BORED PILE CAPACITY BY DIFFERENT STANDARD PENETRATION TEST METHODS

A RESEARCH REPORT

Submitted by

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Transforming Education Transforming India

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DECLARATION

I hereby declare that the dissertation report titled **"BORED PILE CAPACITY BY DIFFERENT STANDARD PENETRATION TEST METHODS"** is an authentic record of my own research work carried out as a requirement for the preparation of M.Tech dissertation for the award of Masters of Technology Degree in Geotechnical Engineering from Lovely Professional University, Phagwara, Punjab, under the guidance of Ms. Chetan Sana Khan, during the period between August 2016 and November 2017. All the information furnished in this report is based upon my intensive work and is completely genuine to the best of my knowledge. And no part of the uncited work in this report has ever been published before in any journal or presented for the award of any degree or honor.

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CERTIFICATE

Certified that this project report entitled ***"*BORED PILE CAPACITY BY DIFFERENT STANDARD PENETRATION TEST METHODS*",*** submitted individually by **INSHA WANI** student of Civil Engineering, Lovely professional University carried out the work under my supervision for the award of degree. This report has not been submitted to any other university/institution for the award of any degree.

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ABSTRACT

The prediction of the axial capacity of the piles has been difficult since the beginning of the geotechnical engineering. In recent years, the ability to test the bearing capacity of a pile in a field test data has been determined in addition to static and dynamic analysis used by the engineers of geotechnical engineering. The Standard Penetration Test (SPT) is the most commonly used field test and the capacity test of the Standard Penetration Test is one of the most used applications of this test. On the other hand, the acceptance of numerical analysis of geotechnical problems is increasing, and the calculations are increasingly limited elements are more and more used in the design of foundations. In this research, the various methods of estimation of the load from the SPT data were compared by numerical methods. Comparison was made between numerical and experimental results which are presented and discussed. In recent years, the ability of testing the bearing capacity of field test data of piles has been determined in addition to the static and dynamic analysis done by the geotechnical engineers. A new method which is based on the N values of the SPT is provided and calibrated. The data which has been collected is observed, the extension zone failure, piles plunging failure of the approach which was proposed. It is recognized that the axial capacity of the piles is the main area of uncertainty in the design of the foundation. Various approaches have been developed for overcoming the uncertainty of the prediction. These methods are some assumptions which have been simplified or empirical approaches to the soil layers, the interaction between the soil and pile structures and the distribution of resistance of soil along a pile. So, there is no provision of quantitative values that are really useful directly for the designing of the foundation. The bearing capacity of the piles can be determined by five approaches: static analysis, dynamic analysis, dynamic test, stack load test and on-site test.

Many civilian projects, such as large bridges, harbors, and facilities of oil extraction, cannot rely only on shallow surfaces for their stability. As a result, pile foundations are used for supporting the superstructure by the movement of the load from the soft surface layers to the deeper subterranean layers. Establishing pile foundations under load is a complex problem that is not yet well understood.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

In recent decades, on site testing has seen a considerable progress resulting from the reported development of technology in this area; the first use was in the design of the foundation. The improvements in technical fields have enabled to gain more realistic knowledge of soil characteristics and its behavior at different depths. They result in becoming very helpful and excellent geotechnical tools for a geotech engineer. In recent times, the usage of boring piles has increased all over the world because of the moderate bearing capacity which they possess and is suitable for a number of projects, their low cost, adjustments in length, low vibrations, and decreased noise levels during installations.

During past years determining the soil's bearing capacity from the results of in situ testing of the static and dynamic analysis which is used by the engineers of geotechnology. Various methods and approaches have been used for the estimating the bearing capacity of piles using data by using Standard Penetration Test.

Civil projects, e.g., large highways, bridges, harbors, facilities for oil extractions, these projects cannot completely depend on foundations which are shallow for the stability. So, pile foundations are required to support the superstructures. There is a transfer of the load from the soft layers of surface to the deep and firm underlying layers. The creation of pile foundation for the loading is a problem which is not quite understood well. Prediction of capacity of pile of bearing load is a challenge for the design by engineers. Estimation of piles load-bearing capacity, so is, one of the tests of pile loading (PLT) and the analysis of pile dynamics tests(PDA) that can be performed, and depends upon on how important the project is. A number of methods have been developed with time for overcoming the uncertainty in prediction.

Prediction of the piles axial load capacity is a challenge in the geotechnical area. Various methods have been formulated for overcoming the uncertainty involved in the prediction. These approaches have an inclusion of assumptions and the empirical approaches which include stratigraphy of soil, soil and pile interaction, and distributed resistance of the soil along the pile. So, a true quantitative value is not provided which will be useful in design foundation.

1.2 APPROACHES USED

The determination of bearing capacity for piles can be done using approaches as under:

1) The data interpretation is done by the full scaling of tests of pile loading.
2) Dynamic analysis is done on the basis of wave equation analysis.
3) Pile driving analyzer to use for dynamic testing.
4) Static analysis to use in effective stress or approaches for total stress by applying parameters of soil.
5) In situ investigation tests and methods used for finding results.

Due to the rapid development of the tests done on sites and their instruments, there is an understanding of the soil, and also an understanding of different types of soils and their limitations, inadequacies, and laboratory tests. In the direct methods, different parameters of soils which obtained from the results of SPT and using the methodology of bearing capacity of the Pile estimation same as used for static methods.

Due to the uncertainties involved in analyzing and designing the pile foundations, in many cases, it has become mandatory to perform pile loading tests on the full scale. These tests are expensive; consume a lot of time and often the costs are difficult to justify according to the projects if small or ordinary.

1.3 STANDARD PENETRATION TEST

The Standard Penetration Test (SPT) is the in-situ test which is mostly used. The pile capacity determination using SPT is the earliest application of this test. It includes two approaches:

(I) Direct approach

(II) Indirect approach

The direct approach is applicable to the values of N and some modification Factors. A considerable uncertainty is in existence related to filtering and average of data regarding the resistance of pile, the zone of failure around the base of the pile, etc. The capacity of pile depends upon the soil compressibility and SPT is amongst one of the methods which is commonly used for testing and is used for indication of on site compressibility of soil. The blow count /300mm (N SPT) of SPT along with the length of pile, within zone of failure, is used for measuring the compressibility of the soil for purpose of study.

Liao and Whitman suggested in their paper the value of N for SPT as the correction for the pressure of overburden as given. The modification was not used for clay

N correct =Cn* N SPT

Cn=√ (95, 76/σ'v);

Cn is the correction for effective overburden pressure;

σ'v is effective overburden pressure (kPa).

The standard penetration test (SPT) is the mostly used in situ test. There are limitations which are associated with SPT related to repeatability and interpretation. It's because of the uncertainties of the energy which was delivered by the different SPT hammers to the anvil system and also the process of the test.

1.4 METHODS USED

The methods of dynamic analysis are applied to driving piles and are on the basis of mechanics of wave for the system of the pile and soil. The uncertainty is in the hammer impact effect, and the changes in the soil strength from the conditions at the driving of pile time and the changes in the strength of the soil at the conditions at the time of driving of pile and at the loading time. This gives rise to uncertainties in the bearing capacity. An analysis of the wave equation and its input assumptions is done which significantly biases the results.

The dynamic approaches used testing is based on the observation of strain and acceleration near the head of pile during driving process. From the measurements, the capacity of the can be measured and calculated using pile driving analyzer (PDA) and analysis done numerically of the data. It can only be used by someone experienced and the results of the test applied essentially to a considerable situation of field testing.

The method of static analysis estimates shaft and resistances of base separately. For the resistance shaft, both in soils which are cohesive and non-cohesive soils, a debate exists over the right choice Ks, the coefficient of horizontal stress. The theory of bearing capacity is applied to estimation of resistance of bse in non-cohesive soils.

In the recent years, in-situ techniques applications of testing have an increase in the designing of geotechnical engineering. Because of the rapid development of testing instruments used on the site, there is an improved understanding of behavior of soils.

Two main methods as discussed above for the application of SPT data to designing of piles are indirect and direct methods. In indirect methods using of soil parameters, like friction angle which is estimated from the SPT data, the unit end bearing capacity of the pile (q_p) and the unit skin friction of the pile (q_s) can be evaluated from the parameters of strength through formulas of semi-empirical and theoretical methods. The indirect method takes no account of the horizontal stress, and neglects compressibility of soil and strain softening. Different from the indirect methods, the direct methods does not require performing laboratory tests and calculation of the intermediate values such as coefficient of earth pressure and coefficient of bearing capacity.

