Prince Mohammad Bin Fahd University
College of Engineering
Department of Civil Engineering

Senior Design Project (ASSE III)

Fall 2014/2015

Structural & Geotechnical Design of a General Hospital and Multilevel Car Parking in the Area of Half Moon Bay

Presented by

Aiham A. Arnous 201102378
Tala Almutairi 201000244
Salman Basheer 201102120

Supervised by

Dr. Tahar Ayadat
Dr. Andi Asiz

Acknowledgment

We take this opportunity to convey our earnest gratitude and intense respect to our Supervisors, Dr.Tahar Ayadat and Dr. Andi Asiz for their impeccable enlightment, supervision and consistent upliftment throughout this project. The endorsement, assistance and advice given by them shall carry us prolonged way in the voyage of our life.

We also take this opportunity to convey a profound sense of gratitude to the Dean of College of Engineering, Dr. Jamal Nayfeh for his gracious support, precious information and enlightment, which helped us in accomplishment of our Engineering Degree.

We would like to thank all faculty members of Civil Engineering Department Dr. Omar Ouda and Eng. Danish Ahmed for their valuable information provided by them in their respective fields. We are grateful for their co-operation during our project and other engineering courses.

Ultimately, we thank our Families and Friends for encouragement and help.

ABSTRACT

Recently, the Half Moon Bay area is undergoing some remarkable developments. Many construction projects were launched in the area, notably around Al-Khaldiyah main road (e.g. PMU University, PMU accommodations, the new City, etc.). The construction of a hospital in the area (notably for emergency cases) becomes a necessity. Larger cities may have several hospitals of varying sizes and facilities. The best-known type of hospital is the general hospital, which is set up to deal with many kinds of disease and injury, and normally has an emergency to deal with immediate and urgent threats to health.

The main objectives of this project are to select the appropriate emplacement of the general hospital, to design the hospital structure (structure of three/four stories), and to design a multilevel car parking to be constructed in the Half Moon area. In this project, appropriate foundation systems are proposed and analyzed. The project includes a structural and a geotechnical design of the hospital structure and the car parking in addition to some access roads.

TABLE OFCONTENT

CHAPTER 1: INTRODUCTION

1.1. General

According to the Ministry of Health of Saudi Arabia, the medical sector in the Kingdom has always been to follow-up and attention because it affects the economy nerve. Also it is the key to development in all its forms and is closely linked to sustainable development that success depends mainly on the availability of the crew facilities of the medical teams and equipments for health care system (i.e. hospitals) and its subservient facilities (i.e. clinics, dispensary, etc.). So the medical sector is one of the most important sectors that contribute effectively to the rise of any country. Without medical sector or with inadequate medical sector, life will not exploit the primary advantages of any economical site, nor investment opportunities for the production of health and wellness. This means that the plan of the national health care of the kingdom must be consistent and in harmony with the development strategy for the long term, which is supervised by the Ministry of Economy and Planning. Access to the objectives set out in the strategy of development depends, among other factors on the development of the medical sector and its flexibility in responding to the requirements of the plan and its interaction with the dynamic development, and this will not be achieved unless there is in the medical sector in all patterns of energy capacity over the plan.

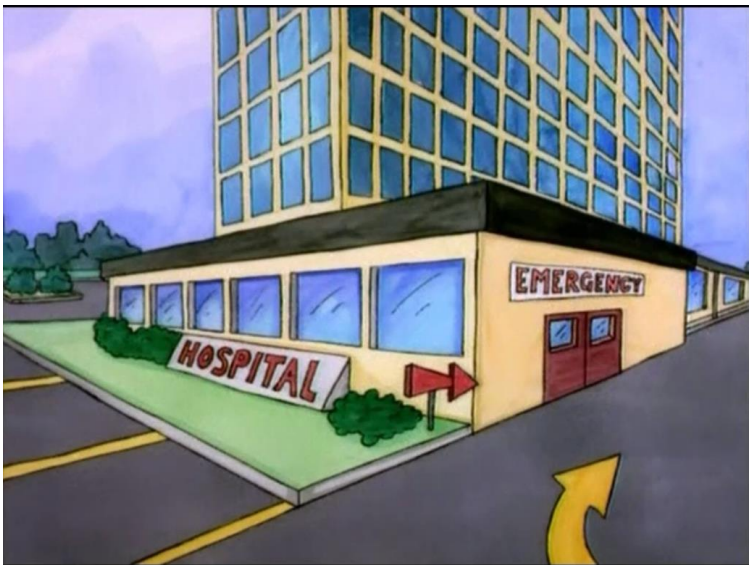
The Kingdom of Saudi Arabia has a sophisticated and modern network of health care system and has a total number of health care centers of about 1925 centers, 225 governmental hospitals, and 87 private hospitals, of which giving the total number of beds to be equal 128366 beds.
Operations continue to be the construction of governmental and private hospitals that presents the medical services of all areas all around the Kingdom with a tendency to involve the private sector in the ownership, operation and maintenance of the health care centers.

The total number of the hospital carried out by the ministry until the end of the year 1434 AH more than about (220) two hundreds twenty constructed hospitals based on one of the international standards and several trends have presented major services to each person to cope with the great development of these cities and to meet the increase of population, have also been raising the level of a number of individual public health center to become a double or triple in

the over all sizes and carried out many beds and patients all around the cities in addition to the implementation of the obstacles in the hinterlands or remote areas . In addition to the hospitals that exist within each region and contribute to present the services to the cities and provinces of the region to each other and then linking the region to the rest of the areas when it requested a specialist hospital for some cases or medical issues , also carried out health centers that serve the various centers and communities as well as privet hospitals , which amounted to a total number yet over (87) eighty seven , and has contributed to these hospitals and thankfully in the process of construction and development , which swept across all regions of the kingdom and spread across the services provided to citizens everywhere (transportation, education and social and agricultural , construction and architecture , etc.)

Hospitals in Saudi Arabia differ in terms of patient capacity. Some hospital carried the capacity of about hundreds beds and some of about tenths beds. All hospital are maintained to have not less than (50) fifty beds in all cases, and for the public hospitals in the main cites to have not less than (250) two hundred fifty in all cases. Hospitals has constructed and taking into consideration the high-temperature resistant and to reverse the lack of strong sunlight. Also, the radiation control is taking into consideration to protect peoples from its side effects. The government is working now to rebuild and repair almost all public hospital.

In Saudi Arabia the crew facilities of the medical teams and equipments are the main means of health care system. The ratio of deaths in Ministry of Health hospitals is to be about 81% are due to road traffic accidents and 20% of their beds are occupied by traffic accidents victims (Ansari et al., 2000).



1.2. Project Objectives

The main objectives of this project are to select the appropriate emplacement of the general hospital, to design the hospital structure (structure of nine/twelve stories), and to design a multilevel car parking to be constructed in the Half Moon Bay area.

In this project, appropriate foundation systems are proposed and analyzed. The project includes a structural and a geotechnical design of the hospital structure and the car parking in addition to some access roads.

The project is composed by the following stages or parts:

1- Development of the different architectural plans of the hospital and the car parking (including plans & faces views).
2- Emplacement of the hospital and its multilevel parking in the area of Half Moon Bay.
3- Structural design of a thirteen story general hospital and a multilevel car parking.
4- Geotechnical and foundation design of the different foundation system.
5- Pavement design of the access roads to the hospital and parking (prototype sections).
6- Development of the hospital prototype.
7- Final project report.

1.3. Scope of the report

The present report is composed of six chapters. A detailed description of the project and a historical background is presented in chapter 2. The soil report is introduced in chapter 3 including site & laboratory investigations, and soil profile. Following that, the design of the proposed hospital with its multilevel parking is presented in chapters 4. The geotechnical designs of some elements of the hospital with its multilevel parking are discussed in chapter 5. The report is achieved by some specific and general conclusions.

CHAPTER 2: Description of the project

2.1 Introduction

A general hospital on Halfmoon bay is an important thing to be constructed as it is a newly developing area. Population is increasing day by day, many people are settling near Halfmoon bay area and above all it is a recreation area. That is we have many beaches, resorts on Halfmoon bay. So for in case of any unseen or any health problem, there is a need for hospital in this area. It provides a direct health care in any health issues for many people on the local beaches and notably to people at PMU University. It will be used daily and extensively by staff, students, workers, and all other visitors of the local beaches. However, many accidents due to traffic and accidents on the beach can occur which can lead to injuries and sometimes death also. Due to the improper distribution of hospital we can observe that there is no hospital incase of emergency as well as for normal situation. If a person staying in Halfmoon bay area has to visit a hospital he has to travel 30-35km at least to reach the nearest hospital. And sometimes this distance can play a key role in saving a person's life. Imagine if a person has a heart attack then he has to drive 30-35 km, which is risky in that condition.

This chapter is mainly concerned by the description of the historical background of the site of the project, and the problems associated to the existing location. The chapter will start by describing the historical background of Halfmoon bay's area. Very next will be a description of the Hospital. Following that a brief description would be about multilevel car parking.

2.2 Historical and geographical description of the project

Halfmoon bay area was not considered under the city limits earlier. It used to be outskirts of the city. But as the population is increasing heavily, the need for land has also increased. As PMU started in 2005, since then the construction and development has increased heavily in Halfmoon bay area. Since 2011 the construction of PMU housing accommodation also started which is still

under process. There are beaches and resorts which means there is a large amount of movement going on this area. Geographically, the road is important since it connects the road of the Gulf Cooperation Council and Half Moon Bay.

The road, which is almost straight, extends between the bridge of the Air force base and Half Moon Bay road. Many projects are going on in halfmoon bay area.

2.3 Geometrical description of the project

The general hospital and its multilevel parking will be constructed on about 3.5 away from the intersection of Half Moon and Al-khaldiyah roads. These two buildings will be constructed close to the "Roundabout Tunnel" almost at the middle of the road. As indicated previously, the buildings will be on a road characterized by six lines in both directions extending over about 10 km length (Figures 2.2*a* & *b*).

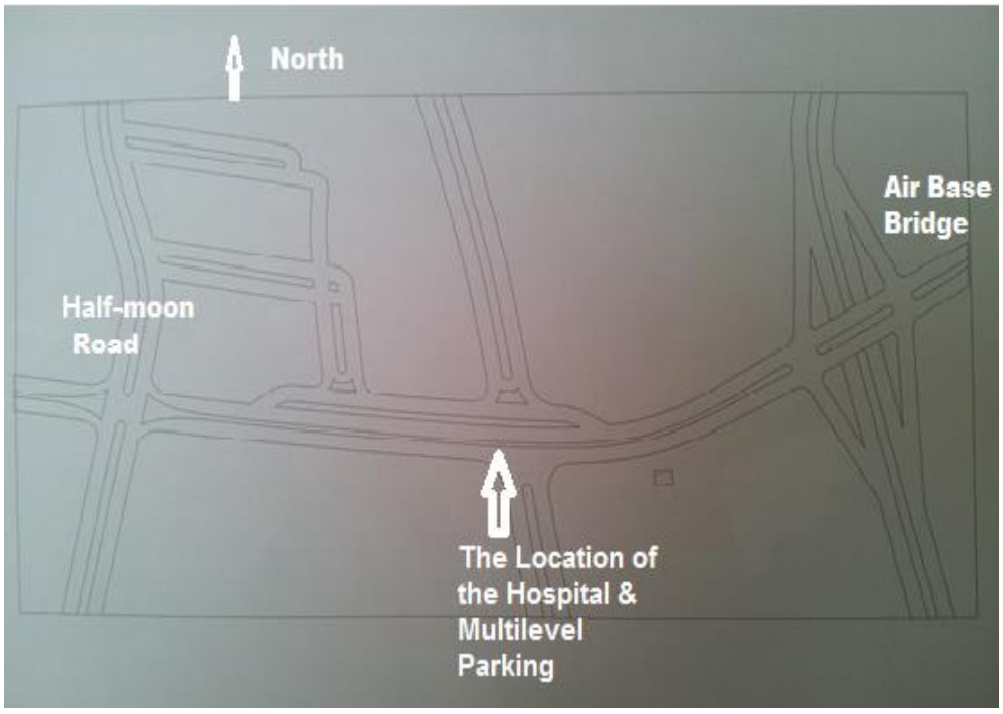


Figure 2.2*a*: The actual plane view of the Hospital in between Halfmoon bay road and GCC road (plan1)

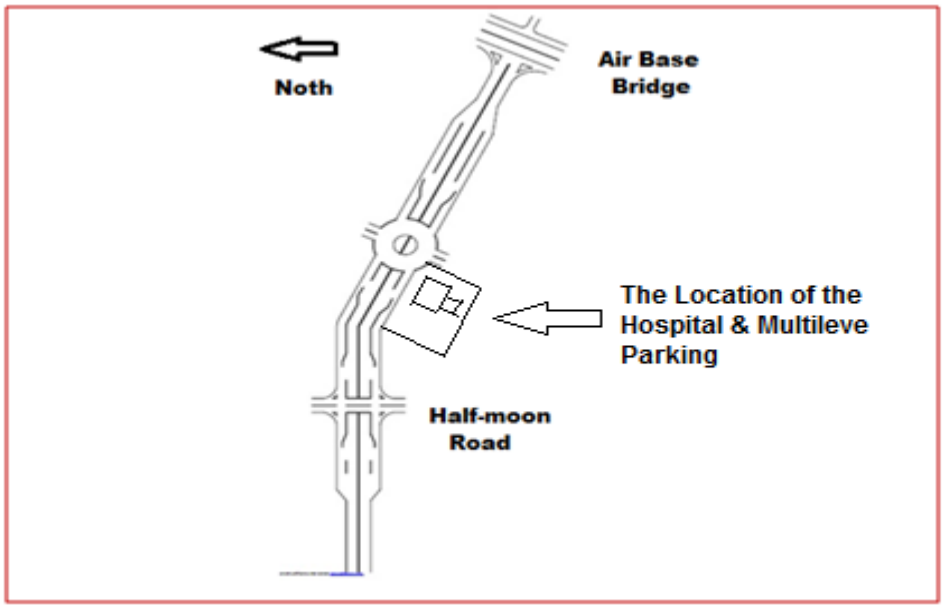


Figure 2.2*b*: The actual plane view of the Hospital (plan 2)

The actual width of the Hospital is 41 meters with an actual length of 50 meters. The hospital is consist of (12) twelve floors or stories with total height of 61 meters. The height of ground and first floor is designed to be (3.70) meters. And the height of other (11) floors is designed to be (4.7) meters (Figures 2.2*c*).

