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College of Engineering
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Management of Al-Khaldiyah Road to optimize Safety and improve sight View

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ABSTRACT

The Kingdom of Saudi Arabia has a network of internal roads sophisticated and modern and has a total road length of about 160 thousand kilometers of which about 47 thousand kilometers are paved roads linking major centers (Ministry of Transport, 2014). In Saudi Arabia the motor vehicle is the main means of transportation. However, between 1971 and 1997; 564 762 people died or were injured in road traffic accidents, a figure equivalent to 3.5% of the total population in Saudi Arabia (Ansari et al., 2000). They reported that during this period 66 914 people have died on the roads in Saudi Arabia due to road accidents, amounting to one person killed and four injured every hour.

The main goal of this paper is to describe a project (proposal) concerning the management of Al-Khaldiyah road (Al Khobar) in order to optimize its safety and improve its sight view. The project is mainly concerned by the proposition of sustainable solutions for the purpose of optimizing the safety use of this important road and also improving its sight view. This includes the design of some appropriate junctions in order to increase convenience, comfort and safety while at the same time enhancing the efficient movement of all road users, and the minimization of traffic conflicts locations at these junctions. A good design should aim at minimizing the severity of potential accidents at these points.

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CHAPTER 1: INTRODUCTION

1.1. General

According to the Ministry of Transport of Saudi Arabia, the transport sector in the Kingdom has always been to follow-up and attention because it affects the nerve economy and because 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 infrastructure for roads and transport, multimedia, so the transport sector is one of the most important sectors that contribute effectively to the rise of any country, without transport sector inept cannot exploit the primary advantages to any site, or investment opportunities for the production of consumption and exporting, and this means that the plan of the national transport 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 transport 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 transport sector in all patterns of energy capacity over the plan (Ministry of Transport, 2014).

It was reported by the Ministry of Transport that the Kingdom of Saudi Arabia has a network of internal roads sophisticated and modern and has a total road length of about 160 thousand kilometers of which about 47 thousand kilometers and paved roads linking major centers (Ministry of Transport, 2014). Operations continue to be the construction of roads that link remote areas of continuous and magnify the amount of movement of goods in the Kingdom and across the road there is a tendency to involve the private sector in the ownership, operation and maintenance of the main roads.

The total length of roads carried out by the ministry until the end of the year 1433 AH more than about (60,000) sixty thousand kilometers constructed according to one of the international standards and several trends have linked major cities to each other to cope with the great development of these cities and to serve traffic large among them, have also been raising the level of a number of ways the individual to become a double and carried out many ring roads and bridges in some cities in addition to the implementation of the obstacles in the southern region (Ministry of Transport, 2014). In addition to the roads that exist within each region and contribute to linking the cities and provinces of the region to each other and then linking the region to the rest of the areas , also carried out secondary roads that branch off from the main roads and serve the various centers and communities as well as dirt roads , which amounted to a total length yet over (139) thousand kilometers , and has contributed to these roads and thankfully in the process of construction and development , which swept across the kingdom spread across the services provided to citizens everywhere (health, education and social and agricultural , construction and architecture , etc.)

Roads in Saudi Arabia differ in terms of capacity of eight tracks for some roads to two-lane road in rural areas. Are maintained highways in the city and other major highways are good, especially the roads in the capital Riyadh. Has constructed roads and taking into consideration the high-temperature resistant and is working to reverse the lack of strong sunlight. The government is working now to rebuild and maintenance of some other ways (Ministry of Transport, 2014).

In Saudi Arabia the motor vehicle is the main means of transportation. Between 1971 and 1997; 564 762 people died or were injured in road traffic accidents, a figure equivalent to 3.5% of the total population in Saudi Arabia (Ansari et al., 2000). They reported that during this period 66 914 people have died on the roads in Saudi Arabia due to road accidents, amounting to one person killed and four injured every hour. Over 65% of accidents occur because of vehicles travelling at excess speed and/or drivers disobeying traffic signals. Of deaths in Ministry of Health hospitals, 81% are due to road traffic accidents and 20% of their beds are occupied by traffic accidents victims (Ansari et al., 2000). Also, 79.2% of patients admitted to Riyadh Armed Forces Hospital with spinal injuries have sustained their injuries as a result of a motor vehicle accident.

Figure 1.1 Examples of roads/accidents in Saudi Arabia (from internet)

1.2. Project Objectives

The main goal of this project is the management of Al-Khaldiyah road in order to optimize its safety and improve its sight view. The project is mainly concerned by the proposition of sustainable solutions for the purpose of optimizing the safety use of this important road and also improving its sight view. This includes: i) the design of some appropriate junctions in order to increase convenience, comfort and safety while at the same time enhancing the efficient movement of all road users, and ii) The minimization of traffic conflicts locations at these junctions. A good design should aim at minimizing the severity of potential accidents at these points.

The project is composed by the following stages or parts:

1- Development of the different plans of the proposed Al-Khaldiyah road project (including top overall view & road cross sections).
2- Design and plans of the different managements and junctions (including, a tunnel and roundabout/tunnel junctions, and a bridge).
3- Geotechnical design of tunnel retaining wall and abutment bridge foundations.
4- Pavement design of a prototype section of the new managed road
5- Development of a prototype of the proposed al-Khaldiyah road.

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 different new managements and junctions of the proposed road is given in chapters 4. The geotechnical design of some elements of the junctions and the road pavement design are discussed in chapter 5. The report is achieved by some specific and general conclusions.

CHAPTER 2: Description of the project

2.1 Introduction

Al-Khaldiyah road is an important and a vital road in the Half Moon Bay. It provides direct access to many local beaches and notably to PMU University. It is used daily and extensively by staff, students and workers. However, many accidents, leading to injuries and deaths, were observed all around the road notably these last two years. In this project, sustainable solutions are analyzed in order to optimize the safety use of this important road.

This chapter is mainly concerned by the description of the historical background of the project, the site of the project, and the problems associated to the existing road. The chapter will start by describing the historical background of the road. Then a description is given concerning the geometrical design of the existing road. Following that a brief description is given concerning the different problems associated with the exploitation of this road.

2.2 Historical and geographical description of the project

Al-Khaldiyah road was constructed almost about 30 years ago and has been expanded in 2005 to become a large four-lane road without median island and lighting. Al-Khaldiyah road, nicknamed in the past as the abundant road, is situated in the eastern region of the kingdom. Geographically, the road is important since it connects the road of the Gulf Cooperation Council and Half Moon Bay. It is bordered from the south-east by Al-Azizia, from the north-east Abu Hadriyah and from the north-west Raas Al-Ghar. Moreover, it is limited from the west by the sea from the east by the city of Dhahran (and the Air Base).

It is characterized by four lines (which become six lines in some places) in both directions extending over about 10 km length. The road, which is almost straight, extends between the bridge of the Air force base and Half Moon Bay road. This road is extensively ridden by PMU university staff and students and by workers in nearby projects. However many accidents were observed in this 10 km road, notably in the last two years. Many injuries and deaths were recorded where some of them are from PMU students (Figures 2.1*a* & *b*).

Figure 2.1*a*. Sample of road accident at the actual Al-Khaldiyah road (photo 1)

Figure 2.1*b*. Sample of road accident at the actual Al-Khaldiyah road (photo 2)

2.3 Geometrical description of the project

Al-Khaldiyah is a regional road situated in west-south of Al-Khobar, precisely in the area of Half Moon Bay. The road is considered as subdivision road linking the cities of Al-Khobar, Dhahran and Dammam, along a distance or a length of about 9.8 kilometers and an actual width of 19.6 m. However the allowable design width of the road is around 60.0 m. As indicated previously, the road is characterized by four lines (which become six lines in some places) in both directions extending over about 10 km length (Figure 2.2).

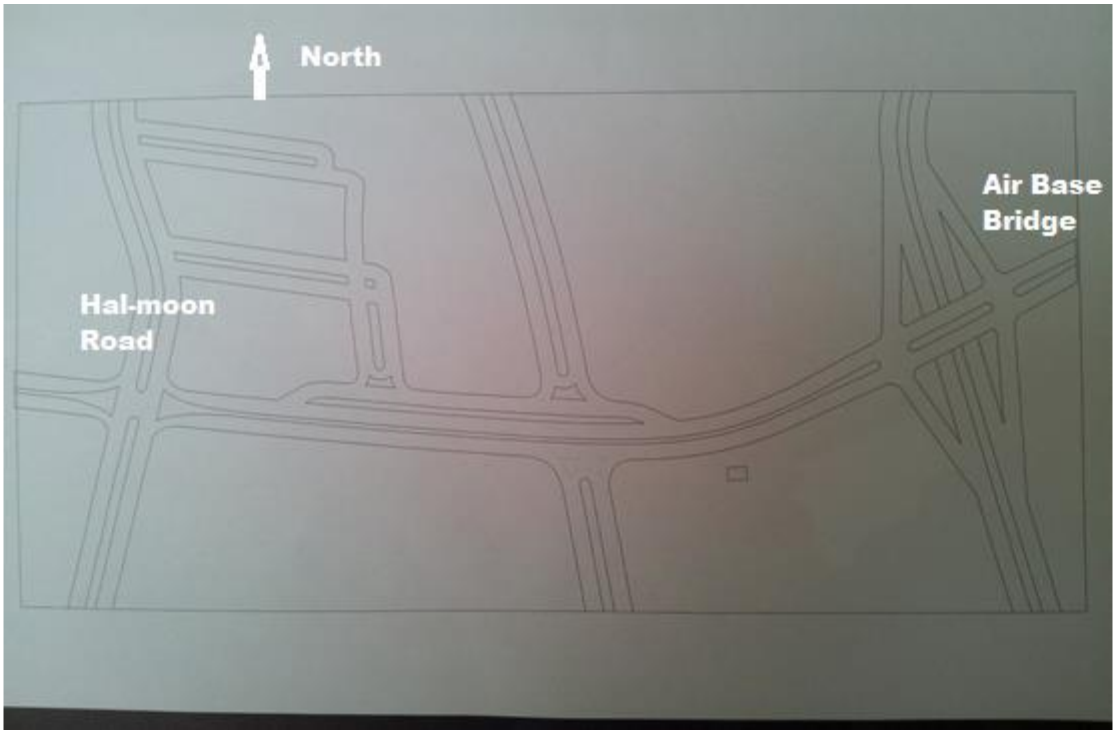


Figure 2.2. The actual plane view of Al-Khaldiyah road

The actual width of the road is 19.8 meters at a rate of 3.65 meters per line for a total of four lines (two lines for each direction). The lines of both directions are separated by a space of 60 cm or by concrete barriers of 40 cm width each. The distance between the roundabout (douar) Al-Azizia to the intersection Al-Khaldiyah/ Half-moon road is about 22.7 km. The length of the exchanger or the crossover situated currently in the middle of Al-Khaldiyah road is approximately 2.4 km from the beginning to its end.

It is worthy to note that:

- The quantity of sand removed daily from the road in bad weather (i.e. sandstorm) is about 240 m^3. This quantity is reduced 1/5 to 1/8 in normal period.
- Based on a survey carried by the students over 4 days, the following data are retained: from 7:15 am to 8:15 am the numbers of cars are in the order of 470 cars; whereas, between 3 pm to 5 pm the number is reduced to around 290 cars (Figure 2.3).

Figure 2.3. Recent photo of Al-Khaldiyah road

Chapter 3 : Soil Report

3.1 Introduction

This chapter is concerned by the description of the site and laboratory investigations, soil report and ground profile of the site of the managed. The information obtained in these investigations is used to design the tunnel retaining wall, the abutment foundation of the bridge, and the pavement design.

In this study, the soil report established for PMU University accommodation was used in the present geotechnical and pavement design. Based on the fact that the soil in the area is almost homogeneous, the data grouped in the soil report was adopted for the whole length of the road. It is worthy to note that some of the information described in the report of Golf Company was reproduced in this report.

3.2 Field Investigation

The purpose and scope of the site investigation is to determine the sub-surface stratigraphy, the geotechnical parameters, the geotechnical parameters, and the surface conditions of the project site.

The scope of work performed by Golf Company considered of:

- Drilling and sampling a total of nine (9) (PH-1 to PH-9).
- Two boreholes (PH-4 & PH-9) were drilled up to 10 meters each below the existing ground level (BGL).
- Remaining seven (7) boreholes (PH-1, PH-2, PH-3, PH-5, PH-6, PH-7 and PH-8) were drilled up to 15.0 meters each BGL
- Performing laboratory tests on representative soil samples to determine physical, and chemical properties;
- Analysis of field and laboratory data.

The field investigation, comprising drilling of boreholes, at the project site was carried out between November 10, 2011 and November 15, 2011. Location of boreholes was decided by the client. Plan showing borehole location is presented on Figure 1 (Appendix A). Brief description about the drilling and sampling methodology is given below. Subsurface stratigraphy and ground water conditions at the site were investigated by drilling and sampling in a total of nine (9) boreholes. Drilled boreholes at the propose structure with termination depths are tabulated below:

Table 3.1. Details of drilled boreholes (from Golf 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

Boreholes were drilled using truck-mounted drilling rig. Drilling was carried out by conventional rotary wash drilling method using 4” diameter tricone. Sampling operation of groundwater in the boreholes was performed in accordance with ASTM D 420. In boreholes, standard penetration test was carried out at regular intervals. Detailed description of subsoil encountered during drilling and depth at which samples were taken are shown on the boring logs included in Appendix A.

Standard Penetration Test (SPT) was conducted in each borehole at 1.0 meter interval up to 6.0 meters depth and thereafter at 1.5m interval up to the termination depth of boreholes. SPT was carried out in accordance with ASTM-D1586. During the test, blow counts and sampler penetration were recorded as a split-spoon sampler was driven into the soil by a 63.5 kg hammer falling from a distance of 76 cm. The position at which a split spoon sample was obtained is indicated on the boring logs. The representative disturbed sample retrieved from the PST sampler were examined and visually classified in the field by our Geologist.

In hard clay layers, undistributed samples (UDS) were retrieved using Triple Tube Core Barred (TCB) having 76mm internal diameter. After taking the sample, the sample tubes locked from top and bottom with plastic sheets. Collected samples do not exposure to air and sunlight and transported to laboratory. The position at which undisturbed sample was obtained is indicated on the boring logs as “UDS” type sample.

All soil samples recovered from the boreholes were visually examined and classified in the field, and then properly packed, labeled and transported to laboratory for testing. Samples of bore logs included in Appendix A provide all the necessary information on sub surface conditions.

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 Gold 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

Samples of soil classification and Index tests such as moisture content, percent of materials (Passing through Sieve No. 200) and Atterberg Limit are included in 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 Golf 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 (from Golf Company)

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 project site is located at Aziziyah area near Half-moon Bay in Al Khobar City, Kingdom of Saudi Arabia. Location of the project site is illustrated in Figure 2 (Appendix A). It is bounded open area. The ground surface at the project site is leveled and approximately 1.00 higher than adjacent asphalted road level.

Based on the field investigation & laboratory analysis of representative soil samples, stratigraphy in the sub-surface up to the maximum drilled depth is determined. The layers encountered and their engineering characteristics are as follows:

Table 3.5. Subsurface Stratification (from Golf 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 Golf 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 A provide all necessary information on sub-surface conditions.

Ground water level was measured 24 hours after the termination of boreholes. It is to be noted 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 (from Golf Company)

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 Golf 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 (from Golf Company)

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

Depending upon the magnitude of structural loads, its type (static or dynamic) and sensitivity of structures to settlements, shallow or deep foundations are to be considered. For the purpose 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 satisfy two (2) independent criteria with respect underlying foundation soil. First, the foundation must have an adequate factor of safety against exceeding the strength of the foundation soil. Second, 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 – Foundation Engineering, 1988) 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 up to 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 Golf 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 Golf Company)

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

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

Table 3.12. Expected Settlement (from Golf 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

Ground water table was encountered at an average depth of 0.5 meters below existing ground level. For foundations placed below the ground water table dewatering is required. For dewatering, "Well Point System" may be adopted.

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 accomplished 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.

CHAPTER 4: GEOMETRICAL DESIGN

4.1 Introduction

The main objectives of this project are: i)- to propose sustainable solutions in order to optimize the safety use of this important road and to improve its sight view, ii)- to design some appropriate junctions in order to increase convenience, comfort and safety, and iii)- to minimize traffic conflicts locations at these junctions.

This chapter covers the geometrical design of the different solutions proposed. A comparative study between these solutions is included in order to select the more appropriate design based on the specificity of the road. Then, a detailed description of the different junctions proposed in the final design is introduced.

4.2 The investigated propositions (solutions)

As mentioned previously, the road is about 10 km long. It is suggested to construct a road with three lines in each direction, in addition to two service roads of two lines each. The service road will be located at both sides of the main road. Moreover, it was decided to divide it into three different equal segments. These segments will be connected to each other by a junction, leading to a total of three junctions. Many junctions were suggested, and the combination of these junctions resulted in three different propositions (three different geometrical designs). These propositions are summarized as follows:

Geometrical design of proposition #1(Figure 4.1):

It is composed by a tunnel junction and two roundabouts. The tunnel junction will be 3.3 km away from the air base bridge (noted junction A). The two roundabouts will be 3.3 km away from each other and from the proposed tunnel. One of the roundabouts is suggested in the intersection between Al-Khaldiyah and Half-moon roads (noted junction C).

Geometrical design of proposition #2 (Figure 4.2):

In this proposition, a bridge is suggested at the junction C (i.e. in the intersection between Al-Khaldiyah and Half-moon roads). However, for the junctions A and B and similar to proposition #1, a tunnel and roundabout are retained. They are 3.3 km away from the air base bridge and from each other.

Geometrical design of proposition #3 (Figure 4.3):

The third proposition consisted on a tunnel at junction A, bridge at junction C and tunnel/roundabout at junction B. The location of these different components is similar to those indicated in propositions 1 and 2.

In order to select the final geometrical design of the managed road, a comparative study was performed. The Comparative study helps to understand the different aspects of the road, in short and long term. The first idea was to manage al-Khaldiyah road in the form to be an expressway in the near future. Accordingly, some problems could be encountered with the first and second propositions. It is believed that, these two solutions can cause traffic jam. In order to avoid this important problem the roundabout of junction C is replaced by a bridge, while, the simple roundabout of junction B is replaced by a tunnel/roundabout. Furthermore, in junction C a tunnel is suggested instead of bridge for an esthetics point of view. The bridge will mask the view of the opposite sides since many constructions will be implanted all along al-Khaldiyah road from both sides (e.g., PMU complex house, residential and commercial budding, etc.).

