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Applicability of Standard Penetration Test in Bangladesh and Graphical Representation of SPT-N Value

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Abstract-Site exploration and estimation of soil attributes are key parts of a geotechnical outline process. Geotechnical engineers must focus the normal qualities and variability of soil properties. In-situ testing is turning out to be progressively essential in geotechnical engineering, as basic laboratory tests may not be solid while more advanced lab testing can be drawn out and exorbitant. One of in-situ testing examples is the Standard Penetration Test (SPT). SPT is utilized to recognize soil type and stratigraphy alongside being a relative measure of quality. SPT is a settled technique for to determine soil properties, for example, bearing capacity, liquefaction and so forth. Various types of tests are being used around the world, institutionalization is essential with a specific end goal to encourage the examination of results from diverse examinations. The nature of the test relies on upon a few elements, including the real energy conveyed to the drill rod, the dynamic properties of the drill rod, the properties of the soil, the strategy for penetrating and the steadiness of the borehole. As per the inaccessibility of hardware, furthermore monetary and time restrictions in an undertaking project, correlations may be used to gauge the geotechnical parameters from the values obtained from the in-situ tests. One of the critical parameters is bearing capacity of the soil which could be assessed from standard entrance test.

Keywords- *SPT, Site Investigation, Data Interpretation, Bangladesh.*

I. SUBSOIL INVESTIGATION DATA AND THEIR INTERPRETATION

Information accessibility and openness can decrease time and the cost of the activities, particularly amid practicality stage. In the most recent couple of years, the quantities of development ventures in Bangladesh have been expanded quickly and ceaselessly. Hence, the quantity of soil boring reports has been gathered generally. Information translation, administration and proper handling, then, can't be viewed as basic errands. The use of the different numerical and graphical procedures can be served the geotechnical engineer as the exceptionally compelling instruments. For non-information zone expectation as well as used to decipher the mind boggling information range with dependability and precision.

In geotechnical engineering, soil development, physical properties and designing properties are critical information. With the great soil data, designers can settle on fitting choice and viably plan However, nature of soil is differ and more convolute in some territory relying on its arrangement procedure or some exasperating condition. Accordingly well subsoil overview arranging amid possibility and point of interest configuration phase of the undertaking is important for adjusting of expense and obtaining the critical information. Albeit noteworthy information are gotten, information administration and elucidation are additionally imperative procedures and not simple assignments to accomplish the subsoil data.

II. IN-SITU TESTS

As expressed via Mair and Wood (1987), in-situ testing is turning out to be progressively vital in geotechnical building, as basic research facility tests may not be dependable while more modern lab testing can be time intensive and expensive. Assessment of properties of soils underneath and nearby the structures at a particular locale is of significance as far as geotechnical contemplations since conduct of structures is unequivocally impacted by the reaction of soils because of stacking. Properties of the soils encompassing the structure are compelling on the bearing limit. From the perspective of the designers, a correct evaluation of these properties requires a conceivable respective assessment of geotechnical and geographical information. Various field tests including Standard Penetration Test (SPT), Cone Penetration Test (CPT), Vane Shear Test, Dilatometer Test, and so forth can be utilized to figure out the quality and other designing properties of the soils.

In-situ tests can enormously build the volume of geometrical researched at an establishment site, with investment funds in both cost and pace when contrasted with inspecting and lab testing. Generally, they have been created to assess particular parameters for geotechnical outline. A few tests specifically measure the reaction to a specific kind of load, for example, a plate load test or a pile load test. These tests check outline presumptions, and potentially focus soil or rock properties by reversal. The two most basic in-situ tests, the Standard Penetration Test and the Cone Penetrometer Test, fundamentally distinguish soil sort and stratigraphy, alongside a relative measure of quality. Translation of these two tests might likewise use backhanded relationships with particular soil properties, yet regularly with high measurable variability (incompletely because of intrinsic testing variability, mostly because of disregarding the soil's anxiety history test, and somewhat because of rough observation). Different tests, for example, the Iowa Borehole Shear Test, the Dilatometer Test, and the Pressuremeter Test, endeavor to specifically quantify in-situ the dirt properties that may be generally decided from lab tests of "undisturbed" (all the more precisely termed "in place") tests. Stress-way varieties, aggravation impacts because of insertion of the test gadget, and option test systems may influence the consequences of these tests. There contains various relationships between in-situ test outcomes and different geotechnical parameters. To utilize these connections with dependability, the specialist must comprehend their premise and potential for lapse, and after that pick the in-situ test(s) that give the most dependable correlation(s) for the wanted soil properties and outline parameters. As a rule, this obliges a test that intently models the expected configuration utilization or straightforwardly measures the soil properties needed for outline.

