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Evaluation of Bearing Capacity for Cast In-Situ Bored Piles

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Abstract: Pile is a structural element constructed to overcome heavy loads from super structure, when proper bearing strata is not available at shallow depth. The prediction of bearing capacity of a bored cast in-situ pile is a complex problem, as it depends on installation method, concrete quality, ground condition and pile geometry. It is considered that the reliable method for finding bearing capacity is pile load test, which is time consuming and costly. The bearing capacity can also be analysed by empirical and analytical methods using soil data and SPT data.

In this paper, empirical methods and graphical methods are used to evaluate beating capacity of cast in-situ bored piles. For empirical methods - IS code method, Meyerhof method, Bazaraa and Kurkur method are employed and for graphical methods - Hansen's method, Chin-Kondner's method, Decourt's Extrapolation method are employed.

All these methods are summarized for comparison with the pile load test values. A database of 3 bored piles is collected from different sites in Kerala. The above chosen SPT methods are calibrated by trial and error method to propose a new formula. A pile structural design also proposed.

Keywords: SPT, Pile load test, Bored pile, Bearing capacity, Structural design.

I. INTRODUCTION

Now a days the use of bored cast in-situ piles has multiplied around the world. Bored cast in-situ piles have moderate bearing capacity, low cost, reduced vibration during installation and allow easy length adjustments. The prediction of bearing capacity of a bored cast in-situ pile is a complex problem. It is necessary to consider factors such as method of boring, installation process, quality of concrete, ground conditions and experienced expertise while designing piles. The method of installation has a great impact on pile foundation i.e., drilling can cause vibration and disturbs the surrounding soil. Even after installation of pile, changes may occur in the soil nature with time. The appropriate pile capacity can be obtained only by conducting a pile load test. The conduction of pile load test for small projects is not economical. In such cases, other methods can be adopted for prediction of pile bearing capacity.

Various methods have been developed for predicting the pile bearing capacity, considering soil-pile interaction, soil stratigraphy and soil resistance along the pile.[1]

The static method in the IS 2911- Part 1/Sec 2 to determine the bearing capacity of bored cast in-situ pile contain many parameters that need to be evaluated using trigonometric functions or graphs and tables.IS code method uses the concept of critical depth for cohesive and cohesionless soil to find angle of internal friction. Recently using the results of penetrometer tests like Standard Penetration test to estimate the bearing capacity of piles had been the subject of considerable number of researchers and several approaches have been proposed [2,8]. Pile capacity by SPT is one the easiest and earliest applications is used.

II. OBJECTIVE

1) To conduct extensive study on the methods to determine ultimate pile capacity in cohesive and non-cohesive soil.
2) To collect required bore log details and pile load test details.
3) To conduct a comparative study of all the static analysis methods selected for determining pile capacity by comparing it with the pile load test values.
4) To suggest best suitable existing method for prediction of ultimate pile capacity for cohesive and non-cohesive soil.
5) To derive new equations to find pile capacity by combining parameters considered in various methods.
6) To suggest a structural design of pile.

III. METHODOLOGY

The main goal of this project is to formulate new equation to find the bearing capacity of the soil in Kerala region and also propose a structural design for the pile. Also, critical evaluation of existing equation will be done to know which is the best existing method to find the bearing capacity of soil.

A. Data Collection

Pile load test data and corresponding soil investigation report of three bored cast in-situ piles are collected. The sites in these areas are covered by fine sand, laterite, gravel, silty sand and clayey sand. The soil report shows that the sites contained weak bearing strata at shallow depth, leading to the construction of pile foundation. The diameter of piles varies from 0.5 m to 1 m and embedment length varies from 9 m to 12 m. Out of three sites, two sites have cohesive soil and other area is covered by cohesionless soil. The summary of pile data is given in Table 1.