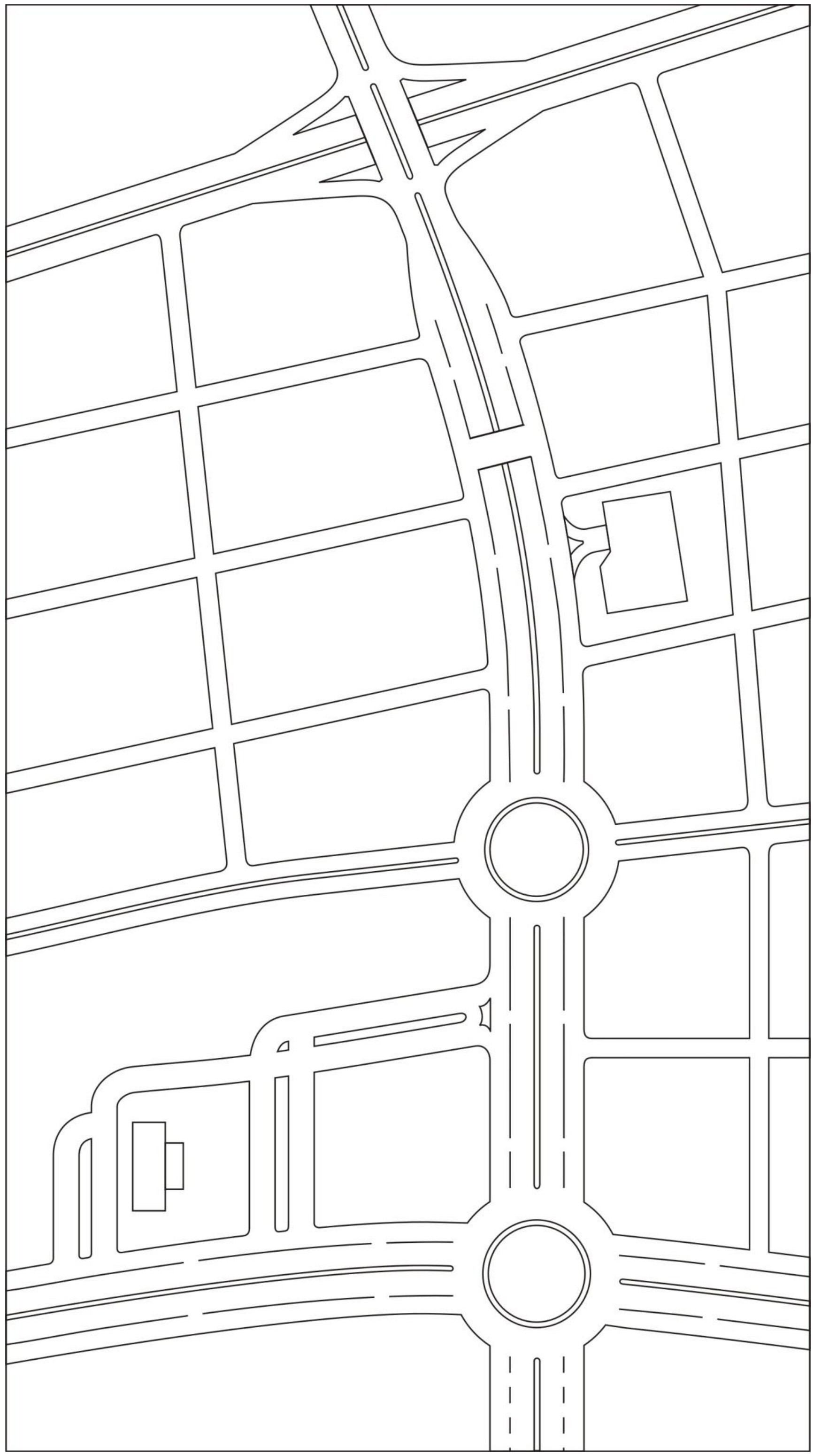


Figure 4.1. Geometrical design of proposition 1 (tunnel and two roundabout)

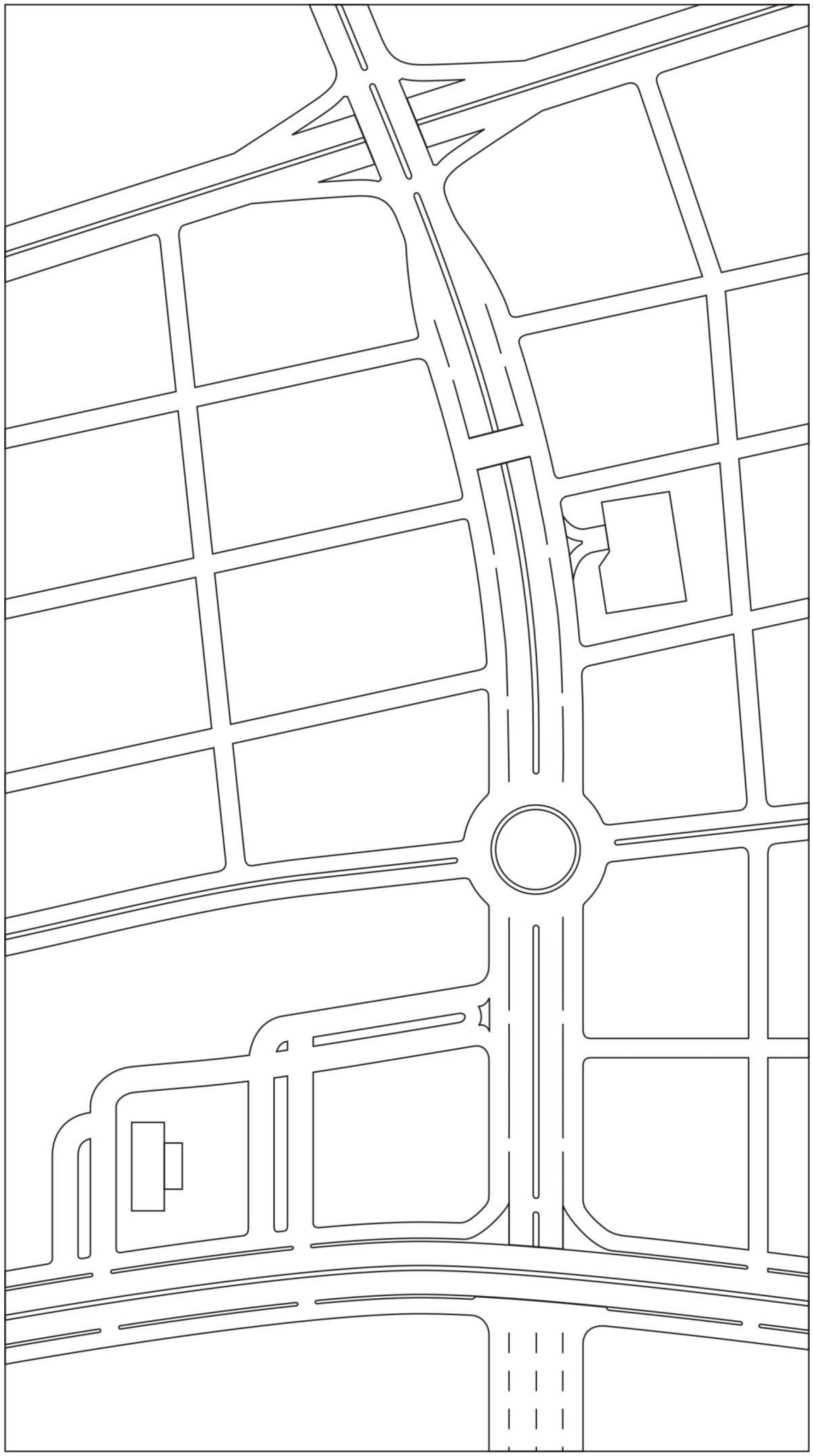


Figure 4.2. Geometrical design of proposition 2 (tunnel, roundabout & bridge)

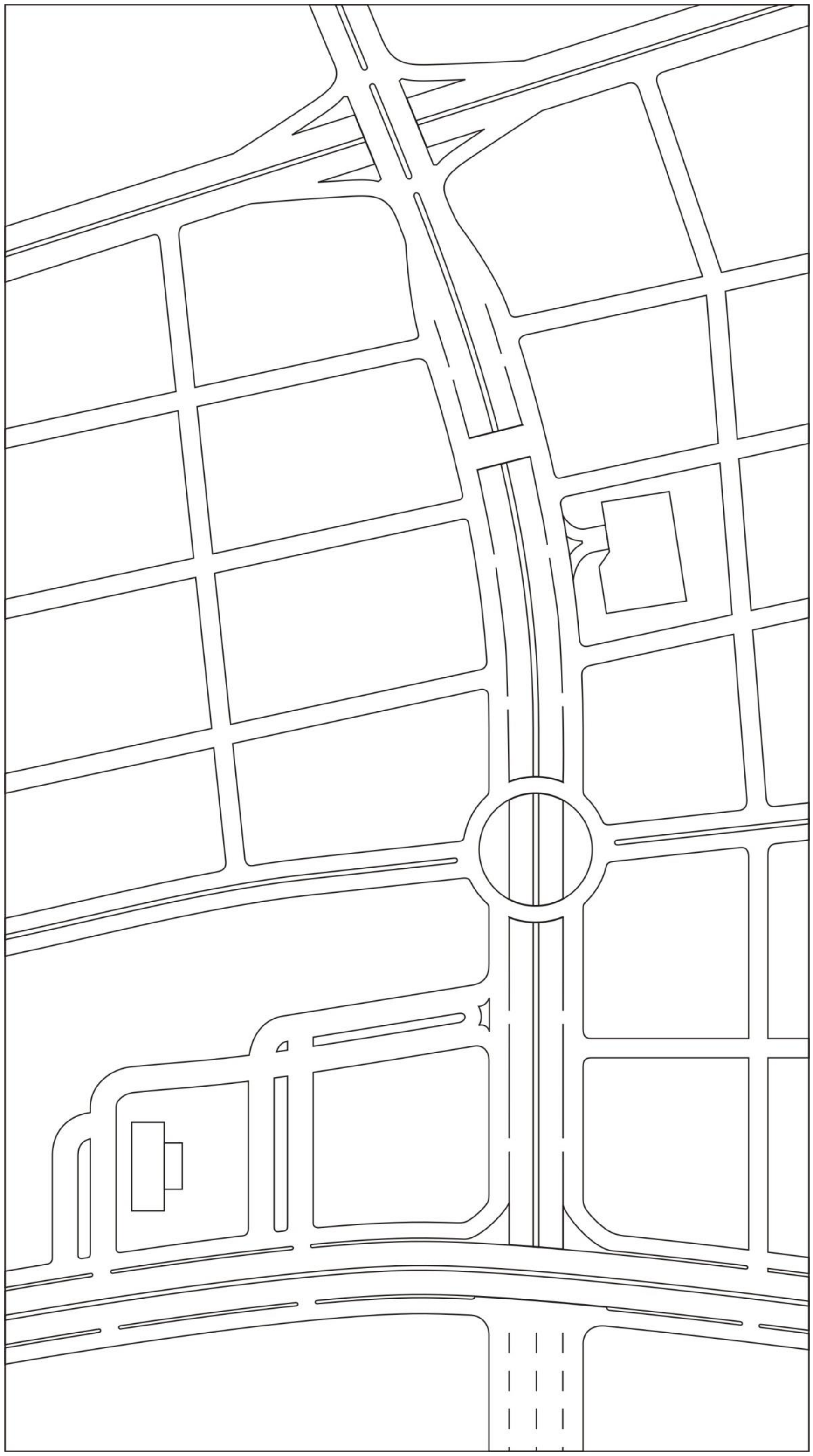


Figure 4.3. Geometrical design of proposition 3 (tunnel, tunnel/roundabout & bridge)

4.3 The Geometrical Design of the Retained Solution:

The Retained solution should be at least sustainable for more than 50 year. The managed road is designed to locate 3 lines in each direction (Figure 4.4). In addition a service road in each side of the road is planned. The service road will be a two line road.

As indicated previously, in the retained solution, Al-Khaldiyah road (10 km long), is divide into three equal segments connected to each other by different junctions, as follows: 1- Tunnel at junction A, situated 3.3 km away from the bridge of air base, 2- Tunnel/roundabout at junction B, situated 3.3 km from junction A, and 3- finally, a bridge located at the intersection of Al-Khaldiyah and Half-moon roads (Figures 4.5*a* to *c*).

From a geotechnical point of view two important structures has to be designed such as: retaining wall all along the tunnel of 6.5 m height, and the foundation of the bridge abutment.

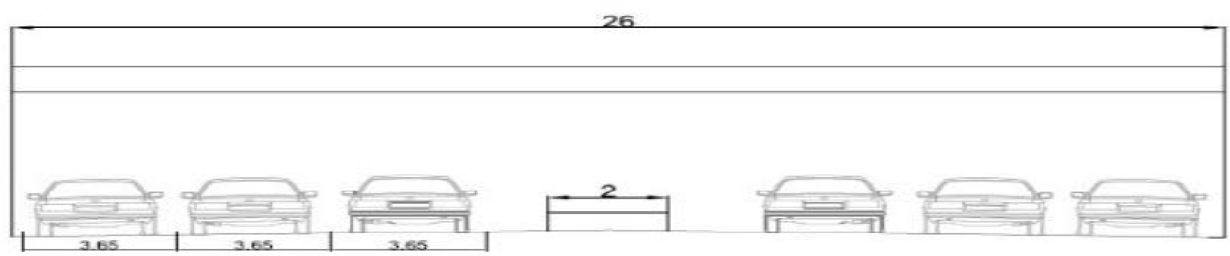


Figure 4.4. Cross section of the main designed road

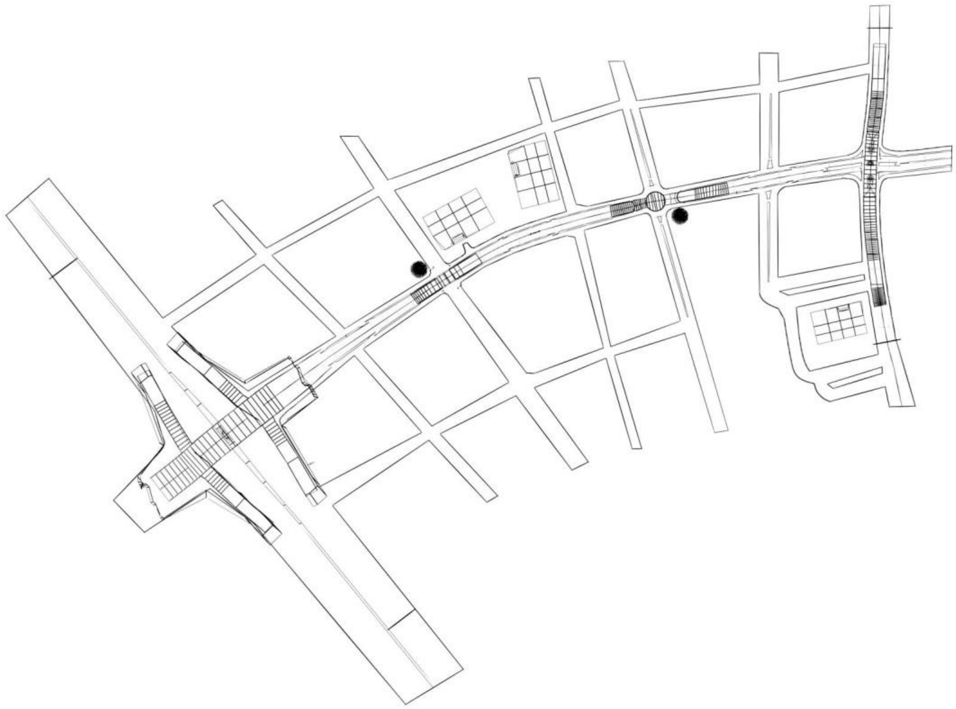


Figure 4.5 (*a*). Overall view of the retained solution (view #1)

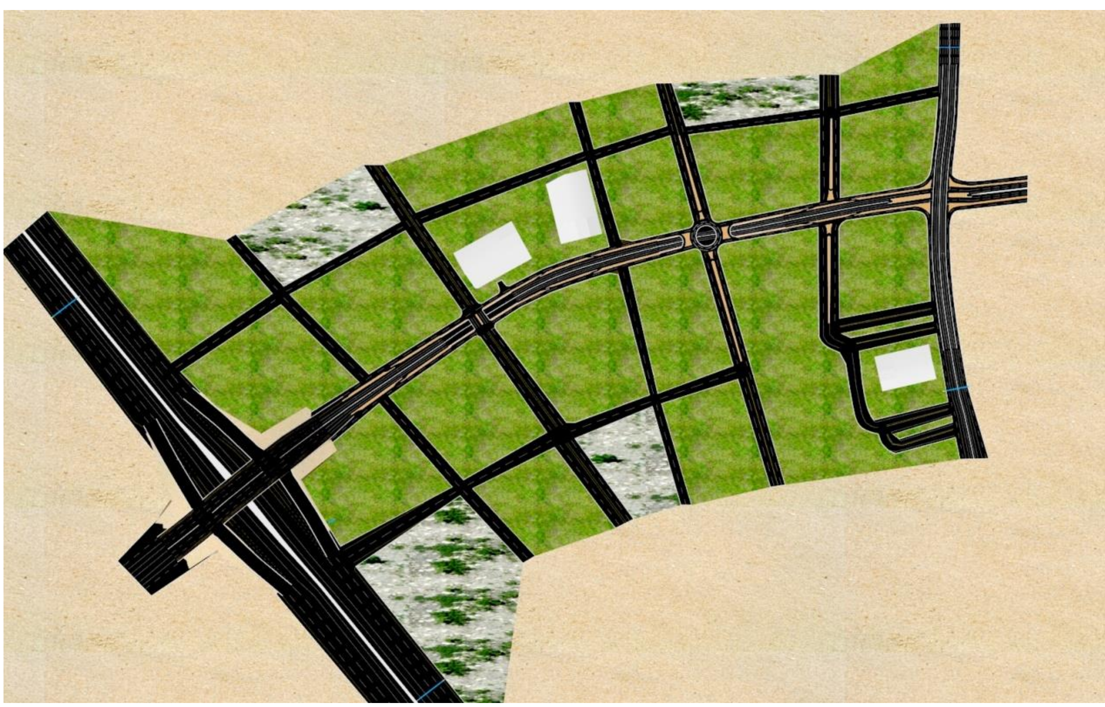


Figure 4.5 (*b*). Overall view of the retained solution (view #2)