Figure 2.2c: The actual plane view of the Hospital (plan 1)

A list of the purpose and the use of each floor:

1. The ground floor, as reception and Pharmacy.
2. First floor, as Administration and Masjid.
3. Second floor, as Specialized Clinics.
4. Third floor, as Specialized Clinics.
5. Fourth floor, as Physiotherapy & Dermatology.
6. Fifth floor, as Cardiology.
7. Sixth floor, as Nursery, Delivery and Caesarean Section.
8. Seventh floor, as Female Ward.
9. Eighth floor, as Female Ward.
10. Ninth floor, as Children Ward.
11. Tenth floor, as Children Ward.
12. Eleventh floor, as Male Ward.
13. Twelfth floor, as Male Ward.

The actual width of the multilevel parking is 37 meters with an actual length of 50 meters. The multilevel parking is consist of (5) five floors or stories with total height of 23 meters. The height of ground floor is designed to be (5) meters. And the height of other (4) floors is designed to be (4.3) meters (Figures 2.2*d*).

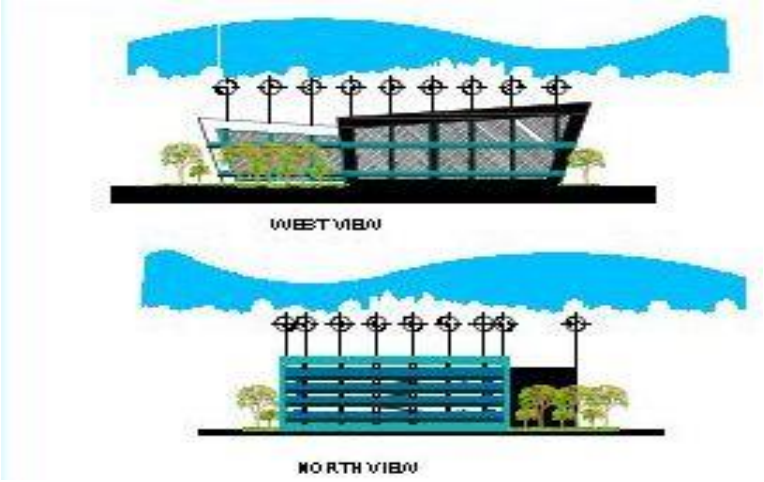


Figure 2.2d: The actual plane view of the Multilevel Parking (plan 1)

It is essential to note that:

- The hospital will have overall bed capacity of one hundred beds (100).
- (10) Ten Ambulance vehicles are kept ready for any emergency call.
- The multilevel parking cars capacity will be about one hundred fifty (150) cars.

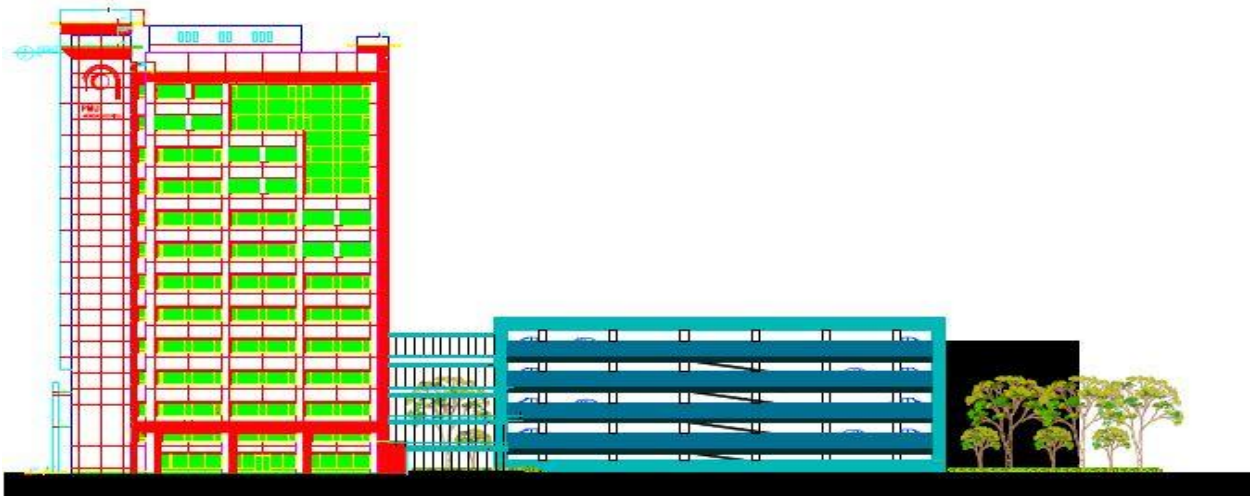


Figure 2.3: The actual plane view of the Hospital & the Multilevel Parking (plan 2)

Chapter 3 : Soil Report

3.1 Introduction

The soil report relating to this chapter is concerned with describing the site of construction, laboratory tests, soil reports and its ground profile. Whatever results we get from these laboratory tests will be used for designing the hospital and multi-level parking.

In this case, we used the soil report which was used for PMU University accommodation in the present geotechnical design. The soil in this area mostly homogenous. We used some of the information which we got from our senior students which were produced by the Gulf Company.

3.2 Field Investigation

The main aim of this site surveying is to calculate the stratigraphy of sub- surface, the geotechnical constraints, the geotechnical parameters, and finally the surface conditions of the project site.

Table 3.1: Drilled boreholes details (from Gulf Company)

Location	Proposed Structure	PH No.	Termination Depth (m)
Prince Mohammad Bin Fahd Housing Complex	Staff Building	PH-1	15.0
		PH-2	15.0
		PH-3	15.0
	Info. Center	PH-4	10.0
	Under Ground Tank	PH-5	15.0
	Building	PH-6	15.0
		PH-7	15.0
		PH-8	15.0
	Clinic Building	PH-9	10.0

3.3 Laboratory Testing

Classification of representative soil and water samples recovered from each borehole was performed utilizing the following tests.

Table 3.2: Standard codes of Laboratory Tests (from Gulf Company)

Type of Test	Standard code
Particle Size Analysis	ASTM D 422
Moisture content tests	ASTM D 2216
Specific Gravity tests	ASTM D 854
Atterberg Limits tests	ASTM D 4318

The soil classification and Index tests samples such as percent of materials (Passing through Sieve No. 200), moisture content and Atterberg Limit are included in the Appendix A. Some samples of Particle size analysis graphs and specific gravity test results are also presented in Appendix A.

Unconfined Compressive Strength (UCS) test was performed as per ASTM D-2166 on representative clay soil samples which are collected by triple tube core barrel. The Unconfined Compressive Strength of tested clay samples 16.45g/cm2. Stress-Strain relationship graph is presented in Appendix-B3. Bases on the test results, the clay stratum encountered at the project site can be categorized under "cemented SILTSTONE". Summary of test result are tabulated below:

Table 3.3: Summary of Unconfined Compressive Strength (UCS) Test Results

(from Gulf Company)

Borehole Numbers	Depth (Meters)	Dry Density (gm/cc)	Unconfined Compressive Strength (kg/cm2)	Soil Description
PH-01	9.50-11.0	1.626	16.45	Cemented SILTSTONE

The classification system of Clark and Walker (1977) developed for the carbonate formation in Middle East. Some samples of the results of carbonate content tests are given in

Appendix A. As per the test results, the percentage of carbonate in soil is varies between 4.920% - 46-216%. In view of these results, the subsoil at the site can be classified as "Calcareous" according to classification chart developed by Clark and Walker (1977). Carbonates Classification System as per Clark & Walker is also presented in Appendix A.

The chemical contents of soil and water were determined in accordance with the following methods:

- Acid Soluble Sulfate, in accordance with BS 812 part 118
- Acid Soluble Chloride, in accordance the BS 812 part 112
- pH Value of soil – in accordance with ASTM D 4972
- Water Soluble Sulfate, in accordance with ASTM D-516
- Water Soluble Chloride, in accordance with ASTM D-512
- pH Value of water – Direct meter reading

Test Results samples are presented in Appendix A. Based on chloride & sulfate, content, concrete foundations exposure classification as per CIRIA Special Publication 31 is tabulated below:

Table 3.4. Chemical Analysis Results

Type of Material	Chemical Concentration		Exposure Classification As per CIRIA Special Publication No. 31
	Sulfate	Chloride	
Soil	0.073%-0.182%	0.459%-3.213%	Class-V

3.4 Site Conditions

The hospital is to be situated near the Prince Mohammed Bin Fahd University, which is approximately pointed as in between the Halfmoon bay road and GCC road, Saudi Arabia. Location of the project site is shown in the Figure. The ground surface at the project site is leveled and approximately 1.00 higher than adjacent asphalted road level.

According to the laboratory analysis and field inspection of illustrative soil samples, stratigraphy in the sub-surface up to the maximum drilled depth is determined. The layers come across and their engineering features are as follows:

Table 3.5: Subsurface Stratification (from Gulf Company)

Borehole No.	Layer	Depth (m)	Soil Description	Range of SPT "N" value
PH-1 PH-2 & PH-3	I	0.00-5.00	Brownish gray, medium dense fine to medium SAND with silt SP-SM to silty SAND (SM)	13-25
	II	2.00-3.50	Brown, loose, poorly graded fine to medium SAND with silt (SP-SM)	8
	III	5.00-7.50	Brownish gray, dense to very dense, poorly graded fine to medium SAND with silt (SP-SM) to silty SAND (SM)	47-71
	IV	7.50-15.0	Yellowish brown to gray, dense to very dense, clayey SAND (SC) to hard, sandy SILT (ML) to sandy silty CLAY (SL-ML)	21-Refusal
PH-4	I	0.00-2.00	Brownish gray, loose, poorly graded fine to medium SAND with silt (SP-SM)	7
	II	2.00-4.00	Dark gray, medium dense, poorly graded fine to medium SAND with silt (SP-SM)	11-17
	III	4.00-7.50	Gray, very dense, fine to medium SAND with silt (SP-SM)to silty SAND (SM)	63
	IV	7.50-10.0	Gray, medium dense, fine to coarse clayey SAND (SC)	20-26
PH-5	I	0.00-1.00	Brown, loose poorly graded fine to medium SAND with silt (SP-SM)	6
	II	1.00-3.00	Gray, medium dense, poorly graded fine to medium SAND with silt (SP-SM)	14-24
	III	3.00-750	Gray, very dense poorly graded fine to medium SAND with silt (SP-SM)	>50
	IV	7.50-10.5	Gray, hard, lean CLAY with sand (SL)	35-48
	V	10.5-13.5	Whitish gray, medium dense, fine to coarse silty SAND (SM)	11-13
	VI	13.5-15.5	Gray hard, sandy silty CLAY (CL-ML)	31-38

Table 3.6: Subsurface Stratification (from Gulf Company)

Borehole No.	Layer	Depth (m)	Soil Description	Range of SPT "N" value
PH-6 PH-7 & PH-8	I	0.00-4.00	Brownish, gray, very loose to loose, fine to medium SAND with silt (SP-SM)	2-10
	II	4.00-5.00	Gray, medium dense, poorly graded fine to medium SAND with silt (SP-SM)	20
	III	5.00-7.50	Gray, very dense, poorly graded fine to medium SAND with silt (SP-SM)	56-Refusal
	IV	7.50-10.5	Brownish gray, hard, lean CLAY (CL)	37-Refusal
	V	10.5-13.5	Whitish gray, medium dense to dense, fine to course silty SAND (SM)	16-41
	VI	13.5-15.5	Gray, hard, plastic SILT (ML)	>100
PH-9	I	0.00-2.00	Brownish gray to dark gray, very dense, fine to medium cemented silty SAND (SM)	>100
	II	2.00-3.00	Dark gray, loose, fine to medium silty SAND (SM)	10
	III	3.00-5.00	Gray, medium dense, fine to medium silty SAND (SM)	13-29
	IV	5.00-7.50	Gray, very dense, poorly graded fine to medium SAND with silt (SP-SM)	53-59
	V	7.50-10.0	Gray, hard, sandy silty CLAY (CL-ML)	25-43

As indicated previously, sample of bore logs included in Appendix provides all necessary information on sub-surface conditions.