TABLE I
SUMMARY OF PILE DATA COLLECTED

Site No	Region	Soil	Pile Dia (mm)	Pile Length (m)	Test Load (T)	Total Settlement (mm)
1	Kakkanadu	Cohesive soil	1000	10	412.5	13.48
2	Annakkara	Cohesionless soil	500	12	45	1.91
3	Ballusseri	Cohesive soil	1000	9.9	169.56	1.47

B. Pile Capacity by Empirical Methods

In this paper we have chosen IS code method, Meyerhof method and Bazaraa and Kurkur method to compare and validate the results of capacity. The summary of these methods is given in Table 2.

TABLE II
SUMMARY OF EMPIRICAL METHODS

Sl No	Method	Unit Base resistance	Unit Shaft resistance	Remarks
1	IS Code Method (IS 2911-2005)	For Cohesive soil $Q_b = C_p N_c A_p$ in (KN) For cohesionless soil $Q_b = P_D N_q A_p$ in (KN)	For cohesive soil $Q_s = \sum_{i=1}^{n} \alpha_i C_i A_{si}$ in (KN) For cohesionless soil $Q_s = \sum_{i=1}^{n} K_i P_{Di} \tan\delta_i A_{si}$ in (KN)	α-Adhesion factor in IS-2911 $\delta = 3\phi/4$
2	Meyerhof (1976)	$r_t = n_b N_b$ in (MPa) N_b= average of N between 8B above to 4B below pile base, $N_b <= 50$	$r_s = n_s N_s$ in (Kpa) N_s= average value of N around pile embedment depth	Failure criteria: Min slope of load-settlement curve n_b=0.12 – 0.40 n_s=1-2
3	Bazaraa and Kurkur (1986)	$r_t = n_b N_b$ in (MPa) N_b= average of N from 1B to 3.75B around pile base	$r_s = n_s N_s$ in (Kpa) N_s= average value of N around pile embedment depth	n_b=0.06 – 0.2 n_s=2-4

NOTE: A_p- C/S area of pile tip in m^2; A_{si}- Surface area of pile shaft in ith layer in m^2; N_c and N_q- Bearing capacity factors; C_p- average cohesion at pile tip KPa; δ - effective angle of internal friction; K=Coefficient of earth pressure; P_D- effective overburden pressure at pile tip; P_{Di}- effective overburden pressure at ith layer.

C. Pile Capacity by Graphical Methods

In case the piles are not loaded to failure, the interpretation methods can be used to find the failure load. Interpretation methods are graphical methods plotted using load and settlement data obtained from pile load test. The chosen interpretation methods are Hansen's method, Chin-Kondner's method, Decourt's Extrapolation method.

1) In Hansen's method (1963), A plot of square root of settlement divided by the corresponding load vs. settlement is made. The ultimate load, *Qu* is determined by the following equation

$$Q_u = \frac{1}{2\sqrt{C_1 C_2}}$$

where, C1 = slope of best fit straight line and C2 = intercept of best fit straight line on the vertical axis.

2) In Chin-Kondner's method (1970) method each settlement value is divided by its corresponding load value. These are plotted against the settlement. The inverse slope of this line is the Chin-Kondner Extrapolation gives the ultimate load.

$$Qu = 1/C1$$

3) In Decourt's Extrapolation method (1999) method, divide each load with its corresponding movement and plot the resulting value against the applied load. The ultimate load, *Qu* is determined by the following equation

$$Qu = C2/C1$$

D. Proposed Method

A new SPT method has been proposed by trial and error to find the bearing capacity of bored cast in-situ pile. In this paper the most commonly used three empirical and three graphical methods. By considering different factors a new equation is formulated.

