

Geotechnical Evaluation of Baktiari Hill Kurdistan District/Iraq



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Abstract:

A comprehensive geotechnical study is carried out in Northeastern part of Iraq for a site in Sulaimaniya Governorate which is located about (4) km. from city center, a site where a grand hotel were constructed later on.

The site is a longitudinal hill representing a double plunging anticline, which itself is the southeastern plunge of Pera-Magroon anticline, regionally the area is highly affected by tectonic movements which led to folding, faulting, jointing, shearing ...etc.

The site is evaluated by studying the core of (9) boreholes with (200) m length through three engineering parameters: Rock Quality Designation (RQD), Fissuration Factor (C-Factor) and Number of Fractures per meter (F/m) besides two laboratory parameters: Unconfined Compressive Strength (σ_c) and Porosity (P_o).

Each borehole is divided into different geotechnical horizons according to the similarity of engineering parameter values, weathering degree, color, bedding, etc. Weighted average of the five above mentioned parameters are calculated for these horizons where each parameter classify the rock mass into five ranks from very weak to excellent with rank values from one to five; these values are adopted to get final evaluation of the boreholes.

Subsurface correlation charts are drawn using Rockworks/15 program depending upon the evaluation of each horizon which is gained by matching rank values of each parameter to get the final rank values of it from weak to excellent which is used for the first time by the authors.

Keywords: Geotechnical horizon, rank value, rock mass rating, numerical value.

Introduction

In order to achieve a comprehensive geotechnical evaluation of a site where a five star hotel of (28) floor is constructed, the core of nine drilled boreholes were investigated for their engineering parameters and laboratory tests, namely Rock Quality Designation (RQD), Fissuration Factor (C-Factor), Number of Fractures per meter (F/m), Uniaxial Compressive Strength (σ_c), and Porosity (P_o). The authors introduced a new approach of rock mass classification by matching the classification gained from each of the five parameters together to get a final one.

Climatic data shows that the mean annual maximum temperature is (25) °C, the mean annual relative humidity is (48) % with average annual rainfall (775) ml. (Climatic Atlas of Iraq, 2001).

Aim

The aim of this study is to evaluate the site through execution of geotechnical study for foundation purposes.

Location

The site is located in the northeastern part of Iraq, Kurdistan district in Sulaimaniya Governorate, Figure 1, four Kilometers from city center towards the northwest, locally known as Bakhtiari

Hill, it is defined by the following coordinates :-

Long. 45° 24' 00" - 45° 24' 30"

Lat 35° 33' 45" - 35° 34' 30"

parts. Thickness of the formation exceed (40) m, while the thickness of individual bed ranges (20-50) cm. thin layer of residual soil with average thickness about (30) cm. covered the area partly.

Previous work

The only engineering study of the site is that carried out by the Consultant Bureau of Sulaimaniya University, where a preliminary study of the site is prepared by drilling nine boreholes too.

Structurally, the current study indicates that the whole area is highly affected by tectonic movements during Alpine Orogeny reflected by highly faulting (observed obviously along the newly road-cut at the southwestern part of the hill).

TOPOGRAPHY AND GEOLOGY

Topography

The site is an elongated hill of length (800) m. and width (450) m., lowest point is (820) m. above sea level, around the hill, while the highest point is (859) m. above sea level.

The beds are dipping about (25°) NW in the western part of the hill and about (15°) NE in the eastern part. The most obvious one of the faults in the area is the one trending N78°W, dipping (82°) SW, uncertainly extends for (120) m where its finally terminated by highly crushed intensively jointed shear zone, Fig.(2). Five shear zones were observed and plotted on the geological map, four of them are in the western part of the area, and the last one is the eastern part indicated by highly crushed and recemented rocks, high grade of weathering compared with the surroundings, besides many shear zones have been detected ,these zones are not plotted on the map due to scale limitation. Two dominant sets of joints have been recognized of (NE-SW), (NW-SE) directions and less dominant set of (N-S) direction .

