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Evaluation of Soil Engineering Characteristics in Jalalpur Region, Pakistan

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ABSTRACT

This study deals with the evaluation of soil engineering characteristic along the proposed route of Jalalpur irrigation project. The proposed JIP (Jalalpur Irrigation Project) is located along the right bank of Jhelum River in Tehsil PDK (Pind Dadan Khan) and Tehsil Khushab of District Khushab. JIP is funded by ADB (Asian Development Bank). The JIP will enhance crop production in Tehsil PDKand Khushab. Famers will be benefited through JIP as they will get regular supply of water through canal. It will also create job opportunities for local people and will lead to the prosperity of the Project area.

Detailed soil investigation along proposed route was carried out by M/S GEOBAND. Straight rotary method of drilling was used. The recovered soil samples and water samples were tested in laboratories. The detailed engineering analysis was performed and soil parameters along with bearing capacities are suggested. Results have indicated variations in SPT values along the proposed route. The top layer of soil along proposed route is mostly Silty Clay with variation along the depth. The proposed bearing capacity for shallow foundation is 1.25 ton/ft^2 (120 kN/m^2) at depth of 5ft (1.5 m) beneath footing, and for bored piles having diameter of 2.5 ft (0.76 m) at a depth of 50 ft (15 m) is recommended as 70 ton (685 kN). The results presented in this study will be helpful in deciding the detailed foundation design of the engineering structures along the proposed route of JIP.

Key Words: Soil Investigation, Drilling, Foundation, Irrigation, Bearing Capacities.

1. INTRODUCTION

Water Resource Institute has ranked Pakistan among Extremely High Water Stressed countries (Ratio of Withdrawal to Supply) [1]. There is an urgent need for the sustainable development of water bodies in Pakistan. The proposed JIP is located along the right bank of Jhelum River in Tehsil PDK and Tehsil Khushab of District Khushab. It is located between longitude from 72^o-20" to 73^o-31 (east) and latitude from 32^o-25 to 32^o-43 (north) along right bank of River Jhelum in Punjab, Pakistan [2]. The location of the project area is shown in Fig. 1.

The JIP project comprises of a main canal of 110 km that will off take from right bank of Rasul Barrage. It will then

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cross right bank of Jhelum river. The canal will irrigate a command area of about 67,987 hectares. The command area of JIP is in the form of a long strip of land bounded by the Salt Range Hills on northern side and right bank of the Jhelum River on southern side. The distribution system of about 176 km comprising of distributaries and minors extends up to the right bank of Jhelum River. The JIP will create new non-perennial irrigation services for enhanced agricultural production on 79,750 ha in PDK and Khushab districts. It will also increase kharif crop intensity by 50%, improve crop yield and reduce land degradation. The JIP will directly benefit over 200,000 rural people; mostly poor. The construction of proposed irrigation scheme also cause the removal of more than 300 main residential and commercial structures permanently and displacement of small business structures of the owners, removal of 9767 trees, crop losses, a few community facilities and pubic structure [3]. The proposed alignment route is shown in Fig. 1.

Smaller Cholistan irrigation project lies toward east of Sutlej river and is contiguous to the commands of Eastern Sadiqia and Bahawal Canal Systems. It has a gross area of about 0.697 million acres and lies in Bahawalpur district. The whole area is a waste crown land without irrigation water either from surface or ground water source, whereas the land has good potential for irrigated agriculture similar to lands adjoining the command areas of Eastern Sadiqia and Bahawal Canal Systems. The abandoned area of Hakra Branch is also a part of the Project Area.

The purpose of the study is to determine the sub-surface conditions, physical, mechanical and chemical properties of the investigated ground, and to recommend safe bearing capacities of the ground.

2. MATERIALS AND METHOD

The characteristics of soils were investigated by drilling boreholes along proposed alignment and in adjacent areas. Standard penetration test along with permeability test was also performed in drilled holes. The samples collected from site investigation were tested in Laboratory.

