BRCORP
TECHNOLOGY | INNOVATION | INDUSTRY

International Journal of
Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 03, No. 03, July 2014

Statistical Evaluation of bearing capacity of Khulna Sub-Soil

RAJIB BANIK, NAZMA KHATUN, MASUM SHAIKH, MD. KERAMAT ALI MOLLA
Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna-9203, Bangladesh
Email: banik0801001@gmail.com, masumkuetce@gmail.com, kamolla@ce.kuet.ac.bd

Abstract: For building of small height with one or two storeys, the owners are not interested for soil investigation. For these cases the foundation are designed on the basis of assumed average bearing capacity. The main objective of this research work is to determine an average bearing capacity for the design of low-rise building to be constructed in Khulna city corporation area. Some soil samples were collected from KUET (Khulna University of Engineering & Technology) campus and tested in the Soil Mechanics laboratory of KUET to determine the bearing capacity. Soil reports from more than sixty locations of Khulna were collected from CRTS (Consultancy, research and testing services) of Civil Engineering department KUET, Khulna. From these reports, the values of bearing capacity were taken for the purpose of analysis. Many equations are available in the determination of the bearing capacity of soil such as Terzaghi, Meyerhof and Hansen etcetera. Among these equations, the Terzaghi Bearing Capacity equation was used for the estimation of bearing capacity considering its simplicity and reasonable accuracy. Since the bearing capacity depends also on layer thickness and stratification of soil, soil profile of different locations were drawn. From the reports, the mean, median, mode, standard deviation and coefficient of variation of different values of bearing capacity were determined. The estimated average bearing capacity of Khulna sub-soil of at 5 ft and 10 ft depth are 55.31 kN/m2(0.523 tsf) and 47.097 kN/m2(0.447 tsf) respectively.

Keywords*: Bearing Capacity; Soil Investigation; Mean; Median; Mode; Standard Deviation; Coefficient of Variation.*

1. Introduction:

The concept about the subsoil parameters of any project site is very important to plan and design the foundation of the concerned structure, so that the structure after it construction would remain safe and stable. Khulna city is situated on the Southern region of Bangladesh. The alluvial deposits from different rivers form the soil in this region. Moreover, it was once a part of Sunderban, so the soil of this region is mostly soft and organic having low bearing capacity.

In addition, "Khulna city" is moving forward with large development project including construction of buildings, oil storage tanks, long span bridges, harbors, port structures, flood protection embankments, barrages etcetera. That is why, it is very important for foundation engineer to go for a detail investigation of sub-soil for a detailed knowledge and sound understanding of bearing capacity before going for construction of structures.
With this end in view, the authors have undertaken a comprehensive program on statistical analysis of bearing capacity of Khulna sub-soil with the following objectives:

a) To execute exploratory test in order to collect sufficient data for the safe and economic design of foundation of structure.
b) To draw the bar diagrams for bearing capacities of different location of Khulna city.
c) To draw soil profile of several location of Khulna City.
d) To construct histograms for the values of bearing capacities of different location of Khulna city.
e) To determine mean, mode, median, standard deviation and coefficient of variation of bearing capacities of different locations of Khulna region.
f) To determine an average bearing capacity of Khulna sub-soil.

1.1 Bearing Capacity:

The conventional method of foundation design is based on the concept of bearing capacity or allowable bearing pressure of the soil. The bearing capacity is defined as the load or pressure developed under the foundation, without introducing damaging movements in the foundation and in the superstructure supported on the foundation. Since damaging movements may result from foundation failure (collapse) as well as from excessive settlement, the following criteria must always be satisfied:

a) Adequate factor of safety against failure (collapse)
b) Adequate margin against excessive settlements.

In order to provide an adequate factor of safety against foundation collapse, the ultimate bearing capacity must be known. Usually a factor of safety of 3 is used for maximum load normally expected to act upon the foundation (Das 2002).