CHAPTER 2: TERMINOLOGY

2.1 DEFINITIONS

For the terms used in this research, the following definitions shall apply.

1. ALLOWABLE LOAD: Maximum load that can be safely applied to the base unit, taking into account both soil resistance and soil pressure, under expected load and soil conditions.
2. NET PRESSURE: The total pressure minus the excess pressure, ie the pressure of the overburden on the soil at the level of foundation
3. BEARING CAPACITY: The general term is used to describe the bearing capacity of the soil at foundation level or rock in terms of average pressure which allows it to support and transfer loads of structure.
4. BEARING SURFACE: The contact surface between a foundation unit and the soil or rock upon which the foundation rests. The contact area between the foundation and the soil or rock on which the foundation is resting.
5. DESIGN BEARING CAPACITY: The maximum average net pressure applied to soil or rock by the foundation that rock the soil or foundation will be transported safely without any risk of shear failure and settlement. It is equal to smaller than at least two values of the net allowable load and the safety bearing pressure. This pressure can also be called Allowable Bearing Pressure.
6. GROSS ULTIMATE BEARING CAPACITY: The maximum average gross pressure of the loading at the base of the foundation which starts shear failure of the soil which is supporting.
7. ALLOWABLE BEARING CAPACITY: The maximum net average pressure of loading that the soil will safely carry with a factor of safety considering risk of shear failure and the settlement of foundation. This is the minimum required safe bearing capacity and safe bearing pressure.
8. NET ULTIMATE BEARING CAPACITY: Average net increases in the base of foundation due to the loading which results in shear failure of supporting soil. It is equal to the total ultimate load minus the pressure of overburden.

9. SAFE BEARING CAPACITY: The maximum loading average pressure rate is the soil which will be transported safely without the risk of shear failure. This can be calculated by division of the net carrying capacity by the safety factor.
10. SAFE BEARING PRESSURE: The maximum average pressure of loading that the soil will carry safely without the risk of permissible settlement.
11. CLAY MINERAL: A small group of minerals, commonly known as clay minerals, essentially composed of hydrous aluminum silicates with magnesium or iron replacing wholly or in part some of the aluminum.
12. CLAY SOIL: A natural aggregate of soil of minerals which are microscopic and submicroscopic grains of minerals which are a product of decomposition by chemicals and rock composition disintegration.
13. FACTOR OF SAFETY**:** The ratio of the ultimate capacity to the design (working) capacity of the foundation unit.
14. GEOTECHNICAL ENGINEER: Engineer having Master's degree in geotechnical engineering and also having at least three years of experience in geotechnical design or construction.
15. GROUND WATER LEVEL/ GROUND WATER TABLE: The level which pore water pressure is equal to atmospheric pressure at the level of water. It is the surface at the top of a free body of water (peizometric water level) in the ground.
16. OVERCONSOLIDATION RATIO (OCR): The ratio of pressure of pre-consolidation (maximum pressure in the past) to the effective overburden pressure existing on the soil.
17. PILE: A deep and slender foundation unit which is made up of materials such as steel, concrete, wood, or combination of materials that transmit the load to the ground by skin friction, end bearing and resistance of lateral soil.
18. BORED PILE/CAST IN-SITU PILE/REPLACEMENT PILE: A pile which is formed into a preformed hole of the ground, usually made of reinforced concrete having diameter which is small than 600 mm.
19. PILE CAP: A pile cap is footing which is needed to transmit the load of the column to a group of piles.
20. PILE HEAD/PILE TOP: The upper small length of a pile.

21. PORE WATER PRESSURE: The pressure which is induced in the water and water filling pores of the soil. This is also referred to as neutral stress.
22. SOIL: it is a loose or soft deposit of particles of mineral of organic origin which can be separated by using gentle mechanical means as agitation in water.
23. Clay: it is a natural aggregate which are microscopic and submicroscopic mineral grains having less than 0.002 mm size and moderate plastic in wide range of water contents.
24. GRAVEL: Particles of rock which pass through 75-mm sieve and are retained on a No. 4 (4.75-mm) sieve.
25. SAND: Aggregates which are rounded, sub-rounded, angular, sub-angular or flat fragments of more or less unaltered rocks or minerals which are larger than 75 µm and smaller than 4.75 mm in size.
26. Silt: the Soil passing a No. 200 (75-µm) sieve which is non-plastic or slightly plastic and exhibit little or no strength when air dry.

2.2 ABBREVIATIONS USED

1) N_o = Observed STP value
2) CN = Correction factor
3) Nc' = Corrected N- value
4) γ = Bulk unit weight
5) γd = Dry unit weight
6) γsat = Saturated unit weight
7) G = Specific gravity of soil
8) LL = Liquid Limit
9) PL = Plastic Limit
10) LSF = Local shear failure
11) Cc = Compression Index
12) B = Width of foundation
13) SBC=Safe bearing capacity
14) qu = Unconfined compressive strength
15) Cu = Un-drained shear strength
16) C' = Effective cohesion parameter

17) Φ’ = Effective Angle of shearing resistance

18) Φm = Mobilized Angle of shearing resistance

19) D_f = Depth of foundation

20) Q = Effective surcharge

21) Nγ, Nq&Nc = Bearing capacity factors

22) Sγ, Sq&Sc = Shape factors

23) dγ, dq&dc = Depth factors

24) PI = Plasticity index

25) GWT = Ground Water Table

26) EGL = Existing ground level

27) W′ = W.T. correction factor for BC from SPT values

28) p^{-} = Natural overburden stress

29) L = Length of foundation

30) EGL = Exiting ground level

31) eo = Original void ratio

32) DS= Disturbed sample

33) UDS=Un-disturbed sample

34) NSBC= Net Safe bearing capacity

CHAPTER 3

3.1 IN-SITU TESTS FOR PILE BEARING CAPACITY DETERMINATION

Although there are some problems on the explicit interpretation of the results of SPT, the test is the most used in-situ test in practice of geotechnical engineering because simplicity and affordable costs involved. Five common SPT methods to estimate the piles bearing capacity have been surveyed and presented in Table 1.

Table 1 Direct methods of SPT for the prediction of bearing capacity of piles

No.	Method	Unit shaft resistance (KPa)	Unit base resistance (MPa)	Explanations
1	Aoki & De'Alencar	$r_s=(ak/3.5)N_s$	$r_t=(k/1.75)\ N_b$ N_b: average of three value of SPT blows around pile base	Failure criteria : Vander veen method Energy ratio for N: 70% For sand: a=14 & k=1 ,For clay: a=60 & k=0.2
2	Shioi & Fukui	$r_s=n_s N_s$	For driven piles: $r_t=(1+0.04(D_b/B))N_b \leq 0.3N_b$ For pipe piles: $r_t=0.06(D_b/B)N_b \leq 0.3N_b$	Energy ratio for N: 55% n_s=2 for sand and 10 for clay
3	Meyerhof	$r_s=n_s N_s$	$r_t=0.4\ N_1\ C_1\ C_2$ N_1: N value at the base level	Failure criterion : Minimum slope of load-movement Curve Energy ratio for N: 55% Low disp. piles: n_s=1 High disp. piles: n_s=2
4	Briaud & Tucker	$r_s=\dfrac{0.1}{\dfrac{1}{k_s}+\dfrac{0.1}{r_{s.max}+r_{s.res}}}-r_{s.res}$	$r_t=\dfrac{0.1}{\dfrac{1}{k_t}+\dfrac{0.1}{r_{t.max}-r_{t.res}}}+r_{t.res}$	Failure criteria: penetration of pile head equal 10% of pile Diameter
5	Bazaraa & Kurkur	$r_s=n_s N_s$	$r_t=n_b\ N_b$ N_b: average of N Between 1B above and 3.75b under pile base, $N_b \leq 50$	n_s=2~4; n_b=0.06~0.2
	N_s: average value of N around pile embedment depth.			
	N_b: average value of N around pile base.			
	$C_1=((B+0.5)/2B)^n$; n=1, 2, 3 respectively for loose, medium and dense soil when pile diameter (B)>0.5 m, otherwise C_1=1.			
	C_2=D/10B when penetration in dense layer (D)>10B, otherwise C_2=1.			
	$k_t=1868400(N_b)^{0.0065}$, Nb average of SPT blow-count between 4B above and 4B under the pile base			
	$k_s=20000(N_s)^{0.27}$			
	$r_{t.max}=1975(N_b)^{0.36}$			
	$r_{s.max}=22.4(N_s)^{0.29}$			
	$r_{t.res}=557L\ ((k_s{*}p)/(A_t{*}E_p))^{0.5}$, L: length of pile, p: perimeter of pile, At: cross section area of pile, Ep :Elastic modulus of pile			
	$r_{s.res}=r_{t.res}\ (A_t/A_s)$, A_s: Surface area of pile			