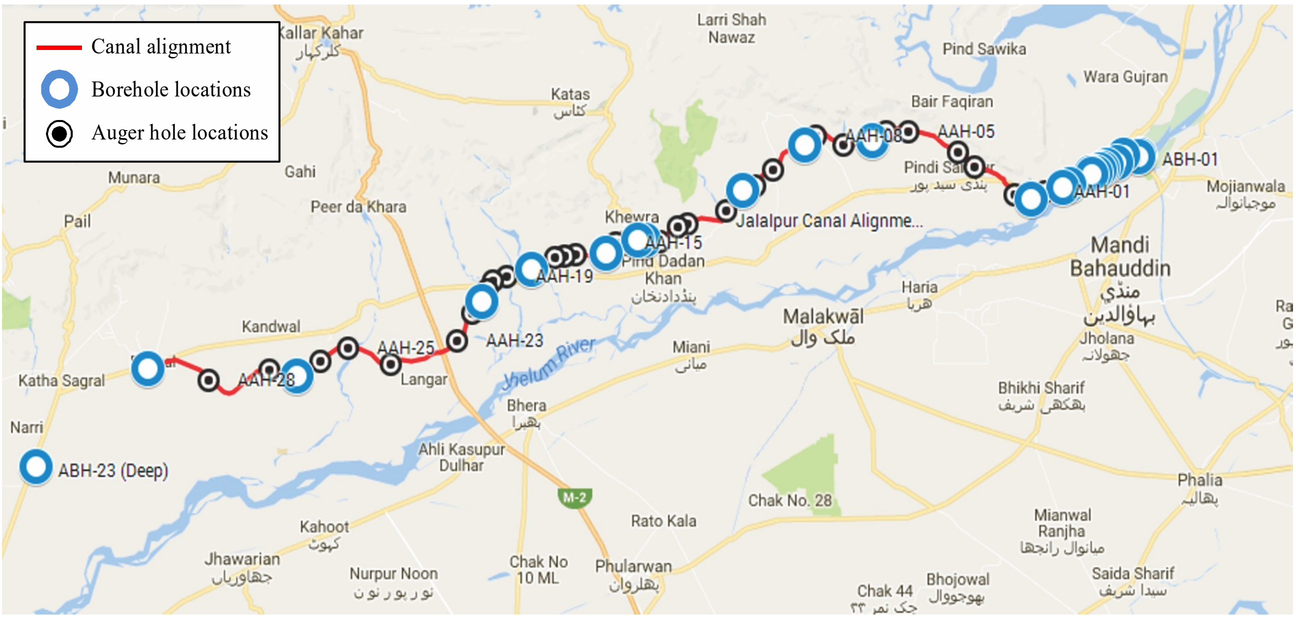


FIG. 1. PROJECT LAYOUT SHOWING BOREHOLE (ABH) AND AUGER HOLE (AAH) LOCATIONS

2.1 Field Investigation

2.2.1 Drilling of boreholes

The exploratory boreholes were drilled in the project area by M/S GEOBAND. Straight rotary method of drilling was employed with bentonite slurry as drilling fluid. In total, 23 boreholes (ABH) were drilled along the route (Table 1). Two (2) boreholes were also drilled to a depth of 200 feet (60m). In addition to that, auger holes were also drilled (AAH).

TABLE 1. DETAILS OF SAMPLES COLLECTED DURING DRILLING

Borehole No.		No. Samples with Depth	
No.	Drilling Depthft (m)	Undisturbed	Disturbed
ABH-01	50 (15)	2	2
ABH-02	50 (15)	1	1
ABH-03	36 (11)	3	-
ABH-04	36 (11)	1	-
ABH-05	36 (11)	3	1
ABH-06	36 (11)	3	1
ABH-07	36 (11)	3	-
ABH-08	36 (11)	4	1
ABH-09	36 (11)	3	-
ABH-09A	36 (11)	1	2
ABH-10	36 (11)	3	0
ABH-11	36 (11)	1	-
ABH-12	36 (11)	1	2
ABH-13	80 (24)	7	1
ABH-14	36 (11)	4	2
ABH-15	70 (21)	4	-
ABH-16	40 (12)	2	2
ABH-17	38 (11)	2	1
ABH-18	77 (23.5)	2	2
ABH-19	36 (11)	2	1
ABH-19A	41 (12.5)	4	1
ABH-20 (Deep)	200 (60)	3	0
ABH-20A	36 (11)	3	-
ABH-21 (Deep)	200 (60)	3	2
ABH-22	51 (15)	3	1
ABH-23	85 (26)	3	-
Total	1488 (435)	71	23

