials' Visual Description***	***Summary of Tests Results and Materials Properties***
From the ground surface toe the end of all borings	Loose to medium dense, varicolored, sub rounded to rounded, Alluvial Deposits Composed of gravels, sand and fines of silt and clay.	M.C: 2.1-8.2% SPT: 15,30 and 39
From the ground surface to the end of excavation at the two test pits.	Loose to Medium dense, varicolored, sub rounded to rounded, ALLUVIAL DEPOSITS composed of gravels, sand and fines of silt and clay	M.CL 2.1-3.0% PI:N.P Gravel : 48-61% Sand: 32-46% Silt & Clay: 6-8% SPT*:14 & 38

.C: Moisture Content PI: Plasticity Index SPT: Standard Penetration Test
DCP: Dynamic Cone Penetration
** SPT Values from DCP results, SPT= DCP/5.*

Profile AA'
Figure No.2



Appendix B: Earthquake Map



SO 09043 **Figure No. 2: Generalized Subsurface Profile (AA')** Page 11 of 20

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Evaluation of Existing Concrete

The following table shows a summary of the obtained compressive strength of the tested cores categorized according to the structural elements:

Structural Element	***No. of Tested Specimens***	***Minimum Strength (N/mm^2)***	***Average Strength (N/mm^2)***
Concrete Slab	**4**	**21.1**	**24.3**

The obtained compressive strength of the concrete cores were shown in table No. 3. The Ministry of Public Works Technical Specifications for Buildings; 1996, requires the following two conditions (1&2) for the core compressive strength of the hardened concrete, simultaneously:

1) The average compressive strength for the core specimens for each sample shall not be less than 85 % of the specified characteristic strength.

2) The lowest core specimen compressive strength is not less than 75 % of the specified characteristic compressive strength.

- It is to be recognized that the characteristic cube compressive strength was not specified. However, by applying the above two conditions on the obtained concrete core strength values and using back calculation, the following values of the recommended characteristic strength for the different elements could be obtained:

Structural Element	***Characteristic Strength (N/mm^2) considering;***		***Recommended characteristic cube strength value (N/mm^2)***
	Min. Core strength Value	***Average Core Strength Value***	
Concrete Slab	28.1	28.6	28

<u>The recommended characteristic cube strength value as shown above could be used by the structural engineer for analysis and design.</u>

6.2 Existing Foundation System

6.2.1 Existing Slab

Regarding the existing slab it was noticed that:

- The measured slab thickness ranged from 7.8 cm to 11.6 cm.
- The slab reinforcement consists of a mesh of deformed (8 –mm dia.) steel bars spaced at 25 cm in both directions.
- The bottom face of the concrete was inspected. No evidence of sulphate attack was noticed.
- The slab concrete was block-cracked to the extent that some potholes were r esulted.
- It was revealed that the slab supporting soil suffers from excessive settlement to the extent of about 3cm or more. This lack of support caused the noticed cracks and potholes.

6.2.2 Isolated Footings

Regarding the isolated footings, the following was revealed: -

❖ The cross sectional dimensions are 1.0m by 1.0m with a thickness of 0.7m. These footings were connected by upper tie beams with a thickness of 10 cm and a width of 1.0m.

❖ No evidence of cracks was noted on the outer surface of the footings concrete. Furthermore, no evidence of tilting or differential settlement cracking was noticed through the connecting ties beams.

❖ The upper face of the footing is at the level of the surrounding ground. Therefore, the foundation depth is approximately equal to the footing thickness. (i.e. 0.7 m).

Based on the above, it can be concluded that: -

❖ In spite of the satisfactory concrete strength, the existing thin concrete slab is unsatisfactory. That is due to the lack of support caused by excessive settlements through the underneath foundation soil, and the corroded reinforcement steel. Therefore, this slab should be removed and reconstructed.

