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MATLAB Modeling of SPT and Grain Size Data in Producing Soil-Profile

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Abstract-The study was carried out to find out a suitable numerical procedure for establishing a graphical presentation of the soil profile of a site using SPT values and grain size analysis data. MATLAB numerical tool was used for this purpose and the soil properties was estimated using established empirical correlations. A computer Software was developed where SPT values at borehole locations, percent of grain sizes, water table and GPS coordinates of the site were used as inputs. Rectangular grids in 2-D or 3-D space were created for interpolation or extrapolation of the gridded data in 'meshgrid' format. The output yielded intermittent SPT profile and the contour plot matrix for subsoil soil condition of a site. The output soil-profile is presented by a 3-D shaded surface plot that would be useful for preliminary selection of a project site, land use planning, zoning ordinances, pre-disaster planning, capital investment planning,

Fifteen borehole data of SPT values and grain sizes along a 20 km stretch of ongoing Janjira approach road project of Padma multipurpose bridge in Madaripur district were used to verify the usability of the developed Software. Disturbed soil sample were collected up to depths of 19.5m depth in every 1.5m interval to perform grain size analysis test. Excel spreadsheet was used where more than 500 data including SPT-N values, percent sand and fines at depths, GPS coordinated, reduce level and ground water table. The soils at the site were predominantly alluvial deposits. All these data were used in MATLAB interactive environment for numerical computation, visualization and programming. The purposes of the study were to find SPT contour profile and soil-profile of a particular alignment of the site and to extract borehole Log form SPT profile and soil-profile of a specific location of the alignment.

Outcome of this study can be used in microzonation studies, site response analysis, calculation of bearing capacity of subsoils in the region and producing a number of parameters which are empirically related to SPT values.

Keywords- *Numerical analysis, SPT, Grain Size, Soil-Profile*

I. INTRODUCTION

For safe and economic infrastructural development, it is important that subsoil conditions at any proposed civil engineering site be properly investigated prior to commencement of the final design or construction activities. In other words, there is need to know the characteristics of the formations (rocks and soils) on which the foundation of such structures and ancillary objects are intended to rest or buried. This is for the obvious reason that such engineering structures or objects (e.g. roads, bridges, dam embankments, buildings, etc.) must be anchored on or buried in earth materials of proven integrity. Generally, the overall investigation should be detailed enough to provide sufficient information for the geotechnical engineer to reach conclusions regarding the site suitability, design criteria, probable construction problems and environmental impact. Both laboratory and in situ or field (surface and subsurface) techniques are routinely used to obtain information about engineering properties of rocks and soils. Laboratory techniques include Atterberg limits, pH determination, groundwater quality testing, etc., while geological mapping, geophysical survey, shell and auger boring, core drilling, soil sampling (disturbed and undisturbed), standard penetration tests, pressure meter tests, permeability tests, water level measurements, test pits are the commonly used field techniques. These techniques are usually deployed in synergy for a given site. The overall consideration in the choice of a method or a combination of methods is the cost implication, although this consideration should not override the need for proper investigation. This study focuses on the standard penetration test. It is one of the relatively cost-effective and yet informative field techniques most commonly used in subsurface probing. [1]

Data availability and accessibility can reduce time and the expense of the projects, especially during feasibility stage. In the last few years, the numbers of construction projects in Bangladesh have been increased rapidly and continuously. Consequently, the number of soil boring reports has been accumulated largely. Data interpretation, management and appropriate processing, then, cannot be regarded as simple tasks. The utilization of the various numerical and graphical techniques can be served the geotechnical engineer as the very effective tools. Not only for non-data area prediction but also used to interpret the complex data area with reliability and accuracy.