TABLE IIII
PROPOSED METHOD

Proposed Method	Unit Base resistance	Unit Shaft resistance	Remarks
For Cohesive soil	$Q_b = C_p N_c A_p$ in (kN)	$Q_s = k_1 n_s N_s$ in (kN) N_s= average value of N around pile embedment depth	k_1= 6 if $N_s \geq 20$ k_1= 6.5 if $N_s < 20$ $N_c = 9$ from IS-2911
For cohesionless soil	$Q_b = k_1 N_b \times 10^3$ in (kN) N_b= average of N between 8B above to 4B below pile base, N_b<=50	$Q_s = k_2 \sum_{i=1}^{n} K_i P_{Di} \tan\delta_i A_{si}$ in (kN)	k_1=0.07 k_2 =0.25 δ=3ϕ/4

NOTE: A_p- C/S area of pile tip in m^2; A_{si}- Surface area of pile shaft in i^{th} layer in m^2; N_c Bearing capacity factor; C_p- average cohesion at pile tip KPa; δ - effective angle of internal friction; K=Coefficient of earth pressure; P_{Di}- effective overburden pressure at i^{th} layer.

E. Structural designing of pile

In this project a structural design of pile at different location suggested. Structural design is done by manual calculation on the basis of the geotechnical report.

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IV. RESULT AND DISCUSSION

A. *Pile Capacity by Empirical Methods*

The results of Empirical methods were calculated as shown in Table 4

TABLE IIIv

PILE BEARING CAPACITY CALCULATED BY EMPIRICAL METHODS

Pile No	Test load (MT)	Is Code Method (MT)	Meyerhof Method (MT)	Bazaraa and Kurkur (MT)
1	412.5	61.24	547.80	414.85
2	45	137.28	53.33	55.62
3	169.56	130.03	502.73	324.70

The following were noted in the empirical and analytical methods,

1) Bazaraa and Kurkur method shows more comparable value with the test load except for the Ballusseri site. This deviation is due to the high N (standard penetration resistance) value.
2) Meyerhof method shows comparable value for the site Annakkara only. The deviation from the test load in site Kakkanadu and Ballusseri is due to high N value.
3) For IS Code method it shows a very low value for the site Kakkanadu because of low cohesion value. For site Annakkara the higher depth of the soil influences the capacity hence it reflects in the value. For site Ballusseri somewhat better value get when compared to other sites, this is due to higher cohesion value (compared to another site).

B. *Pile Capacity by Graphical Methods*

1) Hansen's method (1963)

The below figures (from 1 to 3) are the graphs of different location Kakkanadu, Annakkara and Ballusseri respectively.