❖ Taking in consideration the satisfactory concrete strength, and the absence of any surface cracks in the isolated footings, such footings might remain in place, provided that:
  - A surrounding 1.5m-width concrete pavement is constructed to protect the foundation soil from any water seepage. Such protection is necessary taking in account the relatively shallow foundation depth.
  - Reinforcement steel is exposed at several locations to be inspected to ensure that it is not affected by corrosion. It is more appropriate to perform such exposing and inspection after the removal of the adjacent slab.

6.3 Soil Investigation

According to the field investigation, laboratory testing, soil properties, engineering analysis, and practical experience; the following conclusions and recommendations are drawn regarding foundation design and construction:

6.3.1 Foundation Type and Depth

The foundation of any future construction will bear on the "loose to Medium dense, varicolored, sub rounded to rounded, **alluvial deposits** composed of gravels, sand and fines of silt and clay" layer that were encountered at the ground surface.

The recommended foundation ground is suitable to support the project loads on any shallow foundation system such as individual footings with tie beams and/or strip footings.

The foundation depth (i.e., the minimum foundation embedment depth) may vary according to the architectural requirements but should not be less than **1.2m** below the adjacent finished level of ground surrounding the building.

6.3.2 Recommended Bearing Capacity and Settlement

No undisturbed samples could be obtained from the boreholes for strength testing because of poorly-cemented nature of the recommended foundation ground materials.

Standard Penetration Tests Results of the sand materials were used to calculate the allowable bearing capacity for this type of materials. Meyerhof had suggested the following equations for computing the allowable bearing capacity for a 25 mm settlement (Ref. 4).

$$\mathbf{qa} = \frac{N}{0.05}\left(1+0.33\frac{Df}{B}\right) \quad \text{for } B \leq 1.2$$

$$\mathbf{qa} = \frac{N}{0.08}\left((B + 0.3)/B\right)^2 \quad \text{for } B > 1.2$$

Where,

qa : allowable bearing capacity (kPa)
N : Corrected No. of blows in SPT.
B : Width of foundation (m).
Df : depth of foundation (m).

The obtained number of blows was 15, 30, and 39. However, due to the limited number of readings and to allow for local variations a design number of blows of 12 will be considered, Taking (B) as 1.3m. The obtained allowable bearing capacity will be 227kPa or 2.3kg/cm^2 for the recommended foundation ground. According to these calculations and based on our previous experience with similar materials; a net allowable bearing pressure value of **2.0kg/cm^2** is recommended for the whole site area bearing on "loose to Medium dense, varicolored, sub rounded to rounded**, ALLUVIAL DEPOSITS** composed of gravels, sand and fines of silt and clay".

The settlement will depend on the loads and foundations shape and dimensions. The foundation settlement was checked using the methods proposed by Schultze and Sharif.

The above authors established an empirical relationship between SPT N- values dimensions and embedment depth to obtain the short-term settlement of foundations on sands.

$$S_e = \frac{S \cdot q_{all(net)}}{N^{0.87}\,(1+0.4D/B)}$$

Where :

S= Coefficient of settlement (for strip footing with width or diameter of 1.0m, S=0.62mm/m2. Whereas, S=0.38mm/KN/m2 for one meter wide individual footing.
D=Foundation depth ($D \cong 1.5$ m)
N=12 blows is considered in the Calculations.

Accordingly, settlement values of 8.9mm and 5.5mm are calculated for strip and individual foundation (per meter width), respectively. These settlement values are smaller than the tolerable settlement of 25.4 mm.

However, with the foundation designed and constructed in accordance with the above recommendations, the foundation settlement is expected to be small and within tolerable limits".

Allowable bearing pressures were calculated for the recommended foundation ground from the SPT tests results according to the Jordan National Code for Footings, Foundations and Retaining Structures.

6.3.3 Soil Parameters for Retaining Structures

Soil parameters needed to calculate the earth pressure of a soil on retaining walls and below base slabs (if any); are indicated in Table No. 4.