The level of the ground water was measured 24 hours after the closure of boreholes. It is to be underlined that the ground water level will be influenced by seasonal variations. For measurement of ground water in future (by client), a PVC Piezometer was installed in Borehole PH-1. Ground water measure in each borehole is tabulated below:

Table 3.7. Ground Water Level:

Borehole No.	Ground Water Level (BGL)	Borehole No.	Ground Water Level (BGL)
PH-1	0.55	PH-6	0.50
PH-2	0.38	PH-7	0.50
PH-3	0.40	PH-8	0.50
PH-4	0.50	PH-9	0.50
PH-5	1.00		

On the basis of the recorded SPT blow counts, soil design parameters, such as angle of internal friction and coefficient of earth pressure are derived using the empirical correlation. Taking into considerations the localized subsoil variations between the drilled boreholes, generalized soil parameters are tabulated below:

Table 3.8: Soil Design Parameters (from Gulf Company)

BH No.	Layer	Depth (m)	Soil Type	Range of SPT "*N*" values	Ave. SPT	*Ybulk* (kN/m^3)	*Φ* Deg.	C_u kN/m^2
PH-1 PH-2 & PH-3	I	0.00-5.00	SP-SM/SM	18	18	17.0	32	-
	Ia	2.00-3.50	SP-SM	8	8	16.0	29	-
	II	5.00-7.50	SP-SM/SM	47.71	>50	19.5	36	-
	III	7.50-15.0	ML	36 Refusal	>50	18	30	50
	IIIa	12.0-15.0	ML	8-10	9			
PH-4	I	0.00-2.00	SP-SM	7	7	16.0	29	-
	II	2.00-4.00	SP-SM	11-17	14	16.5	31	-
	III	4.00-7.50	SP-SM/SM	63-66	>50	19.5	36	-
	IV	7.50-10.0	SC	20-60	22	17.5	30	50
PH-5	I	0.00-1.00	SP-SM	6	6	16.0	29	-
	II	1.00-3.00	SP-SM	14-24	19	17.0	32	-
	III	3.00-7.50	SP-SM	56-Refusal	>50	19.5	37	-
	IV	7.50-10.5	CL	35-48	42	19.0	-	200
	V	10.5-13.5	SM	11-13	12	16.0	30	-
	VI	13.5-15.5	CL-ML	31-38	35	18.5	-	150
PH-6 PH-7 & PH-8	I	0.00-4.00	SP-SM	4-10	8	16.0	29	-
	II	4.00-5.00	SP-SM	20	20	17.0	32	-
	III	5.00-7.50	SP-SM	56-Refusal	>50	19.5	36	-
	IV	7.50-10.5	CL	37-Refusal	>50	19.5	-	200
	V	10.5-13.5	SM	15-41	14	17.5	32	-
	VI	13.5-15.5	ML	21-Refusal	>50	19.5	20	50
	I	0.00-2.00	SM	>100	>100	19.5	36	-
	II	2.00-3.00	SM	10	10	16.0	29	-
	III	3.00-5.00	SM	13-29	21	17.0	32	-
	IV	5.00-7.50	SP-SM	53-59	>50	19.5	37	-
	V	7.50-10.0	CL-ML	25-43	34	18.5	-	150
Cu=Unconfined Comp. Strength; Φ = Angle of Internal friction degrees; ybulk= bulk density								

Table 3.9: Coefficient of Earth Pressure

Angle of Internal Friction (Φ) degrees	Coefficient of Earth Pressure		
	At Rest Condition (K_o)	At Active Condition (K_a)	At Passive Condition (K_p)
28	0.531	0.361	2.77
29	0.515	0.347	2.88
30	0.500	0.333	3.00
31	0.485	0.320	3.12
32	0.470	0.307	3.25
33	0.455	0.295	3.29
34	0.441	0.283	3.54
35	0.426	0.271	3.69
36	0.412	0.260	3.85
37	0.398	0.248	4.03
38	0.384	0.238	4.20

3.5 Foundation Design Considerations

Subject to the magnitude of structural loads, its type that is static or dynamic and sensitivity of structures to settlements, shallow or deep foundations are to be considered. For the persistence of selection of suitable foundations system under static loads, the magnitude of structural loads on footings could be grouped under three categories as given below;

Magnitude of Load (kN)	Load Category
Up to 500	Light of moderate
Between 500 - 1000	Moderate Heavy
More than 1000	Heavy

A suitable foundation of any structure designed in accordance with recommended Net Safe Bearing Capacity must fulfill two (2) independent conditions with respect to underlying foundation soil. Firstly, the foundation must have an adequate factor of safety against exceeding the strength of the foundation soil. Secondly, the vertical movement of the foundation soil must be within the tolerable limits for the structure.

In view of these two important facts, all types of considered and recommended foundation in this report will satisfy the above criteria.

The Safe Bearing Capacity for footings are calculated as per Chapter IV of "Foundation Analysis and Design" by Joseph E. Bowles. The settlements in non-cohesive soils are computed as per Schmertmann's Method (Schmermann and Hartmann, 1979) The engineering properties of soil are evaluated mainly on the basis of results of the Standard Presentation Test (SPT) N values. The Modulus of Elasticity (E) of the soil is obtained from the correlation between E and SPT blow counts.

The following allowable settlement values are followed:

- Total vertical settlement for isolated spread or strip foundations: 25 mm
- Differential vertical settlement for isolated and strip foundations: 18 mm
- Total vertical settlement for raft foundation: 50 mm
- Differential vertical settlement for raft foundations: 18 mm
- Factor of safety of 3 provided against bearing capacity.

It is proposed to construct Prince Mohammed Bin Fahd Housing Complex at the project site. Variation in subsoil condition has been observed across the site with depth. Loose of SAND was encountered generally upto about 4.0m depth. The depth of the loose layer of SAND in each borehole is tabulated below:

Table 3.10: Depth of loose layer of sand (from Gulf Company)

PH No.	Depth of loose SAND BGL (m)	PH No.	Depth of loose SAND BGL (m)
PH-1	-	PH-2	2.00-3.50 & 12.0-13.5
PH-3	-	PH-4	0.00-2.00
PH-5	0.00-1.00	PH-6	0.00-4.00
PH-7	0.00-4.00	PH-8	0.00-4.00
PH-8	0.00-4.00	*BGL = Below Ground Level*	

Ground surface at the project site is approximately 1.0 m higher than the adjacent asphalted road level.

Table 3.11: Fill height at the proposed constructions (from Gulf Company)

Location	Proposed Structure	PH No.	Termination Depth (m)	Total Height of Backfilling	No. of Floors
Prince Mohammad Bin Fahd Housing Complex	Staff Building	PH-1	15.0	3.60	Six Storey
		PH-2	15	3.60	
		PH-3	15	3.60	
	Info. Center	PH-4	10	2.50	Single Storey
	Under Ground Tank	PH-5	15	3.60	N/A
	Building	Ph-6	15	3.60	Single Storey
		PH-7	15	3.60	
		PH-8	15	3.60	
	Clinic Building	PH-9	10	3.60	

Maximum expected settlement at the proposed construction due to the surcharge load from the fill is given below:

Table 3.12: Expected Settlement (from Gulf Company)

Proposed Construction	Fill Height (m)	Maximum Expected Settlement (mm)
Staff Bldg. (PH-1, 2 & 3)	3.60	11.0
Building (PH-6)	3.60	31.0
Info. Center	3.60	10.0
Clinic Building	3.60	12.0

Table 3.13: Recommended NABC & Recommended Footing Type (from Golf Company)

Proposed Structure	BH No.	Foundation *Depth (Df) BGL (m)	Foundation Type	Foundation Width "B" (m)	Recommended NABC "qa"(kN/m2)	Recommended Footing
Staff # 2	PH-1 PH-2 & PH-3	1.0	Isolated Spread	B≤ 2.0	200	Rigid Raft
				2.0 < B ≤ 3.0	170	
			Strip Footing	B ≤ 2.0	160	
				2.0 < B ≤ 3.0	150	
Info. Center	PH-4	1.0	Isolated Spread	B≤ 2.0	160	Spread/ Strip Footing
				2.0 < B ≤ 3.0	140	
			Strip Footing	B≤ 2.0	140	
				2.0 < B ≤ 3.0	120	
Mosque	PH-6 PH-7 & PH-8	1.0	Isolated Spread	B≤ 2.0	160	Rigid Raft
				2.0 < B ≤ 3.0	120	
			Strip Footing	B≤ 2.0	120	
				2.0 < B ≤ 3.0	100	
Clinic Bldg.	PH-9	1.0	Isolated Spread	B≤ 2.0	200	Spread/ Strip Footing
				2.0 < B ≤ 3.0	160	
			Strip Footing	B≤ 2.0	150	
				2.0 < B ≤ 3.0	130	
**Depth below the finished grade level*						

Table 3.14: Recommended Net allowable Safe Bearing Capacity (from Golf Company)

BH No.	Foundation *Depth (D_f) (m)	Foundation Type	Foundation Width "B" (m)	Recommended NABC "q_a" (kN/m^2)	Remarks
PH-1,2, 3, 4, 5 & PH-9	1.0	Rigid Raft	10.0	140	-
			15.0	90	
			20.0	70	
PH-6, 7 & 8	1.0	Rigid Raft	10	100	-
			15	180	
			20	70	
**Depth below the finished grade level*					

3.6 Dewatering

The ground water table was discovered at an average depth of 0.5 meters below the prevailing ground level. For foundations placed below the ground water table dewatering is required. For dewatering, "Well Point System" may be implemented.

A typical dewatering procedure for well point system could be as following:

- Excavate to near anticipated ground water level after the protection of the sides by suitable shoring system.
- Install well points around the perimeter of the area to be excavated.
- The well points should extend below the foundation to a depth of at least about 1.5times the excavation depth below the ground water level. The well points shall be spaced at about two meter center to center (other spacing criteria may be adopted to suit the field conditions)

Dewatering should be completed by pumping the water from the well points. After successful dewatering, excavate the remaining soils to the desired final grade. Supplemental well points may be necessary to lower the ground water levels below the bottom of interior of the excavations.

3.7 References

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Soil Mechanics in Engineering Practice (1967), bye Terzagi & Peck.

Soil Mechanics (1979), by Lambe and Withman. Jhon Wiley & Sons, New York

Earth Manual (1963) United States Department of Interior, Bureau of Reclamation.

CIRIA Special Publication No. 31. CIRIA Guide to Concrete Construction in the Aric Region, Construction Industries and Research and Information Association, Londo.

Foundation Analysis and Design (1988), by Joseph E. Bowles. MC Graw-Hill International Book Company, London.

CHAPTER 4: STRUCTURE DESIGN

4.1 Introduction

This section includes the structural design and many other aspects of the hospital and multilevel car parking. For calculations we will use SAP2000 software which is a program used for structural analysis. First the hospital floors unit will be calculated and then we will calculate for multilevel car parking. It's main function is to make use of appropriate steel reinforcements for the different concrete elements and the solicitations which will ultimately be transferred to the foundation system.

4.2 Design of the Hospital floors unit

As indicated in chapter 2, the hospital is composed of twelve floors or stories. Each floor will cover an area of 41m×34m. The dead and live load considered for the design area are taken from the Saudi Building Code (SBC). The live load is taken to be 5 KN/m^2. However, a factor of safety of 1.6 is applied on the live load; while, a factor of 1.4 is applied on the dead load. In addition, all safety factors are calculated automatically in SAP2000.

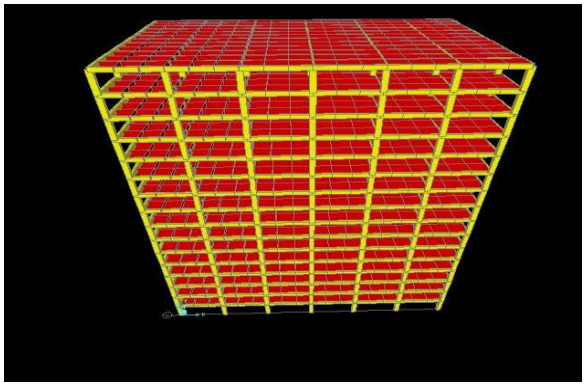


Figure 4.1: Design of hospital floors unit (SAP2000).