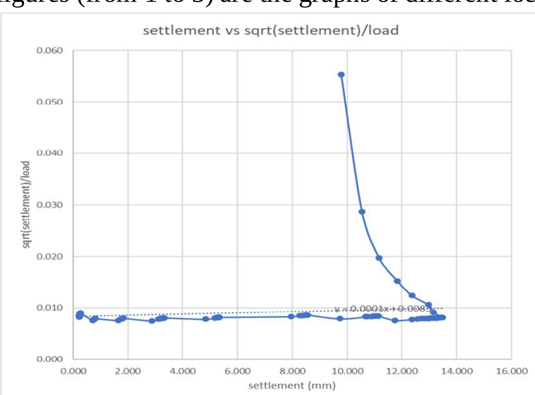


Fig 1 – graph of site Kakkanadu

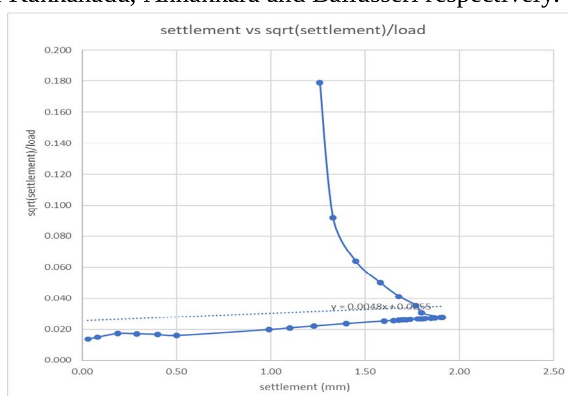


Fig 2 – graph of site Annakkara

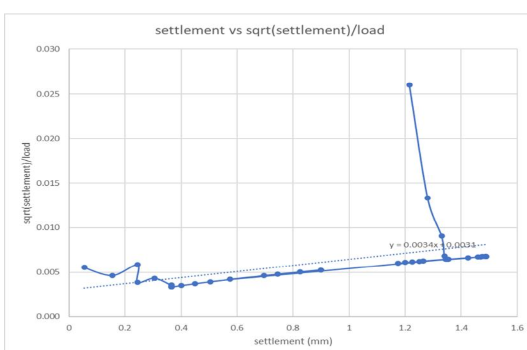


Fig 3 – graph of site Ballusseri

2) Chin-Kondner's method (1970)

The below figures (from 4 to 6) are the graphs of different location Kakkanadu, Annakkara and Ballusseri respectively.

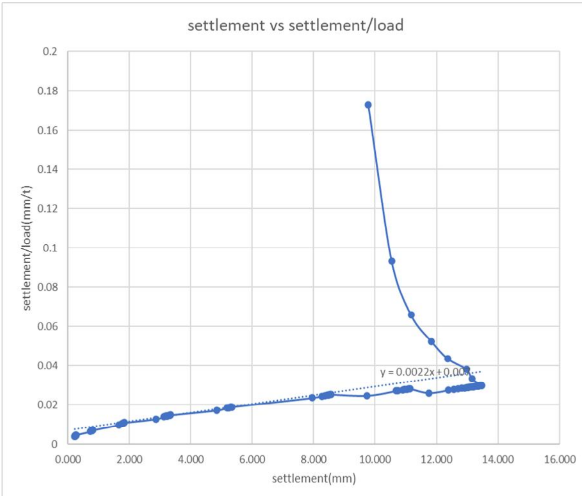


Fig 3 – graph of site Kakkanadu

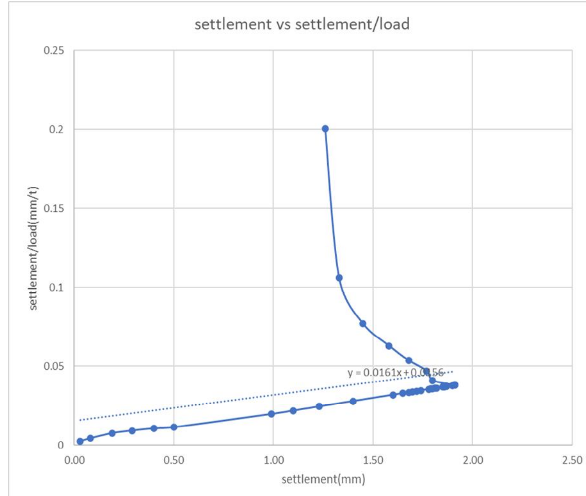


Fig 4 – graph of site Annakkara

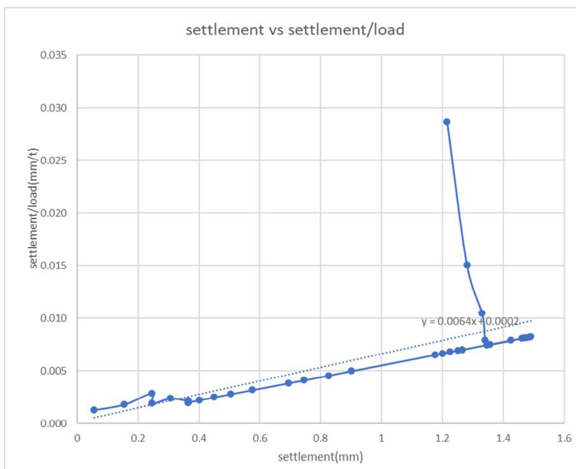


Fig 6 – graph of site Ballusseri

3) Decourt's Extrapolation method (1999) method

The below figures (from 7 to 9) are the graphs of different location Kakkanadu, Annakkara and Ballusseri respectively.