Bearing capacity equations suggested by the several authors are given below:

Terzaghi (1943):

$q_{ult} = CN_CS_C + qN_q + 0.5\gamma B\, N\gamma S\gamma$

$N_q = a^2/a\cos^2(45+\varphi/2)$

$A = e^{(0.75\pi-\varphi/2)\tan\varphi)}$

$N_c=(N_q-1)\cot \varphi /2$

$N_y=\tan \varphi/2(k_{py}/\cos^2-1)$

For:	strip	round	square
$S_c=$	1.0	1.3	1.3
$S_c=$	1.0	0.6	0.8

Where, C=cohesion of soil (kN/m^2),
γ=unit weight of soil (kN/m^3),
$q=\gamma D_f$, D_f =depth of footing (m),
B= width of footing (m),
$N_C, N_q, N\gamma$=bearing capacity factors,
$S_C, S\gamma$=shape factors.

Meyerhof (1963):

Vertical load: $q_{ult}=CN_cs_cd_c +q^{-}N_qs_qd_q +0.5_yBN_ys_yd_y$

Inclined load: $q_{ult}= CN_cd_ci_c+ 0.5_yBN_yd_yi_y$

Between these two equations, Terzaghi bearing capacity equation is widely used for the estimation of bearing capacity due to its simplicity and reasonable accuracy.

2. Methodology:

2.1 Field and Laboratory Investigation:

2.1.1 Collection of Soil Samples:

In this investigation, soil samples were collected from the selected six sites of KUET campus and the physical properties and bearing capacity of soil were determined in the laboratory of KUET. Soil samples were taken at a depth of about 5 ft from the existing ground surface. The laboratory investigation made on the soil samples have been described in this chapter. To investigate the behavior of soil it would be very desirable to use the undisturbed sample.

2.1.2 Laboratory Testing:

Various laboratory test were done to determine the physical properties of soil including

a) Atterberg Limits.
   - Liquid limit
   - Plastic limit

b) Wet and Dry Density.
c) Natural Moisture Content.
d) Unconfined Compression (UC) Test.

2.2 Data Collection and Storage:

Sixty-six (66) sub-soil investigation reports containing two hundred nineteen (219) borehole data from CRTS for different places of Khulna zone were collected. All soil data were stored in a Microsoft Excel database. This Excel sheet consists of borehole data, depth, soil type in various depths and so on.

After this, the Khulna map formed the base layer for development of geographic information system (GIS) model (see Fig-1). The map had been developed in view of two aspects, first for locating the bore logs to the utmost accuracy on a scale of 1:100000 and second for identification of bore logs by various symbols. The digitized map had several layers of information. Some of the important layers considered were the boundaries (outer and administrative), highways, major roads, minor roads, streets, and borehole locations (Ansary, 2010).

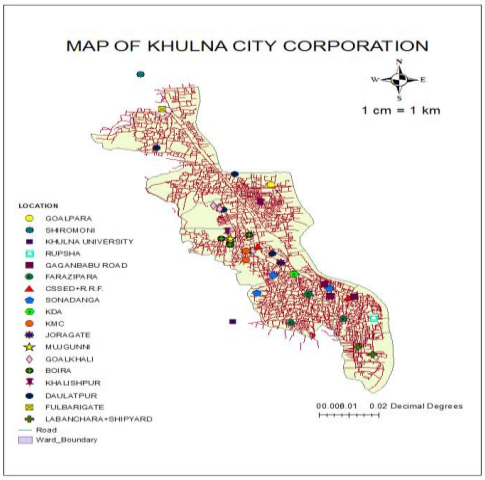
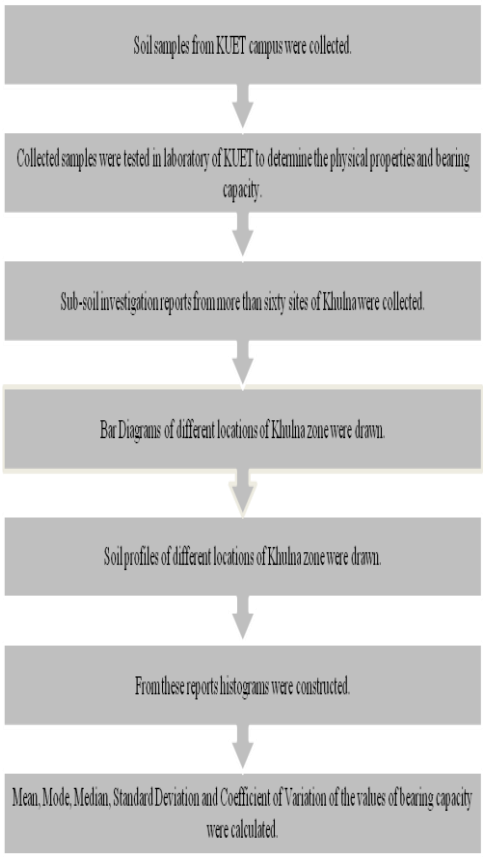