III. STANDARD PENETRATION TEST

One of in-situ testing methods is the Standard Penetration Test (SPT). SPT is used to identify soil type and stratigraphy along with a relative measure of strength. SPT, developed in the United States, is a well-established method of investigating soil properties such as bearing capacity, liquefaction and so on. As many forms of tests are in use worldwide, standardization is essential in order to facilitate the comparison of results from different investigations, even at the same site.

In many parts of the world, the Standard Penetration Test (SPT) is still considered one of the most common in-situ tests to evaluate the strength of soil and often the only in-situ test performed during a site investigation. While the standard penetration test is probably the most common in-situ test performed in Bangladesh, the term “standard” is misleading. Although the test is relatively simple to perform, only skilled drillers routinely achieve meaningful results.

In 1902, Gow designed a 1inch diameter heavy wall sampler to be driven with a 110 pound weight. In 1927, Hart and Fletcher developed the standard 2-inch-diameter "split-spoon" sampler. Later, Fletcher and Mohr standardized the test using a 140-pound hammer with a 30-inch drop to measure the blow count for three consecutive 6-inch increments of penetration, reporting the total blow count for final 12 inches as the NSPT value. Terzaghi and Peck (1948) published early geotechnical design correlations, which popularized the SPT and encouraged its acceptance as a "standard". The three styles of SPT hammer in common use deliver energy to the drill rods that varies from about 35% to 95% of the theoretically available driving energy of 4200 in-lbs. This variation, plus the use of non-standardized drilling techniques, led Schmertmann (1978) to investigate their effect on the value of NSPT, which he found to exceed a factor of two. In addition, Schmertmann (1979) also found that NSPT varied approximately inversely in proportion to the hammer energy delivered to the drill rods.

With the advent of modern computers, energy measurement devices allow technicians to easily measure the actual driving energy entering the rods as described in ASTM D4633. The engineer can then correct the measured value of NSPT to N60, the equivalent blow count at 60% of the theoretical hammer energy (thought to represent the average energy in the correlation database). Skempton (1986) presented a method to compute N60 values from raw NSPT data, which is incorporated in ASTM D 6066. Unfortunately, N60 values rarely appear on boring logs. The barrel on the old samplers had the same inner diameter as the shoe. Today, an alternative sampler barrel in common use has a larger inside diameter to accommodate liners with an inner diameter the same as the shoe. However, liners are rarely used. Skempton suggests multiplying the N-value by 1.2 for this correction. Automatic trip hammers, now in widespread use, may deliver almost 95% of the theoretical energy if well-maintained. For these hammers, a correction of 1.58 may be needed to get N60. Without making the N60 correction, designs tend to be overly conservative and costly. Even with the best techniques, predicting how the soil responds to static structural loading based on the results of a dynamic test can be highly inaccurate.

It is acknowledged that all tests have a number of limitations, advantages as well as drawbacks and application of different tests on various types of soils requires an extensive study in decision making processes (Bowles 1997; Budhu 2007). Standard penetration test is barely the most common in-situ test in geotechnical engineering, which is used in evaluating the strength variation of soil strata underlying structures (Sivrikaya & Togrol 2006). The test is applicable to a widely ranged soil conditions. Although the use of this test is prevalent in subsurface investigations, it has some major drawbacks. The results are affected from many factors and discrepancies in test results are noted in the literature due to use of equipment from different manufacturers, drive hammer configurations, hammering system, use of liner inside the split barrel sampler, overburden pressure, length of drill rod and other problems in application. The test exhibits different driving resistances in silts and clays of varying moisture contents.

The standard penetration test, developed around 1927, is currently the most popular and economical means to obtain information (both on land and offshore). The method has been standardized as ASTM D 1586 since 1958 with periodic revisions to date. The test consists of the following:

(i) Driving the standard split-barrel sampler of dimensions a distance of 460 mm into the soil at the bottom of the boring.

(ii) Counting the number of blows to drive the sampler the last two 150 mm distances (total = 300 mm) to obtain the *N* number.

(iii) Using a 63.5 kg driving mass (or hammer) falling “free” from a height of 760 mm. several hammer configurations are available.