All columns are considered to be connected (from the ground to the twelfth floor). The following data are used in the SAP design: i)- The columns are identical and have a cross section of 110 cm×80 cm, ii)- 6 #20 are considered as the longest side and 4 #20 in the shorter side, iii)- The concrete is of the type 4000 psi, iv)- The tie reinforcement is taken #4 every 20 cm, and v)- The reinforcement of the columns is considered the same in the vertical direction from ground to twelfth floor.

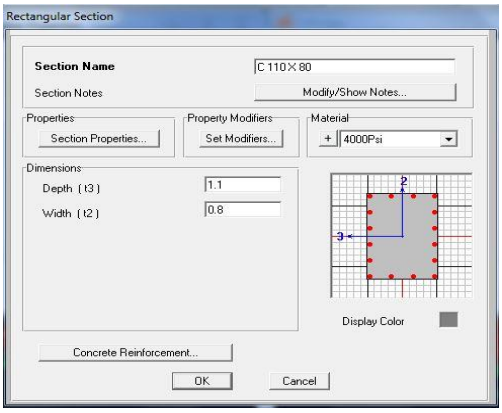


Figure 4.2: Reinforcement of the columns.

All the area is designed in plane-stress with a concrete of the type 4000 psi concrete, a thickness of 28 cm, and the load is considered acting or distributed over the entire area.

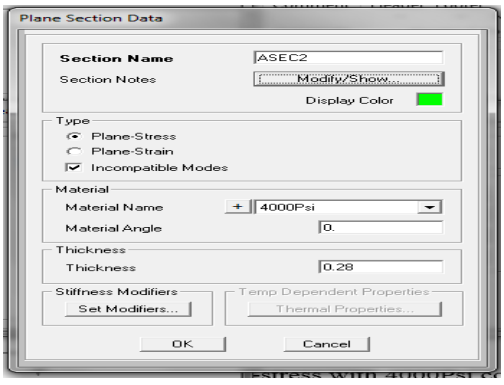


Figure 4.3: Plane section data.

The results obtained from the software SAP2000 are represented as follows:

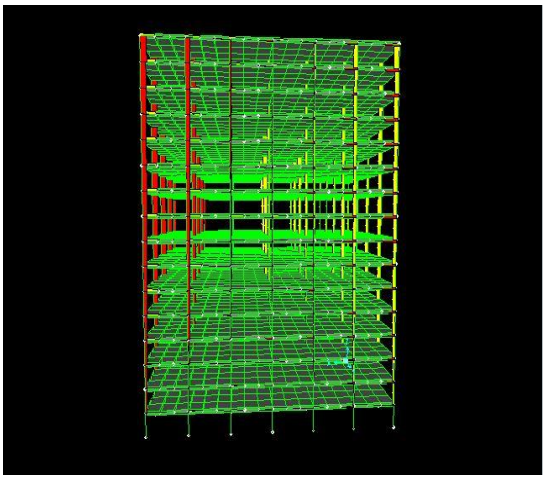


Figure 4.3: Deformation Shape (SAP2000)

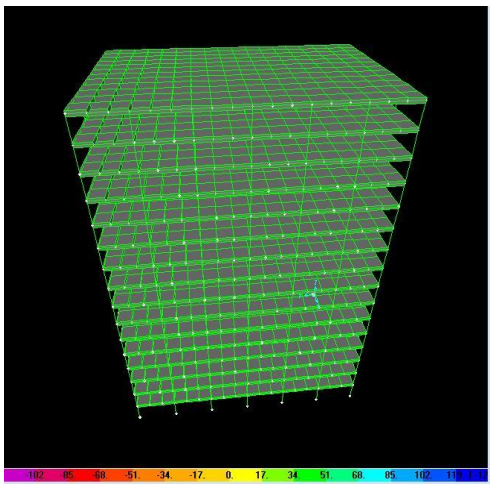


Figure 4.4: Stress on the Slabs (SAP2000)

4.3 Design of the multilevel car parking

The multilevel car parking is a five floors (stories) structure. It is covering an area of about 1517 m^2. The dead and live load considered for the design area taken from the Saudi Building Code (SBC). The live load is taken to be 5 KN/m^2. However, a factor of safety of 1.6 is applied on the live load; while, a factor of 1.6 is applied on the dead load. In addition, all safety factors are calculated automatically in SAP2000. Obviously, all the loads are transferred to the beams and then to the columns.

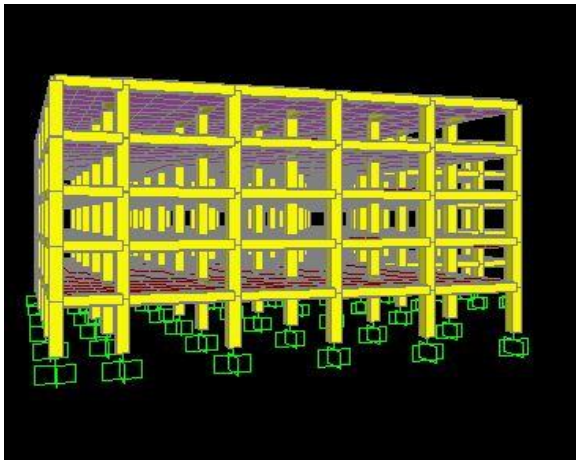


Figure 4.7: Design of Multilevel parking #1 (SAP2000)

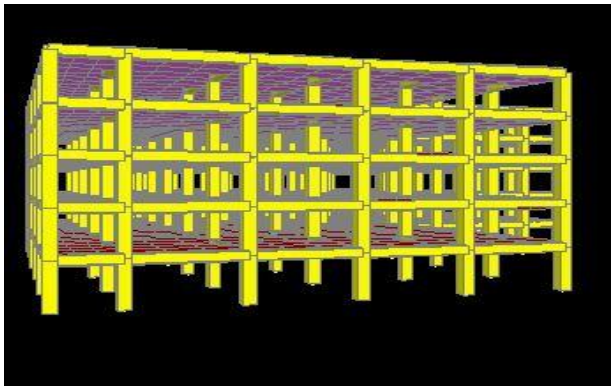


Figure 4.8: Design of the Multilevel parking #2 (SAP2000).

Similarly to the hospital floors unit, the columns are designed to have a cross section area of 110 cm× 80cm. They are taken to have 6 #20 in the longest side and 4 #20 in the shortest side. The tie reinforcement is considered to be #7 every 15 cm.

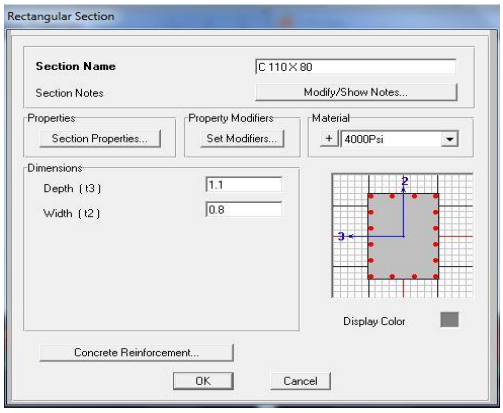


Figure 4.9: Multilevel parking columns design (SAP2000).

The thickness of the multilevel parking slabs is 30 cm and is made of a concrete corresponding to the type 4000 psi. The live load is considered to be 5 kN/m^2 distributed over the entire area.

Figure 4.10: Multilevel parking Shell Section Data (SAP2000).

The following figure shows the results obtained from SAP2000 corresponding to the assessment of collapse failure of the Multilevel parking structure. It is clear from this figure (based on the orange color) that all the columns are designed with an adequate safety and cost. Moreover, it is indicated that all the beams can handle the applied loads which are safely transferred to the slabs.

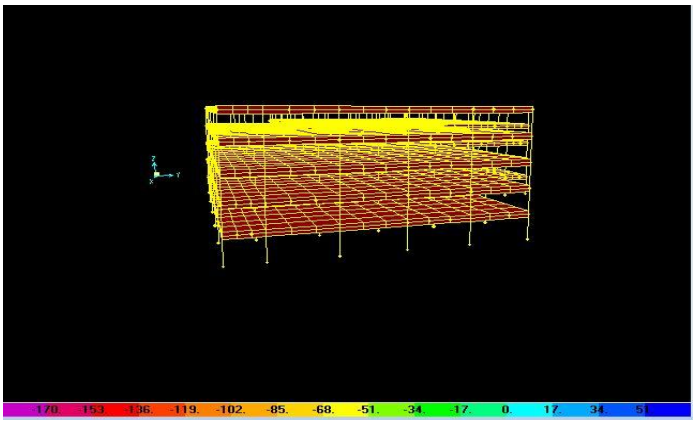


Figure 4.11: Stress on the Slabs (SAP2000)

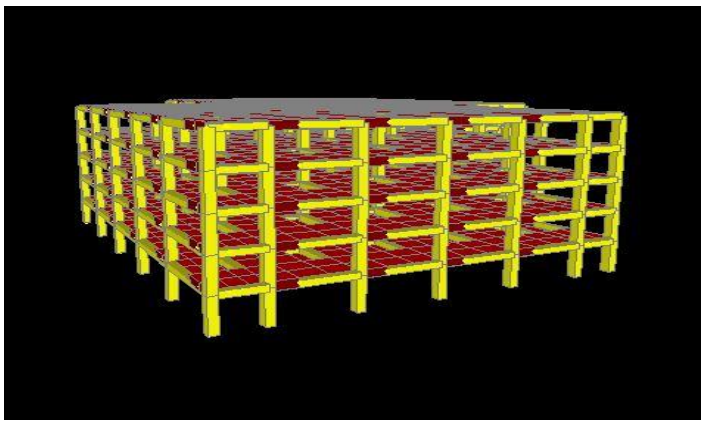


Figure 4.12: Results of deformation shape (SAP2000)

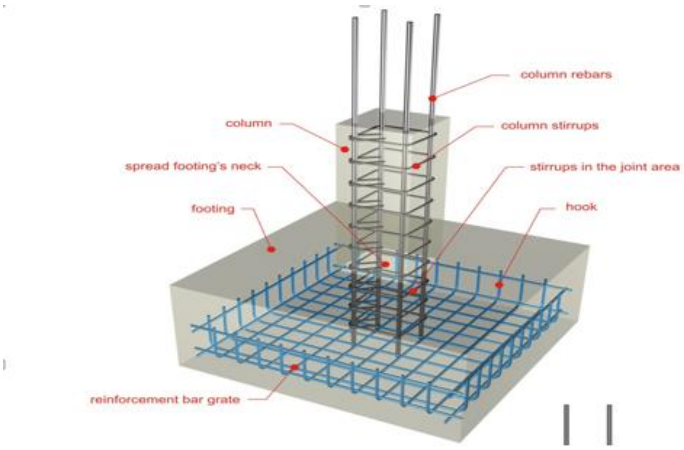
CHAPTER 5: GEOTECHNICAL DESIGN

5.1. Introduction

This chapter is concerned by the geotechnical design of the different elements of the general hospital with its multilevel parking. This section includes the calculations and verification of the suitable foundation system for different elements of those two buildings. We will first check for isolated foundation. If it does not works then we will go directly for Raft foundation. But if we opt for Raft foundation we need to verify the settlements.

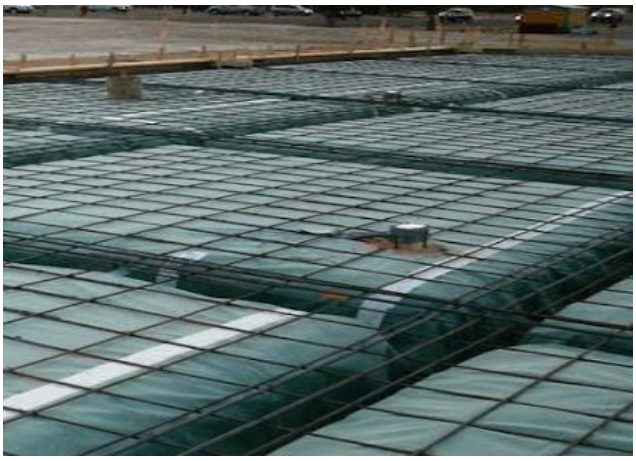
5.2. Isolated foundation

Isolated foundations (footings) are standalone families that are part of the structural foundation category. Several types of isolated foundations can be loaded from the family library, including pile caps with multiple piles, rectangular piles, and single piles.



Raft foundation

Raft foundation is a thick concrete slab reinforced with steel which covers the entire contact area of the structure like a thick floor. Sometimes area covered by raft may be greater than the contact area depending on the bearing capacity of the soil underneath. The reinforcing bars runs normal to each other in both top and bottom layers of steel reinforcement. Sometimes inverted main beams and secondary beams are used to carry column loads that require thicker foundation slab considering economy of the structure. Both beams cast monolithically with raft slab.