Table 2 Direct methods of SPT involved for prediction of pile bearing capacity

Method	Unit Base (Q_b) and Unit Shaft (Q_s) resistance	Remarks
Meyerhof (1976)	$m N_b \le \left(\frac{L}{D}\right)$ Q_b (MPa) = k N_b Q_s (kPa) = $n_s N_s$	N_b:average of N between 10D above and 5D below pile base N_s: average value of N around pile embedment depth. bored piles: n_s=1, k=0.012, m=0.12 driven piles: n_s=2, k=0.04, m=0.4
Bazaraa & Kurkur (1986)	Q_b (MPa) = $n_b N_b$ Q_s (kPa) = $n_s N_s$	N_b:average of N between 1D above and 3.75D below pile base, $N_b \le 50$ n_b= 0.06 - 0.2 n_s= 2 – 4 N_s: average value of N around pile embedment depth
Decourt (1995)	Q_b (MPa)= k_b N_b Q_s (kPa) = α (2.8 N_s+10)	driven piles and bored piles in clay: α =1 bored piles in granular soils: α=0.5-0.6 driven piles in sand: k_b=0.325 bored piles in sand: k_b=0.325 driven piles in clay: k_b=0.1 bored piles in clay: k_b=0.08 N_b: average of N around pile base N_s: average value of N around pile embedment depth.
Shariatmadari et al.(2008)	Q_b (MPa)= 0.385 N_{gb} Q_s (kPa) = 3.65 N_{gs}	N_{gb}: the geometrical average of N values between 8D above and 4D below pile base N_{gs}: geometrical average of N values along the pile

When using these methods, the following inadequacies appear:

1. All the methods based on SPT used for the prediction of the bearing capacity of pile, ignore the excessive pore water pressure which is generated during the testing and therefore results may not be reliable in low permeability of soils such as clays and silts. Since the procedures of designing involve mainly the consideration of the long term capacity of piles, the SPT data is generally the only applicable approach for the sands or non-cohesive granular soils.
2. Among the five SPT methods which are presented in Table 1, Shioi & Fukui and Bazaraa & Kurkur did not specify any failure of criterion for bearing capacity determination. This fact can be confusing in prediction; therefore, a failure criterion should be pointed out.
3. In all SPT methods, an arithmetic average of N values surrounding the pile base and along pile body have a relation to the pile base bearing capacity and resistance of pile shaft, while the variation of N values of SPT in peaks and troughs can make the results biased.
4. All approaches have very limited failure zones. This strongly affects the calculation of the pile bearing capacity, so that the zone is carefully chosen to properly estimate th

base bearing capacity of the pile. Aoki & De'Alencar, Shioi & Fukui and Meyerhof methods do not specify this zone and as a result, choosing a consistent value for N is done with some uncertainty.

In Briaud & Tucker and Bazaraa & Kurkur methods, the energy ratio of N values was not specified; however this index has a direct relation to the pile bearing capacity and affects the results

CHAPTER 4: REVIEW OF LITERATURE

4.1 LITERATURE REVIEW

1. A. Boufia et al present that it is currently recognized that on-site testing methods are best suited for predicting the foundations of pile bearing capacity. In the code design basis as well as in the literature many design methods are described based on SPT, mainly experimental. This article presents a data of 46 pile load axial tests conducted in 27 sites in the UAE with comprehensive geotechnical data. The piles are pierced in a sandy loamy soil. An assessment of some of the methods currently used to calculate the sandstone soil capacity on the basis of the SPT test was carried out. The comparison of the predicted values of those derived experimentally from the pile tests led to the arrangement of these approaches related to their predictive ability of carrying the piles drilled into the sand.
2. A.R. Bazara et al prepare a method that has been proposed to use the standard penetration values to predict stable load curves of different piles used in Egyptian soil. This method is based on H. G. Bulus-E. H. Davis solved the elasticity with modifications to calculate the variation in the value of the coefficient of Young’s modulus of soil with method of construction and the increasing load on the pile. Design diagrams are displayed for a quick estimate of settlement and ultimate loads. 82 actual tests were conducted for tests of pile loads and boring piles in Egyptian soil, and close agreement was reached between expected and expected load curves and stability.
3. Amel Benali et al in their research present that in recent decades, field trials have witnessed considerable progress resulting from technological developments recorded in the area, and their use in the designing of the foundation. These improvements in the technical aspect have enabled better understanding of soil properties and behavior at varying depths. They have become helpful tools for the geotech engineer. Recently, the using of bored piles has increased worldwide thanks to the bearing capacity which moderate and is suitable for many projects having relatively low cost, length adjustments, low vibration and low rate of noise levels.. This paper has attempted at a formulation and calibrate of a new method based on the N value of the SPT. Average of data, extension zone failure, and failure in plunging, piles were observed in the approach proposed. The

database has been collected and analysis has been done, which include 40 large-scaled load tests spreading across different terrains and layers around the world. Features of the soil vary from soft mud to hard clay, and dense sand and mixtures of clay, silt and sand. Lengths of piles vary from 2 to 57 meters and diameter of piles is from 100 to 1220 mm. The performance analysis of the new SPT method proposed and is performed with other predicted methods using different criteria. The method proposed is suitable for the designing practically the bored piles, because of the fixed results.

4. Anil Misra et al present the methodology of reliability based on design methodology (RBD), for example a load method and factor design of resistance (LFRD), are recognized for the designing of drill shafts. The method to complete drill shaft designing has the following advantages:
    a. Considerations of change features and functional characteristics of this configuration.
    b. Current methods of assessing the pile capacity based on the SPT indicate certain shortcomings. To overcome these shortcomings, a new approach has been developed in view of the extension of the failure zone, data processing and the failure mechanism for diving.

The use of reports (qc/ba) / N60 proposed by Robertson et al., And the conversion of the Eslami & Fellenius CPTU method to the SPT format showed that the new method has an acceptable accuracy in estimating bearing capacity. In addition, using a database consisting of 6 historical piles, including 43 large-scale static load tests, 17 dynamic tests and SPT data at a minimum distance from the piles site, predictive methods were compared and verified. Comparison related to the current methods was performed by looking for the error with the cumulative probability and the normal log approach. The results observed from the comparison shows that error in the new method falls within an acceptable range and that the variation is small compared to the other methods.

Determination of the bearing capacity of piles is a topic which catches intrest in geotechnical engineering. The complexity in the nature of the piles and the lack of appropriate analytical models to predict bearing capacity of piles is a reason why geotechnical engineer tends to investigate further. Among the various common approaches, the tests of pile load and dynamic tests with pile driving analyzer and process matching signals may be good results, but these procedures are costly consume time and difficult to justify for regular projects or small. The methods of prediction of the direct bearing capacity of the piles have been developed based on the on-site test data, in particular SPT and CPT, whose applications have increased in recent years.

5. E.G. Balakrishnan et al present that the common practice of designing single bored piles in the remaining stability configurations is based primarily on stability as a function of failure of shear, and the pile distortion is rarely analyzed. However, the criteria of acceptance for single piles during tests of pile load during construction are mainly based on permissible adjustment criteria as specification done in codes. The study shows a reliable method for prediction of load distribution curves of the excavated piles in the adjacent contiguous formation (Kenny Hill Formation) is proposed in Kuala Lumpur.
6. E.G. BALAKRISHNAN et al, the authors present the current practice of designing of single bored piles in the weathered residual formations. It’s based mainly on the considerations against the stability of the failure of shear and deformations analysis of pile, which is carried out rarely. But the criteria for acceptance of the single piles during the tests of pile load in the period of construction depend on the criteria of permissible settlement as per the specification and codes. In the research, a method which is reliable for the prediction of deformation of load and the distribution of load curves and is presented for the piles bored in the weathered residual formation (Kenny Hill Formation) in Kuala Lumpur which is based on:
7. Ergys anamali et al in this research the researcher discusses the evaluation of load of axial capacity on pile foundations using the ground drilling method using Standard Penetration Test data and Piezocone Penetration Tests. The tests were conducted as part of the program of investigation of P.N.G. Station power plant, near Simani Beach, in the swamp of Hoksara, in the western part of Albania. The axial load design is based on an experimental formula which uses the values of SPT and CPTU. The study presents results based on the analysis of the axial load capacity of the casting piles by different methods of analytical calculation, which is based on the results of on-site tests, and also the reference to the Japanese Building Standards Act. At the end of the work, the

differences between the calculation methods are displayed by the use of test results in different site tables and graphs.