In geotechnical engineering, soil formation, physical properties and engineering properties are very important data. With the good soil information, engineers can make proper decision and effectively design However, nature of soil is vary and more complicate in some area depending upon its formation process or some disturbing condition. Thus well subsoil survey planning during feasibility and detail design stage of the project is necessary for balancing of cost and acquiring the significant data. Although significant data are obtained, data management and interpretation are also very important processes and not easy tasks to achieve the subsoil information.[2]

Bangladesh Geological Survey indicates that the project site Jajira of Madaripur district, in general, is underlain by recent alluvium. The Padma superficial alluvial river deposits typically comprise normally-consolidated, low strength compressible clays, or silts and fine sands of low density. The thickness of these deposits is usually quite variable and can exhibit considerable changes over short distances depending on the profile of the former river channel in which they were deposited. The underlying deposit is predominantly dense sand. The Janjira approach road length is 10.579 km.

The purpose this study is to elaborate the usage of numerical and graphical methods to manage and interpret the soil data and establish geotechnical database system to provide information support to others geotechnical work. Furthermore this system can be used as a decision support system for geotechnical engineers.

II. OBJECTIVES OF THE STUDY

Evaluation of properties of soils beneath and adjacent to the structures at a specific region is of main importance in terms of geotechnical considerations. From the viewpoint of the engineers, a correct assessment of these properties necessitates a plausible evaluation of geotechnical data. The study was aimed to prepare a model to produce a soil profile at a particular location using the adjacent soil data. The principal objectives of the study were:

- To develop a MATLAB computer model that could produce the soil profile at a particular location using GPS coordinates or chainage location.
- To validate the model using known soil profile data.

III. METHODOLOGY

A. General

The present study was aimed at developing a model to generate soil profile at a selected location using SPT and grain size data of neighboring boreholes. MATLAB was used which provides the user with a convenient environment for performing many types of calculations. In particular, it provides a very nice tool to implement numerical method.

B. MATLAB

MATLAB (matrix laboratory) which is a multi-paradigm numerical computing environment and fourth-generation programming language which allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python.[3] MATLAB functions are similar to C functions or FORTRAN subroutines. MATLAB programs are stored as plain text in files having names that end with the extension ``m''. These files are called, m-files. Each m-file contains exactly one MATLAB function. Thus, a collection of MATLAB functions can lead to a large number of relatively small files. Two m-files were created for this study: one for SPT contour plot and another for surface plot of Soil-Profile. Script files can be used as MATLAB functions, which can be used interactively. In addition to providing the obvious support for interactive calculation, it also is a very convenient way to debug functions that are part of a bigger project.

C. Multidimensional Interpolation

The interpolation methods for one-dimensional problems can be extended to multidimensional interpolation. *Tow-dimensional* interpolation deals with determining intermediate values for functions of two variables, $z = f(x_i, y_i)$. Assuming values at four points: $f(x_1, y_1), f(x_2, y_2), f(x_3, y_3)$ and $f(x_4, y_4)$. To interpolate between these points to estimate the value at an intermediate point $f(x_i, y_i)$, using a linear function, the result is a plane connecting the points. Such functions are called *bilinear*. [4]

A simple approach for developing the bilinear function:

First, by holding the y value fixed and applying one-dimensional linear interpolation in the x direction. Using the Lagrange form, the result at (x_i, y_1) is

$$f(x_i, y_1) = \frac{x_i - x_2}{x_1 - x_2} f(x_1, y_1) + \frac{x_i - x_1}{x_2 - x_1} f(x_2, y_1)$$

And at (x_i, y_2) is

$$f(x_i, y_2) = \frac{x_i - x_2}{x_1 - x_2} f(x_1, y_2) + \frac{x_i - x_1}{x_2 - x_1} f(x_2, y_2)$$

These points can be used to linearly interpolate along the y dimension to yield the final result:

$$f(x_i, y_i) = \frac{y_i - y_2}{y_1 - y_2} f(x_i, y_1) + \frac{y_i - y_1}{y_2 - y_1} f(x_i, y_1)$$

A single equation can be developed by substituting these equations to give-

$$\begin{aligned} f(x_i, y_i) = & \frac{x_i - x_2}{x_1 - x_2} \frac{y_i - y_2}{y_1 - y_2} f(x_1, y_1) \\ & + \frac{x_i - x_1}{x_2 - x_1} \frac{y_i - y_2}{y_1 - y_2} f(x_2, y_1) \\ & + \frac{x_i - x_2}{x_1 - x_2} \frac{y_i - y_1}{y_2 - y_1} f(x_1, y_2) \\ & + \frac{x_i - x_1}{x_2 - x_1} \frac{y_i - y_1}{y_2 - y_1} f(x_2, y_2) \end{aligned}$$

This bilinear interpolation method was used in MATLAB which has built-in functions for two-,three- and n-dimensional piecewise interpolation : interp2, interp3 and interpn.