Geology

The site is located within the Marginal Zone of the Arabian Plate, represented by one geomorphologic unit of structural – denudation origin. It is considered as a part of the southeastern plunge of Pera-Magroon Anticline, by itself it forms a small double plunging anticline. The site is covered by Upper part of Shiranish Formation, Cretaceous in age, represented by well bedded, hard, well jointed, highly faulted light grey limestone, with thin horizons of marl especially at the lower

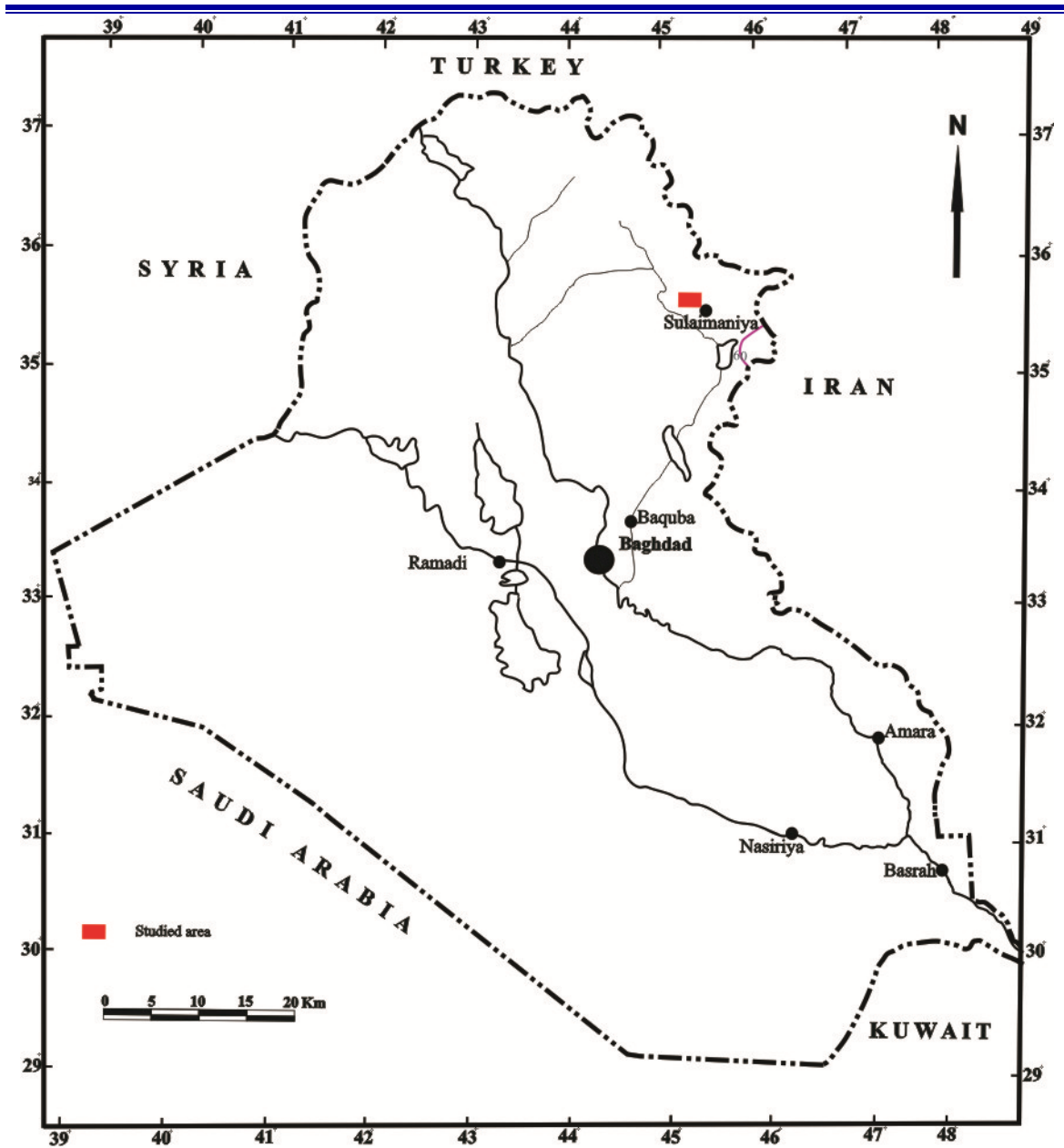


Fig. 1: Location map of the studied area

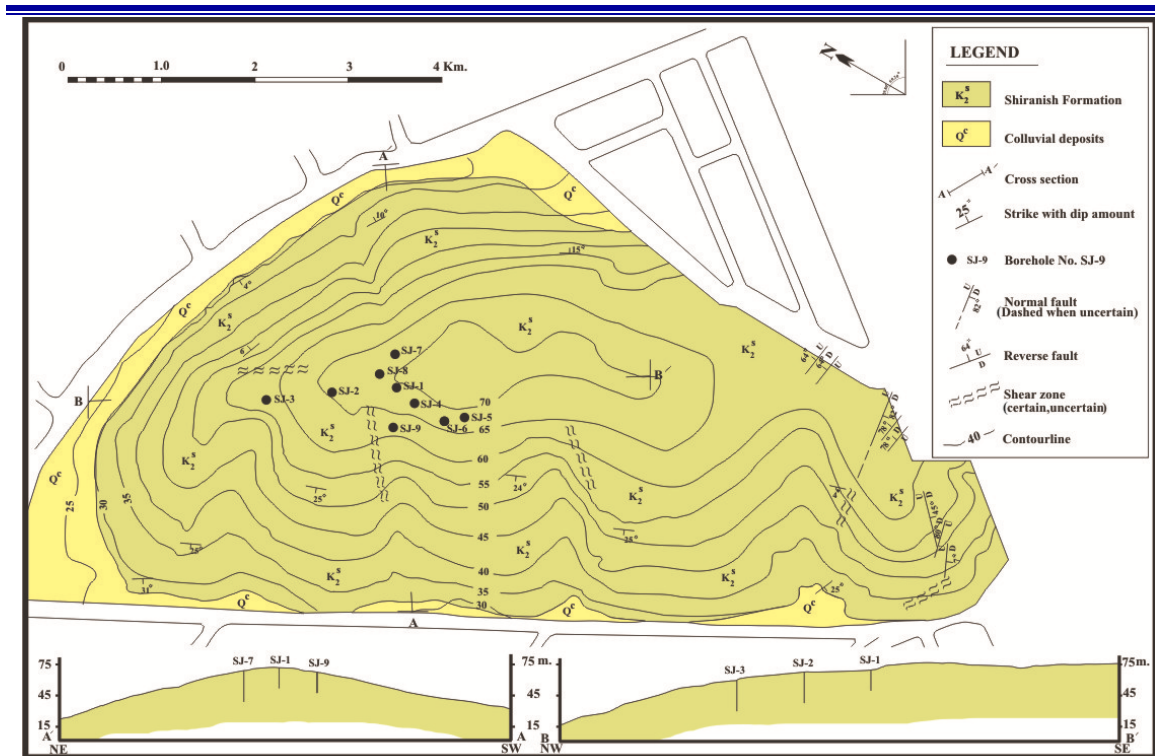


Fig. 2: Geological map of the area.

GEOTECHNICAL EVALUATION

To evaluate the site the following items are carried out:

Subsurface evaluation:

Geotechnical study of the core of nine boreholes with total core length about (200)m, measuring the engineering parameters; Rock quality Designation (RQD), Fissuration Factor (C-Factor), Fracture Frequency (F/m) and execution of laboratory tests; Uniaxial Compressive Strength (σ_c) and Porosity (P_o).

Rock Quality Designation (RQD) % is defined by the following equation: (Deere, 1964)

$$RQD = \frac{\sum \text{Length of intact and sound core pieces} > 100 \text{ mm.}}{\text{Total length of core run, mm}} \times 100$$

Fissuration factor (C- Factor), it depends on number of fractures within a drilling interval, expressed by the following equation: (Hansagi, 1974).

$$C\text{- Factor} = \frac{1}{2S} (P \times H + K / N) \quad \text{where}$$

S = Drilling interval, in cm. must not exceed 1.0 meter.