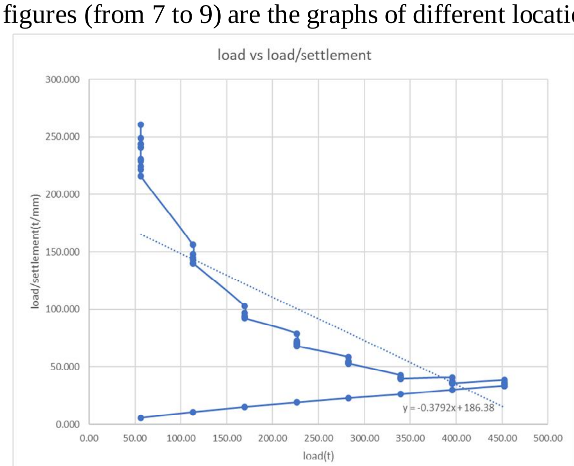


Fig 7 – graph of site Kakkanadu

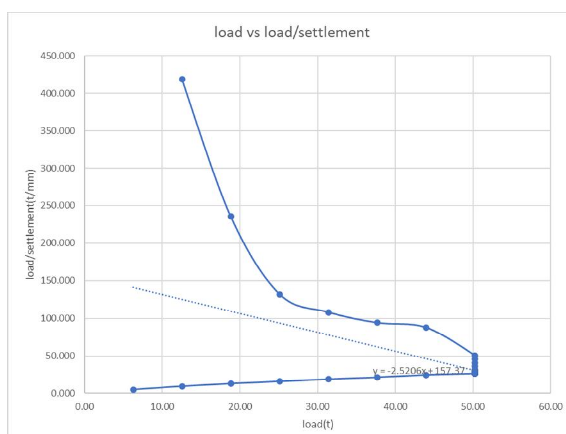


Fig 8 – graph of site Annakkara

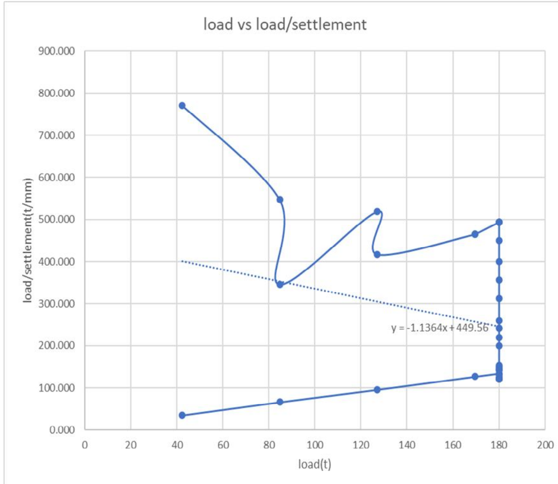


Fig 9 – graph of site Ballusseri

The summarised results of graphical methods were calculated as shown in Table 5

TABLE v

PILE BEARING CAPACITY CALCULATED BY GRAPHICAL METHODS

Pile No	Test load (MT)	Hansen's method (MT)	Chin-Kondner's method (MT)	Decourt's Extrapolation method (MT)
1	412.5	548.82	434.78	491.508
2	45	45.19	62.11	62.433
3	169.56	154.01	156.25	395.6

The following were noted in the graphical methods,

- Chin-Kondner's method shows more comparable value with the test load.
- Hansen's and Decourt's methods also showing comparable results but slight variations Kakkanadu and Ballusseri site respectively.