In other words, where deep foundation like pile foundation are not economical and feasible and isolated column footing is impracticable due to large footing size or over-lapping of neighbor footing , raft foundation is the economical solution.

5.3. Verification of the bearing capacity

5.3.1. Isolated foundation

1- <u>Hospital floors unit:</u>

Based on the results of the SAP2000 (Chapter 4), the foundation should be designed using a load Q = 14510 kN and bending moment M = 22.3 kN.m (Figures 5.7 & 5.8). The value of this moment is very small which can be neglected. The results of the verification are grouped in Table 5.1. It is worthy to mention that:

The stress transmitted to the foundation (q_{max}) is calculated as:

$$q_{max} = Q/A + 6 \times M/B^3$$

Where $A = B^2$ (Area of the foundation).

The principle of bearing capacity is verified if:

$$q_{max} \leq q_{all} \text{ (allowable stress)}$$

Joint Reactions in Joint Local CoordSys

Joint Object 17		Joint Element 17	
	1	2	3
Force	9.881	-20.368	14510.100
Moment	22.317	25.557	-3.228E-02

Figure 5.7. Joint reactions diagram in XZ direction (SAP200)

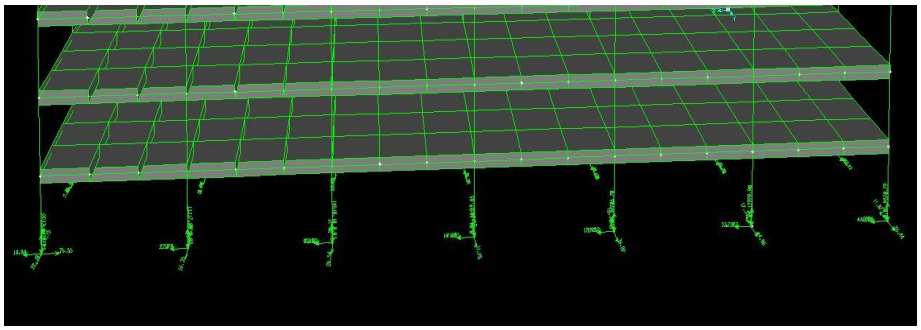


Figure 5.8. Joint reactions diagram in YZ direction (SAP2000)

N (kN)	Moment (kN.m)
14510	22.3

TABLE: Joint Reactions

Joint	F3	Mmax	B	Area	H	S	ς max	check	ς min	check	e	e3	check
Text	KN	KN-m									M/N	B/6	
1	14510.00	22.30	1.50	2.25	1.20	0.18	6572.78	ok	6325.00	ok	0.00	0.25	ok
2	14510.00	22.30	1.50	2.25	1.20	0.18	6572.78	ok	6325.00	ok	0.00	0.25	ok

Table 5.1: Results of bearing capacity verification for hospital floors units

Based on the results of Table 5.1, the following minimal dimensions were retained for the design of the foundation: D = 1.2 m and B = 1.5 m.

Where:

D = embedment depth.

B = width of the foundation.

2- <u>The multilevel parking:</u>

Similarly, based on the results of the SAP2000 (Chapter 4), the foundation should be designed using a load Q = 5940 kN and a bending moment M = 4.8 kN.m (Figures 5.9 & 5.10). The value of this moment is very small due to the dimension of the units and their rigidity). It can be neglected. The results of the bearing capacity verification for such foundation are grouped in Table 5.2.

Figure 5.9. Joint reactions diagram in XZ direction (SAP2000)

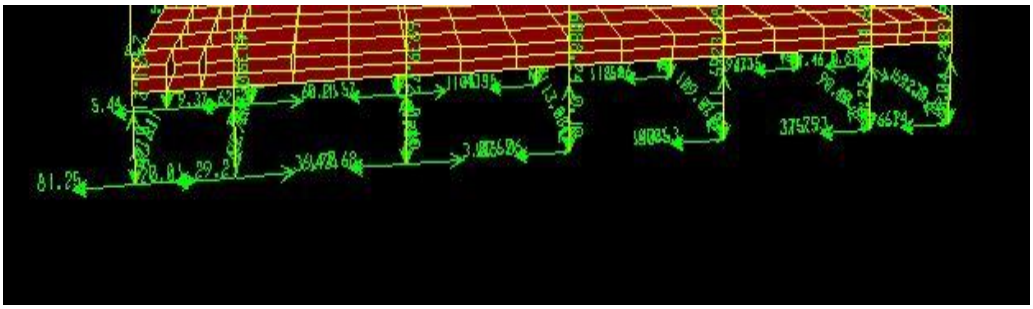


Figure 5.10. Joint reactions diagram in YZ direction (SAP2000)

N (kN)	Moment (kN.m)
5940	4.8

TABLE: Joint Reactions

Joint	F3	Mmax	B	Area	H	S	ç max	check	ç min	check	e	e3	check
Text	KN	KN-m									M/N	B/6	
1	5940.00	4.80	1.00	1.00	1.00	0.08	5997.60	ok	5882.40	ok	0.00	0.17	ok
2	5940.00	4.80	1.01	1.02	1.00	0.08	5879.99	ok	5765.93	ok	0.00	0.17	ok

Table 5.2 . Results of bearing capacity verification for foundations

Based on the results of Table 5.1, the following minimal dimensions were retained for the design of the foundation: D = 1.0 m and B = 1.0 m.

Where:

D = embedment depth.

B = width of the foundation.

Based on the results summarized in Tables 5.1 and 5.2, isolated foundation is useable and appropriate for the hospital and its multilevel car parking.

CHAPTER 6: CONCLUSION

6.1. Introduction

As mentioned before, the Kingdom of Saudi Arabia has a sophisticated and modern network of health care system. It has a total number of health care centers of about 1925 centers, 225 governmental hospitals, and 87 private hospitals, which gives the total number of beds to be equal 128366 beds.

Related to the faced problem during the construction, it found that loose sand and silt could found in the saturated soil and with water it can behave like a liquid when they are shaken by any external reasons (i.e. earthquake). Earthquake waves cause water pressures to increase in the sediment and the sand grains to lose contact with each other, leading the sediment to lose strength and behave like a liquid. In general, three factors are required for liquefaction to occur: i) Loose-granular sediment, ii) Saturation of the sediment by ground water (water fills the spaces between sand and silt grains), and iii) Strong shaking. When liquefaction occurs, the ability of a soil deposit to support foundations for buildings and bridges is reduced, causing turnover (Lose of bearing capacity).

In this chapter, some relevant conclusions, drawn from this investigation, are summarized. These general conclusions are concerned by the design and repartition of the different components of the hospital and its multilevel cars' parking; the structural and geotechnical design and the prototype.

6.2. General Conclusions

The main objectives of this project are the design of a general hospital (a structure of twelve stories) and a multilevel car parking which will be constructed in the Half Moon Bay area.

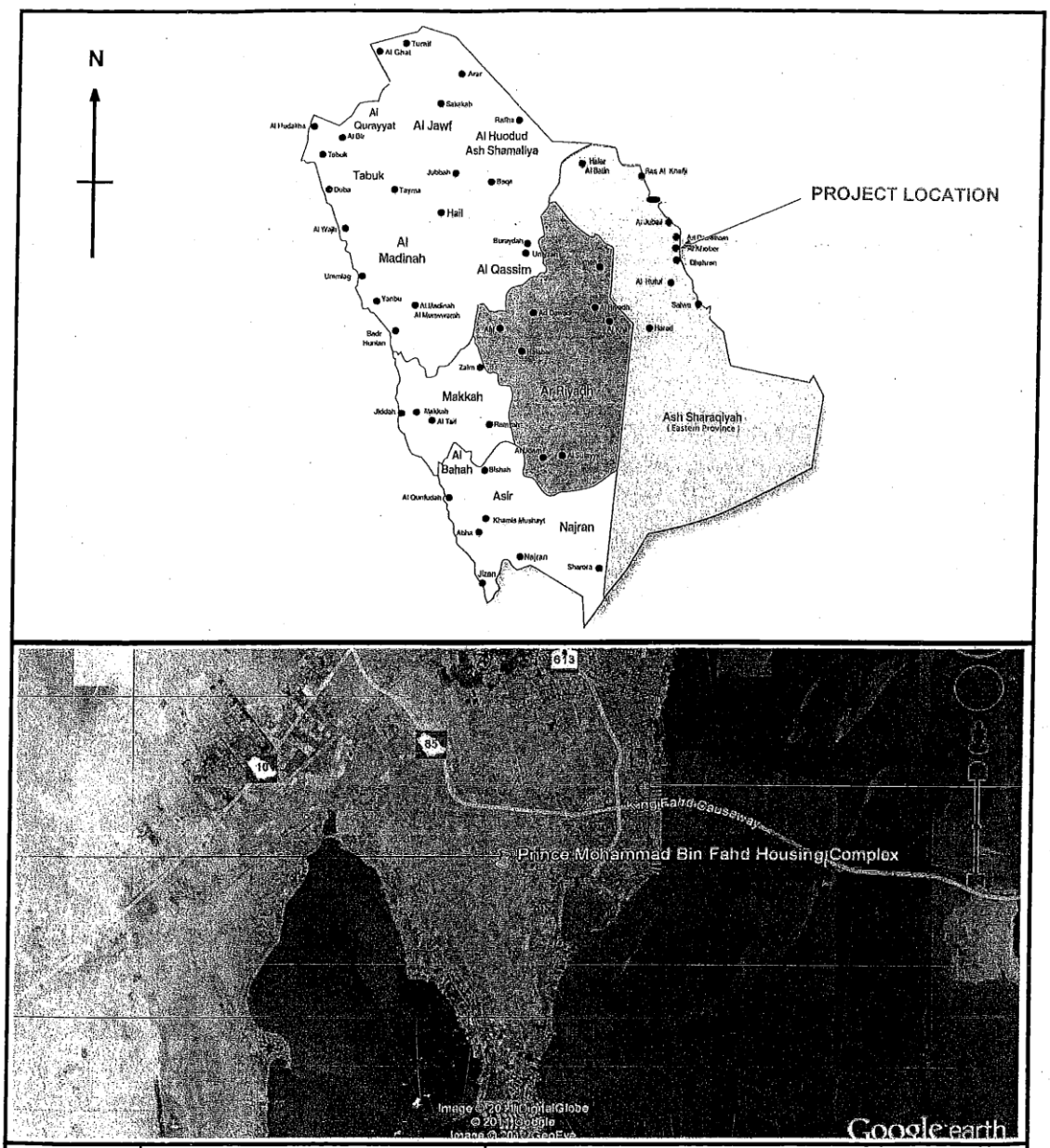
The project included:

- The design and repartition of the different components of the hospital and its multilevel cars' parking (such as twelve stories hospital, multilevel cars' parking).
- Development and design of a prototype for the project.
- Structural design of the different elements of the project (i.e. hospital floors units prototype and a parking) using appropriate computer software, in this case SAP2000.
- Geotechnical design which include the solution proposed for the foundation systems for the different elements of the project.

The general conclusion drawn from this project can be summarized as follows:

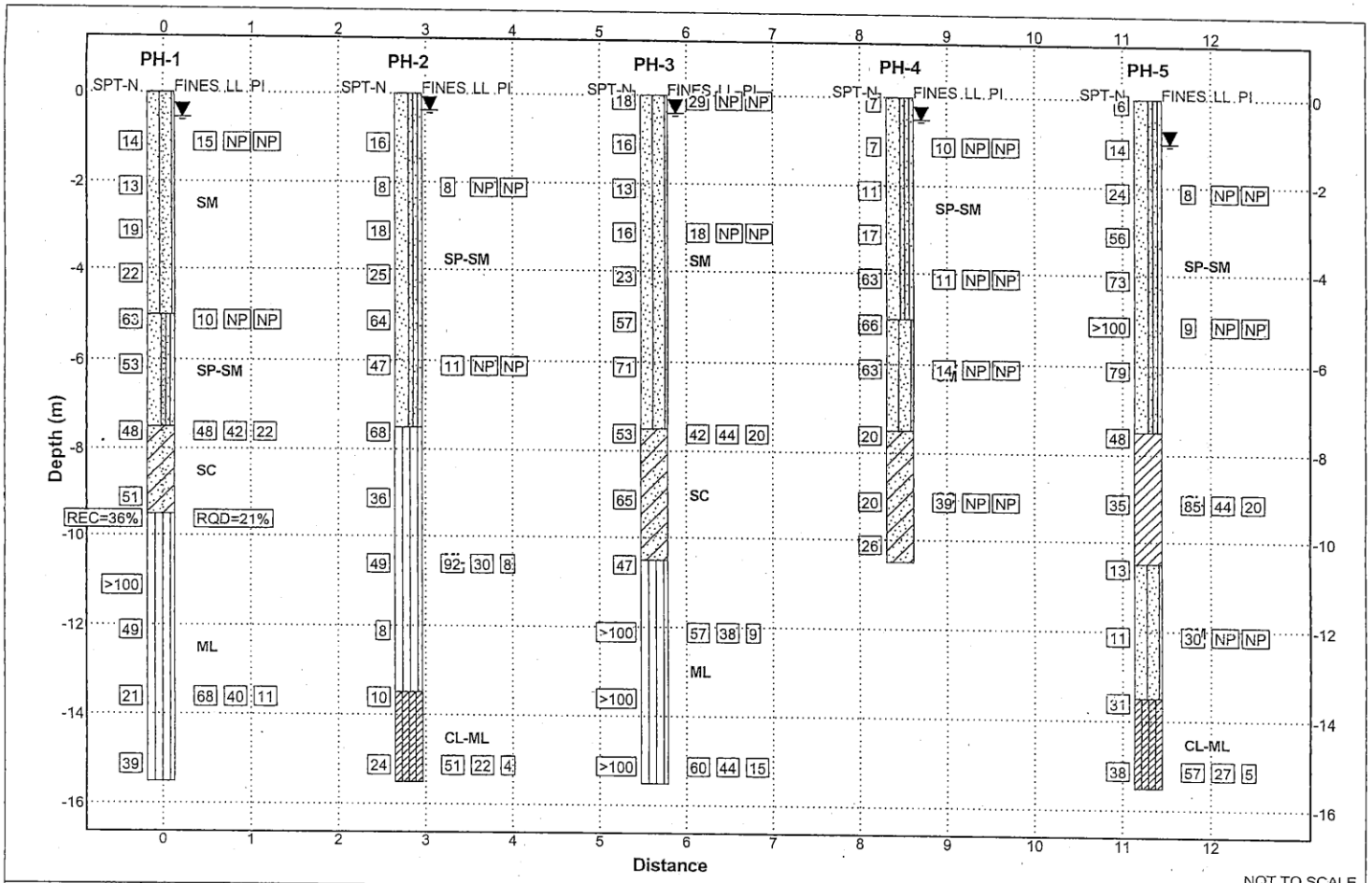
- A hospital and its multilevel car parking were developed and designed in a liquefiable soil (near to a beach). The site of the project extends over an area of about 60000 m^2. It is composed of twelve stories hospital and multilevel car parking. Furthermore, many access roads and different facilities were designed inside the habitation area.
- A prototype of the project was developed. The prototype shows the different components of the hospital and its multilevel car parking, as well as, the sand area and part of Al-Khaldyiah road.
- A structural design using computer software (SAP2000) was performed, on the different components of the project, in order to determine the appropriate reinforcements and the different solicitations transmitted to the foundations systems.
- A geotechnical investigation was carried out in order to select the appropriate solutions for the problem. Moreover, a geotechnical design was performed on the different foundation system proposed.
- One type of foundation system was adopted for this project which is isolated foundation.

APPENDIX A

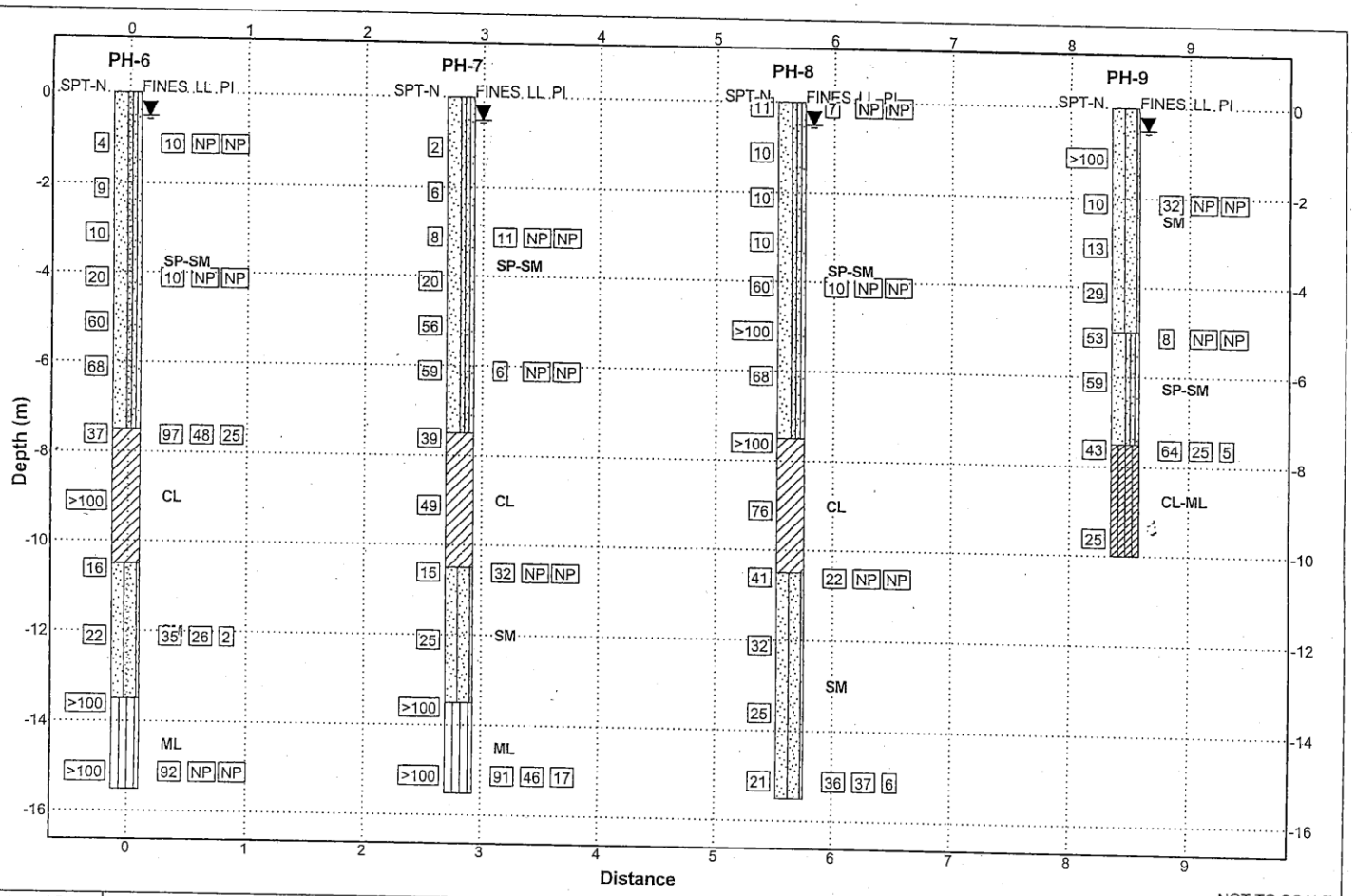


GULF CONSULT	**GULF CONSULT** (GEOTECHNICAL DIVISION)	**VICINITY PLAN**
		Project : Prince Mohammad Bin Fahd Housing
		Client : **Azmeel Contracting Company**
		Location : **Aziziyah, Halfmoon Bay**
		Job No. : GC/4759JO/12196-R/11
		SCALE: Not to Scale — **FIGURE - 1**

DIR



GULF CONSULT	PROFILE KEY SPT-N : SPT 'N'value FINES - % Passing #200 sieve LL - Liquid Limit (%) PI - Plasticity Index (%) NP - Non-Plastic	Project : **Prince Mohammad Bin Fahd Housing Complex** Location : Aziziyah, Halfmoon Bay Job No.: **11-12196** Geotech File No.:	**SUBSOIL PROFILE** Figure No.: **3/1**



PROFILE KEY
SPT-N : SPT 'N'value
FINES - % Passing #200 sieve
LL - Liquid Limit (%)
PI - Plasticity Index (%)
NP - Non-Plastic

GULF CONSULT

Project : **Prince Mohammad Bin Fahd Housing Complex**

Location : Aziziyah, Halfmoon Bay

Job No.: **11-12196** Geotech File No.:

SUBSOIL PROFILE

Figure No.: **3/2**

GULF CONSULT

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GEOTECHNICAL DIVISION
SYMBOLS USED IN BORE LOGS

FIGURE - 4

Job No.: 11-12196


Poorly graded Sand(SP)


Poorly graded sand with silt (SP-SM)


Silty Sand(SM)


Clayey sand(SC)


Sandy silt / SILT with sand (MLS)


Silt (ML)


Well graded sand with clay(SW-SC)


Well graded sand with silt(SW-SM)


Well graded sand with silt and gravel


Coral


Conglom


IGNSCG


METAFG


Fat silt(MH)


Lean clay(CL)


Fat clay(CH)


Silty clay(CL-ML)


Sandy lean clay(CLS)


Poorly graded sand with clay(SP-SC)


Asphalt


Fill


Concrete


IGNSMG


METACG


Gypsum


Boulders


Poorly graded gravel(GP)


Well graded gravel(GW)


Silty gravel(GM)


Gravel with silt & sand (GP-GM)


Well graded gravel with silt (GW-GM)


Clayey gravel(GC)


Limestone


Siltstone


Mudstone


Sandstone


IGNSFG


METAMG


BASALT

Job No.: 11-12196

FIGURE - 5

CLASSIFICATION CRITERIA FOR SOIL AND ROCK

I. SOIL

Density condition based on Standard Penetration Test for Non-Cohesive & Cohesive Soil *

(A) Sand & Non-Plastic Silt (Granular Soil)	
Relative Density	*Penetration Value (Blow/Feet)*
Very Loose	0-4 Blows
Loose	4-10 Blows
Medium Dense	10-30 Blows
Dense	30-50 Blows
Very Dense	50 & Up

(B) Clay & Plastic Silt (Cohesive)	
Consistency	*SPT "N" Value*
Very Soft	0-2 Blows
Soft	2-4 Blows
Medium	4-8 Blows
Stiff	8-15
Very Stiff	15-30
Hard	30 & Up

* *"Foundation Engineering"* by Peck, Hanson & Thornburn

II. INTACT ROCK

Relation Between RQD & In-Situ Rock Quality	
Rock Quality	*RQD (%)*
Excellent	90-100
Good	75-90
Fair	50-75
Poor	25-50
Very Poor	0-25

Strength		
Term	Unconfined Comp. Strength	
	Mpa	*Ksf*
Extremely Strong	>200	>4000
Very Strong	100-200	2000-4000
Strong	50-100	1000-2000
Moderately Strong	12.50-50	250-1000
Moderately Weak	5-12.50	100-250
Weak	1.25-5	30-100
Very Weak	0.40-1.25	10-30

WEATHERING

Fresh	Rock fresh with joints and may show slight straining
Moderate	Significant portions of rock show discoloration and weathering effects and show significant loss of strength compared with fresh rock
Severe	Rock shows severe loss of strength and can be excavated with Geologist's pick
Very Severe	Mass effectively reduced to soil with only fragments of strong rock remaining

* *"Rock Mechanic & Engineering Practice"*, by Stagg & Zienkieweics

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-1

Type of Boring : Rotary Wash | Date Started : 11/12/2011

Diameter of Boring : 4" | Date Completed : 11/12/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 0.55

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
1	TR				Gray, medium dense, fine to coarse silty SAND with gravel		
	SPT1	15 8 6			Ditto,		
2	TR						
	SPT2	4 7 6		SM	Ditto, dark gray		
3	TR						
	SPT3	4 6 13			Ditto,		
4	TR						
	SPT4	7 7 15			Ditto,		
5	TR						
	SPT5	17 27 36			Dark gray, very dense, poorly graded, fine to medium SAND with silt	>>	
6	TR						
	SPT6	18 20 33		SP-SM	Ditto,		
7	TR						
	SPT7	21 20 28			Gray, very dense, fine to medium clayey SAND		
8	TR			SC			
9	SPT8	16 25 26			Ditto,		
10	C1				Light yellowish, cemented SILTSTONE with few voids		
11				ML	UCS=16.45kg/cm^2		
	SPT9	50/11cm			Ditto,	>>	
12	TR						

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 1 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. , I.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay

Client : Azmeel Contracting Co.