The exposed drill rod is referenced with three chalk marks 150 mm apart, and the guide rod is marked at 760 mm (for manual hammers). The assemblage is then seated on the soil in the borehole (after cleaning it of loose cuttings). Next the sampler is driven a distance of 150 mm to seat it on undisturbed soil, with this blow count being recorded (unless distance of 150 mm to seat it on undisturbed soil, with this blow count being recorded (unless the system mass sinks the sampler so no N can be counted). The sum of the blow counts for the next two 150-mm increments is used as the penetration count N unless the last increment cannot be completed. In this case the sum of the first two 150 mm penetrations is recorded as N. Pictures and schematic diagram of split spoon samplers, SPT arrangement are shown in Figure 1 through Figure 3.

Figure 1. Split Spoon Sampler used in SPT

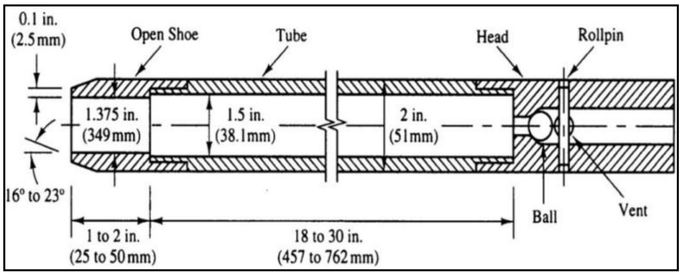

Figure 2. Standard dimensions for the SPT sampler

The boring log shows refusal and the test is halted if-

- 50 blows are required for any 150-mm increment.
- 100 blows are obtained (to drive the required 300 mm).
- 10 successive blows produce no advance.

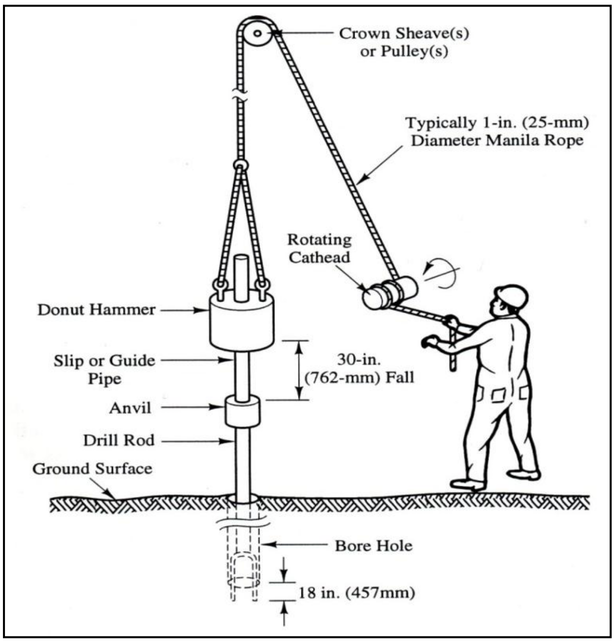

Figure 3. Standard Penetration Test Arrangements

It is evident that the blow count would be directly related to the driving energy, which is theoretically computed as

$$E_{in} = \frac{1}{2}mv^2 = \frac{W}{2g}v^2$$

$$v = (2gh)^{\frac{1}{2}}$$

So, we obtain,

$$E_{in} = Wh$$

Where,

W = weight or mass of hammer and h = height of fall.

This gives , for the standard 63.5 kg hammer and h= 762 mm (30 in.) , the theoretical input driving energy of -

$$E_{in} = 63.5 * 9.807 * 0.762 = 474.5 \text{ (say, 475 J)}$$

Kovacs and Salomone (1982) found that the actual input driving energy E_a to the sampler to produce penetration ranged from about 30 to 80 percent. These discrepancies appear to arise from factors such as –

- Equipment from different manufactures
- Drive hammer configurations
- Hammer Drop
- Sampler
- Overburden pressure
- Length of drill rod

From several recent studies cited it has been suggested that the SPT be standardized to some energy ratio $\boldsymbol{E_r}$ which should be computed as

$$E_r = \frac{\text{Actual hammer energy to sampler}, E_a}{\text{Input energy}, E_{in}} * 100$$

The standard blow count N_{60} can be computed from the measured N as follows:

$$N_{60} = N * \eta_1 * \eta_2 * \eta_3 * \eta_4$$

Where,

η_1= Hammer correction (From avg. energy ratio E_r)

η_2= Rod length correction

η_3= Sampler correction

η_4= Borehole diameter correction.