Table No. 5: soil parameters for eath pressure calculations

Materials Types	*Unit Weight (g/cm3)*	*Cohesion (C) (Kg/ cm2)*	*Angle of Internal Friction (Ø) (Degree)*	*Coef.of Active Earth Pressure (Ka)*	*Coef. Of Passive Earth Pressure (Kp)*	*Coef.of Earth Pressure at Rest (Ko)*
Alluvial Deposits	1.9	0.00	30	0.33	3.00	0.50
Selected fill	2.0	0.10	30	0.33	3.00	0.50
Filter	2.0	0.00	35	0.27	3.69	0.43

6.3.4 Methods of Excavation and Backfilling

Based on the recommended foundation formation, it is expected that the excavation would be carried out through alluvial deposits materials. Therefore, conventional excavation equipments such as loaders and dozers would be satisfactory. Nevertheless, the last excavated 15 cm shall be accomplished using manual equipment unless large boulders or hard materials are encountered. Moreover, the foundation level should be cleaned to be free from accumulation of soil, debris, water, or any deleterious matters. Anyhow, the bottom of excavation, if disturbed, shall be properly compacted before the construction of the foundation.

The temporary excavation side slopes should be properly designed to minimize the instability problems. Otherwise, in the absence of such design; these side slopes shall not be steeper than one horizontal to one vertical (1H: 1V). If these side slopes cannot be achieved for insufficient lateral distance, temporary lateral support (shoring system) should be considered.

Foundation excavation should not be exposed to excessive wetting or drying for prolonged periods. Therefore, it might be found beneficial to protect the excavated sides using any type of water-proof sheets**.**

In addition, it is strongly recommended to protect the foundation materials and excavation from surface water and/or rain water (if any) both during and after construction. This can be accomplished by providing proper drainage and protection systems as well as maintaining the sewer and water systems of the project continuously.

The alluvial deposits materials may be suitable for backfilling purposes; however, the final decision shall be taken during construction and upon further evaluation. In general, backfilling process should comply with the following:

- Backfill materials shall be clean from organic or any other deleterious matters. Moreover, backfill materials shall comply with the following requirements, depending on their source: -

  - For selected (borrow) backfill materials: It should be within A-1, A2-4, or A-2-5 Groups if classified according to AASHTO M-145. Plasticity Index shall not be more than 10. In addition, the maximum size shall not be more than 100mm.
  - For In-situ excavated materials: It should not be within A-6 or A-7 Groups if classified according to AASHTO M-145. The maximum dry density obtained by Modified Proctor Test (AASHTO T 180-01) shall not be less than 1.6 gm/cm3.

- Backfilling around foundation shall be performed in layers of not more than 200mm in compacted thickness, unless the used compaction machinery proved that higher layer thicknesses could be compacted satisfactorily. Mechanical compactors shall be used except that at narrow locations where mechanical compactors could not be used. In such cases, manual weights of not less than 15kg may be utilized. The compaction effort shall be conducted so that the dry density of the compacted materials shall not be less than 90% of the maximum dry density obtained by Proctor Test (AASHTO T 180-01).
- The amount of added water shall be sufficient for compaction purposes only. If any excess of water occurs, compaction shall not be allowed until the moisture content of the existing layer reaches its optimum moisture content. B
- Backfilling around walls and foundations shall be carried out (for the inner and outer sides) subsequently to secure the stability of these structures.