8. Feng Yu et al this research discusses about a new method for the estimation of the base capacity of open- ended steel pipes in sand; it is a problem which involves uncertainty in foundation design of pile. The method is known as the Method of the University of Hong Kong (HKU), and is based on the Cone Penetration Test (CPT) and also considers the mechanism of annulus and resistance mobilization of plug. In this method, annulus resistance is related to the ratio between pile length and diameter - a key which reflects the influence of pile embedment - while resistance of plug is associated with the ratio of length of plug which reflects a plugging degree of soil in a practical and rational manner. Average resistance of the tip of cone to the area near the base of the pile with mechanical consideration of piles ruptured in the sand, driving of the stack (total or partial flush) and the effect of soil compression. The prediction of performance of a new method is evaluated against number of well carried out experiments in this field, which include two large diameters of offshore piles, and comparison to the main methods of CPT in the practice of mainstream engineering.
    a. The evaluation indicates that the way the University of Hong Kong method presents interesting capabilities and has advantages that make it a positive option.
    b. The data of Field performance from fully instrumented pile loading tests.
9. Frank Raushche et al in the research present a method that is displayed to determine the static axial pile capacity of dynamic force and the measurements of accelerometer that are made by the influence of large hammer. The main equation is derived for the calculating resistive forces for penetrating bristles. The limits of the resistant equation are discussed in the paper. Due to the availability of the derivation, it becomes possible to prove that the distribution of the strength of the Case Pile Wave Analysis (CAPWAP) is unique. Assuming that the resistance against penetration can be divided into static and dynamic part, the expression developed is used to calculate dynamics, and to resist penetration. Resulting method has a requirement of the selection of data of the experimentally damping constant, with respect to the size distribution of soil. Correlation of the methods of the capacity of cases and the observed capacity in the static loads test was given for 69 statistic piles which were tested and were also dynamically tested.

10. H.M. Abdul Aziz et al state that a new technique has been recently used to analyze the devices, called the Glo Str Ext method, for drill pile loading tests. This new technology offers an innovative and improved alternative to traditional bored pile methods that have been practiced in recent decades. The results of five case studies involving large-scale fixed load tests for large-capacity drill piles with the details of new and traditional devices placed in the same tool piles are demonstrated to demonstrate the benefits of this new technique. The results show a good correlation between new and traditional devices.

    However, to ensure the typical simplicity, it is considered that the interface of the soil shaft is similar and ideally elasto- plastic. Thus, close expression forms are derived to drill the displacement of shaft load behavior. The expressions are given in terms of modulus of shear of the subclass interface soil interaction of K, subsequently the shear force of the soil interface shaft and response coefficient τu sub grade response of soil, modulus of tip soil of sub grade reaction. The expressions derived are used as well as the simulation method known as Monte Carlo to study the probability of the behavior of the axial displacement. The results are used in the development of probability curves and capacity of load that can be used to identify resistance factors useful for evaluating the designing in the case of the service limit.

    In this analysis of deformation, the installation of pile methods and the behavior which is non linear of the material of pile is incorporated. The analysis which is used for deformation of load was carried out both on the instrumented and non instrumented piles and recorded good results. Thus, this procedure that was used to predict the deformation of load characteristics from a single pile can be used to drill in a change formation during the design phase.

    In this deformation analysis, methods for determining piles and nonlinear behavior of pile material were combined. The proposed deformation analysis was performed on empty and unused piles, which gave good results. Therefore, the proposed method can be used for the prediction of the load-strain characteristics of individual stacks in the variable configuration during the design phase.

11. Issa Shooshpasha et al the prediction of the axial capacity of the piles has been a problem since the beginning of the geotechnical engineering profession. In recent years, the bearing capacity of field test data has been determined in addition to static and dynamic

analysis by geotechnical engineers. The standard penetration test (SPT) is still the most used in situ testing and determination of the carrying capacity by SPT is one of the applications of this test. Whereas, the acceptance of numerical analysis of the geotechnical problem has increased, and the calculations of increasingly limited elements are increasingly being used in the design of the foundations. In this study, different methods were used to estimate the bearing capacity of SPT data and to compare it in numerical form. Comparisons between numerical and experimental results are then presented and discussed.

12. James H Long et al present a database of 43 high-quality drill-shaft load tests that was developed to study the parameters that affect the axial behavior of boreholes and the methods of analysis to predict axial capabilities. The load testing database is limited to drill shafts that provide detailed and accurate documentation for load testing and construction procedures. The database is used for the determination of the effects of construction, engineering and conditions of soil on wellbore capacity. Results of the study indicate that there is greater uncertainty associated with the development of tip capacity constructed with the help of slurry than the equivalent shafts which are constructed under the dry conditions.
13. Jean Louis Briaud et al designed this research to predict a monotonous load response from individual piles under different soil conditions. The 98-load load database was obtained from the Mississippi Highway Administration and was used for evaluation of 13 methods designed for the prediction of final load and five methods for prediction of pile setlement. The methods include the methods of Spta / Su, cone penetration methods, pressure measurement method, and dynamic mode. The accuracy of each method is measured statistically, and risk analysis is performed to correctly assess the safety factor. A cost analysis is also performed to find a safety factor that reduces the cost of construction plus the cost of potential failure.
14. Jean Louis Briaud et al in their research state that three piles have been constructed and tested at national geotechnical experimentation sites in Texas, A & M University to collect data based on the reliability of significant deformation dynamics methods to predict the static capacity of the piles of drilling. The diameter of the excavated piles is 0.915 m and length 10 m, as well as some planned or unplanned defects. The piles were

first tested for static load, and four companies were required to conduct dynamic tests such as statnamic tests and drop weight test - and to predict the results of static load tests. This research shows the comparison between the predicted results and the measurement of load characteristics from the loading load of transport behavior design.

15. Nabil F. Ismael et al, in their research state that the behavior of the piles in the isolated groups in the sand was examined by a field test program at a site in South Surra, Kuwait. This test consisted of a axial load test on piles of bored piles that was simple in stress and pressure. The tests were carried out on piles of two sets of pillars, each consisting of five piles. The spacing between piles in groups was two or three diameters of piles. The soil exploration included standard penetration, dynamic cone and pressure test. Simple pile test results indicated that 70% of the final load was transferred in lateral friction and that the length of the pile shaft was uniform. The pile group competencies were calculated as 1.22 and 1.93 for pile spacing of two and three stack diameters, respectively. Because the organization has control over the design of pile sets in the sand, the group factor specified here is the ratio between the settlement group and the pile settlement with similar loads in the range of elasticity. The comparison between measured values and computed values is based on a simple formula.

    Reliability can be incorporated into rationality in the design process, in this article. Developing a potential mathematical model for displacement drilling. The excavated soil and the interaction between the models are explicitly developed in the approach of "t-z".

16. Scott M. Mackiewicz et al present in their research that as part of a large-scale expansion project in Las Vegas, Nevada, it was evaluated the performance of various analytical design methodologies to predict the shaft strength in solid and soft clay soils with (caliche) sand. The researchers expected side-resistance capability using FHWA (Federal Highway Administration) and other advanced relationships based on on-site testing. Two pre-test tests, known as the Osterberg test, were performed to improve capacity estimates. The design team recommended evaluating shaft shaft fitting for dynamic testing using Apple systems. The results of Osterberg and dynamic load tests were compared with our predictive methods to determine the most appropriate methods for estimating the side resistance of wells drilled under typical heterogeneous soil conditions of the Central Las Vegas Valley. This article describes the installation of drilled wells and provides the

results of dynamic load and Osterberg tests against the design values expected by Foa and other design methods. In addition, comparison of the cost of the testing program with basic cost savings through effective design.