P= Number of core pieces with length equal to its diameter which could be obtained from the solid core.

H= Diameter of the core (cm).

K= Total length of solid core with length equal or more than core diameter.

N= Number of pieces in K.

Data treatment

Each borehole is divided into different geotechnical horizons depending upon the similarity of the calculated engineering parameters (RQD, C-Factor F/m), beside weathering degree, hardness, color, lithology etc. Weighted average of the three engineering parameters besides

those of (σ_c) and (P_o) are calculated for each geotechnical horizon according which the horizons are classified from weak to excellent giving it a **numerical value** from one to five, Table 1. Summation of these numerical values is used to get the final classification of the horizons, as mentioned in Table 2.

Table 1: Rock mass classification according to involved parameters

Rank	RQD % (Deere and Miller,1966)	C-Factor (Hansagi, 1974)	F/m (Baillot, et.al, 1976)	Porosity % P_o (Fatouhi, 1985)	σ_c (MPa) (Edge,1968)	Rock mass Classification
1	0-25	0.0-0.15	Fragmented and crushed	>30	<1.25	Very weak
2	25-50	0.15-0.30	>20	20-30	1.25-5	Weak
3	50-75	0.30-0.45	11-20	10-20	5-50	Moderate
4	75-90	0.45-0.65	5-10	5-10	50-200	Good
5	90-100	0.65-1.00	0-4	0-5	>200	Excellent

Table 2: Final rock mass classification

No. of parameters involved	Interval of ranks summation	Introduced rank	Evaluation
2	2	1	Very weak
	3-4	2	weak
	5-6	3	Moderate
	7-8	4	Good
	9-10	5	Excellent
3	3	1	Very weak
	4-6	2	weak
	7-9	3	Moderate
	10-12	4	Good
	13-15	5	Excellent
4	4	1	Very weak
	5-8	2	weak
	9-12	3	Moderate
	13-16	4	Good
	17-20	5	Excellent
5	5	1	Very weak
	6-10	2	weak
	11-15	3	Moderate
	16-20	4	Good
	21-25	5	Excellent

In the table above the first column refers to the number of parameters gained for each geotechnical horizon, e.g. No. (2) means only two parameters (like RQD and C-Factor are gained) and this is mostly the case where there is poor or no solid core recovery and hence no samples for laboratory tests is gained besides the core is so badly recovered that there is no ability to determine the number of fractures per meter, they were considered or treated as a lack of data regarding rest parameters.

The second column represents the intervals which the ranks summation of the parameters lies. The third column is the introduced rank developed by matching the five parameters, and the last column is the descriptive term for the rank.

For example, for a horizon where only two parameters are gained, the ranks summation of the two parameters will range from two to ten, with the following intervals (2, 3-4, 5-6, 7-8, 9-10) corresponding to the introduced rank (1, 2, 3, 4 and 5) respectively...and so on .

Geotechnical horizons for each Borehole are treated according to Table 2, while the final evaluation is shown in Tables 3-11, where thickness, lithologic description etc....are clarified.

For instance, in Table 4, Borehole No. S-J2, horizon No. (3); two parameters are

involved to evaluate the rock mass, namely (RQD) and (C-Factor), where no data were gained concerning the rest three parameters.

Engineering rank of (RQD) is two and for (C-Factor) is one with rank summation three, hence, and according to Table 2, with the number of parameters involved = (2), the value three is correspond to a weak rock mass. In the same Borehole, the following horizon, number four, the whole five parameters have been gained with total rank summation of (16) which corresponds to a good rock mass state, as a final layout similar successive horizons are merged in one horizon.