***Figure-1**: Borehole Location of Khulna Region*

2.3 Procedure:



3. Results and discussion:

This paper describes the results obtained from the laboratory tests conducted by standard methods. Moreover, it represents the bearing capacity of different locations of Khulna sub-soil, soil profile, histogram of bearing capacity and statistical parameters of the values of bearing capacity of soil.

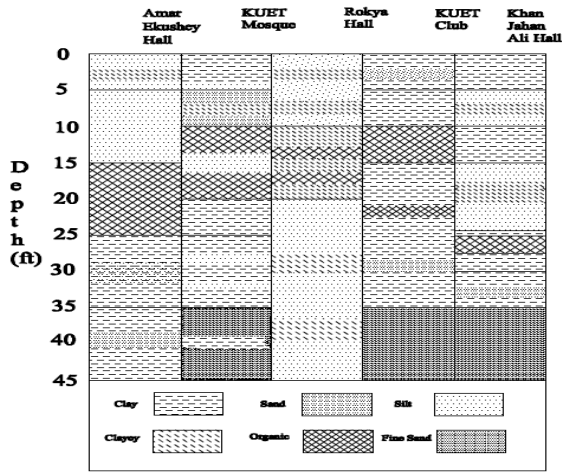


***Figure-3**: A Typical Soil Profile (KUET campus)*

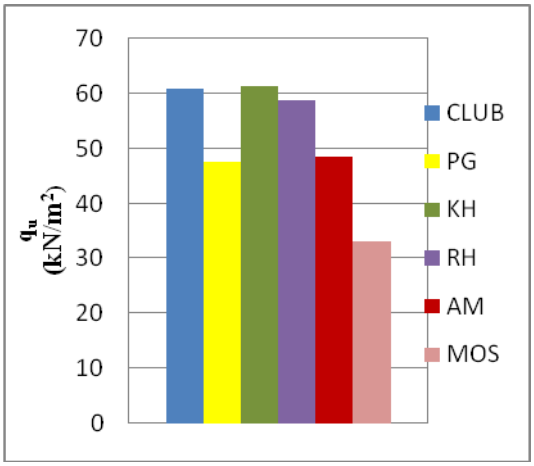


***Figure-2**: Histogram of bearing capacity of a typical site (KUET campus)*

The Mentioned figures (fig-2 and fig-3) show the typical soil profile of Khulna region (KUET campus) and the histogram of bearing capacity of a typical site (KUET campus).