C. Proposed Method

The results of Empirical methods were calculated as shown in Table 6

TABLE vI

PILE BEARING CAPACITY CALCULATED BY PROPOSED METHODS

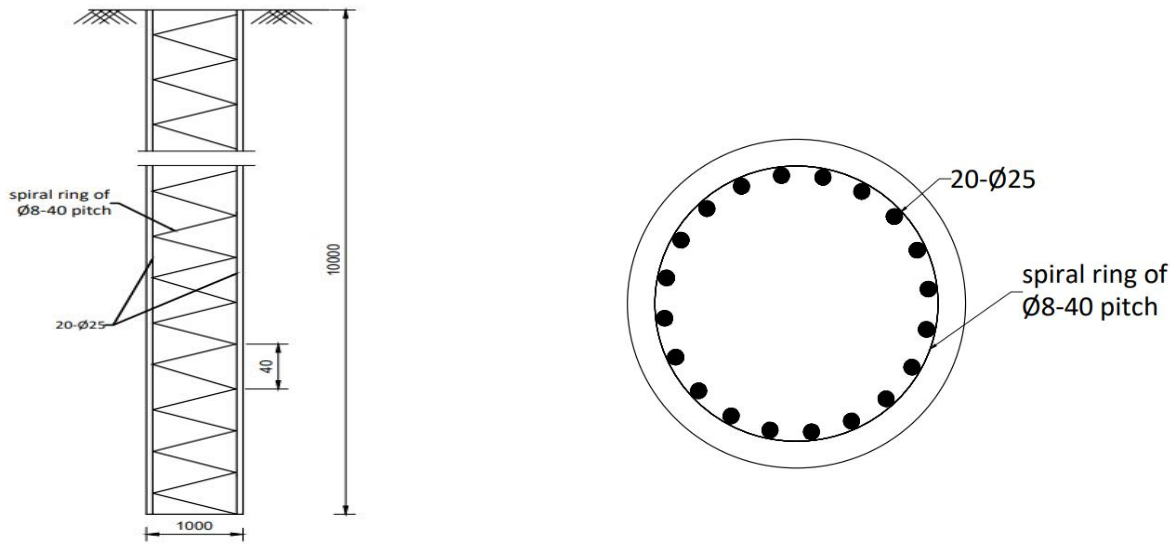
Pile No	Test load (MT)	Proposed method (MT)	Error %
1	412.5	416.36	0.93
2	45	45.95	2.11
3	169.56	172.57	1.77

The following were noted in the proposed method,

- Proposed equation has very comparable values with the test load.
- Error (%) in different location is under 5% hence its validated with the pile load test data.

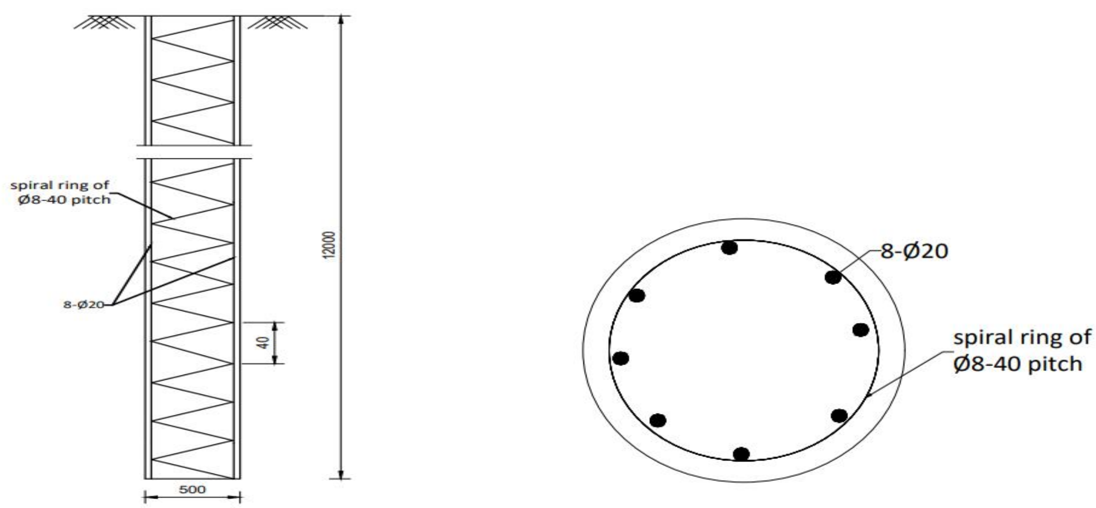
D. Structural design of pile.