17. Shariatmadari et al in this state that in recent years, the bearing capacity of field test data has been determined in addition to the static and dynamic analysis by geotechnical engineers. In this paper, different approaches to estimate the bearing capacity of SPT data were explained and compared. A new method based on the value of SPT, N is provided and calibrated. Average data, failure zone extension and piles have been observed in the proposed approach. A database of 43 large-scale pile loading experiments was collected and 17 dynamic tests had analysis done using the signal matching technology. SPT data was also included near the pile locations in the database. Comparing current methods by error analysis with cumulative probability and log-normal approach suggests that the proposed method expects pile capacity with greater accuracy and less dispersion than other methods. The results of the prediction of a good agreement on measured capacity suggest that the proposed method can be used as an alternative to determine the load capacity of piles in geotechnical practice.
    a. The basic designing is easy and more efficient when the structure designing is done according to the method to complete, where there is no need to find the definition of load combinations, and
    b. The data of performance on field of the instrumented tests of bored pile load.

The methods of Mayrhoff, Proud & Tucker predict the capacity with reasonable accuracy. Therefore, a new approach based on an equivalent N-value SPT or SPT-CPTU parameters can be considered in geotechnical practice. The weathering profiles and the characteristics of engineering properties are to be considered in this formation

CHAPTER 5: OBJECTIVES OF RESEARCH

The furnishing of this research is applicable to the designing and construction of bearing capacity of piles with respect to Standard Penetration Test (SPT).

Development of a new method has to be done for estimation of pile's bearing capacity is based on results of SPT tests in various types of soils.

The criterion of failure for this type of method is plunging. It happens when the pile undergoes rapid rate of movement under the slight increase of load. A failure diagram for ideal plunging is shown below in the Figure1. The diagram's first part is known as the semi elastic portion. It demonstrates the elastic interaction of the pile and soil system which continues to point A, the head movement of pile can be very small. The other part of the diagram presents the plastic behavior and it extends to point B from the point A. this part is known as the semi plastic portion. Here the head movement of pile has an increase rapidly and very less rate of increment of load.

There is sometimes an inadequacy to this definition because the failure in plunging has a requirement of large movement. The ultimate load is sometimes not a function of pile and soil system capacity but a function of man and pump system.

In the figure 2, the diagrams present show different types of load settlement.

Various methods are used for predicting failure of pile or ultimate load from the obtained results of tests of pile load. In some researches, for example, Davisson presents an offset limit load, 80% according to Brinch Hansen criteria, Chin Konder as suggested by many books of geotechnical engineering. Based on the analysis done by Fellenius, the most improved method to study the failure of plunging is Brinch Hansen's criteria of 80%. In some other analysis performed by other authors by using the database of 30 case studies of pile load test which is achieved by failure of plunging, and six types of methods of interpretation are compared and the same showed those achieved by Fellenius were concluded.

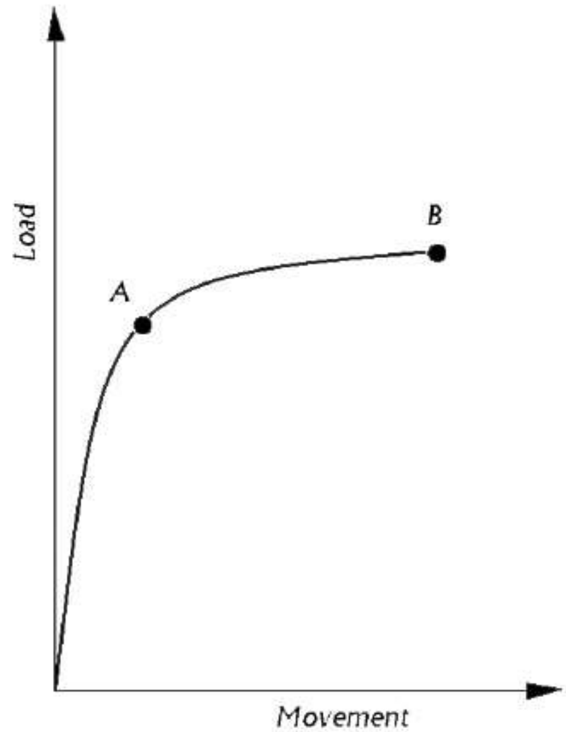

Figure 1 Ideal Failure of Plunging For Load Set Diagram

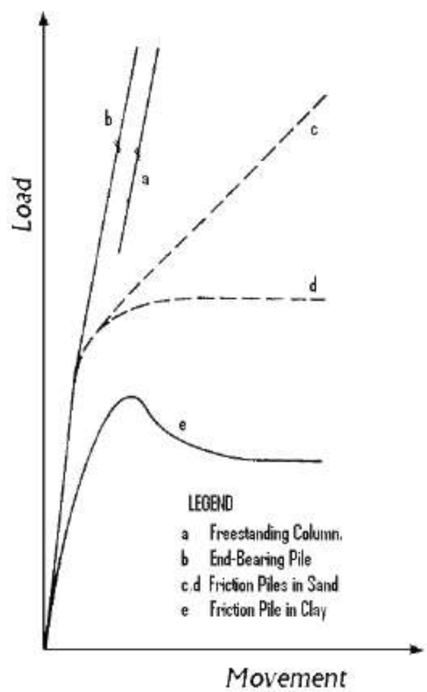

Figure 2 Different Types of Load Sets

In many cases, the N value presented a broad range of variation because of the heterogeneity of the soil layers. For accomplishing a proper unit shaft and resistance of base it is necessary that resistances of soil properties are considered by presenting average value of N.

Many a time's two methods of average, arithmetic and geomety are put in use for finding the mean value of series of numerals.

The arithmetical average is calculated as:

$$N_a = (N_1+N_2+\ldots N_n)/n$$

N_a represents the arithmetical average of N_1 to N_n. The geo mean is calculated as:

$$N_g = (N_1 * N_2 * \ldots * N_n)^{1/n}$$

N_g is the geometrical average of N_1 to N_n.

For obtaining base unit pile resistance from the results of SPT, the failure zone and process of failure has to be specified around pile base.

CHAPTER 6: MATERIALS

6.1 STANDARD PENETRATION TEST RESULTS

The results from the geotechnical investigations of standard penetration test can be compiled in an investigation report. This report consists of the boring logs which have the boring logs and the results of the other tests conducted.

The report states the limitations of the results. The report also proposes required laboratory and field tests, justifying the need for further work. The representation of geotechnical information includes an account of the field and laboratory tests. It includes the following information:

1. The requirement and scope of the report which includes description of site and the topography.
2. The dates during which the tests were performed.
3. The report also consists of
   a) Evidence of groundwater
   b) Depth of groundwater
   c) Boring logs
   d) Test results
   e) Density
   f) Depth to which boring is done
   g) Depth to which Standard Penetration is done

The presenting of the geotechnical report also includes he methods, procedures, results which include data of

A) Studies done at desks
B) Investigations done on field, such as groundwater measurements, collecting samples.
C) Tests done in laboratory

The data acquired from field and laboratory tests are submitted in the report based on the ASTM criteria or any other equivalent standard applicable in investigation.

The durability of every civil engineering project depends upon the soundness of underlying soil, therefore proper soil investigation is done at site before construction phase and necessary steps of soil improvement are taken if needed. Investigation of the conditions underground at particular site is required for the economical design of the elements of substructure. It's also necessary for obtaining sufficient information for feasibility and economic studies for any project. In general, the main purpose or Objectives of site investigation are:

1. Information for the determination of most suitable type of foundation which is required (whether shallow or deep), founding depths and geotechnical design parameters.
2. Information for allowing the geotechnical consultant for making recommendations on the allowable bearing capacity of soil, expected foundation settlement.
3. Location of the groundwater table and other hydrological conditions at the site.
4. Need of any ground improvement technique.