***Table-1**: Bearing capacity of Khulna City at a depth from 0-5ft*

Location	Qu(kN/sqm) Average	Location	Qu(kN/sqm) Average
Boyra	40.5	Mujgunni	38.58
Khalishpur	34.5	Khulna Shisu Shadan (Girls)	72.33
Khulna 4 no gate	49	Jail khana Food store house	25.27
KMC	62	Fulbari Gate	48
Sheikh Para	57	Jora Gate	103.41
Sonadanga	57.5	KDA Plot no 122 Mujgunni	69.67
100 Bed Diabetic Hospital	30	RPACT	45.67
Khulna Thana Quarter	60	Police Phari, Chandmari, Rupsha	50.77
T.T.C	34	Central Mosque, KU	31.23
Goalkhali	35.25	Padma Oil Company, Daulatpur	64.30
Shisu Sadhan	66	Imam Training Center, Boyra	61.10
BOC	29.5	Regional Environment Research Center	63.33
Boikali	38	Residence of O.C., Sonadanga	47.98
Tarer Pukur	52	Residential Building, at 3 no. Baniakhamar Mouza	74.06
KMC (Mosque)	59	Residential Building, Kalishpur	30.32
KMC (Student Hall)	53	Hadi Tower, Gagan Babu Road, 2nd Lane	40.0
ICMA	52	Residential Building, Maheswar Pasa, Daulatpur	38
Fire Service	62	Six Storied Building,R.R.F. Police Line	53.55
New Market	48	Naval Colony	71.90
Labanchara	25.15	Shipyard School & College Building	44.81
Goalkhali(Hostel Building)	96.22	Divisional Server Station	63.09
Shiromoni	76.45	Goalpara	70.73
Delta Life Ins. Co. Ltd.	52	Farajipara	81.5
Moheswarpasha Shisu Sadhan	95.51	Plot no 389, Mujgunni R/A	31.9
Rupsha	67.41	Helatola	51

S.I & A.S.I	77.05		KMC(Gymnasium)	64
Senhate River Fire Station and Civil Defence, Daulatpur	95.37		Shisu Shadan (thumbi house)	70
Women Oppression Protection Project at Five Divisional Towns	80.5		Gallamari Bridge	65.1
Postal Training Center, Boyra	39.61		Ahashan Ahmmad Road	93.0
Sobujbag	64.90		B.N Collge	81.8
Zilla Police Line,Shiromoni	90.44		10 Storied Commercial Building G.M.Baksh &CO., Helatola	78.55
Khulna WASA	97.86		Tarer-Pukur (Residential Building)	79.39
Student Hostel (No 2) at KMC	80.03		Residential Building , FulbariGate	33

Table-1 represents the value of bearing capacity (in kN/m^2) of soil different locations of Khulna city at a depth from 0-5ft.