BORING NO. PH-1

Type of Boring : Rotary Wash

Diameter of Boring : 4"

Sampling Hammer Wt & Drop : 140 Lbs & 30"

Date Started : 11/12/2011

Date Completed : 11/12/2011

Ground Elevation (m) :

Depth at Gr. Water Table (m): 0.55

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
13	SPT10	20 21 28		ML	Whitish gray, hard, sandy SILT		
	TR						
14	SPT11	4 8 13			Ditto, very stiff		
	TR						
15	SPT12	11 16 23			Ditto,		
16					Boring Terminated at 15.50 meters depth		
17							
18							
19							
20							
21							
22							
23							
24							

Legend : SPT1: Standard Penetration Test and No. A : Auger Boring
TR : Tricone Drilling NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 2 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-5

Type of Boring : Rotary Wash | Date Started : 11/15/2011

Diameter of Boring : 4" | Date Completed : 11/15/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 1.00

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
1	SPT1	2 3 3		SP-SM	Brown, loose, poorly graded, fine to medium SAND with silt		
	TR						
2	SPT2	4 7 7			Ditto, medium dense		
	TR						
3	SPT3	6 9 15			Ditto, dark gray		
	TR						
4	SPT4	11 21 35			Ditto, very dense		
	TR						
5	SPT5	15 31 42			Ditto,	>>	
	TR						
6	SPT6	22 38 50/13cm			Ditto, cemented	>>	
	TR						
7	SPT7	27 32 47			Ditto,	>>	
	TR						
8	SPT8	10 17 31		CL	Gray, hard, lean CLAY with sand		
	TR						
9	SPT9	10 13 22			Ditto,		
10	TR						
11	SPT10	4 5 8		SM	Whitish gray, medium dense, fine to coarse silty SAND		
12	TR						

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 1 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-5

Type of Boring : Rotary Wash | Date Started : 11/15/2011

Diameter of Boring : 4" | Date Completed : 11/15/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 1.00

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
13	SPT11	6 5 6		SM	Gray, medium dense, fine to medium silty SAND		
	TR						
14	SPT12	5 10 21		CL-ML	Gray, hard, sandy silty CLAY		
	TR						
15	SPT13	11 16 22			Ditto,		
16					Boring Terminated at 15.50 meters depth		
17							
18							
19							
20							
21							
22							
23							
24							

Legend : SPT1: Standard Penetration Test and No. A : Auger Boring
TR : Tricone Drilling NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 2 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-6

Type of Boring : Rotary Wash | Date Started : 11/14/2011

Diameter of Boring : 4" | Date Completed : 11/14/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 0.50

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
1	TR			SP-SM	Brownish gray, very loose, poorly graded, fine to medium SAND with silt		
	SPT1	3 2 2			Ditto,		
2	TR						
	SPT2	3 3 6			Ditto, loose		
3	TR						
	SPT3	2 4 6			Ditto,		
4	TR						
	SPT4	3 7 13			Ditto,		
5	TR						
	SPT5	16 20 40			Ditto, very dense		
6	TR						
	SPT6	20 25 43			Ditto,	>>	
7	TR						
	SPT7	16 15 22		CL	Brownish gray, hard, lean CLAY		
8	TR						
9	SPT8	13 25 50/14cm			Ditto,	>>	
10	TR						
	SPT9	5 7 9		SM	Whitish gray, medium dense, fine to coarse silty SAND		
11	TR						
12							

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 1 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-6

Type of Boring : Rotary Wash | Date Started : 11/14/2011

Diameter of Boring : 4" | Date Completed : 11/14/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 0.50

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
13	SPT10	10 9 13		SM	Whitish gray, medium dense, fine to medium silty SAND		13
	TR						
14	SPT11	50/8cm		ML	Gray, hard, plastic SILT	>>	14
	TR						
15	SPT12	50/6cm			Ditto,	>>	15
16					Boring Terminated at 15.50 meters depth		16
17							17
18							18
19							19
20							20
21							21
22							22
23							23
24							24

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 2 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel.8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-8

Type of Boring : Rotary Wash | Date Started : 11/13/2011

Diameter of Boring : 4" | Date Completed : 11/13/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 0.50

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
1	SPT1	3 7 4		SP-SM	Brownish gray, medium dense, poorly graded, fine to medium SAND with silt		
	TR						
2	SPT2	2 7 3			Ditto, loose		
	TR						
3	SPT3	3 4 6			Ditto,		
	TR						
4	SPT4	3 3 7			Ditto,		
	TR						
5	SPT5	12 25 35			Ditto, very dense		
	TR						
6	SPT6	16 33 50/13cm			Ditto, cemented	>>	
	TR						
7	SPT7	17 29 39			Ditto,	>>	
	TR						
8	SPT8	16 42 50/8cm		CL	Greenish gray, hard, lean CLAY with sand	>>	
	TR						
9	SPT9	17 30 46			Ditto,	>>	
10	TR						
11	SPT10	17 18 23		SM	Whitish gray, dense, fine to coarse silty SAND with gravel		
	TR						
12							

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 1 OF 2

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SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

Location : Aziziyah, Halfmoon Bay | Client : Azmeel Contracting Co.

BORING NO. PH-8

Type of Boring : Rotary Wash | Date Started : 11/13/2011

Diameter of Boring : 4" | Date Completed : 11/13/2011

Ground Elevation (m) : | Sampling Hammer Wt & Drop : 140 Lbs & 30" | Depth at Gr. Water Table (m): 0.50

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Symbol	Classification	DESCRIPTION	Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)	REMARKS
	SPT11	9 14 18			Gray, dense, fine to coarse silty SAND		
13	TR						13
	SPT12	5 7 18		SM	Ditto, medium dense		
14	TR						14
15	SPT13	6 10 11			Ditto,		15
16					Boring Terminated at 15.50 meters depth		16
17							17
18							18
19							19
20							20
21							21
22							22
23							23
24							24

Legend : SPT1: Standard Penetration Test and No. | A : Auger Boring
TR : Tricone Drilling | NE: Not Encountered
C1 : Rock Core Run and Number

SHEET 2 OF 2

GULF CONSULT- Geotech Division. P.O. BOX 684, Al-Khobar. Tel 8944468 / 8954242 - Jubail Tel. 3410017 / 3410018

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SUMMARY OF LABORATORY TEST RESULTS
(BOREHOLE SAMPLES)

APPENDIX B1

PROJECT: PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX

CLIENT: AZMEEL CONTRACTING CO.

JOB NO.: 11-12196

BOREHOLE NUMBER	DEPTH (METER)	MC (%)	% PASSING THRO' SIEVE #			ATTERBERG LIMITS		CHEMICAL ANALYSIS RESULTS			SOIL CLASSIFN.
			# 4	# 40	# 200	LL (%)	PI (%)	SO_3 (%)	Cl (%)	CO_3 (%)	
PH-1	1.00 - 1.50	18.2	83	40	15	NP	NP	0.182	2.859	46.214	SM
	5.00 - 5.50	13.7	100	74	10	NP	NP	--	--	--	SP-SM
	7.50 - 8.00	26.1	97	69	48	42	22	--	--	--	SC
	13.50 - 14.00	31.8	96	82	68	40	11	--	--	--	ML
PH-2	2.00 - 2.50	17.5	100	88	8	NP	NP	0.126	3.213	8.655	SP-SM
	6.00 - 6.50	16.4	100	92	11	NP	NP	--	--	--	SP-SM
	10.50 - 11.00	31.9	100	97	92	30	8	--	--	--	ML
	15.00 - 15.50	29.8	96	76	51	22	4	--	--	--	CL-ML
PH-3	0.00 - 0.50	6.4	100	95	29	NP	NP	--	--	--	SM
	3.00 - 3.50	16.0	100	93	18	NP	NP	0.094	2.816	4.920	SM
	7.50 - 8.00	26.6	85	62	42	44	20	--	--	--	SC
	12.00 - 12.50	29.5	96	77	57	38	9	--	--	--	ML
	15.00 - 15.50	23.4	91	70	60	44	15	--	--	--	ML
PH-4	1.00 - 1.50	14.7	100	74	10	NP	NP	0.138	2.791	5.789	SP-SM
	4.00 - 4.50	15.1	100	81	11	NP	NP	--	--	--	SP-SM
	6.00 - 6.50	15.1	100	80	14	NP	NP	--	--	--	SM
	9.00 - 9.50	26.2	98	63	39	NP	NP	--	--	--	SC
PH-5	2.00 - 2.50	17.0	100	56	8	NP	NP	0.088	0.459	4.093	SP-SM
	5.00 - 5.50	13.4	100	68	9	NP	NP	--	--	--	SP-SM
	9.00 - 9.50	32.1	100	97	85	44	20	--	--	--	CL
	12.00 - 12.50	25.7	86	51	30	NP	NP	--	--	--	SM
	15.00 - 15.50	27.4	94	77	57	27	5	--	--	--	CL-ML
PH-6	1.00 - 1.50	16.3	100	69	10	NP	NP	0.073	2.460	6.176	SP-SM
	4.00 - 4.50	13.6	100	77	10	NP	NP	--	--	--	SP-SM
	7.50 - 8.00	29.4	100	98	97	48	25	--	--	--	CL
	12.00 - 12.50	23.2	95	58	35	26	2	--	--	--	SM

NOTE:
MC - Moisture Content
SO_3 - Sulfate
Cl - Chloride
CO_3 - Carbonate
LL - Liquid Limit
PI - Plasticity Index

GULF CONSULT

SUMMARY OF LABORATORY TEST RESULTS
(BOREHOLE SAMPLES)

APPENDIX B1

PROJECT: PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX

CLIENT: AZMEEL CONTRACTING CO.

JOB NO.: 11-12196

BOREHOLE NUMBER	DEPTH (METER)	MC (%)	% PASSING THRO' SIEVE #			ATTERBERG LIMITS		CHEMICAL ANALYSIS RESULTS			SOIL CLASSIFN.
			# 4	# 40	# 200	LL (%)	PI (%)	SO_3 (%)	Cl (%)	CO_3 (%)	
PH-6	15.00 - 15.50	22.7	100	98	92	NP	NP	--	--	--	ML
PH-7	3.00 - 3.50	15.5	100	82	11	NP	NP	0.148	2.989	8.023	SP-SM
	6.00 - 6.50	14.7	100	72	6	NP	NP	--	--	--	SP-SM
	10.50 - 11.00	23.0	93	55	32	NP	NP	--	--	--	SM
	15.00 - 15.50	25.7	100	97	91	46	17	--	--	--	ML
PH-8	0.00 - 0.50	5.2	100	83	7	NP	NP	0.104	2.963	5.411	SP-SM
	4.00 - 4.50	14.3	100	84	10	NP	NP	--	--	--	SP-SM
	10.50 - 11.00	23.1	82	44	22	NP	NP	--	--	--	SM
	15.00 - 15.50	25.6	89	59	36	37	6	--	--	--	SM
PH-9	2.00 - 2.50	16.8	100	94	32	NP	NP	0.127	2.688	8.220	SM
	5.00 - 5.50	10.9	100	78	8	NP	NP	--	--	--	SP-SM
	7.50 - 8.00	29.4	99	82	64	25	5	--	--	--	CL-ML

NOTE:
MC - Moisture Content
SO_3 - Sulfate
Cl - Chloride
CO_3 - Carbonate
LL - Liquid Limit
PI - Plasticity Index

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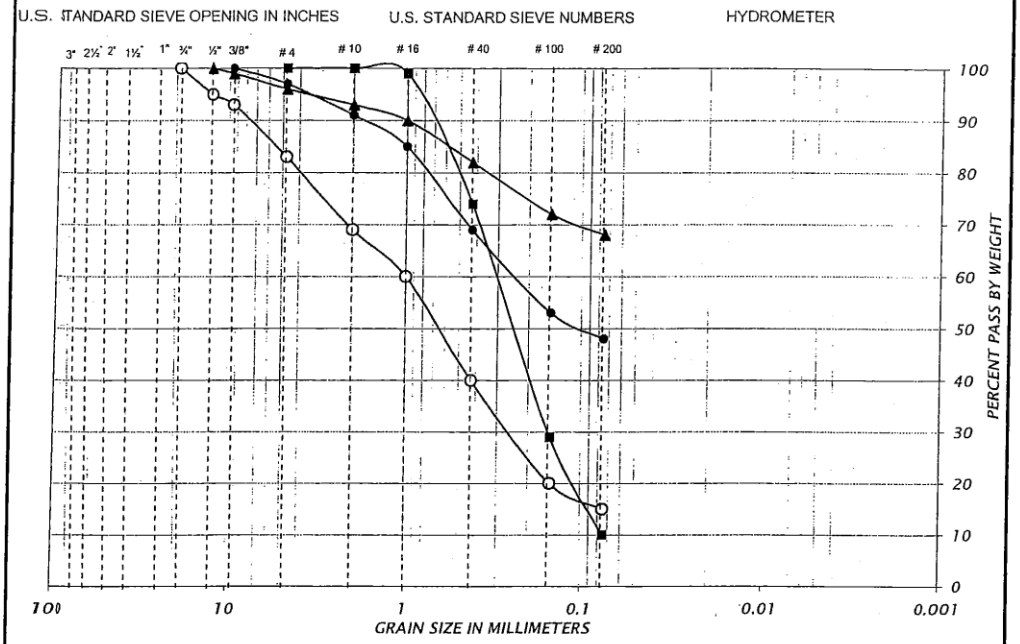
PARTICLE SIZE ANALYSIS

Appendix-B2

Client : AZMEEL CONTRACTING CO.
Project : PRINCE MOHAMMAD BIN FAHD HOUSING COMPLES
Location : AZIZIYAH, HALFMOON BAY
Job No. : 11-12196 Geotechnical File No.:



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

Symbols	Borehole / Test Pit No. & Sample No.	Depth (m)	% Passing			Atterberg Limit		Classifn.*
			# 4	# 40	# 200	LL (%)	PI (%)	
—○—	PH-1/SPT-1	1.00 - 1.50	83	40	15	NP	NP	SM
—■—	PH-1/SPT-5	5.00 - 5.50	100	74	10	NP	NP	SP-SM
—●—	PH-1/SPT-7	7.50 - 8.00	97	69	48	42	22	SC
—▲—	PH-1/SPT-11	13.50 - 14.00	96	82	68	40	11	ML

TEST METHOD : ASTM STD.