2.2.2 Collection of Soil and Water Samples

UDS (Undisturbed), DS (Disturbed) and Split Spoon samples were obtained from the boreholes. DS samples using a Split barrel tube sampler were obtained where SPT was performed in the soil.

The samples recovered were immediately examined, described, classified, identified, wrapped in water proof plastic sheets, placed in proper sequence in heavy duty wooden boxes and taken to laboratory for testing.

All the samples were protected against the weather condition, until they had been transported to the laboratory for testing. Care was taken during handling, packing, transportation and storing of samples to protect them against all structural and moisture alterations. Details of samples collected during drilling of boreholes are given in Table 1. The UDS and water samples are generally collected at an average depth of about 5m.

2.2.3 Standard Penetration Tests

SPT (Standard Penetration Tests) were performed in all the boreholes at a general depth interval of 1.0m. The SPT consists of driving a Standard 50mm outside diameter split spoon sampler into soil at the bottom of boreholes, using repeated blows of a 63.5 kg (623 N) hammer falling through 760mm. The SPT N values are the number of blows required to achieve a penetration of 300mm, after an initial seating at the depths of the tests [4]. Appropriate description of the retrieved samples was noted on the borehole logs. The details are presented in Table 1.

2.2.4 Permeability Tests

Total forty-four (44) constant head permeability tests were performed in boreholes.

2.2.5 Laboratory Testing

The samples recovered from boreholes were tested in Laboratory. Grain size, chemical analysis, soil property, moisture content and direct shear tests were performed.

3. RESULTS AND DISCUSSIONS

3.1 Field Investigation

Sub-surface stratification along the alignment of proposed canal generally consists of layers of Silty Clay/ Clayey Silt and Silty Sand with presence of Sandy Gravel in few boreholes. The top layer mostly consists of Silty Sand /Silty Clay and Sand at greater depth.

3.1.1 Field and Corrected SPT N_{60} Values

Graphical presentations of variation of SPT blow counts both for field and corrected "N_{60}" [5] values along the proposed Canal alignment for ABH-10 and ABH-20 are shown in Fig. 2(a-b). The field result shows that SPT N_{60} values generally lies in-between 10 and 20 along canal alignment closer to the ground; with increasing trend along depth. The profile of ABH-16 is shown in Fig. 3.

Figure 2: SPT variation along depth for (a) ABH-10 and (b) ABH-20

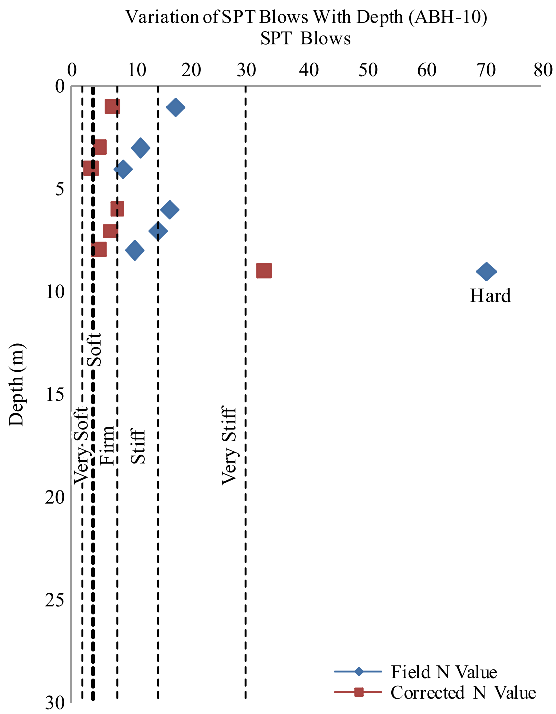
3.1.2 Field Permeability Tests

Permeability test results have indicated variation in permeability values. The minimum and maximum values observed in borehole are of order of 10^{-3} and 10^{-6} cm/s respectively.