IV. INPUT AND OUTPUT FOR SOIL-PROFILE

A MATLAB program was developed in this study that uses SPT and grain size data from 15 boreholes of Padma bridge approach road Janjira site. The boreholes were done along the chainage of approach road in a 20 km stretch with approximately 500 m spacing. The present study was aimed at generating the soil profiles at the intermittent locations. In the following sections the modes of data input and output are described.

A. Project Site

As mentioned earlier, the project site Jajira of Madaripur district, in general, is underlain by recent alluvium with Padma superficial alluvial river deposits.The underlying deposit is predominantly dense sand. The Janjira approach road length is 10.579 km. The project site and the borehole locations are shown in Figures 1, 2 and 3.

Figure 1. Site location (Jajira Approach Road of Padma Multipurpose Bridge Project) at Madaripur district.

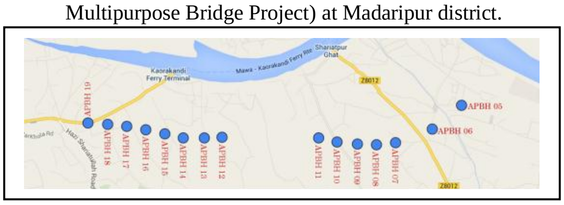

Figure 2. Location of all 15 boreholes within chainage 17600 to 27600 (Jajira Approach Road)

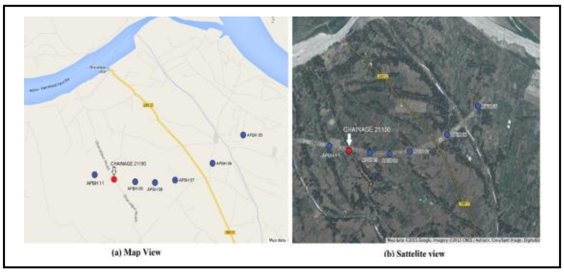

Figure 3. Location of predicted borehole at chainage 21100 (7 Boreholes within chainage 17600 to 21600)

B. INPUT Data

The chainage and GPS locations of the 15 boreholes are presented in Table 1. Data of SPT and grain size of the boreholes as presented in Table 2 and Table 3 were given as input data using Excel spread sheet.

TABLE I. CHAINAGE AND GPS COORDINATES OF BOREHOLES

Borehole Name	Chainage	Latitude degree	longitude degree
APBH 05	17600	23.40657	90.25319667
APBH 06	18600	23.40108	90.24574333
APBH 07	19600	23.39786667	90.23663
APBH 08	20100	23.39741333	90.23177167
APBH 09	20600	23.39755833	90.226955
APBH 10	21100	23.39803	90.22179167
APBH 11	21600	23.39892667	90.21706667
APBH 12	24100	23.39914667	90.19285167
APBH 13	24582	23.39899167	90.18823333
APBH 14	25100	23.399	90.183
APBH 15	25600	23.4	90.1783
APBH 16	26100	23.4009	90.1735
APBH 17	26600	23.4016	90.1687
APBH 18	27100	23.4021	90.1639
APBH 19	27600	23.4024	90.1589

TABLE II. SPT DATA OF BOREHOLES

	APBH 05	APBH 06	APBH 07	APBH 08	APBH 09	APBH 10	APBH 11	APBH 12	APBH 13	APBH 14
chainage-depth	17600	18600	19600	20100	20600	21100	21600	24100	24582	25100
1.5	4	5	5	5	6	5	2	5	5	5
3	4	5	3	3	20	5	6	17	17	3
4.5	6	6	26	16	18	33	5	10	9	13
6	10	7	27	31	12	31	24	6	10	14
7.5	11	7	31	26	28	30	19	8	11	12
9	11	8	30	15	29	9	23	11	26	16
10.5	12	2	32	17	24	12	32	12	22	14
12	17	15	33	15	21	13	35	22	24	9
13.5	15	37	32	14	20	14	20	24	18	4
15	29	29	31	26	32	11	18	23	21	5
16.5	27	30	38	24	43	23	25			7
18	30	16	42	23	34	22	22			42
19.5	26	21	46	22	39	21	19			25