In our research, 100 bore logs have to be used. Out of 100 50 borings and standard penetration test has been completed.the standard penetration tests were carried out over the Kashmir region in different areas. The areas for which the tests have been conducted and are yet to be conducted are as under

Table 3 areas where SPT has to be conducted

A	B	C	D
S.NO	DISTRICT	NO. OF SPT's CONDUCTED	AREAS
			NOWHATTA
			NASEEM BAGH
			ELLAHI BAGH
			VICHERNAG
1	SRINAGAR	8	ZOOHAMA SHUMNAG
			ANCHAR
			BAGHAT BATAPORA
			BREN NISHAT
			SHADIPORA SUMBAL
2	BANDIPORA		AHAN SUMBAL
			HARDVILA BEERWAH
			SHARAKWARA
3	SHOPIAN	4	KALANTARA
			KUTHPOTA
			KRAD RANIPORA
			THAMAN VERINAG
			REHMAT E ALAM
			DONIPORA
			DABRAN
			RATHERPORA
			DALWAN
			MATALHAMA
			WAMPORA
4			VOPZAN
A	B	C	D
			KANGANHILL
	ANANTANAG	22	SHANGUS
			BRINTY
			DOORU DANGERPORA
			PANZATH WAMPORA
			POOLIDORA VERINAG
			AKHRAN
			BAHGHIDAR
			BATAGUND VERINAG
			CHERIMARG
			YARIPORA
			DANOW BOGUND
			DURU SHAHABAD
			HILLAR KOKERNAG
			HANDWARA
			KANDI PAYEEN
			KHUDPORA TANGDAR
			NAICHAN TANGDAR
5	KUPWARA	7	BRARIPORA
			HANDWARA
			CHURPAWA
			HADWARA
			GONIPORA
			HANDWARA
			CHURSOO
			AWANTIPORA
			BEFINA ROAD
			BALIHAMA
A	B	C	D
6	PULWAMA	6	NOORPORA
			ALLUCHI BAGH
			PAMPORE
			GANGIPORA PAHROO
			JANDWAL PULWAMA
7			CHANCER
			BRAR LAWADPORA
	KULGAM	6	HUMSHALI BAGH
			YK PORA
			CHANDAN PAJAN
			VESSU
			GOPALPORA KULGAM
			AMARPORA SOPORE
			HARDSHIVA SOPORE
A	B	C	D
			PANIZARAH
			GORIPORA BOMAI
			MRIGUND PATTAN
			DELINA
			BILIL COLONY
8	BARAMULLA	13	BARAMULLA
			BONIGAM KUNZAR
			CHAKE KAWOOSA
			DAULATPORA
			CHOORU PATTAN
			GUNDI REHAMN
			GUTIYAR BARAMULLA
			HANJIWARA PATTAN
			GANDERBAL
			GANGERHAMA
9	GANDERBAL	4	CENTRAL UNIVERSITY
			ICHRI LAAR
			BARWELL KANGAN
			KANDOORA BEERWAH
			KRANSHIVAN
			BATHAR BUDGAM
			ALAWPORA
10	BUDGAM	9	ATINA BEERWAH
			DANGERPORA
			BUDGAM
			GATIPORA SOIBUGH
			HAKNIPORA BUDGAM
			HARDVILA BEERWAH

The boring log for one of the sites is presented below

6.2 BORING LOG FOR SHARAKWARA (SHOPIAN)

6.2.1 Introduction: Reliance Jio Infocom Limited (hereinafter referred to as the RJIO) has intended to install Ground Based Masts (GBM's/ GBT's) for telecommunication purpose through-out the country, as part of the proposed 4G Project. RJIO has appointed Space Engineers Consortium Pvt Ltd as a Consultant for carrying out Geo-technical investigation of these proposed sites. This report deals with the results obtained during field investigation, laboratory testing analysis of data and recommendations thereto, of tower located in residential area namely Shrakwara having site ID BRML-ENB-9001. The land belongs to Mr. Mohammad Ramzan Khan.

6.2.2 Scope of Work: The scope of work includes:

1. One bore hole of 10.0m depth.
2. Conducting Standard Penetration Test at specified intervals
3. Taking undisturbed samples at specified intervals
4. Marking of water table position
5. Conducting laboratory tests as per I.S code of practice
6. Submission of detailed Geo-technical report.

6.2.3 Field Work:

6.2.3.1 150mm diameter bore hole was drilled with an augur up to the specified depth of 10.0m below the existing ground surface level near the bore hole location. Boring operation did not require circulation of Bentonite mud or casing of the bore hole. No caving occurred in the bore hole during boring operation.

6.2.3.2 Disturbed and un-disturbed samples of were collected from the bore hole. Disturbed samples were collected partly from the split spoons sampler used for conducting SPTs and partly from the soil mass brought up by the auguring tool. For un-disturbed sampling, thin walled tube samplers conforming to IS: 2132–1972 was used. While taking these samples, extreme care was taken to avoid disturbance to the sampling tubes and moisture loss during subsequent handling of the samplers. 3.3 Standard Penetration tests (SPTs) are conducted in accordance with the requirements of IS : 2131 – 1981 using the specified split spoon sampler and 63.5 kg drop weight with a fall of 75 centimetres. Numerical value of the blows recorded for last 30 cms penetration is taken as $N_{observed\ (obs)}$ value as per codal requirements the N_{obs} values are to be corrected for the effect of overburden pressure at the test depth. These corrected values are denoted as N'. In case of fine sands and silts below ground water table, the N' values greater than 15 are also to be corrected for "dilatency" effect and denoted as N". Nine SPTs were conducted at 2.0m depth intervals at depths of 2.0m, 4.0m, 6.0m, 8.0m, & 10.0m, TABLE – 4 below shows the values of N_{obs}, N' & N" for the nine tests.

Table 4 Values of Nobs, N' & N" for the nine tests

S. No	Depth (m)	Nobs	N'	N"	Remarks
1.	2.0	6	11	10	N' values are based on effective overburden pressure as per codal requirements.
2.	4.0	20	25	20	
3.	6.0	52	62	38	
4.	8.0	67	72	43	
5.	10.0	74	75	45	

6.2.4 Laboratory Tests: Following tests were conducted on disturbed / undisturbed soil samples.

I. Particle size analysis/Gradation.

II. Bulk / dry density.

III. Consistency Limits (Liquid and Plastic Limits)

IV. Natural moisture content.

V. Shear strength parameters C & φ by Direct Shear test

VI. Un-confined compression test.

VII. Specific gravity.

Test results are given in the test result sheet which is annexed as Annexure-II.

6.2.5 Sub-soil profile:

6.2.5.1 Particle size analyses indicate that about 56 to 97% component of the sub-soil upto the explored depth is smaller than 75 micron size. The sub-soil strata are thus entirely "Fine grained" as per System of classification.

6.2.5.2 The sub-soil strata at the site is essentially silty clay with seams of sand at 3.0m depth.

6.2.5.3 The observed SPT values (N) vary from 6 to 74 5.4 The sub-strata is of soft to medium consistency from 2.0m to 3.0m and very stiff to hard consistency from 3.0m to the drilled depth of 10.0m.

6.2.6 Safe Bearing Capacity Values Safe bearing capacity computations have been made based on:

i. Local Shear failure criteria:

ii. Settlement criteria

i. Local Shear failure criteria:

Net ultimate bearing capacity q'_d is obtained by the expression.

$$q'_d = 2/3 x C x N'_c x S_c x d_c x i_c + q'(N'_q - 1) S_q x d_q x i_q + ½ x B x \gamma x N'_\gamma x S\gamma x d_\gamma x i_\gamma x W'$$

N'_c, N'_q, N'_Υ = factors of Bearing capacity

S_c, S_q, S_Υ = factors of shape

d_c, d_q, d_Υ= factors of depth

I_c, I_q, I_Υ= factors of inclination

B = foundation width (m)

W′ = factor for correction for water table

ϒ= bulk unit weight of foundation soil (t/m3)

ii) Settlement criteria:

$$S \text{ (Settlement in mm)} = C_c/(1+e_0) \times H \times 1000 \times \log((P_0+\Delta P)/P_0)$$

Cc = compressibility index

e_0 = void ratio initial

H = compressible layer thickness (m)

P_0 = stress intensity initially at C/L of compressible layer (t/m2)

δP = incremental pressure intensity due to superimposed loading at C/L of the compressible layer (t/m2)

S_{cor} (corrected settlement) = S x D_f x R_f

D_f = depth factor

R_f = rigidity factor = 0.8

1) The computations have been made for shallow foundations of 3m x 3m, and 3.5m x 3.5m size founded at depth of 2.0m and 3.0m below the level of ground surface.
2) As the value of "ϕ" – the angle of internal friction is less than 29o throughout the explored depth, local shear failure that is supposed to be likely mode of shear failure. Computations done for this criteria are based on provisions of IS : 6403 – 1981.
3) Depth of "Influence zone" adopted is 2xB, where B = Footing width.
4) Values of parameters of shear strength "C" (cohesion), ϕ^o – (internal friction angle); soil's bulk / dry unit weight, Liquid limit and specific gravity (G) etc. adopted in the computations are the average values of these parameters for the "Influence Zone".
5) Safe bearing capacity values are based on a factor of safety = 2.5.
6) For the sake of clarity some codal definitions related to bearing capacity are reproduced below

a. ***Safe bearing capacity***: - The maximum intensity of loading which the foundation safely carries without any risk of shear failure of soil and any settlement that may occur.
b. ***Safe bearing pressure or net soil pressure for specified settlement***:-The intensity of loading that will cause a permissible settlement or specified settlement of the structure.
c. ***Allowable bearing capacity***: - The net intensity for loading which the foundation carries without foundation having any settlement in excessive permissible value which is considered and does not exceed safe bearing capacity.