IV. A SIMPLE MODEL TO INTERPRET SPT-N VALUE

As SPT-N values vary with depth, for a specific alignment; if N-values are presented in a table to take input from MATLAB, a strong numerical visualization and interpretation tool, contour plot can be obtained [7]. To develop this model, various built-in function of MATLAB software was used. The input data are presented in Table 1.

TABLE I. INPUT OF SPT-N VALUES

Depth (m)	17+600	17+800	Naodoba Bridge (ch. 18+005~18+195)	18+300	18+600	Box Culvert at ch.18+420	18+800
1.5	4	2		4	5		4
3.0	4	1		5	5		3
4.5	6	3		3	6		2
6.0	10	6		5	7		4
7.5	11	18		10	7		9
9.0	11	5		3	8		24
10.5	12	16		3	2		18
12.0	17	9		3	15		26
13.5	15	27		12	37		6
15.0	29	7		27	29		10
16.5	27	19		11	30		10
18.0	30	27		27	16		36
19.5	26	25		30	21		38
21.0		20		36			13
22.5		24		44			24
24.0		14		42			11
25.5		12		38			13

A contour plot of matrix is created by using script file of MATLAB. The SPT-N value was presented in MS EXCEL spreadsheet so that MATLAB can take the input data easily. The graphical presentation of SPT-N value is universal now, as the new plot can be obtained easily by changing the input data from spreadsheet only. The variation of SPT-N value with depth is presented as a contour map in Figure 4. From Fig. 4 it can be inferred that the N- value is increasing with the increasing depth. For this particular data set, up to 10-12m of depth, SPT-N value is within 5 to 10. But the SPT-N is increased significantly afterwards. Some soft pockets can be visualized at 17800 m chainage within 15-16m depth, at 18600 m chainage within 13-15m depth etc. The quality of soil can be judged easily with this plot. On the other hand the highest SPT-N value ranged from 35 to 40 is found around the chainage 18100m to 18600m , within depth 21-25 m.

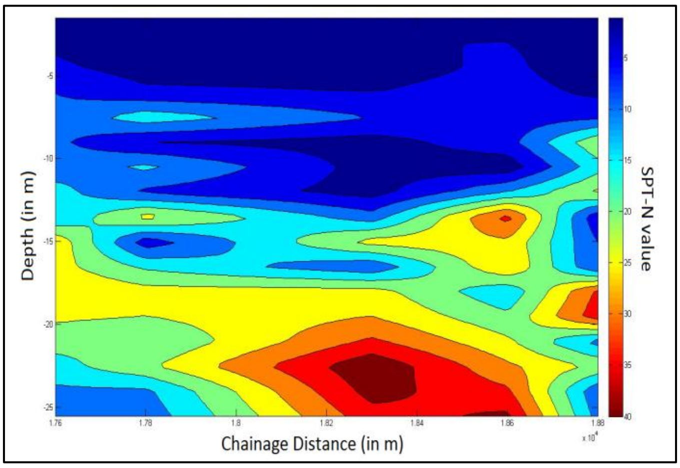

Figure 4. Variation of SPT-N value with depth

V. CONCLUSION

A subsoil or ground exploration is embraced to focus vertical and flat varieties in ground sort and ground properties which incorporate the in-situ anxiety conditions, twisting and quality parameters and the elements characterizing the time-subordinate conduct. A fitting ground examination can empower a configuration designer to survey the conduct of the ground when it is stacked or emptied. Amid the last half century, there has been a colossal increment in the size and intricacy of development works. This highlights an expanding requirement for better expectations of ground conduct. An exact forecast of developments of a multi-story building, neighboring a current building, is crucial amid and additionally after its development. The new structure supporting such components that create vibrations needs an extraordinary establishment for strength. Examination of the circulation, sort and physical properties of subsurface materials are, in some structure or other, needed for the last plan of most structural building structures.

SPT-N values obtained from the Standard Penetration Test can give solutions to the following problems-

- Foundation issues or determination of the stability and disfigurements of undisturbed subsurface materials under superimposed loads, in slants and cuts, or around establishment pits and passages; and determination of the pressure of subsurface materials against supporting structures when such are required.

- Construction issues or determination of the degree and character of materials to be unearthed or area and examination of soil and rock stores for utilization as development materials in earth dams and fills, for street and landing strip bases and surfacing and for concrete aggregates.

- Groundwater issues or determination of the profundity, hydrostatic pressure, flow and composition of the ground water, and in this way the peril of drainage, underground disintegration; the impact of the water on the strength and settlement of structures; its activity on different development materials; and its suitability.

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