TABLE III. GRAIN SIZE DATA OF BOREHOLES

Start	End	Avg		APBH-05		APBH-06		APBH-07		APBH-08	
			Chainage	17600		18600		19600		20100	
				Sand %	Fine %	Sand %	Fine %	Sand %	Fine %	Sand %	Fine %
1.35	1.8	1.35	D1	86	14	92	8	94	6	90	10
2.85	3.3	3.075	D2	93	7	83	17	94	6	92	8
4.35	4.8	4.575	D3	94	6	84	16	86	14	93	7
5.85	6.3	6.075	D4	91	9			92	8	89	11
7.35	7.82	7.585	D5			84	16			88	12
8.85	9.3	9.075	D6	87	13			87	13		
10.35	10.8	10.575	D7	88	12			89	11	91	9
11.85	12.3	12.075	D8	90	10	85	15	92	8	94	6
13.35	13.8	13.575	D9	85	15	89	11	87	13	89	11
14.85	15.3	15.075	D10	89	11	90	10	87	13	90	10
16.35	16.8	16.575	D11			92	8	90	10	92	8
17.85	18.3	18.075	D12	96	4	95	5	67	33	92	8
19.35	19.8	19.575	D13			94	6				

C. Output Plots

The MATLAB program developed in this study yields SPT contour and grain size surface plots as output. They are presented in Figure 4. The program also gives soil profile at any intermittent locations once chainage or GPS are given as input. The typical predicted output soil profiles (borehole log) are presented in Figure 5 and Figure 6.

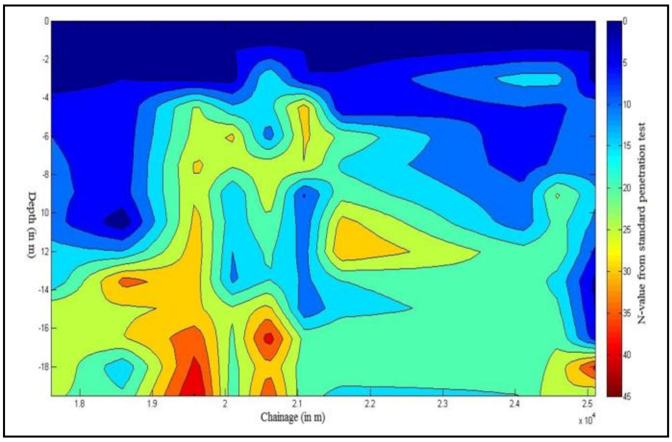

Figure 5. SPT contour profile from chainage 17600 to 25100

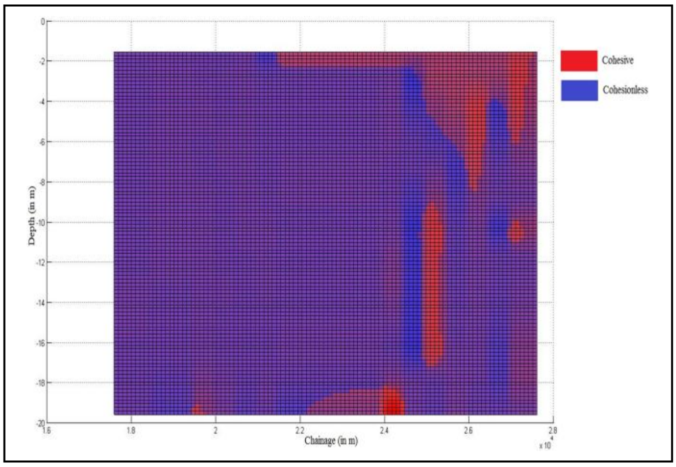

Figure 4. Vertical soil profile along with chainage (up to 19.5m depth)