7. In the instant case, safe bearing pressure computations are made for a permissible settlement of 40mm.
8. A general arrangement drawing of the proposed tower was not provided by the client. No information was either given about the likely foundation loading due to superimposed loads. The computations for settlement criteria were therefore made taking the safe bearing capacity values arrived at for shear failure criteria as the likely foundation pressure due to superimposed loading.

Following are the safe bearing capacity, bearing pressure and allowable bearing capacity values computed on above said criteria.

Table 5 safe bearing capacity, safe bearing pressure and allowable bearing capacity values

S.No.	Depth (m)	Safe Bearing Capacity Shear Criteria (t/m^2)		Safe Bearing Pressure Settlement Criteria (t/m^2)		Allowable Bearing Capacity (t/m^2)	
		3mX3m	3.5mX3.5m	3mX3m	3.5mX3.5m	3mX3m	3.5mX3.5m
1	2.0	10.99	11.09	7.55	8.09	7.55	8.09
2	3.0	12.27	12.36	9.09	9.65	9.09	9.65

6.2.7 Conclusions & Recommendations

1) The sub strata at the location investigated is "fine grained" as per IS system of classification and mainly comprises of clayey silt/silty clay of low to medium plasticity.
2) Ground water table has been observed at average of 3.70m below existing ground surface level.
3) The allowable bearing capacity for design shall be considered as per following table.

Table 6 allowable bearing capacity

S.No.	Depth (m)	Safe Bearing Capacity Shear Criteria (t/m^2)		Safe Bearing Pressure Settlement Criteria (t/m^2)		Allowable Bearing Capacity (t/m^2)	
		3mX3m	3.5mX3.5m	3mX3m	3.5mX3.5m	3mX3m	3.5mX3.5m
1	2.0	10.99	11.09	7.55	8.09	7.55	8.09
2	3.0	12.27	12.36	9.09	9.65	9.09	9.65

In case during actual execution, the sub-soil strata is found to be materially different than reported on here a reference should be made to us.

4) Any loose pocket observed during excavation at depth of foundation shall be back filled with M10 grade concrete.

RECORD OF BORING

Bored for	: Reliance Jio Infocom Limited		
Type of Boring	: Augur/Wash Boring	Site ID	: I-JK-BRML-ENB-9001 Shrakwara
Diameter of Boring	: 150 mm/Nx	Boring No.	: 01
Depth of Boring	: 10.0 m	Sample Type	: UDS/SPT
Water Table	: 3.70m		
Date of Start	:	Date of Completion :	

Depth (m)	Description of Strata	Laboratory soil Classification IS system	Legend	Ground water Level (m)	Field S.P.T Value (N)	Remarks
1	2	3	4	5	6	7
2.0	Brownish silty clay/ clayey silt	CI			2,3,3 = 6	
3.0	Brownish clayey silt with fine sand					
4.0	Greyish clayey silt	MI		WL at 3.70m	7,9,11 = 20	
5.0	Greyish silty clay					
6.0					17,22,30 = 52	
8.0	Greyish clayey silt/ silty clay				25,32,35 = 67	
10.0		ML-SM			31,36,38 = 74	

Figure 3 Boring log

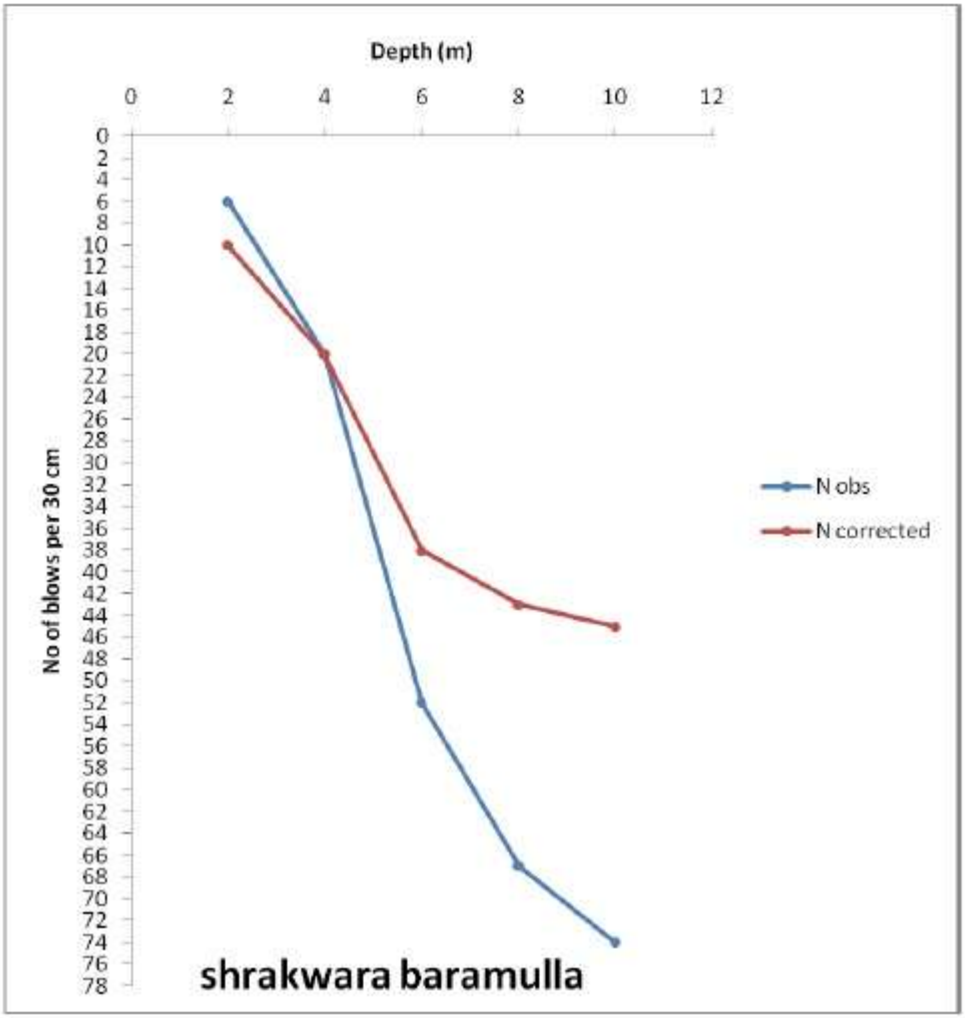

Figure 4 graph between depth and number of blows

6.3 SAMPLE CALCULATION

Depth of ƒdn = 3m, ƒdn size = 3m x 3m

I.z = 6m

Shear Criteria

C_{av} = 0.29 kg/cm^{2}`

ϕ_{av} = 14^{0}

$\phi' = \tan^{-1} (0.67 \tan\phi) = 9.48^{0}$

N'_c = 8.15, N'_q = 2.37, N'_γ = 1.13

S_c = 1.3, S_q = 1.2 S_γ = 0.8

$N_\phi = \tan^2 (\pi/4 + \phi'/2) = 0.0186$

$d_c = 1 + 0.2 \times D/B \sqrt{N_\phi} = 1.02$

$d_q = d_\gamma$ = 1.01, $\phi' < 10^0$

w' = 0.5

q'_d = 2/3 x 0.29x1.3x1.02x8.15 +0.54 x (2.37-1) x1.2x1.01

+ ½ x 3 x 0.0009x 1.13 x 1.01x 0.5

= 30.69 t/m²

F.O.S = 2.5

$q_{d\ net}$ = 12.27 t/m^2

$q_{d\ cross}$ = 17.68 t/m^2

Settlement Criteria

C_c = 0.12 H = 6m e_0 = 0.79

$$S = \frac{C_c}{1 + e_o} \times H \times 1000 \left(\frac{P_o + P_\Delta}{P_o}\right)$$