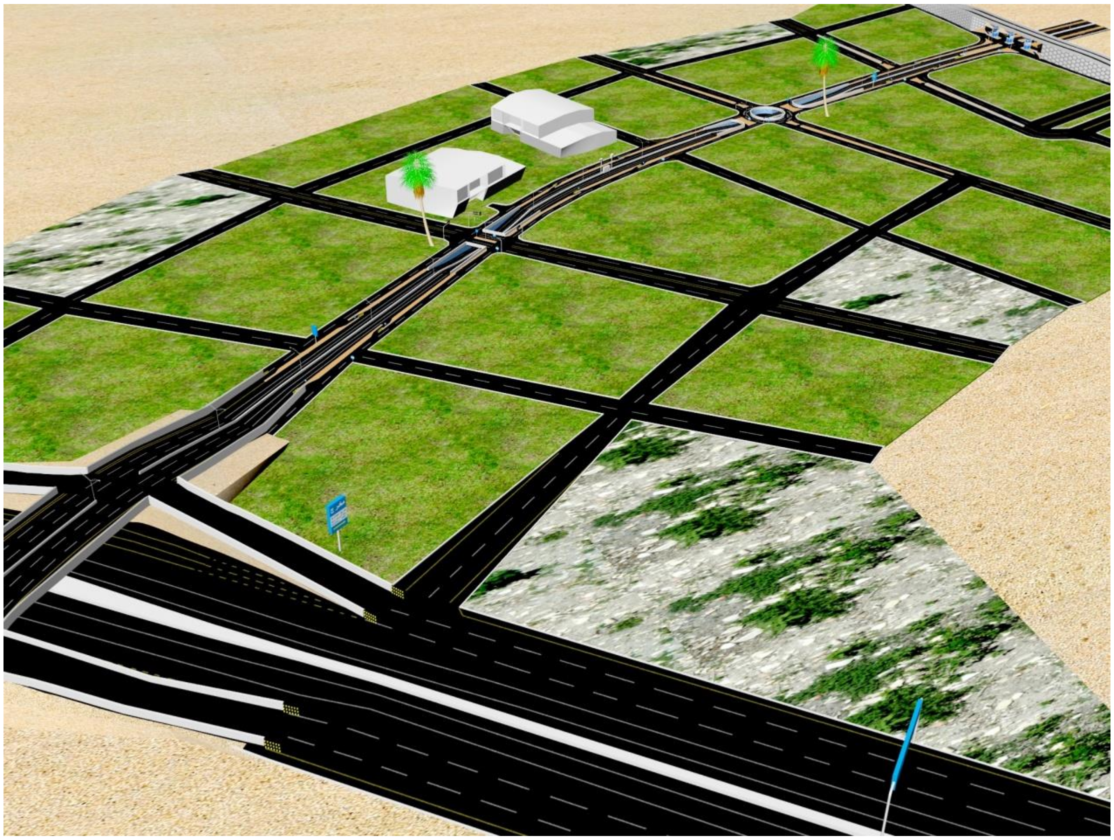


Figure 4.5 (*c*). Overall view of the retained solution (view #3)

4.3.1. Junction A: The tunnel

The tunnel section is 3.3 km away from Air Base Bridge. It has a height of 5.5 m and it is surrounded by a retaining wall of 6.5 m height. The slope of the road in the tunnel is about is 6% (Figure 4.6*a* & *b*)

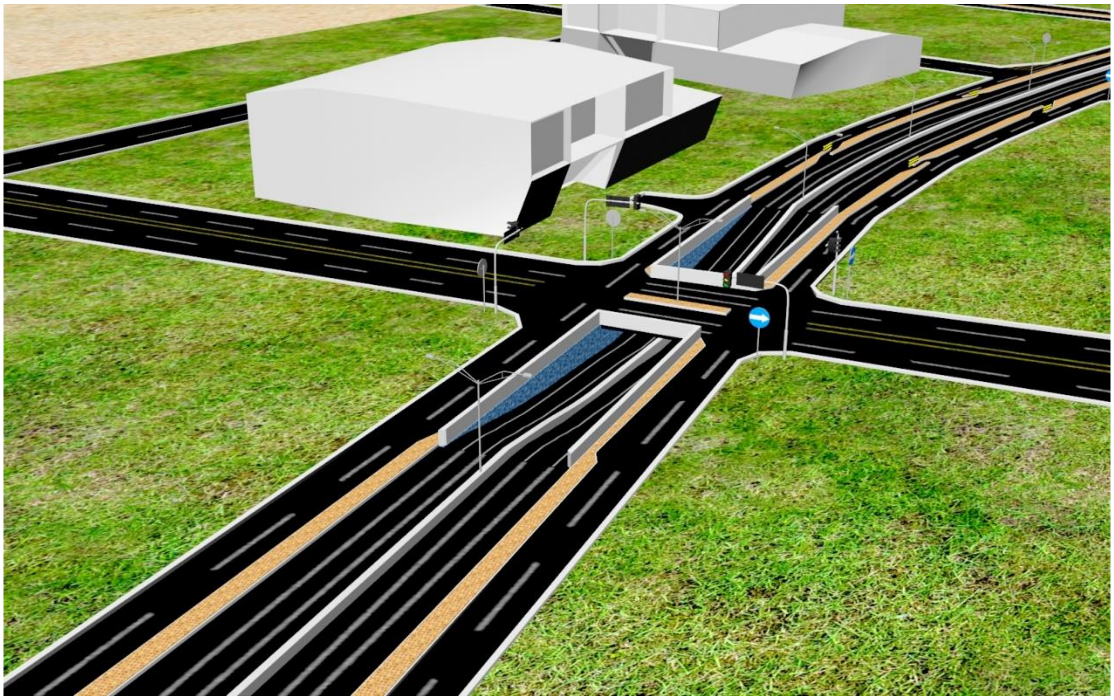


Figure 4.6 (*a*). View of the tunnel (view #1)

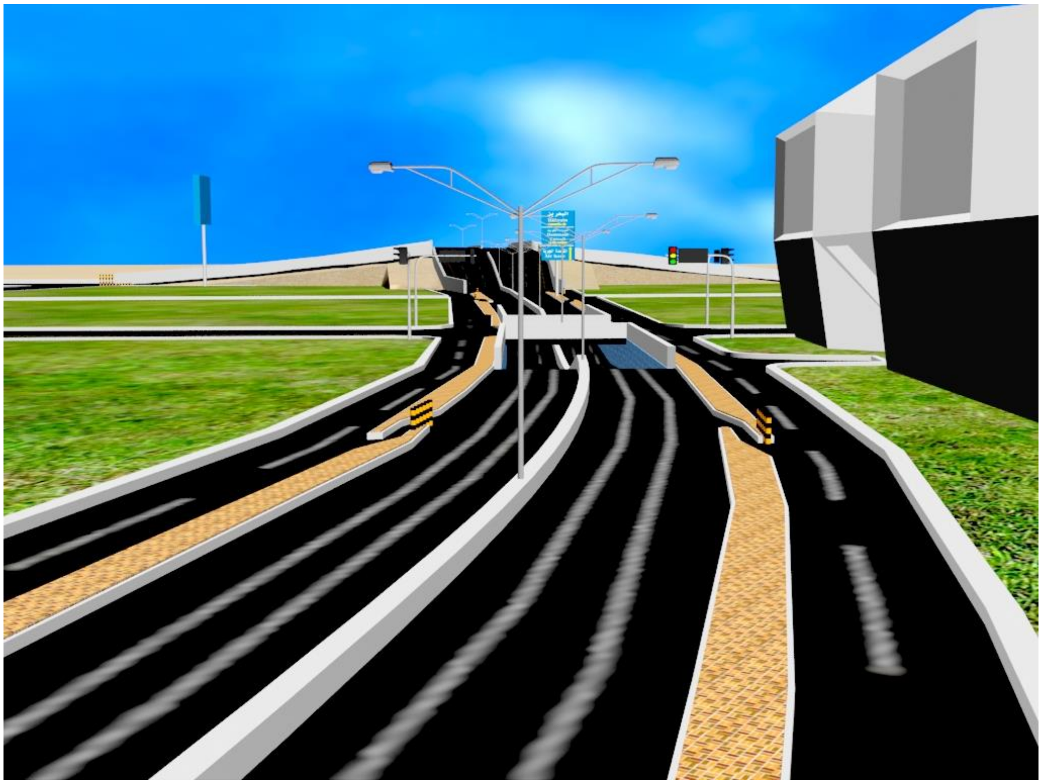


Figure 4.6(*b*). View of the tunnel (view #2)

4.3.2. Junction B: The tunnel/roundabout

The tunnel/roundabout junction is about 6.6 km away from Air Base Bridge. Similarly, tt has a height of 5.5 m and surrounded by a retaining wall. The slope of the road in the section of junction B is about 6% (Figure 4.7*a* & *b*).

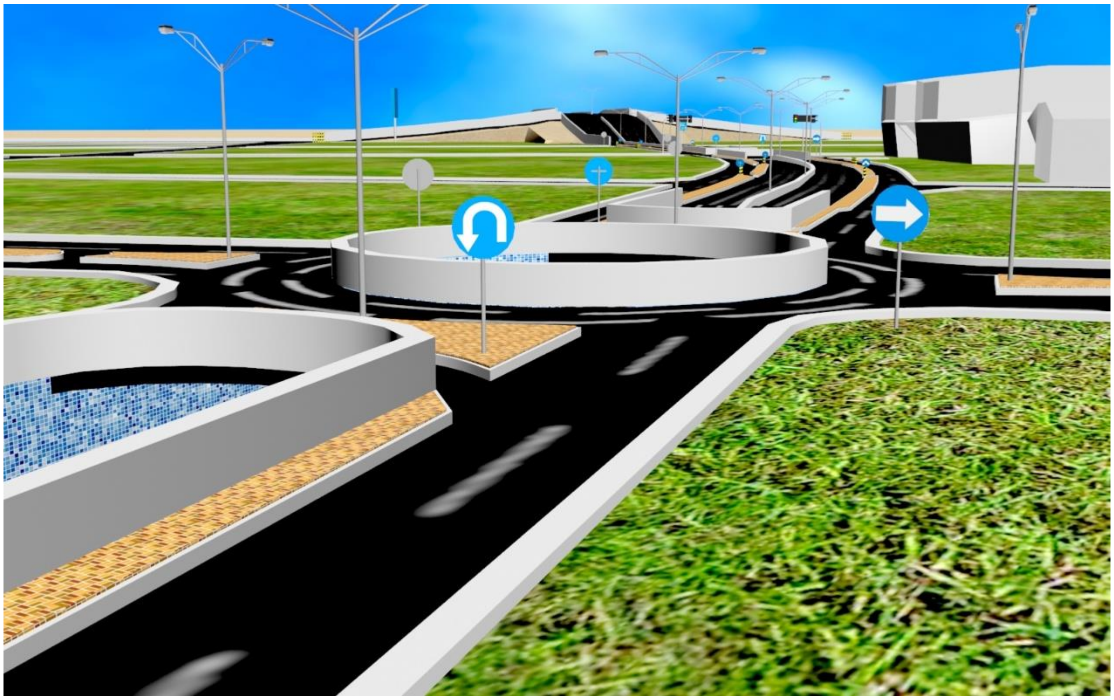


Figure 4.7(*a*). View of the tunnel/roundabout (view #1)

Figure 4.7(*b*). View of the tunnel/roundabout (view #2)

4.3.3. Junction C: The Bridge

The bridge is located at the intersection of Al-Khaldiyah and Half-moon roads. It is composed of four freeways, where two freeways are used as U-turn (Figures 4.8*a* to *c*).

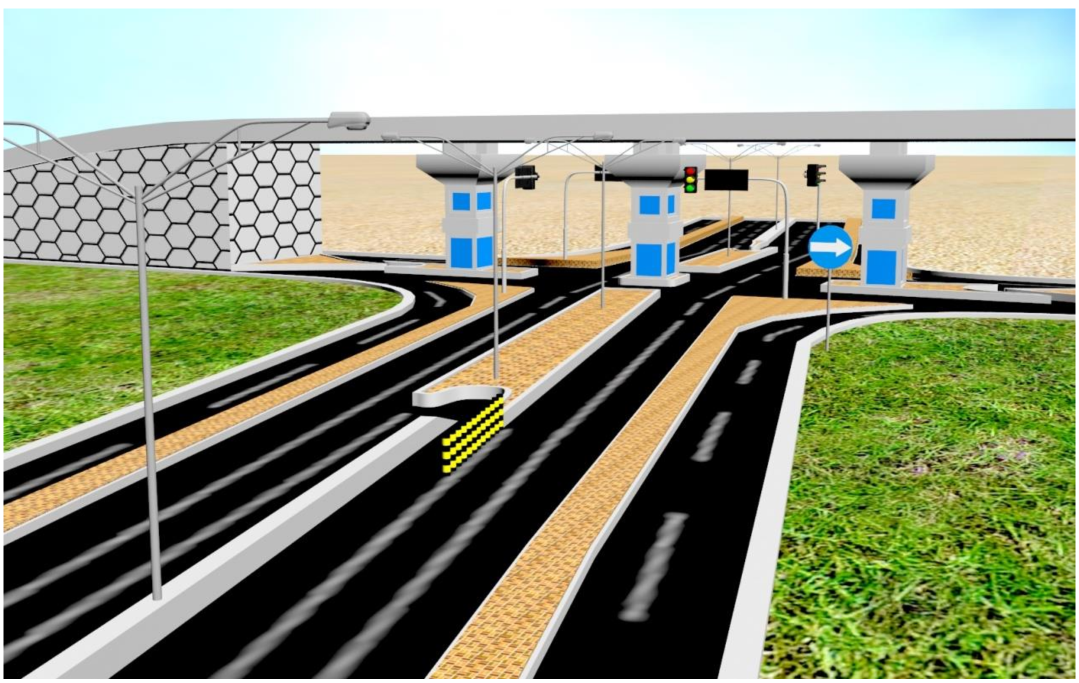


Figure 4.8(*a*). View of the Bridge (view #1)

Figure 4.8(*b*). View of the Bridge (view #2)

Figure 4.8(*c*). View of the Bridge (view #3)

4.4 Conclusion

The main goal of this project is to manage Al-Khaldiyah road in order to optimize safety and improve its sight view. It makes sense to believe that the final design proposed in this investigation (i.e. the retained solution) will resolve and comfort the entire safety problem and all conflict of the road. The final design suggested in this project will contribute to:

1- At the highest level, is the design of a safe road leading to sustainable prevention of serious injury and death crashes, with sustainable requiring all key result areas to be considered.

2- At the second level is real time risk reduction and improving the sight view of the road.

3- The third level is about reducing the crash risk and improving driver behaviour and enforcement.

CHAPTER 5: GEOTECHNICAL DESIGN

5.1. Introduction

As mentioned in previous chapters, the main goals of this project is to design some appropriate junctions for Al-Khaldiyah road in order to increase convenience, comfort and safety while at the same time enhancing the efficient movement of all road users, and also to minimize any traffic conflicts locations at these junctions. Three junctions were suggested which include many geotechnical elements including a long cantilever retaining wall (for tunnel and roundabout tunnel) and an abutment foundation for the bridge.

This chapter is concerned by the geotechnical design of these two different elements of the managed road, in this case the retaining wall of the tunnels and the foundation of the bridge. The design will include selection, calculation and stability verification of these two important geotechnical elements.

5.2. Stability of Retaining Wall of the Tunnel

5.2.1 Background

Retaining structures are engineered to retain soil and/or rock from an area, building, or structure and are commonly used to accommodate changes in grade and provide a right of way. There are several types of retaining structures, including gravity, cantilever, sheet pile, and anchored earth and mechanically stabilized earth (reinforced earth) walls. Gravity retaining walls use their weight to resist pressures and are usually made from heavy materials such as concrete. Sheet pile walls typically consist of steel sheet piles that are driven into the ground to support pressures. Cantilever walls are often shaped like an inverted T and are typically made from a thin stem of steel-reinforced, cast-in-place concrete. The pressures from the retained soils or rock are carried through the stem to the structural footing (bottom of the T), are transferred to the soils below and in front of the wall.

The two basic types of retaining walls are cantilever and gravity. Most cantilever retaining walls are made of cast-in-place, steel-reinforced concrete. This type of structure is able to retain the earth behind it by virtue of its internal strength and rigidity. Reinforced concrete retaining walls are expensive to build, cannot be built in very cold weather, and are not especially attractive. These walls are brittle, and if stresses resulting from differential settlement exceed the strength of the concrete, cracks develop affecting the structure's stability and appearance.

Retaining walls must be designed to be stable with respect to four potential external failure modes: global stability, base sliding, overturning, and bearing capacity.

1- Global Stability refers to the stability of the wall, the soil behind it, and the soil below it. The design engineer must be certain that the entire area including the wall does not collapse. A thorough soil analysis must be performed to eliminate the possibility of global failure.
2- Base sliding refers to the outward movement of the bottom of the retaining wall as a result of the lateral forces generated by earth pressure and, if present, water pressure. The force resisting base sliding is the friction between the fill in the bottom layer of the wall and the foundation soil beneath the bottom layer. The designer may increase the front-to-back dimension of the wall if calculations show that the resisting force is less than required. This will increase the area available to develop the resisting force. A second option would be to use a fill with greater frictional characteristics.
3- Overturning refers to the tipping over of the retaining wall as it rotates about the toe of the structure. The overturning force is the sum of each destabilizing force times its moment arm. The stabilizing force, or righting moment, is the product of the weight of the retaining wall and its moment arm, which is the horizontal distance from the toe to the center of gravity of the wall. If calculations show that the righting moment is less than required, one option is to increase the front-to-back dimension of the wall, thereby increasing its overall weight and the magnitude of its moment arm.
4- Bearing capacity refers to the ability of the foundation soil to support the weight of the retaining wall placed upon it. The analysis is the same as for shallow foundations. It is necessary to increase the area of the base if calculations show that the soil beneath the

wall is too weak. This will decrease the pressure (force per unit of area) on the foundation. Another option is to increase the depth into the ground of the retaining wall, thus increasing the ability of the foundation soil to resist the imposed weight.

The different type of stability verification are schematized in the following figures. Furthemore, the different calculation stages for stability assessment are summarized in the followinf section.