All calculations are done manually on the basic of geotechnical report. Pile diameter is considered as per geotechnical report. Figure 1.a and 1.b represents the pile reinforcement details and cross section details of pile of Kakkanadu site. Figure 2.a and 2.b represents the pile reinforcement details and cross section details of pile of Annakkara site. Figure 3.a and 3.b represents the pile reinforcement details and cross section details of pile of Balluseri site.



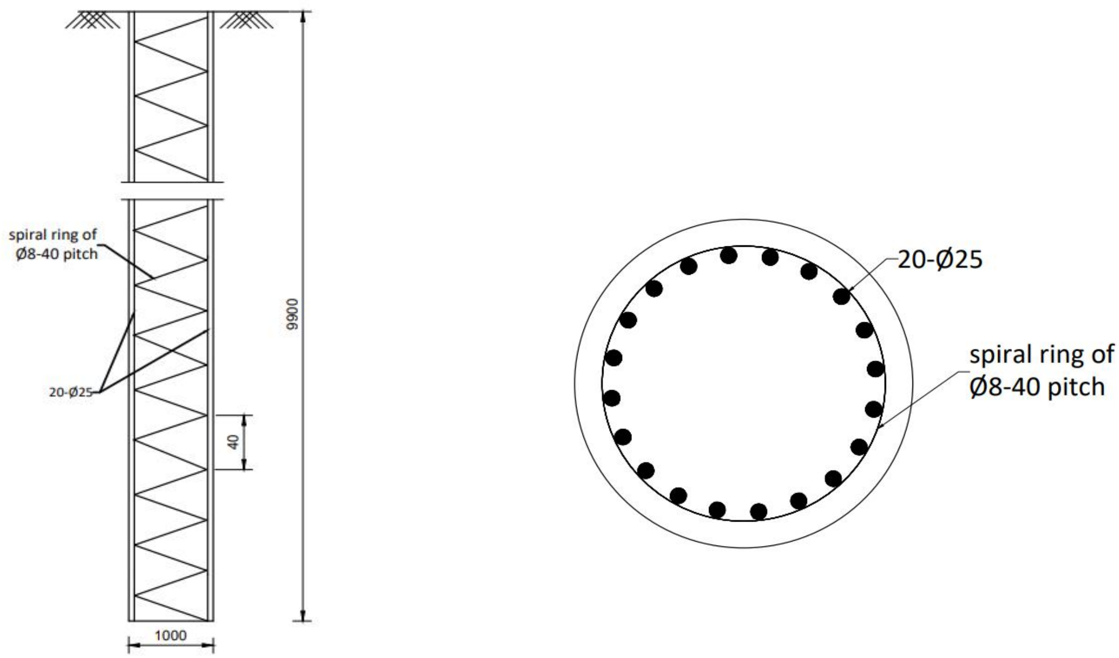
(a) (b)

Fig 1 – pile reinforcement details of site Kakkanadu site



(a) (b)

Fig 2 – pile reinforcement details of site Annakkara site



(a) (b)

Fig 3 – pile reinforcement details of site Ballusseri site

All piles are of M25 grade of concrete and Fe 415 grade of steel. For all piles the longitudinal reinforcement is to be lapped, for Annakkara site lapping should done with in a length of 50d, where d stands for the diameter of longitudinal bar and for Kakkanadu and Ballusseri sites lapping should done with in a length of 40d. For all sites provide master rings of diameter d (which is same as d of longitudinal bar) at a distance of 1000 mm centre to centre spacing.

V. CONCLUSIONS

The bearing capacity determination of pile is always a complex problem faced by engineers and researchers. Among all the methods for capacity calculation, SPT method is found to be flexible in terms of estimation, cost and time. In some cases, unpredictable values are obtained. The geological changes that may occur in soil and the surrounding resources with period of time is one the reasons causing failure of pile.