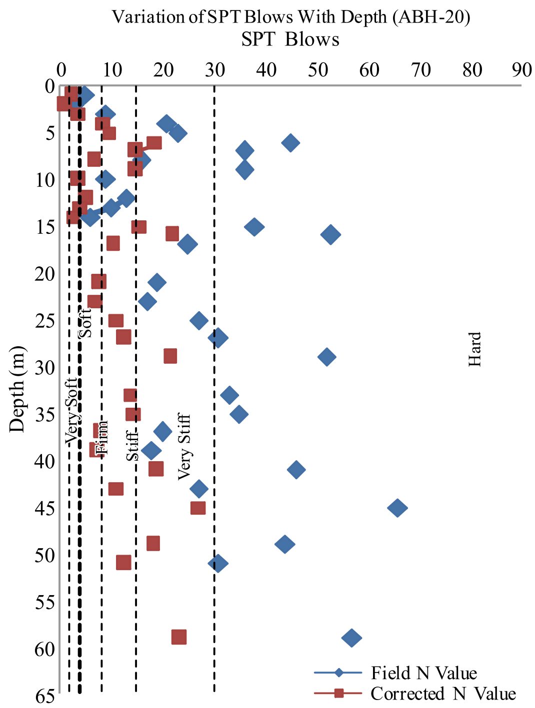
3.1.3 Shear Strength Parameters based on SPT N Value

SPT "N" field values have been corrected to N_{60} with respect to overburden pressures and energy transfer.

Further these corrected N_{60}-values have been used to estimate the Unconfined Compressive Strength of Silty Clay/Clayey Silt soil and effective angle of internal friction for the sand.