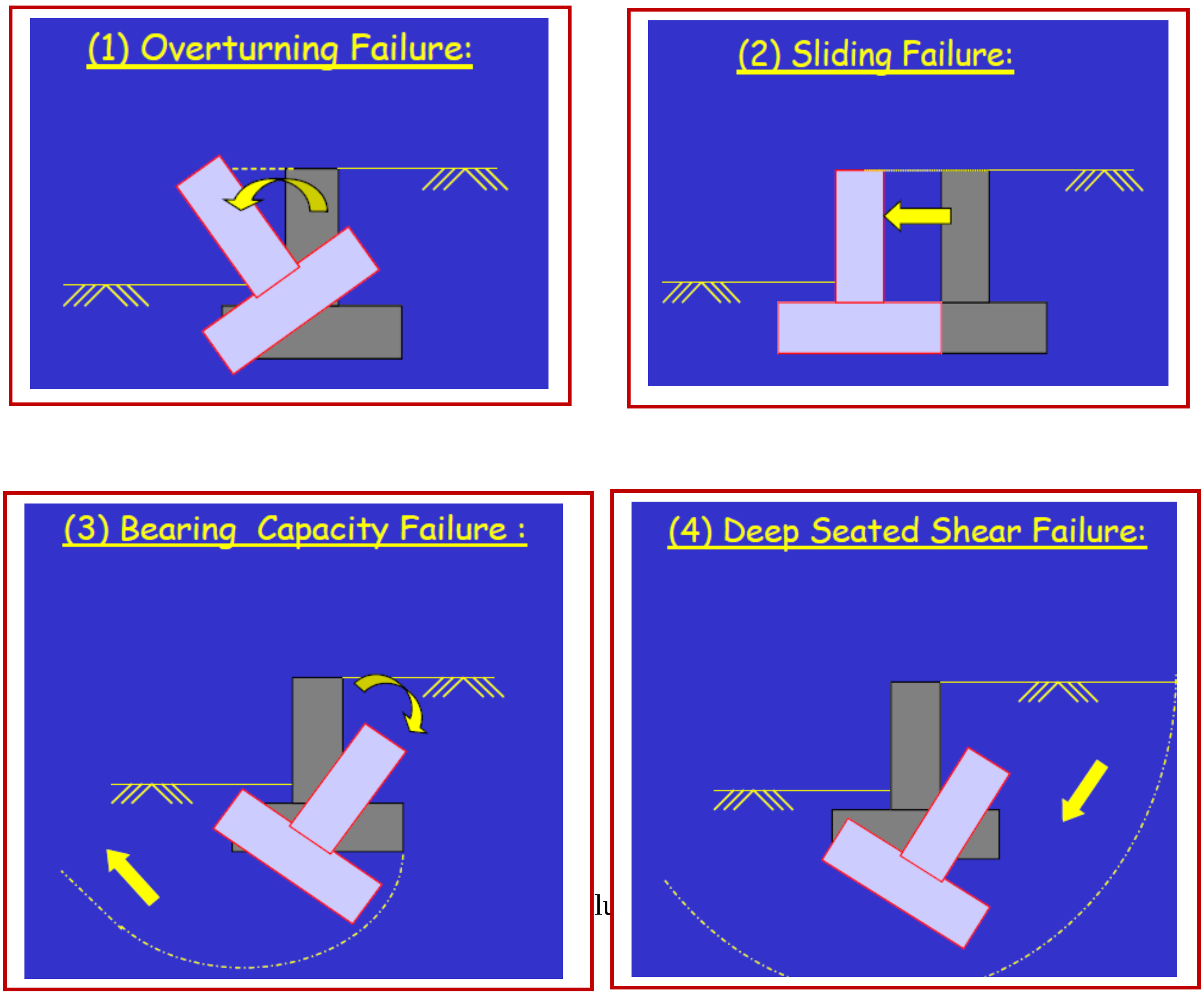


Figure 5.1. Different Modes of Failure of a Cantilever Retaining Wall (from lecture notes)

1- Stability against overturning:

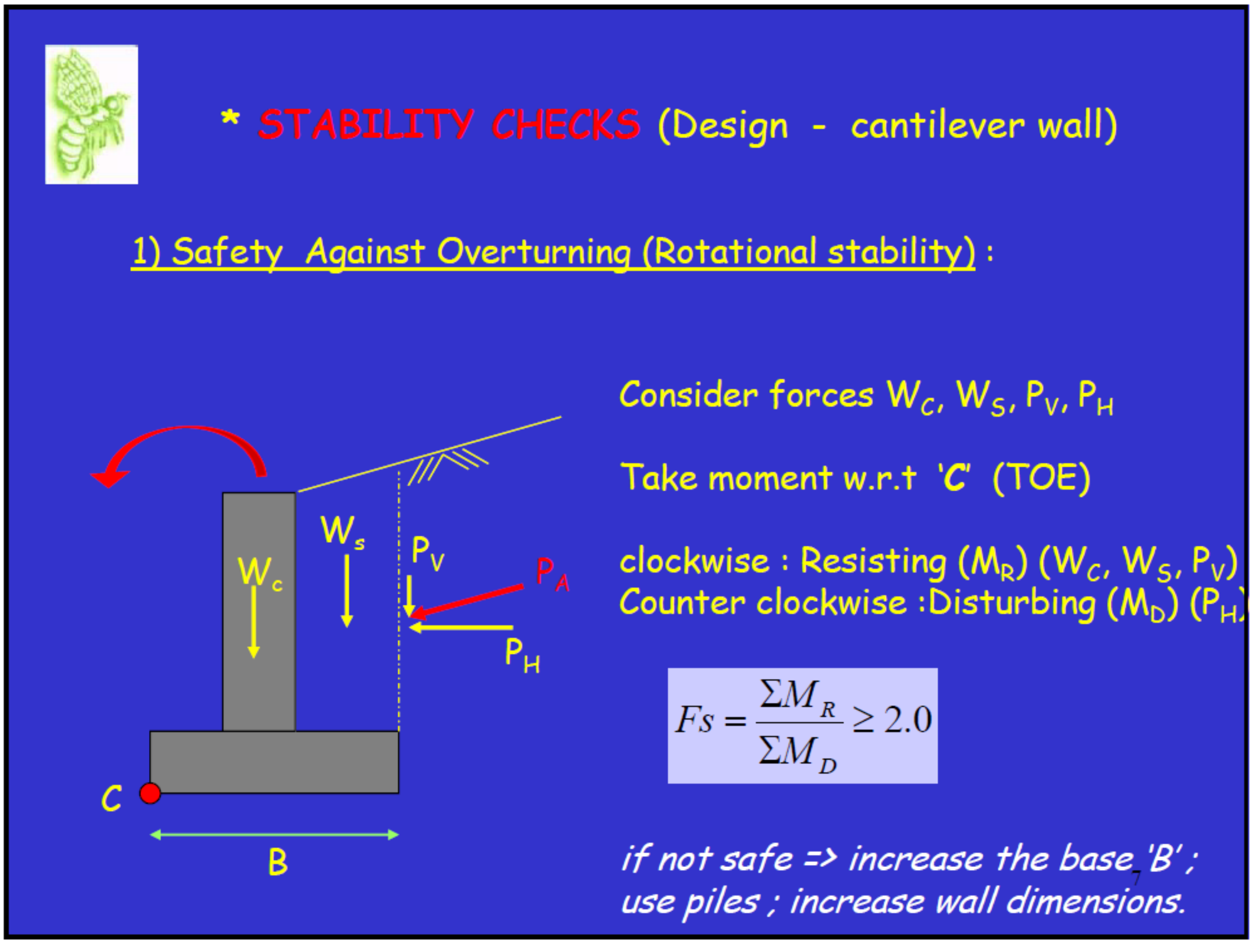


Figure 5.2. Rotational Failure of a Cantilever Retaining Wall (from lecture notes)

2- Stability against base sliding:

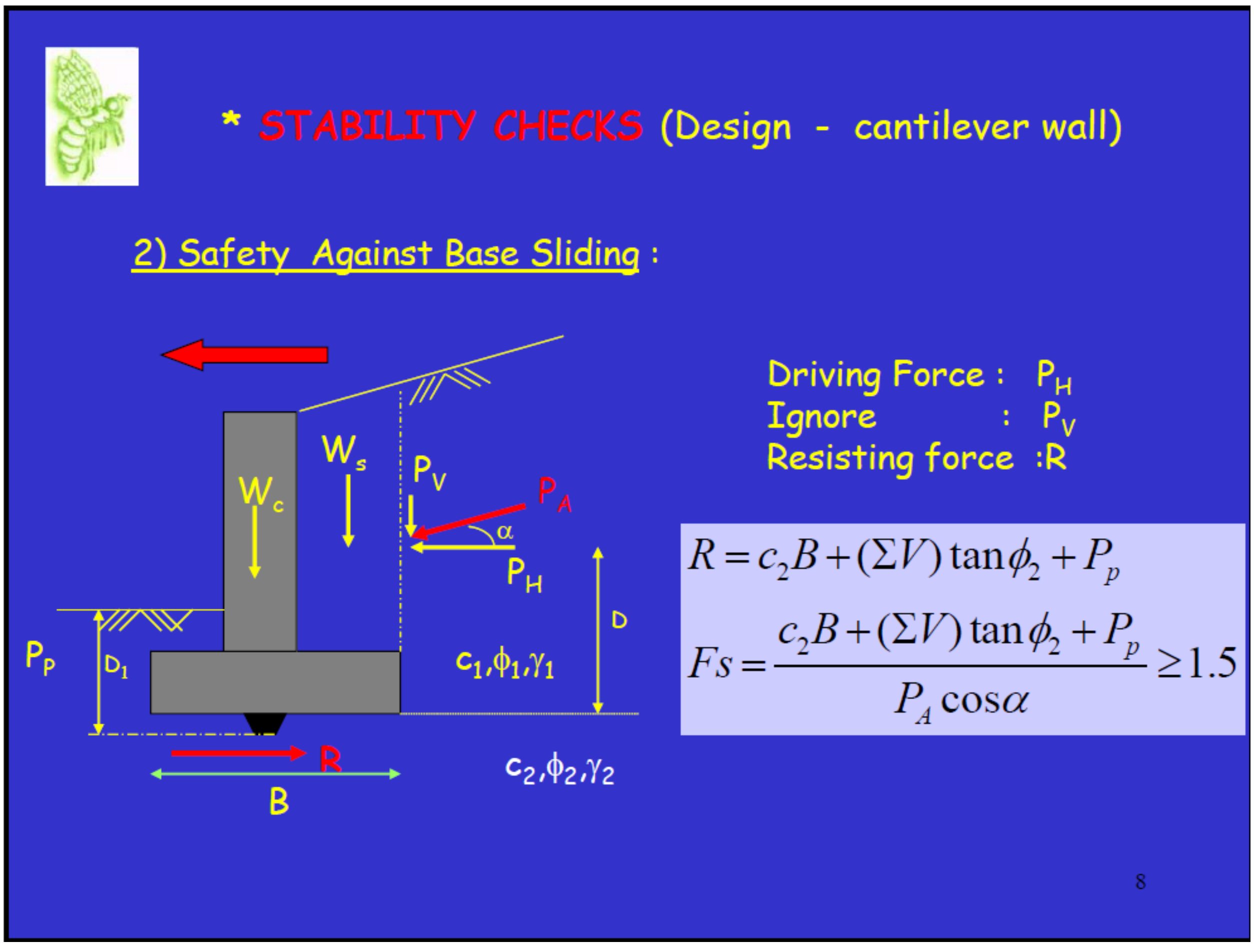


Figure 5.3. Base Sliding of a Cantilever Retaining Wall (from lecture notes)

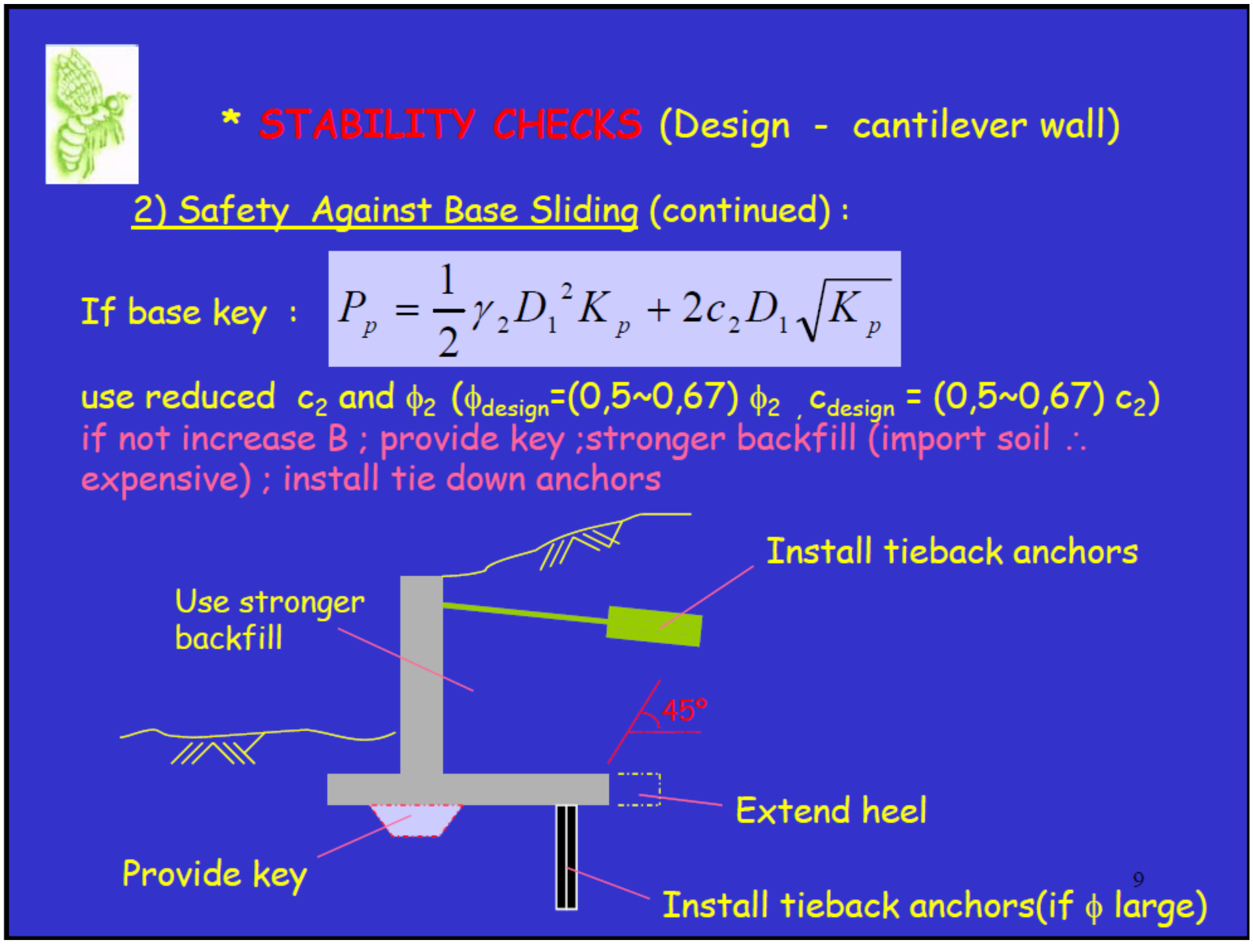


Figure 5.4. Remedial Measures against Base Sliding of a Cantilever Retaining Wall (from lecture note)

3- **Stability against bearing capacity failure:**

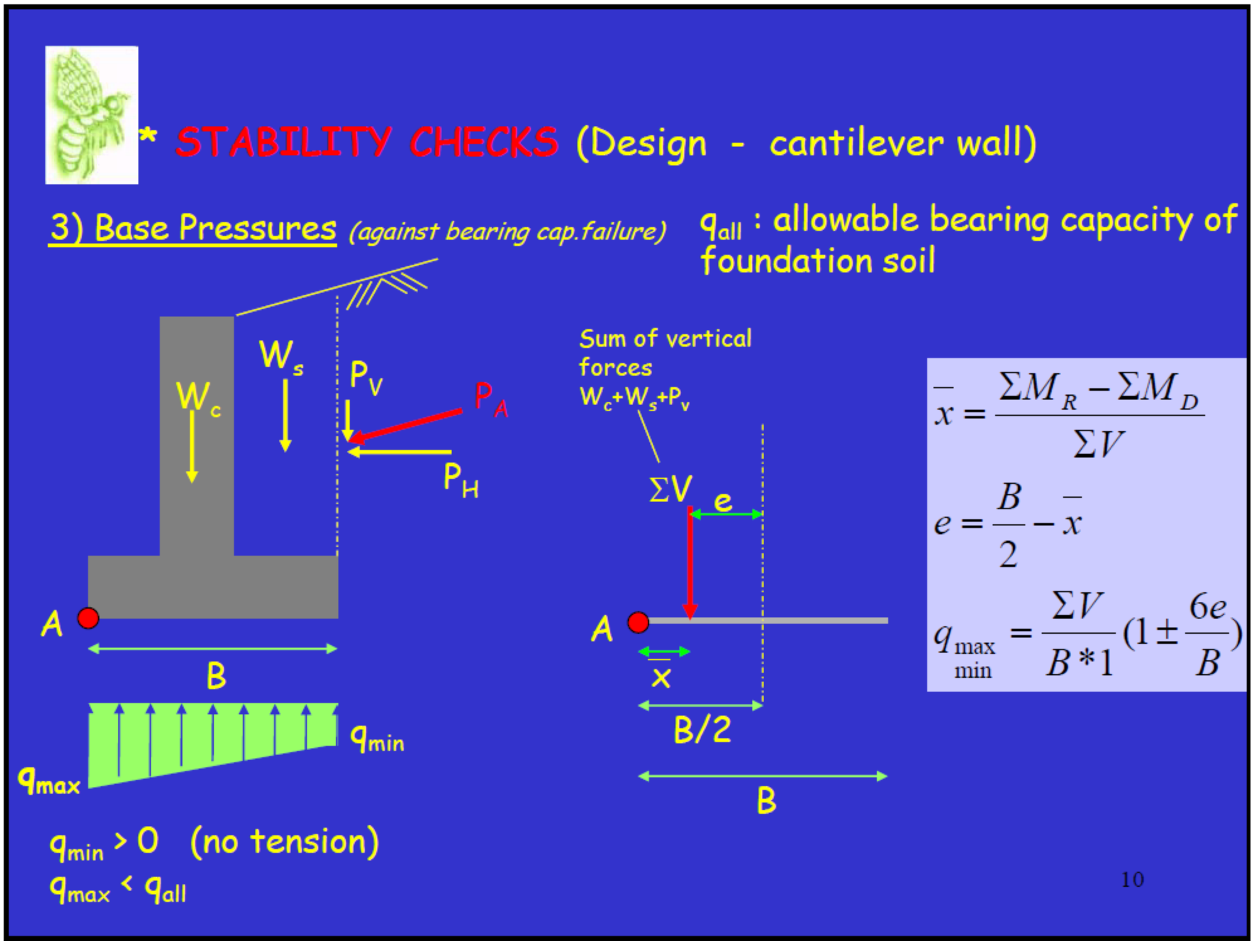


Figure 5.5. Bearing Cap Failure of a Cantilever Retaining Wall (from lecture notes)

5.2.2 Stability assessment

The stability of the retaining wall was verified against the different modes of failure such as overturning, base sliding and bearing cap failure. For this purpose the excel sheet provided by Dr. Ayadat was used. The results of the verification obtained are summarized in Tables *B1* to *B*3 (Appendix B). It is worthy to note that the height of the wall was taken to be 6.5 m.

5.3. Foundation of the bridge abutment

5.3.1 Background

To perform satisfactory, shallow foundation must have the following main characteristics:

1. The foundation has to be safe against shear failure in the soil that support it *(principle of ultimate bearing capacity)*,
2. The foundation cannot undergo excessive settlement *(principle of allowable settlement)*

The failure zone under a shallow foundation can be separated into three parts:

1. The triangular zone ACD immediately under the foundation,
2. The radial shear zones ADF and CDE, with the curves DE and DF being arcs of a logarithmic spiral,
3. Two triangular Rankine passive zones AFH and CEG.