Subsurface geotechnical correlation charts are drawn, Figures 3 and 4 , using Rock work 15 software, in which the horizons of the same rock mass rating are correlated with its equivalents in the Adjacent boreholes which obviously shows that the uppermost horizon of Boreholes SJ-1, SJ-2, SJ-3, SJ-4 and SJ-8 are classified as a weak horizon, while in Boreholes SJ-5 and SJ-6 it is moderate, and in Borehole No. SJ-7, it is good and the whole Borehole No. SJ-9 is moderate.

Generally, the quality of rock mass is increasing relatively toward the northwest from Borehole No. SJ-1, Figure 5 and also along Boreholes No. SJ-1, SJ-4, SJ-6, Figure 6.

Table 3: Geotechnical evaluation of horizons in BH. No. SJ/1

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.5	4.0	3.50	Lst. grey, thinly to medium bedded highly jointed	1	1	3	3	-	8	Weak
2	40.0	5.0	1.00	Lst. whitish grey, thinly to thickly bedded, fine crystalline	5	2	4	3	4	18	Good
3	5.0	9.0	4.00	Lst. light grey to yellowish grey, highly fractured	1	1	3	3	-	8	Weak
4	9.0	17.0	8.00	Lst. light grey, jointed	2	2	3	3	4	14	Moderate
5	17.0	20.0	3.00	Lst. light grey, highly affected by solutions.	1	1	4	-	4	10	Moderate

Table 4: Geotechnical evaluation of horizons in BH. No. SJ/2

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.3	3.0	2.70	Lst. light grey, moderatly weathered.	1	1	2	-	-	4	Weak
2	3.0	4.0	1.00	Lst. Light grey, moderatly weathered.	2	2	-	-	5	9	Moderate
3	4.0	6.0	2.00	Lst. light grey, fragmented, slightly chalky, highly weathered.	2	1	-	-	-	3	Weak
4	6.0	11.0	5.00	Lst. light grey, thinly bedded, fine crystalline.	2	4	3	3	4	16	Good
5	11.0	16.0	5.00	Lst. light grey, with marl intervals	1	1	3	3	4	12	Moderate
6	16.0	20.0	4.00	Lst. light grey, thinly bedded, fine crystalline.	2	3	3	3	3	14	Moderate

Table 5: Geotechnical evaluation of horizons in BH. No. SJ/3

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.3	6.0	5.70	Lst. light grey, highly fractured.	1	1	4	-	-	6	Weak
2	6.0	11.0	5.00	Lst. Light grey, thinly to thickly bedded, hard.	3	4	3	3	4	17	Moderate
3	11.0	12.0	1.00	Lst. light grey, very hard, fine crystalline	5	5	-	-	5	15	Weak
4	12.0	20.0	8.00	Lst. light grey, thinly to thickly bedded.	3	4	3	3	4	17	Moderate

Table 6: Geotechnical evaluation of horizons in BH. No. SJ/4

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.7	4.0	3.30	Lst. yellowish white, partially marly.	1	1	3	3	-	8	Weak
2	4.0	7.0	3.00	Lst. light grey, medium bedded, fine crystalline	3	2	4	3	4	16	Good
3	7.0	9.0	2.00	Chalky Lst. white, porous, fractured.	1	1	2	-	-	4	Weak
4	9.0	10.0	1.00	Lst. light grey, hard, fine crystalline.	3	4	4	3	4	18	Good
5	10.0	20.0	10.00	Lst. light grey, highly affected by solutions.	1	1	4	3	4	13	Moderate

Table 7: Geotechnical evaluation of horizons in BH. No. SJ/5

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.55	4.0	3.45	Lst. light yellow to white, moderately hard porous.	2	2	3	-	4	11	Moderate
2	4.0	8.0	4.00	Lst. light yellow to light grey, thinly bedded.	1	1	2	-	4	8	Weak
3	8.0	11.0	3.00	Lst. light grey, thinly bedded, fine crystalline.	1	1	3	-	4	9	Moderate
4	11.0	13.0	2.00	Lst. light grey, recemented, by calcite, fine crystalline.	1	1	-	-	4	6	Weak
5	13.0	16.0	3.00	Lst. light grey, thinly bedded, highly weathered.	2	3	3	-	4	12	Moderate
6	16.0	18.0	2.00	Lst. light grey, hard, variegated, fine crystalline.	1	1	3	-	4	9	Moderate
6	18.0	20.0	2.00	Lst. light grey, thinly bedded, fine crystalline.	1	2	3	-	4	10	Moderate