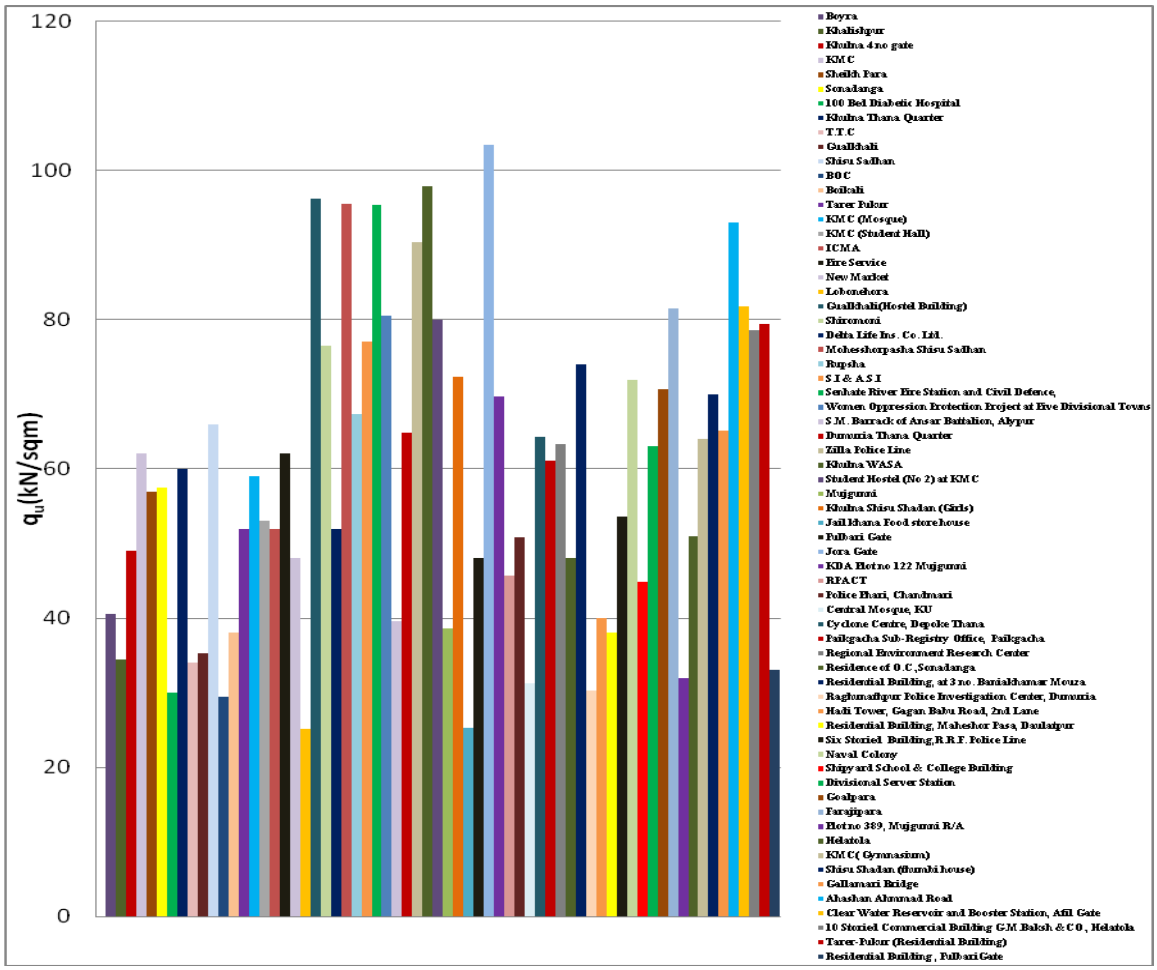


***Figure-3**: Histogram of average Bearing Capacity of Khulna sub-soil for at a depth from 0-5ft*

Figure-3 as well as figure-4 illustrates the Histogram of different locations of Khulna zone at a depth from 0-5 ft and 5-10 ft respectively. In fig-3, the lowest average bearing capacity is found at Labanchara. In Joragate (fig-3), there is obtained maximum average bearing capacity. Again, in figure-4, the highest value is found at Goalpara whereas the lowest value is obtained in Daulatpur.

***Table-3**: Results of Statistical Analysis*

Location	**KUET BH(0-5 ft)**	**Khulna BH(0-5 ft)**	**Khulna BH(5-10 ft)**
Standard Deviation	9.86	20.09	18.34
Mean Deviation	8.44	16.71	15.11
Median	53.79	59.5	44.62
Mode	No mode	52	59
C.V. (%)	19.1	34.04	38.94

a) The median value of bearing capacity of soil of KUET at 5 ft depth and Khulna at 5 ft and 10 ft depth is about 53.79 kN/m^2, 59.50 kN/m^2 and 44.62 kN/m^2 respectively.
b) Coefficients of variation of bearing capacity of soil of KUET campus, Khulna BH (0-5 ft), Khulna BH (5-10 ft) are 19.1%, 34.04%, 38.94% respectively.
c) The above results indicate that the variation between the maximum and minimum values of bearing capacity of KUET campus is lower in comparison to Khulna city areas.
d) The results also show that the variation between the maximum and minimum values of bearing capacity at 0-5 ft was lower than that of 5-10 ft.
e) The histogram and other statistical parameters represent the variation of bearing capacity of different locations of Khulna city that help the foundation designer to design foundation safely and economically.