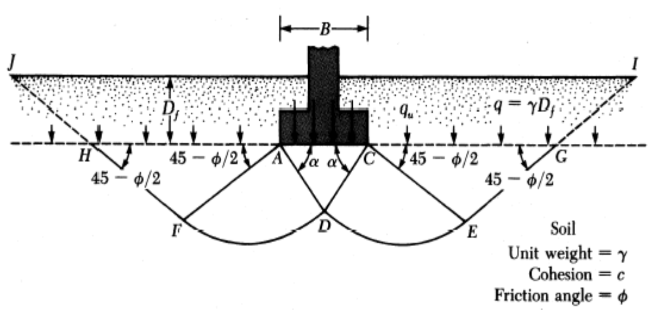


Figure 5.6. Failure Mechanism of Sallow Foundation (from Das, 1999)

Using the equilibrium analysis, Terzaghi expressed the ultimate bearing capacity in the form (strip Foundation):

$$q_u = cN_c + qN_q + \frac{1}{2}BN_\gamma$$

Where:

γ = unit weight of soil,

c = cohesion of soil,

q = γD_f

Table 5.2. Bearing Capacity Factors (from Das, 1999)

Table 3.1 Terzaghi's Bearing Capacity Factors—Eqs. (3.4), (3.5), and (3.6)

ϕ'	N_c	N_q	N_γ[a]	ϕ'	N_c	N_q	N_γ[a]
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.10	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	16.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.65
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	17.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80
25	25.13	12.72	8.34				

[a] From Kumbhojkar (1993)

One-way eccentricity:

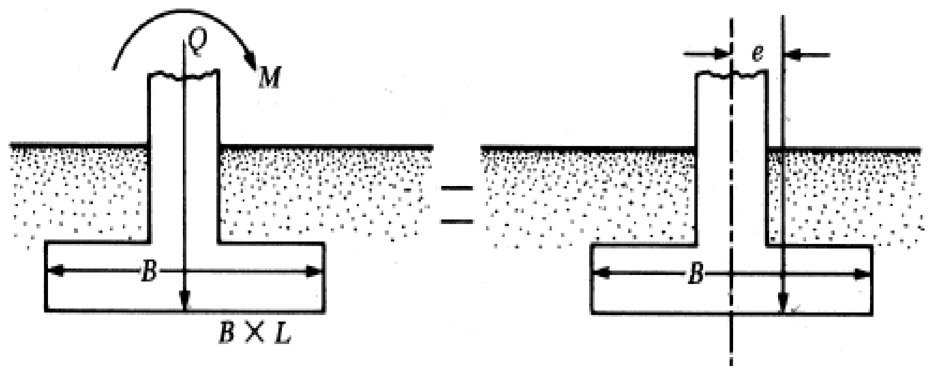


Figure 5.7. One-way Eccentricity of an Isolated Foundation (from Das, 1999)

In many cases, foundations are subjected to moments in addition to vertical load (e.g. base of retaining wall). The distribution of the pressure by the foundation on the soil is not uniform:

$$q_{\max} = \frac{Q}{BL} + \frac{6M}{B^2 L} \qquad q_{\min} = \frac{Q}{BL} - \frac{6M}{B^2 L}$$

Where:

Q = total vertical load,

M = moment on the foundation.

The eccentricity is defined by: $e = \frac{M}{Q}$

By substitution, we obtain: $q_{\max} = \frac{Q}{BL}\left(1 + \frac{6e}{B}\right)$

<u>Remarks:</u>

1) $e = B/6 \Rightarrow q_{min} = 0$

2) $e > B/6 \Rightarrow q_{min}$ negative

The value of q_{max} is then: $q_{\max} = \frac{4Q}{3L(B - 2e)}$

5.3.2 Determination of foundation bearing capacity

The bearing capacity of the foundation of the bridge abutment was calculated using the formula of Terzaghi and the excel sheet provided by Dr. Ayadat. Many values of foundation width and length, and embedment depth were considered (Tables *C1* to *C5*, Appendix C). The appropriate dimension and embedment depth were selected based on the comparison between the applied stress on the ground (q_{max}) and the allowable bearing capacity ($q_{all.}$)

Based on the previous results, grouped in Table 5.1, it can be deduced that the retaining wall of the tunnels are stable against the different modes of failure. Moreover, the comparison between q_{max} and q_{all} indicated that the dimensions which should be selected for the abutment foundation are: D = 3 m, B = 2 m and L =3.5 m.

5.4 Pavement Design of Managed Road

From a geotechnical point of view, the intercepted top sandy soil (fill) cannot be used as sub-base material for the main road and the service roads according to the existing rules. However, the construction of the main road and service roads could be performed following the usual procedures by excavating the soil to a minimum depth of 0.6 m and removing any organic materials if locally intercepted, in accordance with the practicing rules described below. In this case, we will have to expect some defects in the pavement such as cracks and depressions, in short or long term.

However, if the ground in place will be densified (compacted) within the areas of the main road and the service roads, no early defect of paving is anticipated.

Also, it might be necessary to envisage a peripheral drainage around the paved surfaces in order to prevent accumulations of water under pavement coming from the adjacent unpaved zones.

In order to ensure a stable foundation to the pavement, we recommend the following methods for the preparation of the ground:

- If the fill layer is not compacted, fill material and organic matter, disturbed materials if any, should be excavated to a minimum thickness of 0.6 m;
- Proceed with some surface rolling in order to check the presence of any soft or disturbed zones. All flexible zones detected should be excavated and replaced by granular materials of good quality, adequately compacted;

The design of the pavement consisted in the determination of the different thicknesses of the different components of the pavement, in this case subbase, granular base and asphalt concrete surface (Figure 5.8). The method of calculation used was the AASTHO Method. It is mainly based on the Nomograph shown in Figure 5.9. The data used for this purpose was deduced from the soil report described in chapter 3 and it is summarized as follows:

- ESAL: 10 Million (Class design *H* – Highways and expressway)
- Three layers: HMA, base, subbase
- Reliability R = 95%
- Standards deviation = 0.35
- Design Serviceability loss (ΔPSI) = 1.9
- Soil M_R = 5000 psi
- Subbase M_R = 15000 psi and *CBR* = 25
- Base M_R = 30000 psi and *CBR* = 60
- Surface M_R = 400000 psi
- Binder: PG 76-10 (Eastern province)

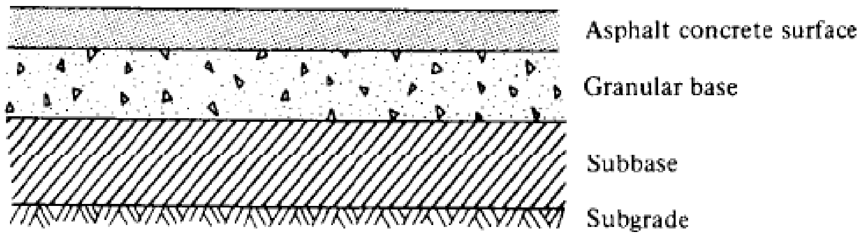


Figure 5.8. Different Components of a Flexible Pavement Design (from internet)

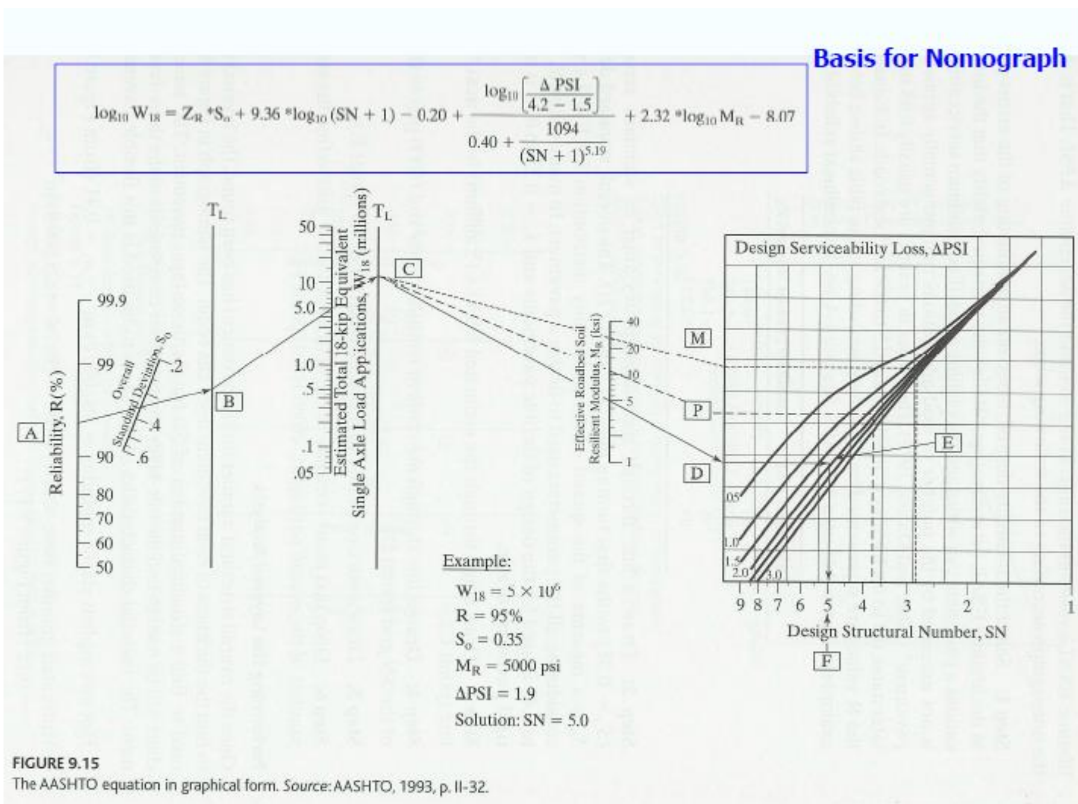


Figure 5.9. AASTHO Nomograph Method (from lecture note)

Calculation Steps:

Determination of SN1

From **Figure 5.10.** Using AASTHO Nomograph Method

$\rightarrow$ *SN1* = 3.2 a_1= 0.42

d_1= (3.2\0.42) = 7.619 in.

Therefore d_1= 8 in. (Verified > 5 in.)

SN1 = 8×0.42 = 3.36

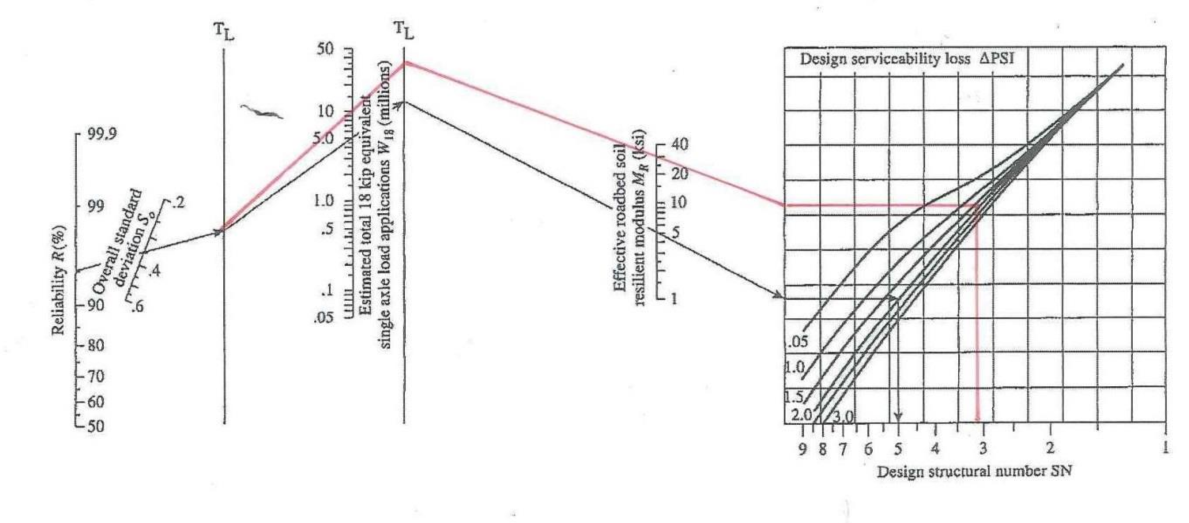


Figure 5.10. Determination of *SN1*

Determination of SN2

From **Figure 5.11.** Using AASTHO Nomograph Method

→ *SN2* = 4 a_2 = 0.119 from fig. 917 (Dr Tahar Notes of Transportation)

d_2 = sn2-sn1\a2

d_2 = (4-3.36\0.119) = 5.38 in

So d_2 = 6 in

SN2 = 6*0.119 = 0.714

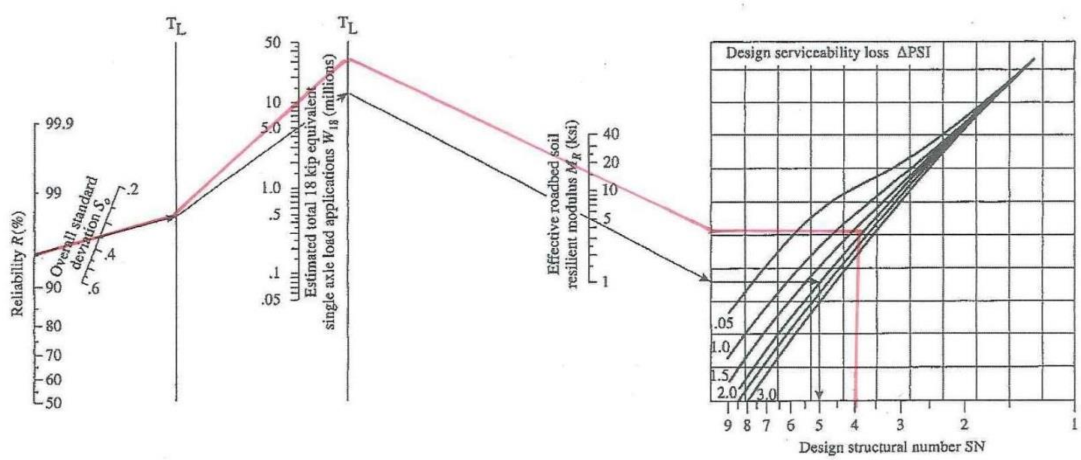


Figure 5.11. Determination of *SN2*

Determination of SN3

From **Figure 5.12.** Using AASTHO Nomograph Method

→ *SN3* = 5.75 a3=0.094 fig. 9.19 (Dr Tahar Notes of Transportation)

d_3 = sn3-(SN2+SN1)\a_3

d_3 = 5.75-(0.714+3.36)\0.094=17.83 in

So d_3 = 18 in

SN3 = 18 * 0.094 = 1.692

SN (total) = 3.36 + 0.714 + 1.692 = 5.766 so: *d* (total) = 8 + 6 + 18 = 32 in

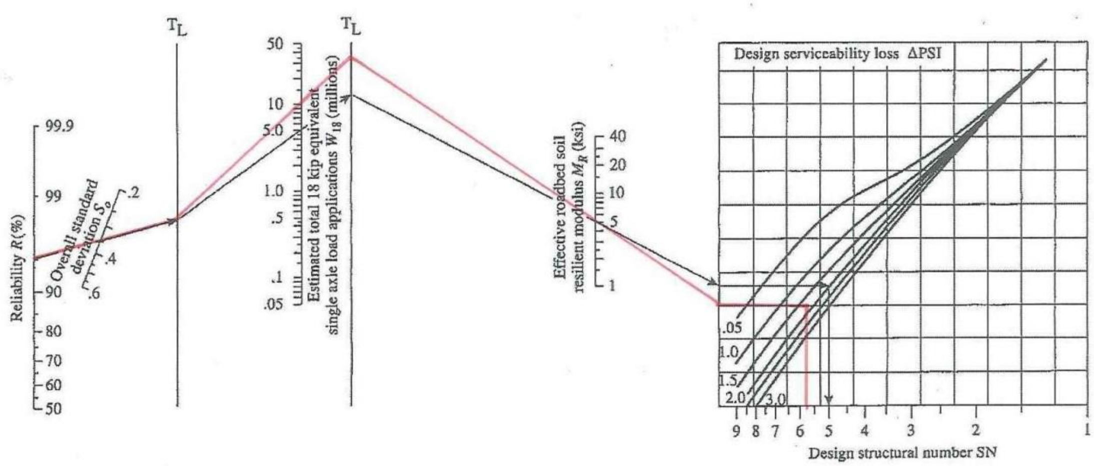


Figure 5.12. Determination of *SN3*

The results obtained for the thickness of the different components are as follows:

- Asphalt Concrete: d_1 = 8 in" (SN_1 = 3.36)
- Granular Base: d_2 = 6" (SN_2 = 0.714)
- Granular Sub base: d_3 = 18in" (SN_3 = 1.692)

Figure 5.13. Example of pavement construction (photo 1)

Figure 5.14. Example of pavement construction (photo 2)

CHAPTER 6: CONCLUSION

6.1. Introduction

The Kingdom of Saudi Arabia has a network of internal roads sophisticated and modern and has a total road length of about 160 thousand kilometers of which about 47 thousand kilometers are paved roads linking major centers. In Saudi Arabia the motor vehicle is the main means of transportation. However, between 1971 and 1997; 564 762 people died or were injured in road traffic accidents, a figure equivalent to 3.5% of the total population in Saudi Arabia. It is reported that during this period 66 914 people have died on the roads in Saudi Arabia due to road accidents, amounting to one person killed and four injured every hour.

This project was concerned by the management of Al-Khaldiyah road (Al Khobar) in order to optimize its safety and improve its sight view (i.e. proposition of sustainable solutions for the purpose of optimizing the safety use of this important road and also improving its sight view). This includes the design of some appropriate junctions in order to increase convenience, comfort and safety while at the same time enhancing the efficient movement of all road users, and the minimization of traffic conflicts locations at these junctions.

In this chapter, some relevant conclusions, drawn from this work, are summarized. These general conclusions are mainly concerned by the geometrical design of the managed road. Comments on the geotechnical and the pavement design of the different elements of the road are also included.