Table 8: Geotechnical evaluation of horizons in BH. No. SJ/6

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.15	4.0	3.85	Lst. light grey, to yellowish grey, fine crystalline.	1	1	4	-	-	6	Weak
2	4.0	14.0	10.00	Lst. Light grey, medium bedded, hard.	3	4	3	3	4	17	Moderate
3	14.0	21.0	7.00	Lst. light grey, medium bedded, with thin horizons of marl.	5	5	-	-	5	15	Weak
4	21.0	30.0	9.00	Lst. light grey, medium bedded hard.	3	4	3	3	4	17	Moderate

Table 7: Geotechnical evaluation of horizons in BH. No. SJ/7

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.10	8.0	7.90	Lst. light grey, medium bedded, fine crystalline.	2	3	3	4	4	16	Good
2	8.0	16.0	8.00	Lst. light greyish white, fine crystalline, thinly bedded.	1	1	3	-	4	9	Moderate
3	16.0	17.0	1.00	Lst. light grey, fine crystalline, variegated with black spots.	3	4	4	3	4	18	Good
4	17.0	20.0	3.00	Lst. light grey, thinly to medium bedded.	1	1	-	-	4	6	Weak
5	20.0	30.0	10.00	Lst. light grey, thinly to medium bedded, fine crystalline.	2	3	3	4	4	16	Good

Table 8: Geotechnical evaluation of horizons in BH. No. SJ/8

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.0	1.0	1.00	Lst. light grey, medium to thick bedded, highly jointed.	1	1	-	-	4	6	Weak
2	1.0	3.0	2.00	Lst. yellowish white, fine crystalline, very hard.	3	4	4	3	4	18	Good
3	3.0	5.0	2.00	Alternation of light grey Lst. with white chalky Lst.	1	1	-	-	3	5	Weak
4	5.0	6.0	1.00	Lst. light grey, fine to medium crystalline, very hard.	3	3	-	-	4	10	Good
5	6.0	14.0	8.00	Lst. light grey, alternated with chalky Lst.	1	1	3	3	4	12	Moderate
6	14.0	20.0	6.00	Lst. light grey, very hard, jointed, moderately weathered.	2	2	3	3	4	14	Moderate

Table 9: Geotechnical evaluation of horizons in BH. No. SJ/9

Horizon No.	Depth (m)		Thick. (m)	General Description	Engineering Rank					Total	Rock mass rating
	From	To			RQD	C.F.	P _s	σ _c	F/m		
1	0.0	10.0	10.00	Lst. milky white, partially chalky, fragmented, porous.	1	1	3	3	4	12	Moderate
2	10.0	11.0	1.00	Lst. yellowish grey, thinly bedded, affected by solutions.	3	2	-	-	4	9	Moderate
3	11.0	15.0	4.00	Lst. light grey, highly porous, partially chalky.	1	1	3	3	3	11	Moderate
4	15.0	20.0	5.00	Lst. light brown and light grey, thinly bedded.	2	3	3	3	4	15	Moderate