(a) ABH-10



(b) ABH-20

FIG. 2. SPT VARIATION ALONG DEPTH

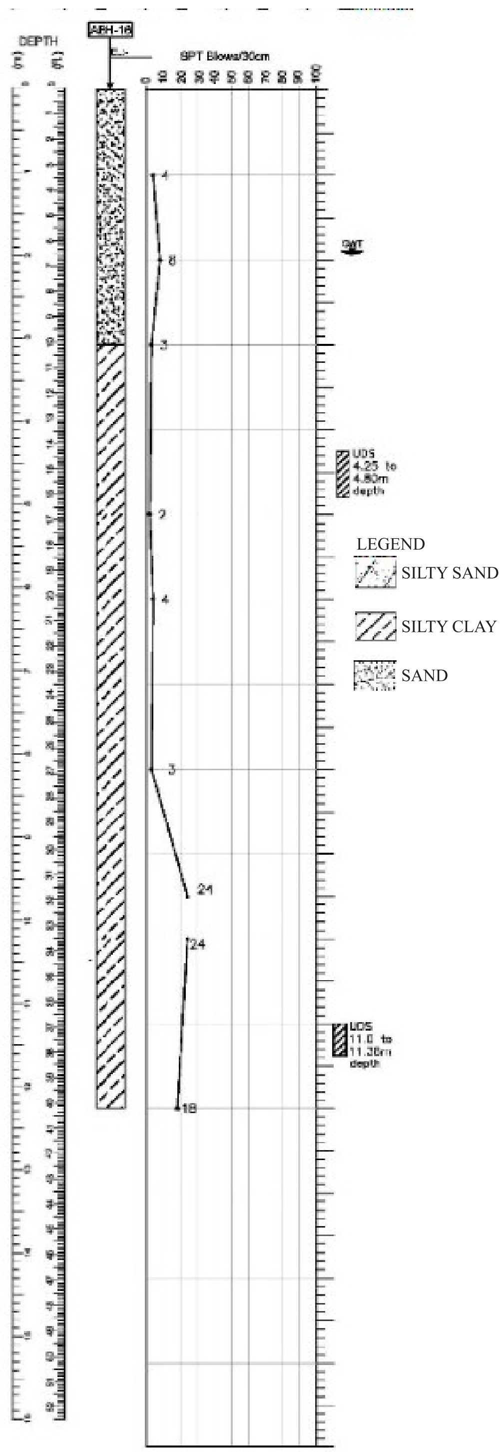


FIG. 3. PROFILE OF ABH-16

Undrained Shear Strength (C_u) and Unconfined Compressive Strength (q_u) of Silty Clay/Clayey Silt has been estimated by using the empirical relationship [6]. Similarly, effective angle of internal friction (ϕ) has been estimated [7] and average along depth is given in Table 2, which shows that effective angle of internal friction, generally varies from 30-36 degrees.

TABLE 2. AVERAGE SPT N, N_{60}, Φ, C_U AND q_u ALONG ALIGNMENT

Borehole	Average Along Depth				C_u***	$q_u = C_u$ x 2
	SPT N	N_{60}*	ϕ**	ϕ (laboratory)	kN/m^2	kN/m^2
ABH-01	20	10	34.1	33.9	-	-
ABH-02	20	10	33.2	33.9	-	-
ABH-03	38	16	35.5	35.0	-	-
ABH-04	46	21	35.9	34.1	-	-
ABH-05	44	19	30.1	34.8	-	-
ABH-06	76	31	30.0	31	138	276
ABH-07	73	36	31.0	34.9	158	317
ABH-08	53	22	35.7	-	96	192
ABH-09	42	17	36.9	35.7	-	-
ABH-09A	84	35	30.0	-	-	-
ABH-10	22	10	32.6	34.3	-	-
ABH-11	32	13	36.3	33.7	-	-
ABH-12	29	12	34.6	-	-	-
ABH-13	14	7	30.7	33.5	32	65
ABH-14	13	5	31.1	-	24	48
ABH-15	14	7	29.0	-	30	61
ABH-16	8	4	30.0	35	16	33
ABH-17	10	4	31.2	-	18	35
ABH-18	13	7	31.5	33.8	29	59
ABH-19	9	4	30.7	-	17	33
ABH-19A	13	5	30.0	-	24	48
ABH-20	19	13	31.8	33.4	55	110
ABH-21	9	10	31.4	33.1	45	90
ABH-22	6	3	30.9	-	11	22

* Seed et. al. [5], ** Hatanaka and Uchidas [7], *** Stroud [6]
Hammer Efficiency factor 0.55, Correction factor for borehole diameter 1, Sample correction factor 1 and Rod length correction factor 0.75

3.1.4 Analysis of laboratory Testing

Grain analysis performed on recovered soil samples. Soil samples are classified as SP-SM, SW-SM, whereas most of the sample classified as SM and CL/ML [8]. Most samples have Plasticity Index between 10 and 20; therefore, there is medium swelling potential capacity of soil [9]. The values of specific gravity were found in the range of 2.07-2.79. The values of bulk density were found in the range of 19 -21 kN/m^3. The natural moisture content varies from 4.9-25.87%. The Unconfined Compressive Strength (kPa) was between 17.7-420 kPa and Angle of Internal friction was between 31-36°.

Based on laboratory test results, following soil parameters are recommended:

For Silty Sand
γ_{bulk} = 18 kN/m^3, ϕ = 30 degrees, G_s = 2.4
For Clayey Silty / Silty Clay
γ_{bulk} = 18 kN/m^3, ϕ = 28 degrees, C = 15 kPa, G_s = 2.4

Due to low concentration of Sulphate and Chloride Content in soil samples of some areas, the use of OPC (Ordinary Port Land Cement) is recommended.

3.1.5 Bearing Capacity Curves for Foundation

3.1.5.1 Geotechnical Foundation Design Criteria

Following criteria is opted for estimation of bearing capacities:

(i) Foundation should be safe against shear failure of the supporting ground. A factor of safety of 3.0 is adopted for this purpose.