* Classification as per ASTM D-2487

LL : Liquid Limit
PI : Plastic Index

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Jubail Support Industry : P.O. Box 10113 Jubail 31961 - Tel. 3410018 - Fax : 3410017

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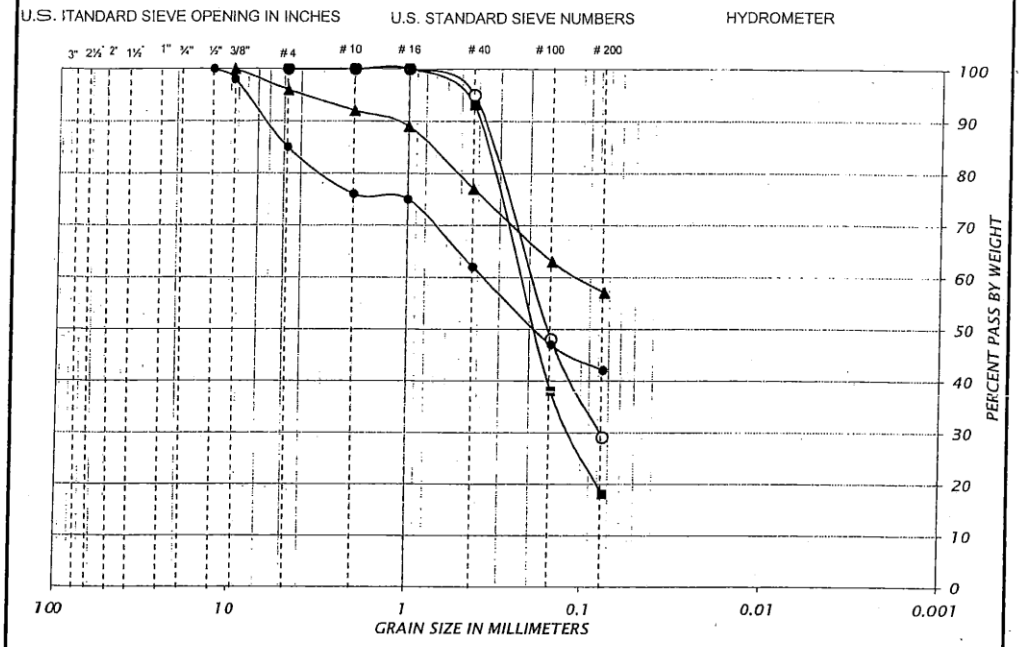
PARTICLE SIZE ANALYSIS

Appendix-B2

Client : AZMEEL CONTRACTING CO.
Project : PRINCE MOHAMMAD BIN FAHD HOUSING COMPLES
Location : AZIZIYAH, HALFMOON BAY
Job No. : 11-12196 Geotechnical File No.:



GRAVEL		SAND			SILT OR CLAY
Coarse	Fine	Coarse	Medium	Fine	

Symbols	Borehole / Test Pit No. & Sample No.	Depth (m)	% Passing			Atterberg Limit		Classifn.*
			# 4	# 40	# 200	LL (%)	PI (%)	
—○—	PH-3/SPT-1	0.00 - 0.50	100	95	29	NP	NP	SM
—■—	PH-3/SPT-4	3.00 - 3.50	100	93	18	NP	NP	SM
—●—	PH-3/SPT-8	7.50 - 8.00	85	62	42	44	20	SC
—▲—	PH-3/SPT-11	12.00 - 12.50	96	77	57	38	9	ML

TEST METHOD : ASTM STD.

* Classification as per ASTM D-2487

LL : Liquid Limit
PI : Plastic Index

Gulf Consult : P.O. Box 684 - Alkhobar 31952 - Tel. 8944468 / 8955036 / 8949872 - Fax : 8949015.
Jubail Support Industry : P.O. Box 10113 - Jubail 31961 - Tel. 3410018 - Fax : 3410017

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UNCONFINED COMPRESSION TEST

ASTM D-2166

APPENDIX-B3

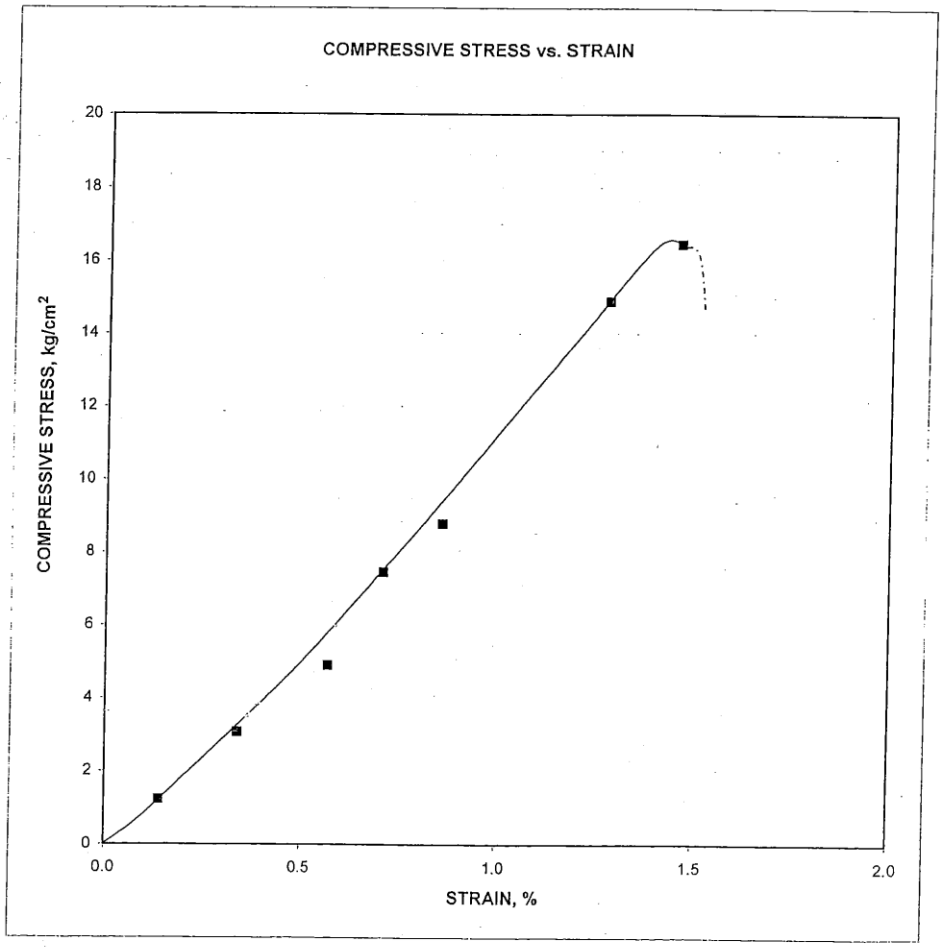
PROJECT : PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX

CLIENT : AZMEEL CONTRACTING CO.			JOB NO.: 11-12196	LOCATION : AZIZIYAH, HALFMOON BAY
BOREHOLE NO.	CORE NO.	SAMPLE DEPTH(M)	FAILURE STRESS (kg/cm^2)	FAILURE STRAIN, (%)
PH-1	C-1	9.50 - 11.00	16.45	1.46

SAMPLE DATA :

Diameter, cm = 5.7	Moisture Content, % = 13.8	Wet unit wt., gm/cc = 1.850
Height, cm = 8.9	Volume, cc = 227.0	Dry unit wt., gm/cc = 1.626

Soil / Rock Description: cemented SILTSTONE



FORM NO.: GLT-307/1	PAGE 1/1 ISSUE NO.02	ISSUE DATE 18/7/01

GULF CONSULT

SPECIFIC GRAVITY OF SOIL TEST

APPENDIX - B4

PROJECT	:	PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX	Job No.	:	11-12196
CLIENT	:	AZMEEL CONTRACTING CO.	Date Received	:	--
LOCATION	:	AZIZIYAH, HALFMOON BAY	Date Tested	:	22/11/2011
TESTED BY	:	NAJEEB.W.	Test Method	:	ASTM D-854

ANALYSIS DETAILS

Borehole No. / Sample No.	Sample Depth, Meter	Mass of Pychnometer (g)	Mass of Soil (g) Mo	Mass of Pychnometer + water (g) Ma	Mass of Pychnometer + water+Soil (g) Mb	Temp. of Pychnometer content ^{0} C Tb	Specific Gravity result G at Tb	Specific Gravity @ 20° c
PH-1/SPT-7	7.50-8.00	93.1	40g	292.7	317.6	24^{0}C	2.649	2.647
PH-1/SPT-11	13.50-14.00	93.7	"	293.3	318.6	"	2.721	2.719
PH-2/SPT-2	2.00-2.50	90.4	"	290.0	314.6	"	2.597	2.595
PH-2/SPT-6	6.00-6.50	89.5	"	289.1	313.8	"	2.614	2.612
PH-2/SPT-9	10.50-11.00	91.7	"	291.3	316.5	"	2.703	2.701
PH-3/SPT-11	12.00-12.50	91.4	"	291.0	316.2	"	2.721	2.190
PH-3/SPT-13	15.00-15.50	93.3	"	292.9	317.9	"	2.667	2.665
PH-4/SPT-2	1.00-1.50	91.0	"	290.6	315.1	"	2.581	2.579
PH-4/SPT-5	4.00-4.50	91.3	"	293.9	318.6	"	2.614	2.612
PH-5/SPT-9	9.00-9.50	93.7	"	293.3	318.2	"	2.649	2.647
PH-5/SPT-11	12.00-12.50	90.7	"	290.3	315.0	"	2.614	2.612
PH-5/SPT-13	15.00-15.50	90.4	"	290.0	315.0	"	2.667	2.665
PH-6/SPT-1	1.00-1.50	89.4	"	289.0	313.7	"	2.614	2.612
PH-6/SPT-4	4.00-4.50	91.7	"	291.3	315.9	"	2.597	2.595
PH-6/SPT-7	7.50-8.00	91.4	"	291.0	316.0	"	2.667	2.665
PH-7/SPT-9	10.50-11.00	93.3	"	292.9	317.7	"	2.632	2.630
PH-7/SPT-11	13.50-14.00	91.0	"	290.6	315.8	"	2.703	2.701
PH-8/SPT-1	0.00-0.50	94.3	"	293.9	318.4	"	2.581	2.579
PH-8/SPT-5	4.00-4.50	92.6	"	292.2	316.9	"	2.614	2.612
PH-9/SPT-5	5.00-5.50	92.6	"	292.2	316.9	"	2.597	2.595
PH-9/SPT-7	7.50-8.00	92.5	"	292.1	317.2	"	2.685	2.683

G At Tb=MO/[MO+(Ma-Mb)]

APPENDIX – B5
CARBONATE CONTENT TEST RESULTS

Client : **Azmeel Contracting Co.**
Project : Prince Mohammad Bin Fahd Housing Complex
Job Number : 11-12196
Location : Aziziyah, Halfmoon Bay

RESULTS:

SOIL SAMPLE		
Borehole Number	**Depth (meter)**	**CO_3 (%)**
PH-1	1.00 – 1.50	46.214
PH-2	2.00 – 2.50	8.655
PH-3	3.00 – 3.50	4.920
PH-4	1.00 – 1.50	5.789
PH-5	2.00 – 2.50	4.093
PH-6	1.00 – 1.50	6.176
PH-7	3.00 – 3.50	8.023
PH-8	0.00 – 0.50	5.411
PH-9	2.00 – 2.50	8.220

APPENDIX - B6
CHEMICAL ANALYSIS TEST RESULTS

Client : **Azmeel Contracting Co.**
Project : Prince Mohammad Bin Fahd Housing Complex
Job Number : 11-12196
Location : Aziziyah, Halfmoon Bay

RESULTS:

SOIL SAMPLE				
Borehole Number	**Depth (meter)**	**Acid Soluble Sulfate (SO_3) (%)**	**Acid Soluble Chloride (Cl) (%)**	**pH**
PH-1	1.00 – 1.50	0.182	2.859	7.46
PH-2	2.00 – 2.50	0.126	3.213	7.82
PH-3	3.00 – 3.50	0.094	2.816	7.29
PH-4	1.00 – 1.50	0.138	2.791	7.65
PH-5	2.00 – 2.50	0.088	0.459	6.62
PH-6	1.00 – 1.50	0.073	2.460	7.39
PH-7	3.00 – 3.50	0.148	2.989	7.94
PH-8	0.00 – 0.50	0.104	2.963	7.53
PH-9	2.00 – 2.50	0.127	2.688	7.74

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