6.2. General Conclusions

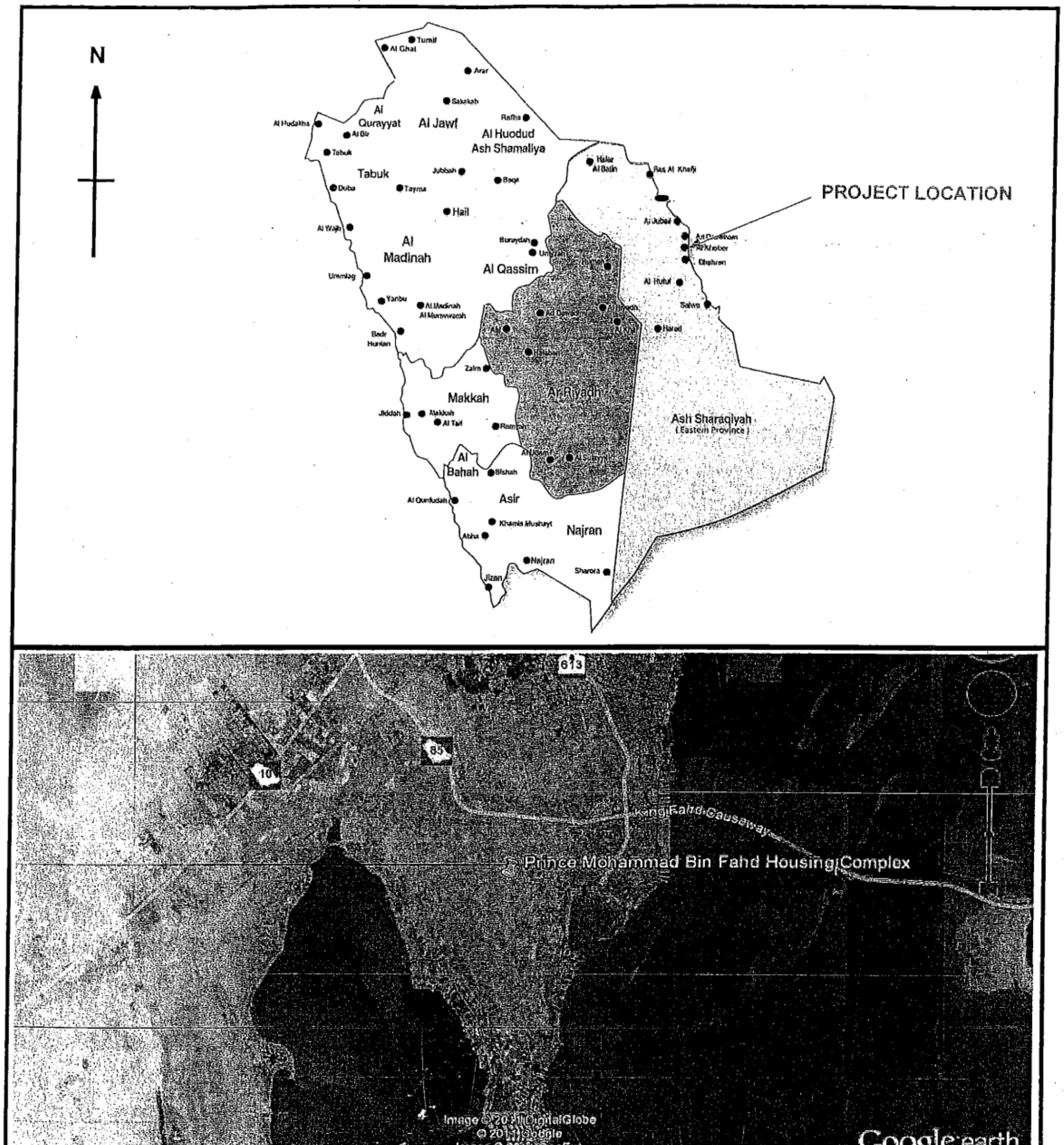
As mentioned previously, the goals of this project were to propose sustainable solutions for the purpose of optimizing the safety use of this important road and also improving its sight view. The project included:

- Analysis and comparative study of three different solutions suggested to increase convenience, comfort and safety of the road, and also to improve sight view.
- Geometrical design of the retained proposition which include the design of some appropriate junctions, such as tunnel, tunnel/roundabout and bridge.
- Geotechnical design of two main different part of the managed road in this case the tunnel retaining wall and the abutment foundation of the bridge.
- Pavement design of a prototype section of the proposed road.

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

- Three different solutions were proposed in order to manage the road of al-Khaldiyah. A comparative study were carried out in order to optimize the management of the road in respect to the movement efficiency of all road users, the minimization of traffic conflicts, comfort and safety of the road, and also the improvement of its sight view.
- The solution retained for the purpose of this project consisted on the prevision of three different junctions in this case: tunnel, tunnel/roundabout and bridge. They are situated respectively at 3.3 km; 6.6 km and 9.8 km from the air base bridge. The new bridge will connect Al-Khaldiyah and Half-moon roads.
- A prototype of the managed road (i.e. the new proposition) was developed. The prototype shows the different components of the roads, as well as, the surrounding facilities.
- A geotechnical design was performed (using appropriate Excel Sheet) in order to assess the stability of the tunnel retaining wall and to select the appropriate dimensions of the abutment foundation of the bridge.
- A pavement design was carried out using AASHTO method and Saudi code to determine the thicknesses of the different components of a section prototype of the managed road (i.e. Asphalt concrete, granular base and subbase).

APPENDIX A



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		SCALE: Not to Scale — **FIGURE - 1**

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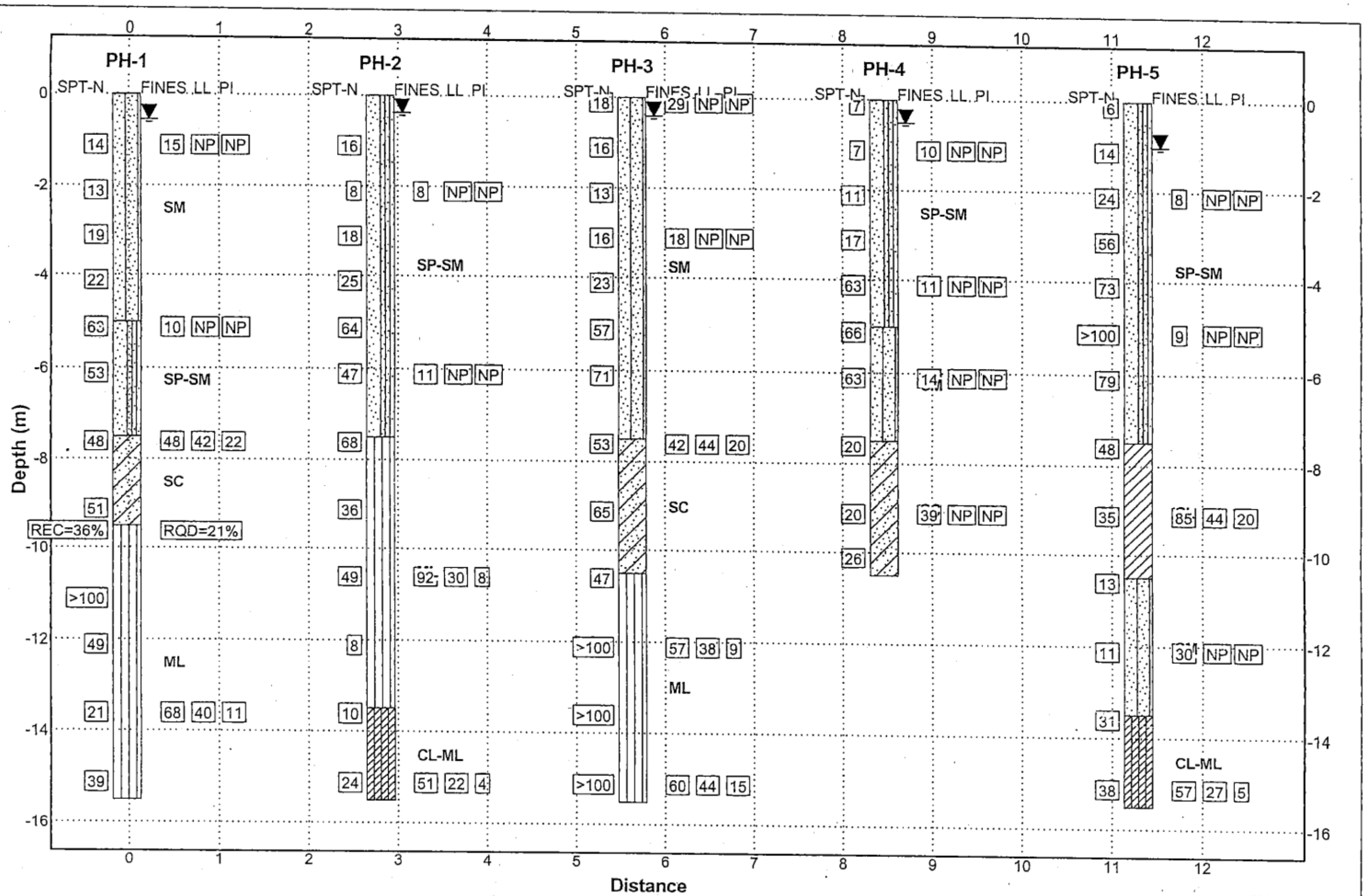


NOT TO SCALE

GULF CONSULT

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

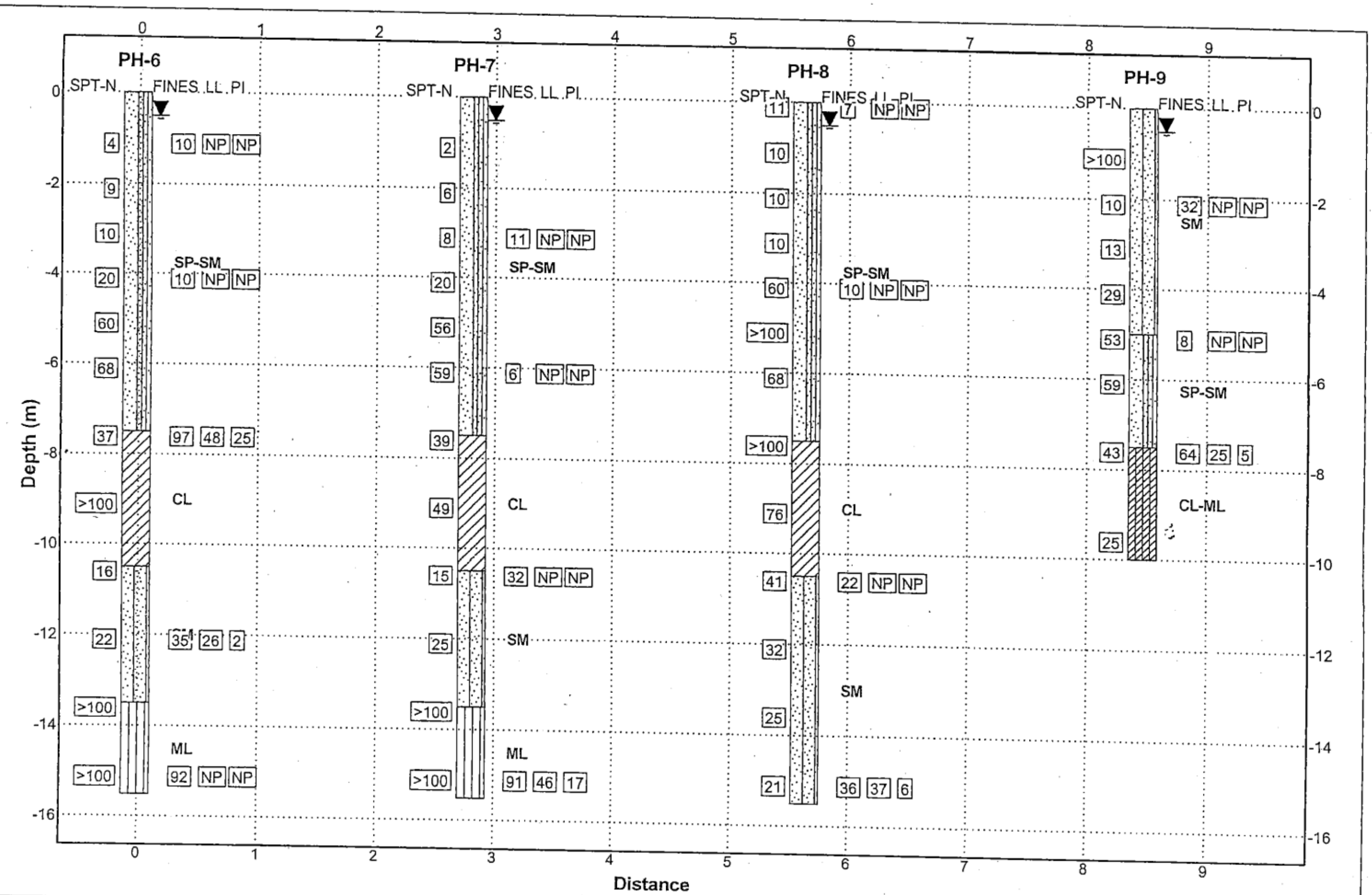
Project : **Prince Mohammad Bin Fahd Housing Complex**

Location : Aziziyah, Halfmoon Bay

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

SUBSOIL PROFILE

Figure No.: **3/1**



NOT TO SCALE

GULF CONSULT

PROFILE KEY
SPT-N : SPT 'N'value
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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.: **3/2**

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SYMBOLS USED IN BORE LOGS

FIGURE - 4

Job No.: 11-12196

Poorly graded Sand(SP)	Fat silt(MH)	Poorly graded gravel(GP)
Poorly graded sand with silt (SP-SM)	Lean clay(CL)	Well graded gravel(GW)
Silty Sand(SM)	Fat clay(CH)	Silty gravel(GM)
Clayey sand(SC)	Silty clay(CL-ML)	Gravel with silt & sand (GP-GM)
Sandy silt / SILT with sand (MLS)	Sandy lean clay(CLS)	Well graded gravel with silt (GW-GM)
Silt (ML)	Poorly graded sand with clay(SP-SC)	Clayey gravel(GC)
Well graded sand with clay(SW-SC)	Asphalt	Limestone
Well graded sand with silt(SW-SM)	Fill	Siltstone
Well graded sand with silt and gravel	Concrete	Mudstone
Coral	IGNSMG	Sandstone
Conglom	METACG	IGNSFG
IGNSCG	Gypsum	METAMG
METAFG	Boulders	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

Diameter of Boring : 4"

Sampling Hammer Wt & Drop : 140 Lbs & 30"

Ground Elevation (m) :

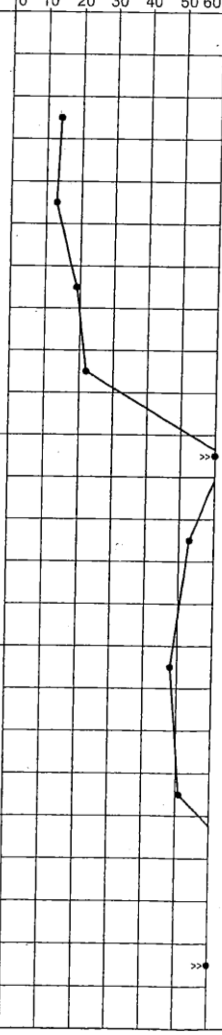
Date Started : 11/12/2011

Date Completed : 11/12/2011

Depth at Gr. Water Table (m): 0.55

Depth (Meters)	Sample Type & Number	Blows Per 15 Cms	Classification	DESCRIPTION
0–1	TR		SM	Gray, medium dense, fine to coarse silty SAND with gravel
1	SPT1	15 8 6	SM	Ditto,
2	TR		SM	
2	SPT2	4 7 6	SM	Ditto, dark gray
3	TR		SM	
3	SPT3	4 6 13	SM	Ditto,
4	TR		SM	
4	SPT4	7 7 15	SM	Ditto,
5	TR		SM	
5	SPT5	17 27 36	SP-SM	Dark gray, very dense, poorly graded, fine to medium SAND with silt
6	TR		SP-SM	
6	SPT6	18 20 33	SP-SM	Ditto,
7	TR		SP-SM	
8	SPT7	21 20 28	SC	Gray, very dense, fine to medium clayey SAND
8–9	TR		SC	
9	SPT8	16 25 26	SC	Ditto,
10	C1		ML	Light yellowish, cemented SILTSTONE with few voids UCS=16.45kg/cm²
11	SPT9	50/11cm	ML	Ditto,
12	TR		ML	

Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)



REMARKS

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

SHEET 1 OF 2

SUBSURFACE EXPLORATION LOG

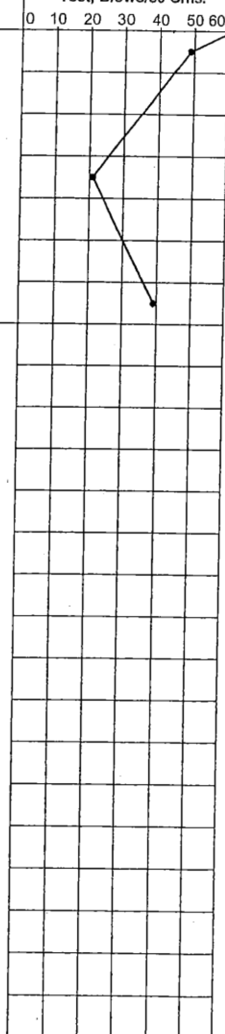
Job No. 11-12196

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.	REMARKS
	SPT10	20 21 28			Whitish gray, hard, sandy SILT		
13	TR						
14	SPT11	4 8 13		ML	Ditto, very stiff		
	TR						
15	SPT12	11 16 23			Ditto,		
					Boring Terminated at 15.50 meters depth		
16							
17							
18							
19							
20							
21							
22							
23							
24							



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

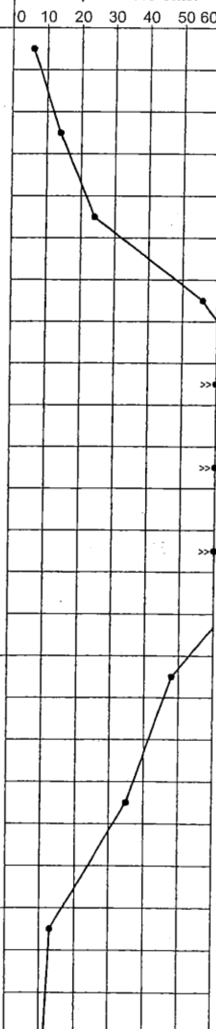
SHEET 2 OF 2

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
Diameter of Boring :	4"
Date Started :	11/15/2011
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	Classification	DESCRIPTION	REMARKS
	SPT1	2 3 3	SP-SM	Brown, loose, poorly graded, fine to medium SAND with silt	
1	TR				1 ▼
	SPT2	4 7 7		Ditto, medium dense	
2	TR				2
	SPT3	6 9 15		Ditto, dark gray	
3	TR				3
	SPT4	11 21 35		Ditto, very dense	
4	TR				4
	SPT5	15 31 42		Ditto,	
5	TR				5
	SPT6	22 38 50/13cm		Ditto, cemented	
6	TR				6
	SPT7	27 32 47		Ditto,	
7	TR				7
8	SPT8	10 17 31	CL	Gray, hard, lean CLAY with sand	8
9	TR				9
	SPT9	10 13 22		Ditto,	
10	TR				10
11	SPT10	4 5 8	SM	Whitish gray, medium dense, fine to coarse silty SAND	11
12	TR				12

Standard Penetration Test, Blows/30 Cms.



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

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SUBSURFACE EXPLORATION LOG

Job No. 11-12196

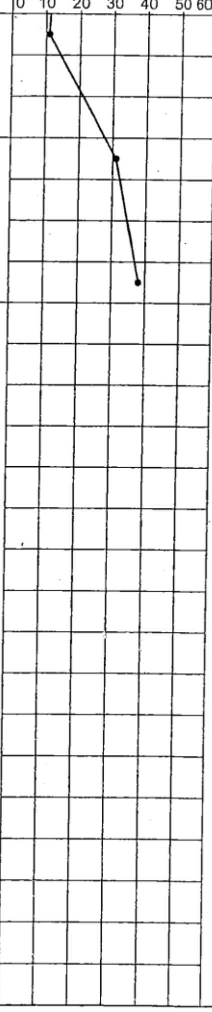
Project : Prince Mohammad Bin Fahd Housing Complex

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

BORING NO. PH-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	REMARKS
	SPT11	6 5 6		SM	Gray, medium dense, fine to medium silty SAND	
13	TR					13
	SPT12	5 10 21		CL-ML	Gray, hard, sandy silty CLAY	
14						14
	TR					
15	SPT13	11 16 22			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

Standard Penetration Test, Blows/30 Cms.