P_o = (3 + 3) x 0.9/100= 5.4

P_Δ = 0.336 x 17.68 = 5.93

$$S = \frac{0.12}{1.79} \times 6000 \log \left(\frac{5.4 + 5.93}{5.4}\right) = 129 \text{ mm}$$

R_f = 0.8, D_f = 0.75

$S_{corrected}$ = 129 x 0.8 x 0.75 = 77mm

$$\text{Safe b/c} = \frac{40}{77} \times 17.68 = 9.09 \text{ t/m}^2$$

Table 7 Test result report

Depth of sample below NSL	Type of sample	Soil Classification	% passing 75µ sieve	Grain Size Analysis Sieve / Hydrometer: % sand	Grain Size Analysis Sieve / Hydrometer: % Gravel	Grain Size Analysis Sieve / Hydrometer: % silt + % clay	Natural moisture content %	Bulk Density γ g/cc	Natural dry density γ_d gm/cc	Consistency Limits: Liquid limit (%)	Consistency Limits: Plastic Limit (%)	Consistency Limits: Plasticity (PI)	Direct Shear / Triaxial Shear Test: Cohesion 'C' Kg/cm²	Direct Shear / Triaxial Shear Test: Angle of repose ϕ (Deg)	U.C. Test: q_u (Kg/cm²)	Consolidation: c_c	Consolidation: e_o	Specific gravity	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2.0	SPT	CI	94	6	-	94				36	24	12						2.62	
3.0	UDS	MI	94	6	-	94		1.90		37	25	12	0.27	14		0.12	0.79		
4.0	SPT	MI	97	3	-	97				38	27	11							
5.0	UDS	MI	96	4	-	96				38	26	12							
6.0	SPT	MI	96	4	-	96				40	27	13						2.62	
8.0	SPT	ML-SM	56	44	-	56				N.P	N.P	N.P							
10.0	SPT	ML-SM	61	39	-	61				N.P	N.P	N.P							

CHAPTER 7: RESEARCH METHODOLOGY

7.1 Selecting site

7.2 Conducting SPT:

The standard penetration test is an empirical test. It's conducted routinely on all sites where the samples for laboratory tests are collected at different depths along the boring advancement.

The results of the test are expressed as standard penetration resistance, or value on N. It's reliably correlated with the value of ϕ of cohesionless soil. It's used as a parameter of strength of soil in the designing of foundations in such type of soil. Several attempts have been made for the correlation of values of N with q_u, which is unconfined compressive strength of cohesive soil, but it's not found reliable. If the q_u values are not determined by testing samples for some reasons, there is no choice except making use of values of q_u which are correlated from values of N, for design proceeding.

The test consists of sampling spoon which is made to penetrate the soil by the dropping of hammer which weighs 650N and released from a height of 750mm. Number of blows are counted for every penetration of 300mm which is the N value designated. In this test the counts of blows are taken for three consecutive layers of 150mm penetration as seating drive. There is a need for a penetration of 450mm of the sampling tube for the SPT. The test is usually performed for cohesionless soil and the result is recorded in the form of the number of blows. These are the blows which are required to cause a standard penetration under some conditions which are specified.

7.3 Conducting laboratory tests:

Different tests are conducted to find the results for various parameters which are indirectly related to find the correlation. The tests are

A) Sieve analysis
B) Grain size analysis sieve/ Hydrometer
C) Natural moisture content

D) Bulk density

E) Limits of consistency

F) Direct shear test/ Triaxial test

G) Under consolidated test

H) Consolidation

I) Specific gravity

7.4 Collecting data from site tests and laboratory tests

7.5 Graphical analysis of variability/ Data analysis (includes Plotting histograms, normal distribution plot, data transformations, etc.)

Variability often leads to uncertainty. For example if unit weight of a soil at a particular location is not known unless it has been calculated on the site. The uncertainty rises because the unit weight has a variation from place to place in the soil.

A) Histograms: The graph is acquired by the division of the range of data into bins and counting the number of values in each bin. The statistical table conveys important information about the variation of the dataset. The histogram conveys the data regarding the variability in the set of dataand the scattered amount about the values lying in the middle of the set.

There are many questions regarding the determination of the number of intervals for a histogram. First, the intervals should depend on the number of data points. As the data points increase, the number of intervals must also be increase. Second, the number of intervals can affect how the data is viewed. If few intervals are used, the distribution of the scatter in the data will not be clear. Unfortunately, there are no specific rules for determination of the appropriate number of intervals to be used. Experimenting with different periods is an approach.

B) Frequency Plot: The frequency of occurrences is obtained at each time interval listed by dividing the number of incidents by the total number of data points. A plot of the curve is called frequency curve. Note that the graph and frequency plot have the same shape and transfer the same information. The frequency plot is just an improved version of the chart. Because it is normalized, the frequency chart is useful for comparing different sets of data.

C) **Frequency Density Plot:** Another plot-related is the frequency density curve. The frequency density is obtained by the division of the interval frequencies in the interval width. A bar plot is called the frequency density plot density frequency. The division of the frequency by the width interval is intended to naturalize the statistical scheme: the area under the frequency density curve (obtained by multiplying the width of the beam by the width) is 100 percent. This normalization is useful in the installation of models of random variables of theoretical data.

D) **Cumulative Frequency Plot:** The cumulative frequency curve is the final graphical tool that is provided to analyze the variability. Cumulative frequency is the frequency of data points whose values are less than or equal to the upper limit of the time interval in the frequency plot. The cumulative frequency is obtained by adding (or accumulating) the interval frequencies for all the intervals between the upper limits. The cumulative frequency curve is called the upper limit of the cumulative frequency curve.

7.6 Quantitative analysis of variability (includes skewness, correlation or dependence, etc)

1) Central Tendency

2) Dispersion or Scatter

3) Skewness

4) Correlation or Dependence

7.7 Correlation in Geotechnical Engineering:

Experimental relationships are often used in geotechnical engineering to link soil properties. For example, the compression index with void ratio or liquid limit L_L, relative density of D_r, with SPT, and ratio of strength S_u / S'_p with plasticity index I_P. The goal is to do a estimation of the soil parameters which are required for analysis and design by using relatively cheaper and easier-to-obtain indirect index properties. If there is indeed an excellent relationship between the properties, it will provide a cost-effective way to obtain the required soil parameters. Experimental relationships can often be far from perfect, and the additional implicit uncertainties associated with this approach should be evaluated.

7.8 System reliability

7.9 Geo-statistics

7.10 Probabilities:

Once a random field model is defined for a site, there are various ways to obtain probabilities which are associated with designing criteria, for example the probability of failure.

7.11 Pile loading test:

Piles are studied and re usually casted in the in-situ and bored with either casting method or continuous auger flying method. Products which are slurry like bentonite are used sometimes and used for maintenance of the borehole of the pile.

Piles are subjected to the axial loading tests and are used non instrumented by strain gauges. They are connected at the top with four dial gauges, with a sensitivity of 0.01 mm for the reading of settlement. Load is applied in increments by hydraulic jack and pump which is fitted with the help of pressure gauge against the platform which is weighted. The procedure of testing consists of two cycles of loading processes. One is to put to 1.5 to 2 times the working load. The increment of the load is maintained till the settlement rate is less than 0.25 mm/hour.

A pile is installed in the site by any of the procedures and can be tested in

1. Compression
2. Tension
3. Lateral load

Though it has similarity to and is as elaborate as plate load test but it cannot be dispensed as the latter, because pile is a deep foundation and being so passes through various layers of soils. The test is more reliable method to ascertain the performance in any of the modes of the loadings which are mentioned. In most of the jobs of piling it is necessary to stipulate the load test and should be conducted on only one pile if not more than that. The case of the plate bearing tests the load in the test on pile involves measuring deflection against the load applied in increments till the soil is failed under the load. The data is plotted in the form of load settlement diagram from which the ultimate load carrying capacity or working load can be interpreted.

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