(ii) Foundation should not settle excessively under the service loads. A limit of 25 mm has been put on the total settlement of individual foundations.

3.1.6 Bearing Capacity Curves for Shallow Foundation Based on SPT N_{60}

The summary of the average SPT N, N_{60} and ϕ along depth is given in Table 2 for boreholes along canal alignment. Variation is observed in average SPT N_{60} value along depth. Minimum 3 and Maximum 36 SPT N_{60} is observed. The angle of internal friction from limited laboratory tests are also compared with estimated angle of internal friction from field SPT values.There is a good agreement between empirically and laboratory estimated angle of internal friction values with few exceptions. The bearing capacity curve has been developed for Silty Sand considering depth of foundation as 1.5m (Fig. 4) using Meyerhof's equations [10]. At this depth, the minimum and maximum SPT N_{60} values among all boreholes are 1 and 17, with mostly values falling below 5. Therefore, SPT N_{60} as 4 and ϕ as 30^o is selected for bearing capacity curve [11]. Keeping in view variation in SPT N_{60} values, it is highly recommended to use SPT N_{60} values of a particular borehole in the vicinity of the proposed structure. The bearing capacity of 1.25 ton/ft^2 (120 kN/m^2) is recommended.

3.1.7 Bearing Load Curves for Deep Foundation (Bored Pile)

The bearing capacity of the pile for bored condition (RC piles under compression) has been determined (Pile Dia 2.5 ft (0.76 m) and 3.5 ft (1 m)) using modified version of Terzaghi's equation/NAVFAC DM 7.2 [12] for medium dense sand condition (Fig. 5(a-b)). The depth of water is considered as 5 ft (1.5 m). Factor of safety adopted for the allowable bearing load is 3, γ = 18kN/m^3, N_q = 10, N_q^* = 55, ϕ = 30^0 and γ_w = 9.81kN/m^3. Skin resistance is considered as constant after 15 D (For medium dense sand). Bearing capacity is the summation of skin and end point resistance. In addition to that, bearing capacity curves have been