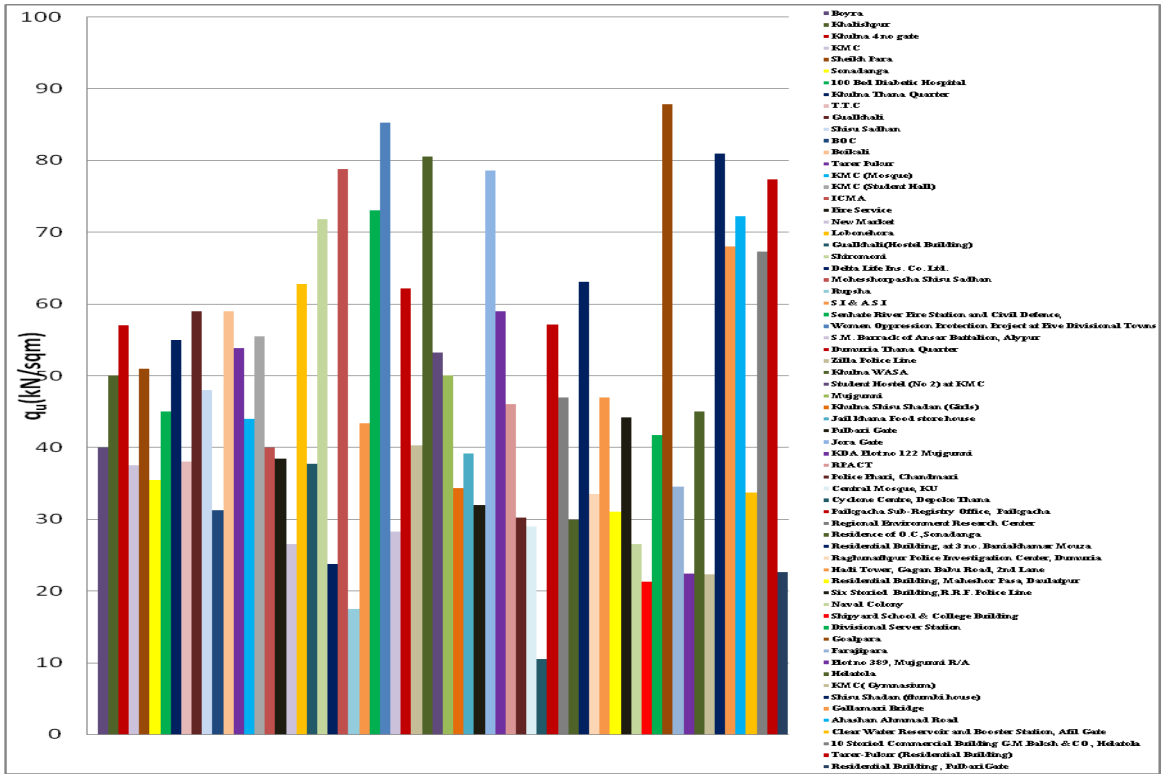


***Figure-4**: Histogram of average Bearing Capacity of Khulna sub-soil at a depth from 5-10 ft*

4. Conclusions:

a) Based on the laboratory investigations, information and computations, the estimated average bearing capacity of soil KUET campus at 5 ft depth is 51.60 kN/m^2 and the estimated average bearing capacity of Khulna sub-soil at 5 ft and 10 ft depth are 55.31 kN/m^2 and 47.097 kN/m^2 respectively.
b) The values of bearing capacity of different locations is very low which indicates that shallow foundation is suitable for two or three storied buildings. For multistoried buildings, deep foundation such as pile foundation should be adopted or the soil beneath the foundation should be improved by some suitable method.

Acknowledgements:
The authors would like to express their thanks to CRTS (Consultancy, research and testing services) and laboratory technicians of Department of Civil Engineering, KUET, for their co-operation and tolerance during this research work. In addition, they wish to express their gratitude to the anonymous reviewers whose suggestions and remarks have greatly helped them to improve the quality of the manuscript.

References:

[1] Ansary, M. A., Siddique, A. and Bashar, M. A. (2010). "Geotechnical Characterization of Soil of Dhaka City". International Conference on Civil Engineering.
[2] Das, B.M. (2002). Principles of Geotechnical Engineering. (Fifth edition), Thomson Book House, Canada.
[3] Gupta, S.P. (1983). Advanced Practical Statistics. S Chand & Company Limited, New Delhi.
[4] RAFIZUL ET AL (2006) "Compressibility Properties of Reconsituted organic soils at Khulna Region of Bangladesh." Proceedings of 4th ICSSE, 367-372, Canada.
[5] Spigel, M. R., Schiller, J. and Srinivasan, A. R. (2001). Probability and Statistics. McGraw-Hill, New York.