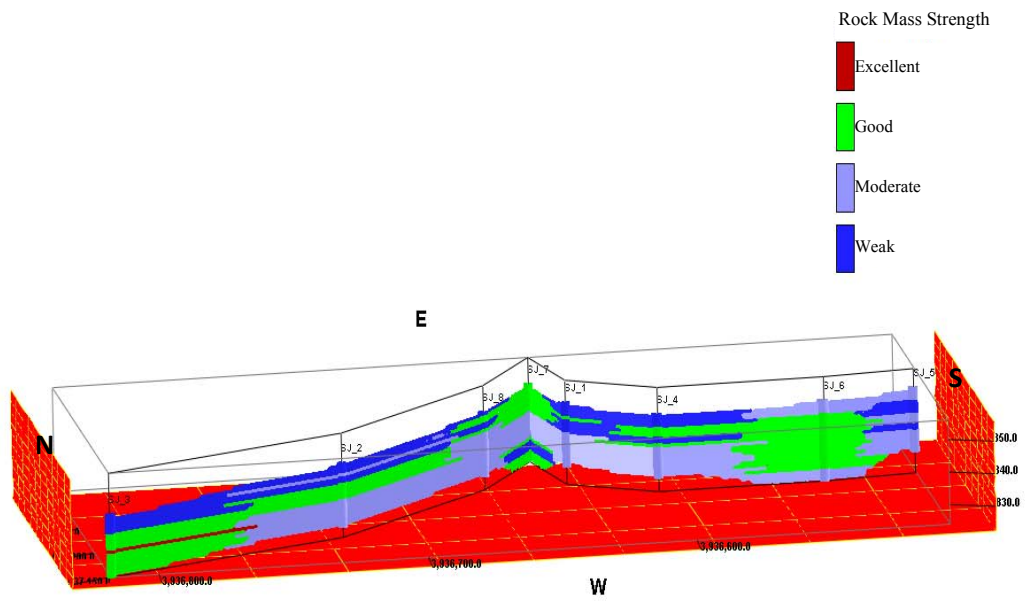


Figure 3: Subsurface geotechnical correlation chart between boreholes SJ_5, SJ_6, SJ_4, SJ_1, SJ_7, SJ_8, SJ_2 and SJ_3.

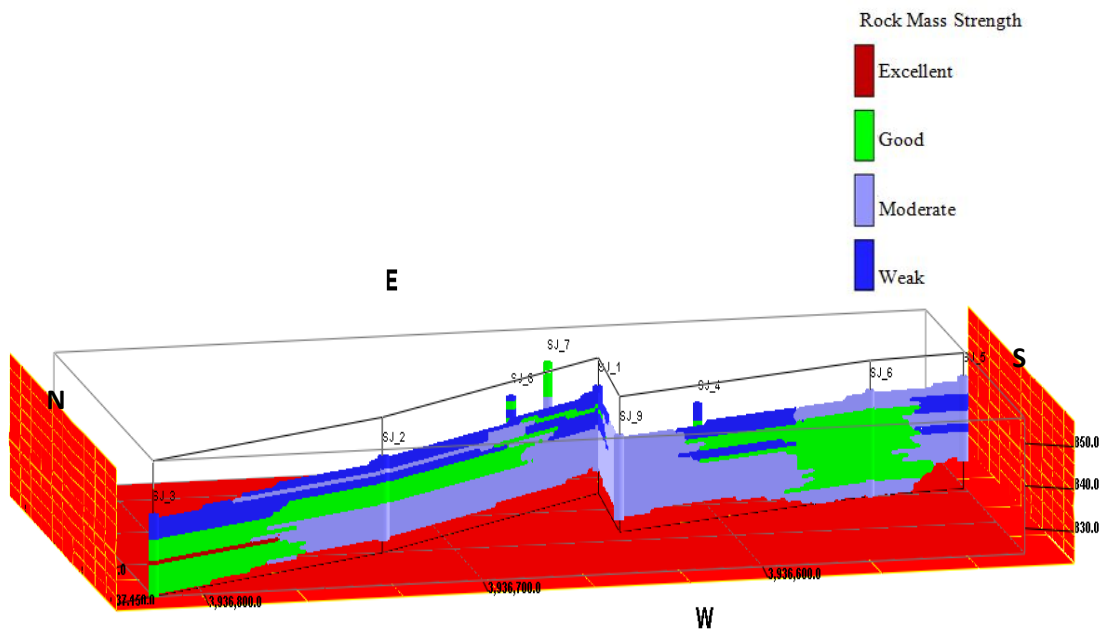


Figure 4: Subsurface geotechnical correlation chart between boreholes SJ_5, SJ_6, SJ_9, SJ_1, SJ_2 and SJ_3.