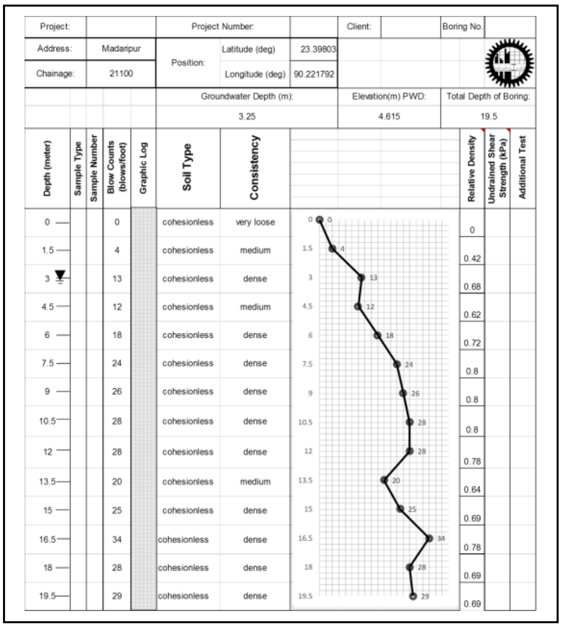

Figure5. Typical Predicted Borehole Log at chainage 21100

D. *Model Validation: Pile Capacity*

The axial geotechnical pile capacity for different diameters was estimated using actual and predicted soil profile. They are presented in Figure 6. Soil parameters were determined empirically to find end bearing capacity and frictional resistance of pile with recognized methods.[5][6] It was observed that the predicted capacities are very close to actual capacities of the piles. As such, the predicted soil profile may be used to estimate the pile capacity at intermittent locations.

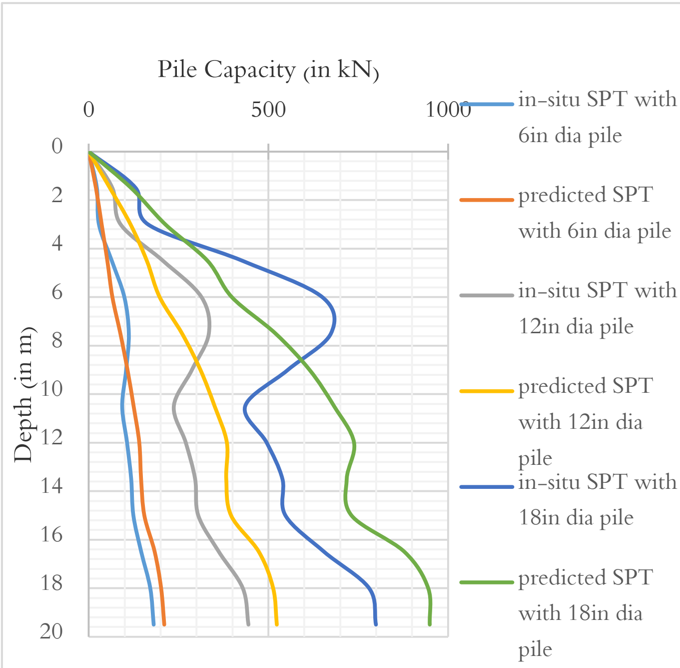

Figure 6. Actual and Predicted Pile Capacity (in kN) at chainage 21100

V. CONCLUSION AND RECOMMENDATION

In this study, A MATLAB computer software model has been developed for SPT and grain size data of boreholes of a particular site in order to generate soil profile at intermittent locations. The program has been validated against known borehole data of Padma multipurpose bridge access road data. Also the predicted borehole data were used to estimate axial pile load at the location. The results can be summarized as follows.

- The MATLAB model developed can predict an intermittent borehole log with reasonable accuracy.
- The developed model gives SPT contours that may be used to identify the soil spatial stiffness of soil.
- The program yields grain size surface plots that may be used to identify the soil profile.
- The estimation of pile capacity suggests that the predicted borehole estimates the SPT values well.

VI. ACKNOWLEDGMENT

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