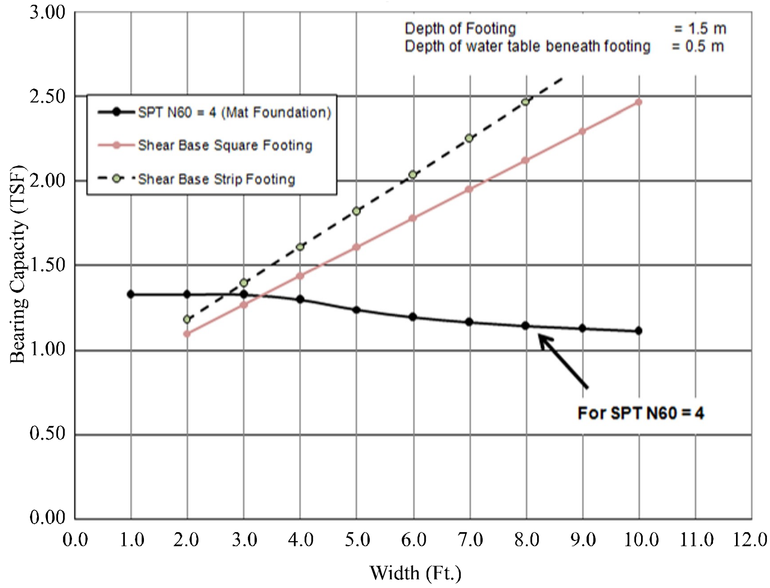
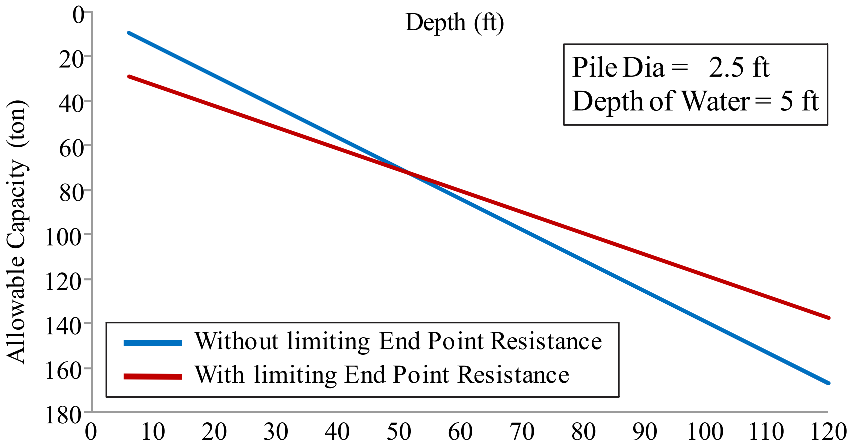
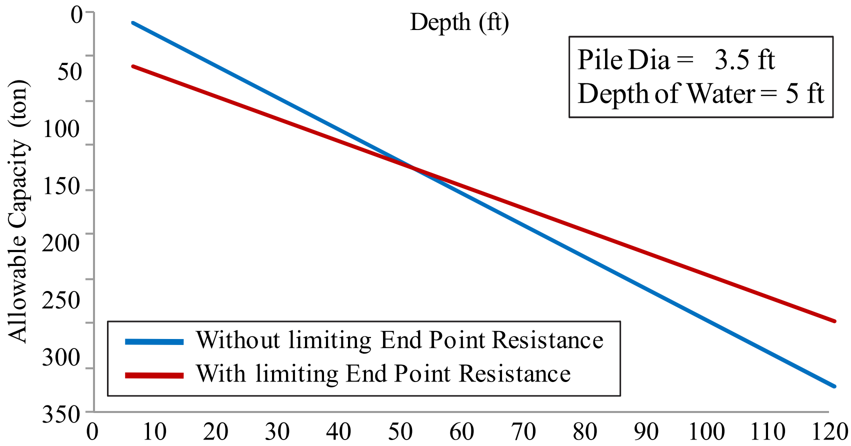


FIG. 4. BEARING CAPACITY OF SHALLOW FOUNDATION



(a) PILE DIA OF 2.5 ft (0.76 m)



(b) PILE DIA OF 3.5 ft(1 m)

FIG. 5. PILE CAPACITY FOR BORED CONDITION

developed considering recommendation of Meyerhoff about limiting end point resistance. Following equations are used to estimate bearing capacity of deep foundation [12]:

$$S = K \times \sigma_v^{'} \times \tan\delta \times A_p \quad (1)$$

$$q_p = \left(0.5 p_a N_q^{*} \tan\phi^{'}\right) A_p \quad (2)$$

Where S is skin friction of the pile, q_p is limiting point resistance, K is lateral earth pressure coefficient, tan δ is friction angle between pile and soil, σ_v is effective stress at the midpoint of the pile, p_a is atmospheric pressure (100 kN/m^2), N_q* is bearing factor coefficient, ϕ' is effective angle of internal friction, and A_p is perimeter areaof the pile.

4. CONCLUSION

In this study, ground condition along proposed route of JIP is investigated. The ground is assessed by laboratory testing and analytical techniques are used to estimate the safe bearing capacities. Following conclusion can be drawn from this study:

(i) The top layer mostly consists of Silty Clay along proposed canal alignment.

(ii) The bearing capacity curve for shallow and deep foundation has been developed. Considering the heterogeneity and complexity of the project area, it is highly recommended to use SPT N_{60} values or design parameters of a particular borehole in the vicinity of the proposed structure.

(iii) The samples recovered shows low to high swelling. Care must be taken with the use of cement type in proposed construction areas.

(iv) The bearing capacity for shallow foundation at depth of 5 ft (1.5 m) beneath footing is recommended as 1.25 ton/ft^2

(v) The bearing capacity for bored piles having diameter of 2.5 ft (0.76 m) and 3.5 ft (1 m) at depth of about 50 ft (15 m) is recommended as 70 ton (685 kN) and 130 ton (1275 kN) respectively.

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