7. IMPORTANT NOTES

- All conclusions and recommendations are based on boring records, examination of samples, and laboratory testing. However, any unforeseen conditions that have not been revealed by the boreholes are beyond our responsibility.
- At the end of excavation and before construction; our office shall be contacted to inspect the excavation, and to confirm that the required ground is reached and all given recommendations are met.
- It is to be emphasized that the client is solely responsible, and our office does not bear any responsibility in case of inappropriate implementation of the recommendations given in this report

Appendix A： Logs of Borings

LOG OF BORING

PROJECT: SABEQ Existing Hangar.	**BORING NO.:** BH1
LOCATION : Ghur Al Safi	**DEPTH:** 8.0 m
DRILLING DATE: 28/06/2009	**APP. ELEVATION:** +1.0m
DRILLER: EAS-AE	**DRILLING METHOD:** Rotary Air Flush
REPORT NO.: SO 09043	**GROUND WATER DEPTH:** Not Exist

DEPTH, m	SAMPLER TYPE	GRAPHIC LOG	GEOLOGIC DESCRIPTION	USCS SYMBOL	RECOVERY (%)	R Q D (%)	S P T -N BLOWS / 0.3m	UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2)	DRY DENSITY (gm/cm^3)
1-- 2-- 3-- 4-- 5-- 6-- 7--			Loose to Medium dense, varicolored, sub rounded to rounded, **ALLUVIAL DEPOSITS** composed of gravels, sand and fines of silt and clay. **From (6.5-8.0) m increasing of fines.*				15		
8-- 9-- 10-- 11-- 12-- 13-- 14-- 15--			End of Boring						

RQD: Rock Quality Designation **SPT:** Standard Penetration Test	***EAS***	**USCS:** Unified Soil Classification System

LOG OF BORING

PROJECT: SABEQ Existing Hangar.	**BORING NO.:** BH2
LOCATION : Ghur Al Safi	**DEPTH:** 10.0 m
DRILLING DATE: 28/06/2009	**APP. ELEVATION:** +1.0m
DRILLER: EAS-AE	**DRILLING METHOD:** Rotary Air Flush
REPORT NO.: SO 09043	**GROUND WATER DEPTH:** Not Exist

DEPTH, m	SAMPLER TYPE	GRAPHIC LOG	GEOLOGIC DESCRIPTION	USCS SYMBOL	RECOVERY (%)	R Q D (%)	S P T -N BLOWS / 0.3m	UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2)	DRY DENSITY (gm/cm^3)
0–10			Loose to Medium dense, varicolored, sub rounded to rounded, **ALLUVIAL DEPOSITS** composed of gravels, sand and fines of silt and clay. **From (6.0-10.0) m increasing of fines.*				39		
10–15			End of Boring						

RQD: Rock Quality Designation **SPT:** Standard Penetration Test	EAS	**USCS:** Unified Soil Classification System

LOG OF BORING

PROJECT: SABEQ Existing Hangar.	**BORING NO.:** BH3
LOCATION : Ghur Al Safi	**DEPTH:** 8.0 m
DRILLING DATE: 28/06/2009	**APP. ELEVATION:** +1.5m
DRILLER: EAS-AE	**DRILLING METHOD:** Rotary Air Flush
REPORT NO.: SO 09043	**GROUND WATER DEPTH:** Not Exist

DEPTH, m	SAMPLER TYPE	GRAPHIC LOG	GEOLOGIC DESCRIPTION	USCS SYMBOL	RECOVERY (%)	R Q D (%)	S P T -N BLOWS / 0.3m	UNCONFINED COMPRESSIVE STRENGTH (kg/cm^2)	DRY DENSITY (gm/cm^3)
0–8			Loose to Medium dense, varicolored, sub rounded to rounded, **ALLUVIAL DEPOSITS** composed of gravels, sand and fines of silt and clay. **From (6.0-8.0) m increasing of fines.*				30		
8–15			End of Boring						

RQD: Rock Quality Designation **SPT:** Standard Penetration Test	***EAS***	**USCS:** Unified Soil Classification System

USAID Jordan Economic Development Program
Deloitte Consulting LLP
Salem Center, Sequleyah Street, Al-Rabiyeh
Amman, 11194 Jordan
Phone: + 962-6 550-3050
Web address: http://www.SABEQ-Jordan.org