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

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	Classification	DESCRIPTION	REMARKS
0–1	TR		SP-SM	Brownish gray, very loose, poorly graded, fine to medium SAND with silt	▼
1	SPT1	3, 2, 2	SP-SM	Ditto,	
	TR		SP-SM		
2	SPT2	3, 3, 6	SP-SM	Ditto, loose	
	TR		SP-SM		
3	SPT3	2, 4, 6	SP-SM	Ditto,	
	TR		SP-SM		
4	SPT4	3, 7, 13	SP-SM	Ditto,	
	TR		SP-SM		
5	SPT5	16, 20, 40	SP-SM	Ditto, very dense	
	TR		SP-SM		
6	SPT6	20, 25, 43	SP-SM	Ditto,	
7	TR		SP-SM		
8	SPT7	16, 15, 22	CL	Brownish gray, hard, lean CLAY	
	TR		CL		
9	SPT8	13, 25, 50/14cm	CL	Ditto,	
10	TR		CL		
11	SPT9	5, 7, 9	SM	Whitish gray, medium dense, fine to coarse silty SAND	
12	TR		SM		

Standard Penetration Test, Blows/30 Cms. (0 10 20 30 40 50 60)

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

SHEET 1 OF 2

SUBSURFACE EXPLORATION LOG

Job No. 11-12196

Project : Prince Mohammad Bin Fahd Housing Complex

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

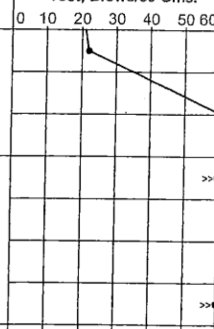
BORING NO. PH-6

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.	REMARKS
	SPT10	10 9 13		SM	Whitish gray, medium dense, fine to medium silty SAND		
13	TR						13
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.
TR : Tricone Drilling
C1 : Rock Core Run and Number

A : Auger Boring
NE: Not Encountered

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SUBSURFACE EXPLORATION LOG

Job No. 11-12196

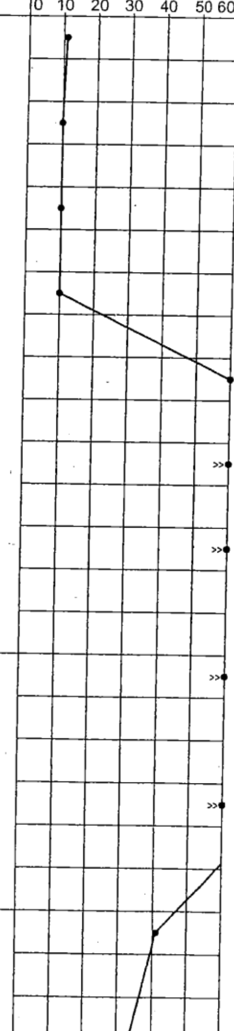
Project : Prince Mohammad Bin Fahd Housing Complex

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.	REMARKS
	SPT1	3 7 4		SP-SM	Brownish gray, medium dense, poorly graded, fine to medium SAND with silt		
1	TR						▼ 1
	SPT2	2 7 3			Ditto, loose		
2	TR						2
	SPT3	3 4 6			Ditto,		
3	TR						3
	SPT4	3 3 7			Ditto,		
4	TR						4
	SPT5	12 25 35			Ditto, very dense		
5	TR						5
	SPT6	16 33 50/13cm			Ditto, cemented	>>	
6	TR						6
	SPT7	17 29 39			Ditto,	>>	
7	TR						7
8	SPT8	16 42 50/8cm		CL	Greenish gray, hard, lean CLAY with sand	>>	8
9	TR						9
	SPT9	17 30 46			Ditto,	>>	
10	TR						10
11	SPT10	17 18 23		SM	Whitish gray, dense, fine to coarse silty SAND with gravel		11
12	TR						12



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

SHEET 1 OF 2

SUBSURFACE EXPLORATION LOG

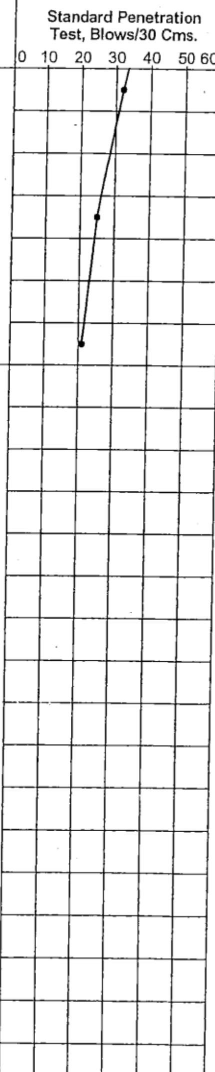
Job No. 11-12196

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.	REMARKS
	SPT11	9 14 18			Gray, dense, fine to coarse silty SAND		
13	TR						13
	SPT12	5 7 18		SM	Ditto, medium dense		
14							14
	TR						
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.
TR : Tricone Drilling
C1 : Rock Core Run and Number
A : Auger Boring
NE: Not Encountered

SHEET 2 OF 2

SUMMARY OF LABORATORY TEST RESULTS
(BOREHOLE SAMPLES)

GULF CONSULT

APPENDIX B1

PROJECT:	CLIENT:	JOB NO.:
PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX	AZMEEL CONTRACTING CO.	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; CO_3 - Carbonate; Cl - Chloride; LL - Liquid Limit; PI - Plasticity Index

GULF CONSULT

SUMMARY OF LABORATORY TEST RESULTS

(BOREHOLE SAMPLES)

APPENDIX **B1**

PROJECT:	CLIENT:	JOB NO.:
PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX	AZMEEL CONTRACTING CO.	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
CO_3 - Carbonate
Cl - Chloride
LL - Liquid Limit
PI - Plasticity Index

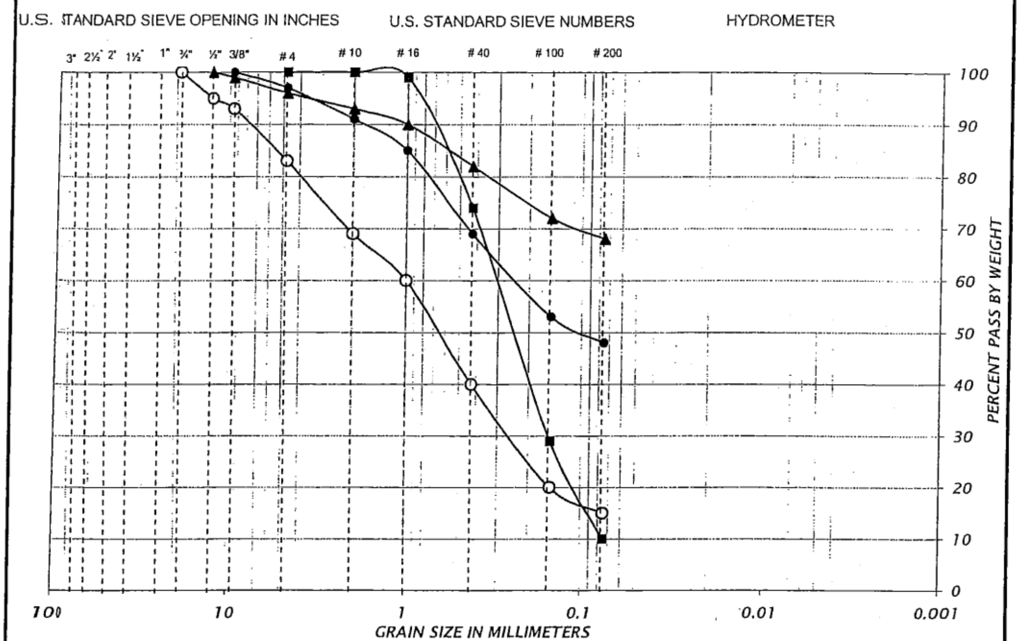
PARTICLE SIZE ANALYSIS

Appendix-B2

GULFCONSULT

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

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

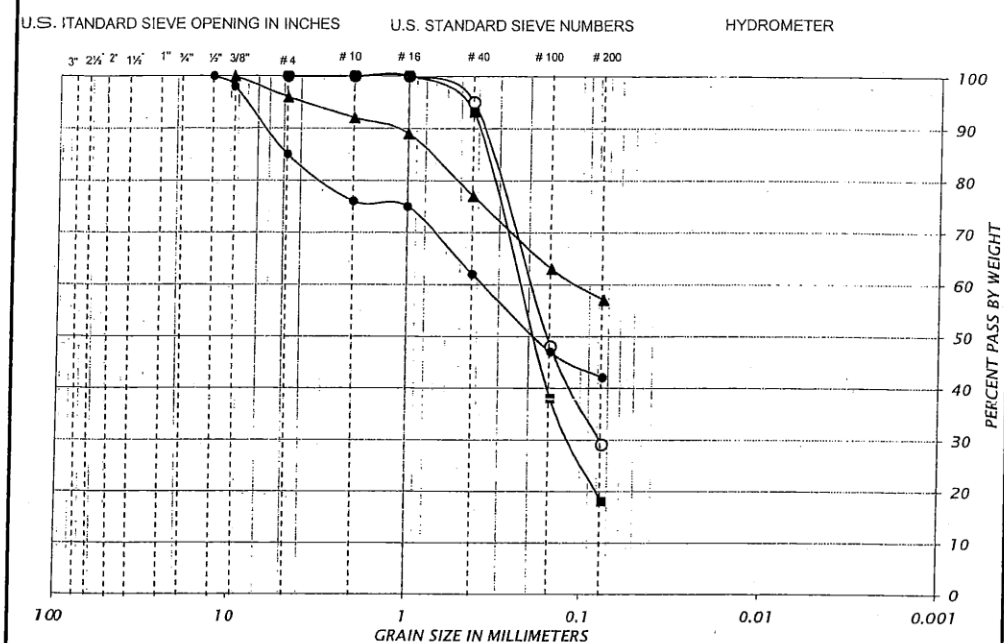
PARTICLE SIZE ANALYSIS

Appendix-B2

GU LFCONSULT

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

GULF CONSULT	UNCONFINED COMPRESSION TEST **ASTM D-2166**	APPENDIX-B3
	PROJECT : PRINCE MOHAMMAD BIN FAHD HOUSING COMPLEX	

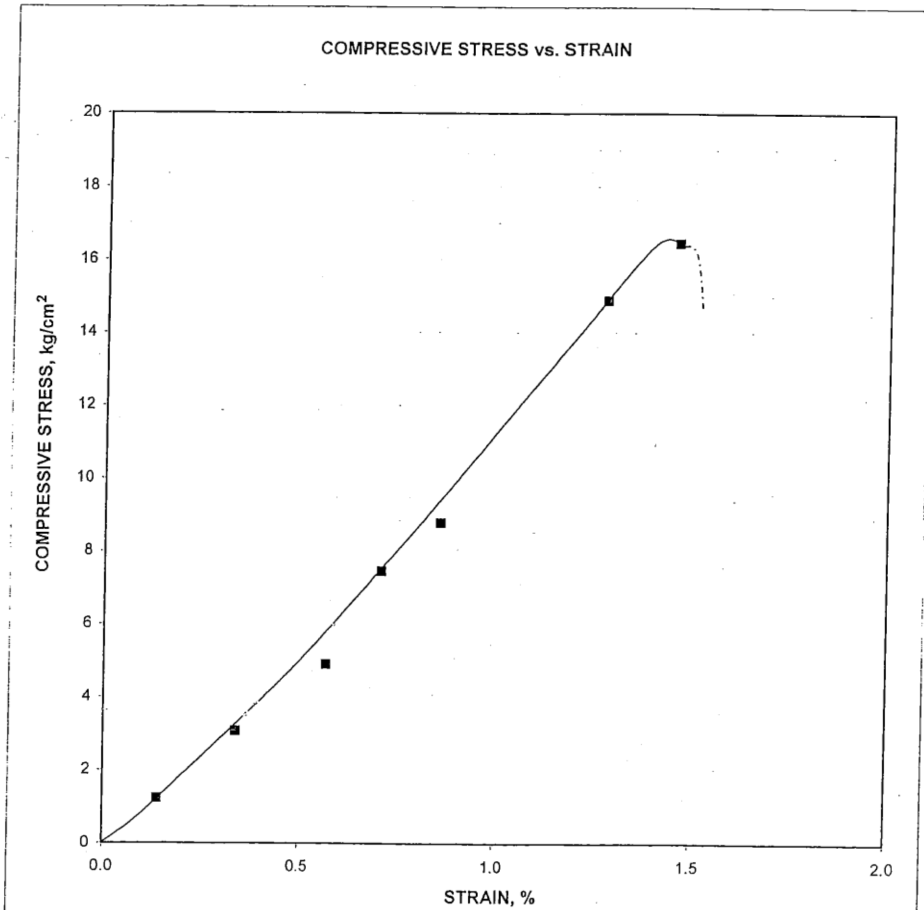
CLIENT :	AZMEEL CONTRACTING CO.	JOB NO.: 11-12196	LOCATION : AZIZIYAH, HALFMOON BAY

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



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 °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°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

APPENDIX B

Stability of Retaining Wall

Bearing Capacity Failure

1- Data:

Width of Wall, L (m)	4
Height of Wall, H1 (m)	6.5
Surchage, q (kN/m2)	50
Top Base of Scrren Wall (m)	0.4
Bottom Base of Screen Wall (m)	0.5
Embeddment of the Wall in the Left, D (m)	1
Soil Unit Weight, γ (KN/m3)	17
Angle of Internatl Friction, φ (o)	30
Coefficient of friction Soil/Wall, μ	0.36395858
Angle Beta (o)	0
Angle Delta (o)	0
Coefficient Ka	0.33330956
Coefficien Kq	0.33330956
Unit Weight of reinforced concrete (kN/m3)	25
Weight of Wall Screen (Rectangular section) (W1, kN)	59.5833333
Weight of Wall Screen (Triangular section) (W2, kN)	7.44791667
Weight of Wall Footing (W3, kN)	54.1666667
Weight of Soil Behind the Wall, W4 (kN)	265.795
Height of Soil Behind the Right of the Wall, H2 (m)	5.9
Height of Soil Behind the Left of the Wall, H2 (m)	1

2- Calculation:

1- Étape 1:

Pa(kN)	*Pq (kN)*	*Pp (kN)*	Rv (kN)	Rh(kN)	e (m)	B' (m)
98.62129888	49.16315996	443.8591573	386.992917	335.7412718	0.86756439	2.26487123

***e* should be ≤ *L*/6**

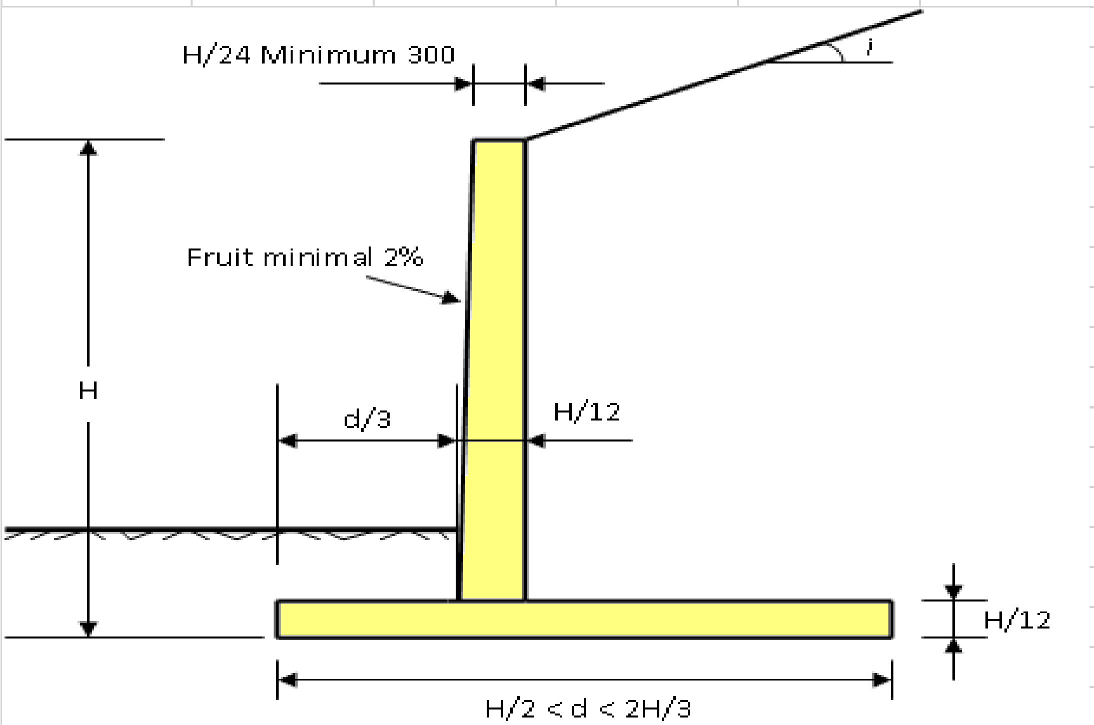
2- Étape 2:

Sigma_s (kN/m2)	Sigma_v (kN/m2)	***Fp***
431.2314821	170.8675141	2.523776883

***L*/6 =** 0.66666667

***Fp* Should be ≥ 2,0 (FHWA 1990)**

3- Figure:



$$e = \frac{P_H * H^{`}/3 + P_q * H^{'}/2 - (\sum_{i=1}^{4} W_i.d_i) - P_p.H_2/3}{W_1 + W_2 + W_3 + W_4}$$

4- Table:

ϕ'	N_c	N_q	N_γ	ϕ'	N_c	N_q	N_γ
0	5.14	1.00	0.00	26	22.25	11.85	12.54
1	5.38	1.09	0.07	27	23.94	13.20	14.47
2	5.63	1.20	0.15	28	25.80	14.72	16.72
3	5.90	1.31	0.24	29	27.86	16.44	19.34
4	6.19	1.43	0.34	30	30.14	18.40	22.40
5	6.49	1.57	0.45	31	32.67	20.63	25.99
6	6.81	1.72	0.57	32	35.49	23.18	30.22
7	7.16	1.88	0.71	33	38.64	26.09	35.19
8	7.53	2.06	0.86	34	42.16	29.44	41.06
9	7.92	2.25	1.03	35	46.12	33.30	48.03
10	8.35	2.47	1.22	36	50.59	37.75	56.31
11	8.80	2.71	1.44	37	55.63	42.92	66.19
12	9.28	2.97	1.69	38	61.35	48.93	78.03
13	9.81	3.26	1.97	39	67.87	55.96	92.25
14	10.37	3.59	2.29	40	75.31	64.20	109.41
15	10.98	3.94	2.65	41	83.86	73.90	130.22
16	11.63	4.34	3.06	42	93.71	85.38	155.55
17	12.34	4.77	3.53	43	105.11	99.02	186.54
18	13.10	5.26	4.07	44	118.37	115.31	224.64
19	13.93	5.80	4.68	45	133.88	134.88	271.76
20	14.83	6.40	5.39	46	152.10	158.51	330.35
21	15.82	7.07	6.20	47	173.64	187.21	403.67
22	16.88	7.82	7.13	48	199.26	222.31	496.01
23	18.05	8.66	8.20	49	229.93	265.51	613.16
24	19.32	9.60	9.44	50	266.89	319.07	762.89
25	20.72	10.66	10.88				