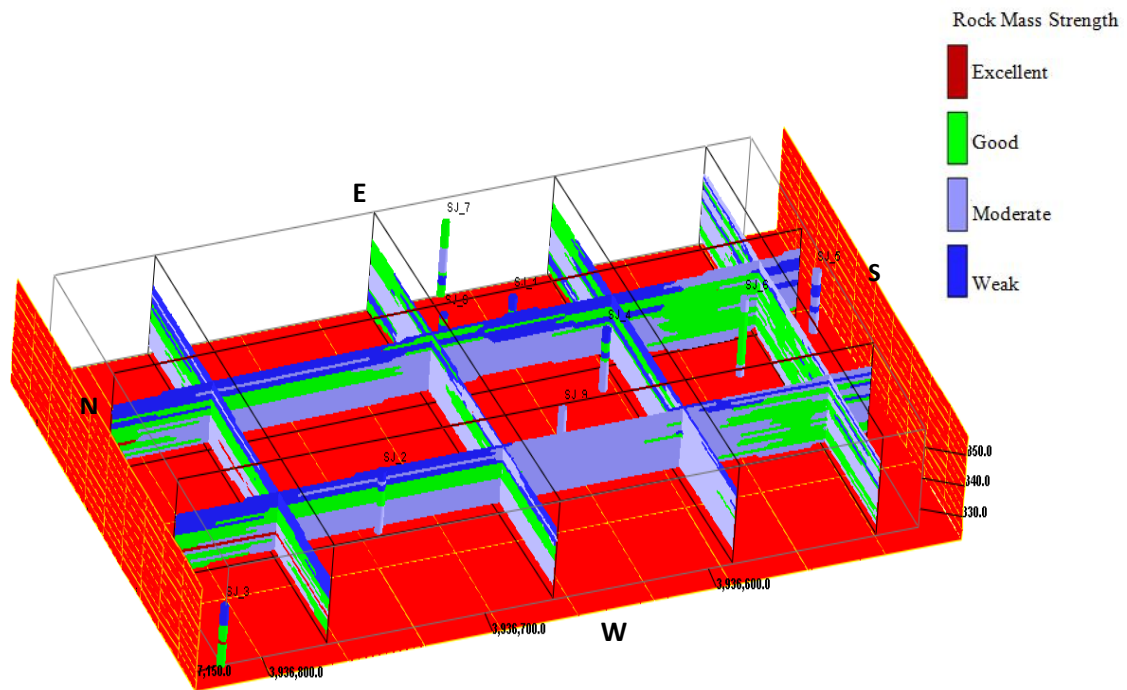


Figure 5: Fence Diagram through the site

Conclusions

1. The site is covered by Shiranish Formation of Campanian-Ma' astrichtian age, which is composed of homogenous succession of light grey fine crystalline well bedded limestone.
2. The area is highly faulted, jointed with many shear zones
3. The uppermost layers are thinly bedded of different weathering degrees.
4. All boreholes start with thin, friable residual soil which covers the hill of thickness (0.1-0.7) m, except B.H No.SJ8 with no soil cover.
5. According to subsurface geotechnical correlation, all boreholes shows weak and moderate rock mass strength unit, except B.H No.SJ7 which start with

good rock mass strength unit, and B.H No.SJ9 which shows moderate rock mass strength unit.

6. No sinkholes and subsurface caves are observed during drilling except in B.H No. SJ8 of (15) cm, and B.H No. SJ7 of (20) cm, the latter is expected to be a marl horizon washed out as indicated by marl remains.

Recommendations

1. Excavation of loose uppermost layer of rock which is obvious in the new cuts in the area of thickness ranges (0.5-1.5) m.
2. Detailed seismic history study of the area.
3. For uppermost layers which start with weak rock mass strength it's highly recommended to be removed.

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