5- Formulae:

$$F_p = \frac{c.N_c + 0,5\gamma.B'.N_\gamma}{R_v / B'}$$

$$R_v = W_1 + W_2 + W_3 + W_4$$

$$\sigma_v = \frac{R_v}{B'} = \frac{W_1 + W_2 + W_3 + W_4}{L - 2e}$$

Stability of Retaining Wall

Overturning Failure

1- Data:

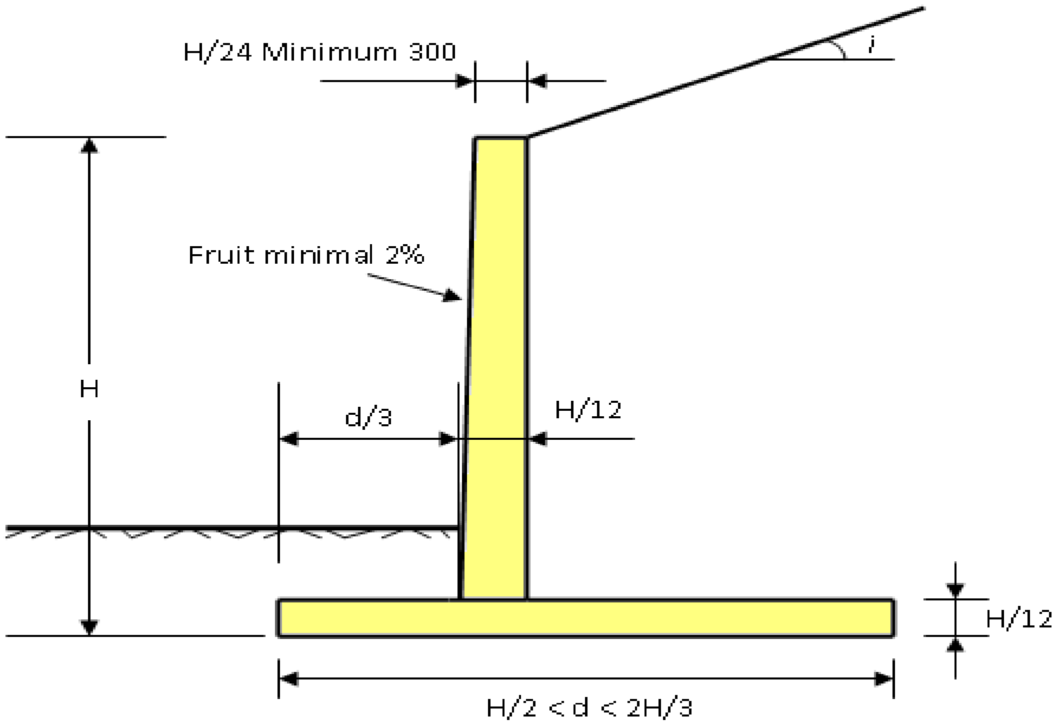
Width of Wall, *L* (m)	4
Height of Wall, H1 (m)	6.5
Surchage, q (kN/m2)	50
Top Base of Scrren Wall (m)	0.4
Bottom Base of Screen Wall (m)	0.5
Embeddment of the Wall in the Left, *D* (m)	1
Soil Unit Weight, γ (KN/m3)	17
Angle of Internatl Friction, φ (o)	30
Coefficient of friction Soil/Wall, μ	0.36395858
Angle Beta (o)	0
Angle Delta (o)	0
Coefficient Ka	0.33330956
Coefficien Kq	0.33330956
Unit Weight of reinforced concrete (kN/m3)	25
Weight of Wall Screen (Rectangular section) (W1, kN)	59.5833333
Weight of Wall Screen (Triangular section) (W2, kN)	7.44791667
Weight of Wall Footing (W3, kN)	54.1666667
Weight of Soil Behind the Wall, W4 (kN)	265.795
Height of Soil Behind the Right of the Wall, H2 (m)	5.9
Height of Soil Behind the Left of the Wall, H2 (m)	1

2- Calculation:

Pa (kN)	*Pq (kN)*	*Pp (kN)*	***Mr (kN.m)***	***Md (kN.m)***	***Fg***
98.6212989	49.16316	443.8591573	746.811369	338.986543	2.20307084

Fr **should be ≥ 2,0 (FHWA 1990)**

3- Figure:



4- Formulae:

$$F_r = \frac{M_r}{M_d} = \frac{W_1.d_1 + W_2.d_2 + W_3.d_3 + W_4.d_4 + P_p * H_3/3}{P_a * H_2/3 + P_q * H_2/2}$$

Stability of Retaining Wall

Sliding Failure

1- Data:

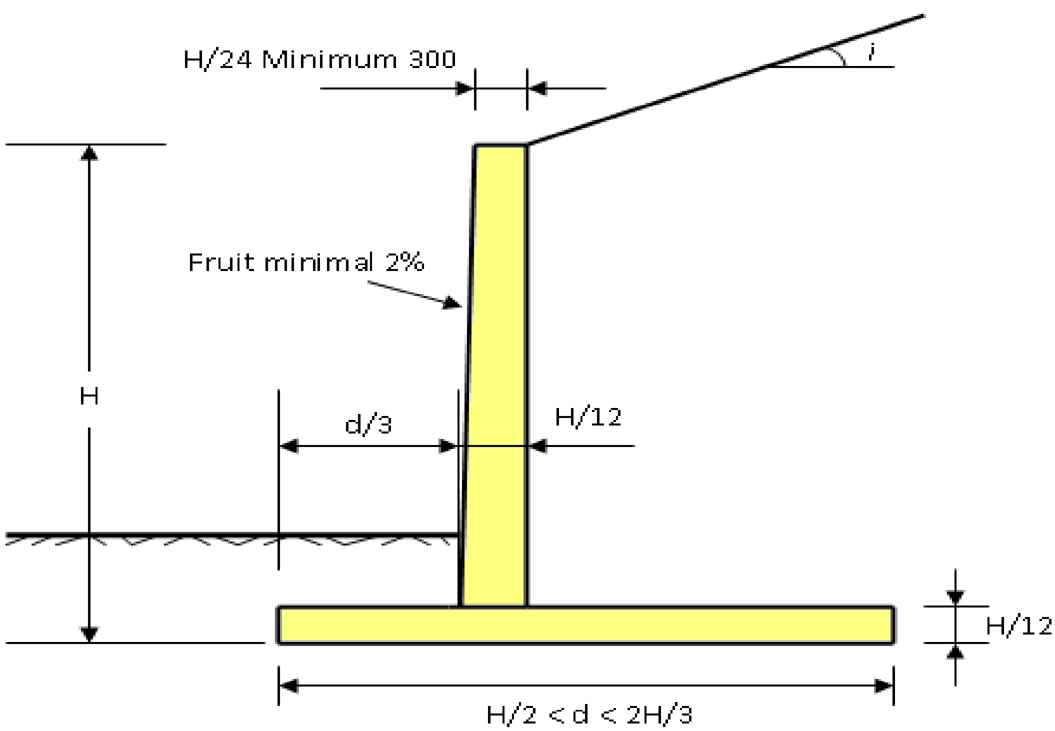
Width of Wall, *L* (m)	4
Height of Wall, H1 (m)	6.5
Surchage, q (kN/m2)	50
Top Base of Scrren Wall (m)	0.4
Bottom Base of Screen Wall (m)	0.5
Embeddment of the Wall in the Left, *D* (m)	1
Soil Unit Weight, γ (KN/m3)	17
Angle of Internatl Friction, φ (o)	30
Coefficient of friction Soil/Wall, μ	0.36395858
Angle Beta (o)	0
Angle Delta (o)	0
Coefficient Ka	0.33330956
Coefficien Kq	0.33330956
Unit Weight of reinforced concrete (kN/m3)	25
Weight of Wall Screen (Rectangular section) (W1, kN)	59
Weight of Wall Screen (Triangular section) (W2, kN)	7.375
Weight of Wall Footing (W3, kN)	60
Weight of Soil Behind the Wall, W4 (kN)	265.795
Height of Soil Behind the Right of the Wall, H2 (m)	5.9
Height of Soil Behind the Left of the Wall, H2 (m)	1

2- Calculation:

PH (kN)	*W (kN)*	*Pp (kN)*	***Fg***
147.784459	392.17	443.8591573	3.96924546

Fg **should be ≥ 1,5 (FHWA 1990)**

3- Figure:



4- Formulae:

$$F_g = \frac{W.\mu + P_p}{P_H}$$

$$W = \sum_{i=1}^{4} W_i$$

$$P_H = P_a + P_q$$

APPENDIX C

Calculation of Foundation Bearing Capacity

Rectangular Foundation (D = 2.0 m)

Force (kN)	Moment (kN.m)
2000	500

3- Calculation of Allowable Bearing Capacity (qadm.)

D (m)	B (m)	L (m)	Gama (kN/m3))	Phi (o)	c (kPa)	Nc	Nq	Ng	qu.net (kPa)	qadm.net (kPa)	qmax (kPa)
2	1	2	9.2	37	0	-	53.8	65.27	1211.7136	403.9045333	1750
2	1	2.5	9.2	37	0	-	53.8	65.27	1223.72328	407.90776	1280
2	1	3	9.2	37	0	-	53.8	65.27	1231.729733	410.5765778	1000
2	1	3.5	9.2	37	0	-	53.8	65.27	1237.448629	412.4828762	816.326531
2	1.5	2	9.2	37	0	-	53.8	65.27	1286.7741	428.9247	1166.66667
2	1.5	2.5	9.2	37	0	-	53.8	65.27	1313.79588	437.93196	853.333333
2	1.5	3	9.2	37	0	-	53.8	65.27	1331.8104	443.9368	666.666667
2	1.5	3.5	9.2	37	0	-	53.8	65.27	1344.677914	448.2259714	544.217687
2	2	2	9.2	37	0	-	53.8	65.27	1331.8104	443.9368	875
2	2	2.5	9.2	37	0	-	53.8	65.27	1379.84912	459.9497067	640
2	2	3	9.2	37	0	-	53.8	65.27	1411.874933	470.6249778	500
2	2	3.5	9.2	37	0	-	53.8	65.27	1434.750514	478.2501714	408.163265
2	2.5	2	9.2	37	0	-	53.8	65.27	1346.8225	448.9408333	700
2	2.5	2.5	9.2	37	0	-	53.8	65.27	1421.883	473.961	512
2	2.5	3	9.2	37	0	-	53.8	65.27	1471.923333	490.6411111	266.666667
2	2.5	3.5	9.2	37	0	-	53.8	65.27	1507.666429	502.5554762	326.530612

Calculation of Foundation Bearing Capacity

Rectangular Foundation (D = 2.5 m)

3- Calculation of Allowable Bearing Capacity (qadm.)

D (m)	B (m)	L (m)	Gama (kN/m3))	Phi (o)	c (kPa)	Nc	Nq	Ng	qu.net (kPa)	qadm.net (kPa)	qmax (kPa)
2.5	1	2	9.2	37	0	-	53.8	65.27	1454.5936	484.8645333	1750
2.5	1	2.5	9.2	37	0	-	53.8	65.27	1466.60328	488.86776	1280
2.5	1	3	9.2	37	0	-	53.8	65.27	1474.609733	491.5365778	1000
2.5	1	3.5	9.2	37	0	-	53.8	65.27	1480.328629	493.4428762	816.3265306
2.5	1.5	2	9.2	37	0	-	53.8	65.27	1529.6541	509.8847	1166.666667
2.5	1.5	2.5	9.2	37	0	-	53.8	65.27	1556.67588	518.89196	853.3333333
2.5	1.5	3	9.2	37	0	-	53.8	65.27	1574.6904	524.8968	666.6666667
2.5	1.5	3.5	9.2	37	0	-	53.8	65.27	1587.557914	529.1859714	544.2176871
2.5	2	2	9.2	37	0	-	53.8	65.27	1574.6904	524.8968	875
2.5	2	2.5	9.2	37	0	-	53.8	65.27	1622.72912	540.9097067	640
2.5	2	3	9.2	37	0	-	53.8	65.27	1654.754933	551.5849778	500
2.5	2	3.5	9.2	37	0	-	53.8	65.27	1677.630514	559.2101714	408.1632653
2.5	2.5	2	9.2	37	0	-	53.8	65.27	1589.7025	529.9008333	700
2.5	2.5	2.5	9.2	37	0	-	53.8	65.27	1664.763	554.921	512
2.5	2.5	3	9.2	37	0	-	53.8	65.27	1714.803333	571.6011111	266.6666667
2.5	2.5	3.5	9.2	37	0	-	53.8	65.27	1750.546429	583.5154762	326.5306122

Calculation of Foundation Bearing Capacity

Rectangular Foundation (D = 3.0 m)

3- Calculation of Allowable Bearing Capacity (qadm.)

D (m)	B (m)	L (m)	Gama (kN/m3))	Phi (o)	c (kPa)	Nc	Nq	Ng	qu.net (kPa)	qadm.net (kPa)	qmax (kPa)
3	1	2	9.2	37	0	-	53.8	65.27	1697.4736	565.8245333	1750
3	1	2.5	9.2	37	0	-	53.8	65.27	1709.48328	569.82776	1280
3	1	3	9.2	37	0	-	53.8	65.27	1717.489733	572.4965778	1000
3	1	3.5	9.2	37	0	-	53.8	65.27	1723.208629	574.4028762	816.3265306
3	1.5	2	9.2	37	0	-	53.8	65.27	1772.5341	590.8447	1166.666667
3	1.5	2.5	9.2	37	0	-	53.8	65.27	1799.55588	599.85196	853.3333333
3	1.5	3	9.2	37	0	-	53.8	65.27	1817.5704	605.8568	666.6666667
3	1.5	3.5	9.2	37	0	-	53.8	65.27	1830.437914	610.1459714	544.2176871
3	2	2	9.2	37	0	-	53.8	65.27	1817.5704	605.8568	875
3	2	2.5	9.2	37	0	-	53.8	65.27	1865.60912	621.8697067	640
3	2	3	9.2	37	0	-	53.8	65.27	1897.634933	632.5449778	500
3	2	3.5	9.2	37	0	-	53.8	65.27	1920.510514	640.1701714	408.1632653
3	2.5	2	9.2	37	0	-	53.8	65.27	1832.5825	610.8608333	700
3	2.5	2.5	9.2	37	0	-	53.8	65.27	1907.643	635.881	512
3	2.5	3	9.2	37	0	-	53.8	65.27	1957.683333	652.5611111	266.6666667
3	2.5	3.5	9.2	37	0	-	53.8	65.27	1993.426429	664.4754762	326.5306122

Calculation of Foundation Bearing Capacity

Rectangular Foundation (D = 3.5 m)

3- Calculation of Allowable Bearing Capacity (qadm.)

D (m)	B (m)	L (m)	Gama (kN/m3))	Phi (o)	c (kPa)	Nc	Nq	Ng	qu.net (kPa)	qadm.net (kPa)	qmax (kPa)
3.5	1	2	9.2	37	0	-	53.8	65.27	1940.3536	646.7845333	1750
3.5	1	2.5	9.2	37	0	-	53.8	65.27	1952.36328	650.78776	1280
3.5	1	3	9.2	37	0	-	53.8	65.27	1960.369733	653.4565778	1000
3.5	1	3.5	9.2	37	0	-	53.8	65.27	1966.088629	655.3628762	816.3265306
3.5	1.5	2	9.2	37	0	-	53.8	65.27	2015.4141	671.8047	1166.666667
3.5	1.5	2.5	9.2	37	0	-	53.8	65.27	2042.43588	680.81196	853.3333333
3.5	1.5	3	9.2	37	0	-	53.8	65.27	2060.4504	686.8168	666.6666667
3.5	1.5	3.5	9.2	37	0	-	53.8	65.27	2073.317914	691.1059714	544.2176871
3.5	2	2	9.2	37	0	-	53.8	65.27	2060.4504	686.8168	875
3.5	2	2.5	9.2	37	0	-	53.8	65.27	2108.48912	702.8297067	640
3.5	2	3	9.2	37	0	-	53.8	65.27	2140.514933	713.5049778	500
3.5	2	3.5	9.2	37	0	-	53.8	65.27	2163.390514	721.1301714	408.1632653
3.5	2.5	2	9.2	37	0	-	53.8	65.27	2075.4625	691.8208333	700
3.5	2.5	2.5	9.2	37	0	-	53.8	65.27	2150.523	716.841	512
3.5	2.5	3	9.2	37	0	-	53.8	65.27	2200.563333	733.5211111	266.6666667
3.5	2.5	3.5	9.2	37	0	-	53.8	65.27	2236.306429	745.4354762	326.5306122

Calculation of Foundation Bearing Capacity

Rectangular Foundation (D = 4.0 m)

3- Calculation of Allowable Bearing Capacity (qadm.)

D (m)	B (m)	L (m)	Gama (kN/m3))	Phi (o)	c (kPa)	Nc	Nq	Ng	qu.net (kPa)	qadm.net (kPa)	qmax (kPa)
4	1	2	9.2	37	0	-	53.8	65.27	2183.2336	727.7445333	1750
4	1	2.5	9.2	37	0	-	53.8	65.27	2195.24328	731.74776	1280
4	1	3	9.2	37	0	-	53.8	65.27	2203.249733	734.4165778	1000
4	1	3.5	9.2	37	0	-	53.8	65.27	2208.968629	736.3228762	816.3265306
4	1.5	2	9.2	37	0	-	53.8	65.27	2258.2941	752.7647	1166.666667
4	1.5	2.5	9.2	37	0	-	53.8	65.27	2285.31588	761.77196	853.3333333
4	1.5	3	9.2	37	0	-	53.8	65.27	2303.3304	767.7768	666.6666667
4	1.5	3.5	9.2	37	0	-	53.8	65.27	2316.197914	772.0659714	544.2176871
4	2	2	9.2	37	0	-	53.8	65.27	2303.3304	767.7768	875
4	2	2.5	9.2	37	0	-	53.8	65.27	2351.36912	783.7897067	640
4	2	3	9.2	37	0	-	53.8	65.27	2383.394933	794.4649778	500
4	2	3.5	9.2	37	0	-	53.8	65.27	2406.270514	802.0901714	408.1632653
4	2.5	2	9.2	37	0	-	53.8	65.27	2318.3425	772.7808333	700
4	2.5	2.5	9.2	37	0	-	53.8	65.27	2393.403	797.801	512
4	2.5	3	9.2	37	0	-	53.8	65.27	2443.443333	814.4811111	266.6666667
4	2.5	3.5	9.2	37	0	-	53.8	65.27	2479.186429	826.3954762	326.5306122

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