In empirical method it is found that Bazaraa and Kurkur method shows more comparable value with the test load. Value of cohesion is influencing the bearing capacity of pile very much. And for graphical method Chin-Kondner's method shows more comparable value with the test load. The proposed method shows very close values to the test load. And also, the error percentage is coming under 5% which shows that the proposed method has better precision performance compared to other chosen methods. Due to its precision, we can consider it as a better method. Also, the structural design of pile at different location also designed in this project.

REFERENCES

[1] Raisa, P.S. and Chandrakaran, S., 2022. "Evaluation of Bearing capacity for cast in-situ bored piles." In Ground Characterization and Foundations: Proceedings of Indian Geotechnical Conference 2020 Volume 1 (pp. 605-614). Springer Singapore.

[2] Tanzila Islam, Islam, Mohammad PY - 2018/12/19 SP - T1 - Estimation Of Pile Bearing Capacity Using Different Methods Er

[3] Shah, A., Advani, P., Patel, J. and Soni, H., 2017. "Estimation of load carrying capacity of bored cast in-situ piles." Int J Eng Technol Sci Res, 4(9), pp.814-819.

[4] Kanakeswararao, T. and Ganesh, B., 2017. "Analysis of pile foundation subjected to lateral and vertical loads." Int. J. Eng. Trends Technol, 46(2), pp.113-127.

[5] Kulkarni, R.U. and Dewaikar, D.M., 2017. "A numerical approach to assess the capacity of rock-socketed piles subjected to axial compression in Mumbai region based on the pile load test data". International Journal of Geotechnical Engineering, 11(5), pp.441-451.

[6] Sultana, F., Zinia, N.K., Akter, F. and Khan, M.M.R., 2016. "Pile Load Testing and Determining Bearing Capacity of Cast in Situ Pile: A Case Study." Global Journals of Research in Engineering, 16(E4), pp.41-45.

[7] Wang, Z., Zhang, N., Cai, G., Li, Q. and Wang, J., 2017. "Assessment of CPTU and static load test methods for predicting ultimate bearing capacity of pile." Marine Georesources & Geotechnology, 35(5), pp.738-745.

[8] Kozłowski, W. and Niemczynski, D., 2016. "Methods for estimating the load bearing capacity of pile foundation using the results of penetration tests-case study of road viaduct foundation." Procedia engineering, 161, pp.1001-1006.

[9] Thounaojam, S. and Sultana, P., 2014. "Prediction of bearing capacity of bored cast-in situ pile." International Journal of Research in Science and Technology, 51.

[10] Hoľko, M. and Stacho, J., 2014. "Comparison of numerical analyses with a static load test of a continuous flight auger pile." Slovak Journal of Civil Engineering, 22(4), pp.1-10.

[11] Wael N. Abd Elsamee, (2012) "Evaluation of the Ultimate Capacity of Friction Piles", Engineering, Vol. 4 No. 11, pp. 778- 789. doi:10.4236/eng.2012.411100

[12] Wael N. Abd Elsamee, (2013) "New method for prediction pile capacity executed by continuous flight Auger (CFA)", Engineering, Vol. 5, pp. 344- 354. doi.org/10.4236/eng.2013.54047

[13] Kulkarni R. U. and Dewaikar D. M. (2016) "A numerical approach to assess the capacity of rock-socketed piles subjected to axial compression in Mumbai region based on the pile load test data", International Journal of Geotechnical Engineering, DOI 10.1080/19386362.2016.1231390.

[14] Shariatmadari N., Eslami A. and Karimpour-Fard M. (2008) "Bearing capacity of driven piles in sands from SPT–applied to 60 case histories", Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 32, No. B2, pp 125-140.

[15] Manjula Devi B., Chore H.S., Sawant V.A. "Analysis Of Laterally Loaded Pile Groups", IOSR Journal of Civil Engineering (IOSR-JMCE), ISSN: 2278-0661, ISBN: 2278-8727, PP: 60-64.

[16] Amel Benali, Ammar Nechnech and Ali Bouafia (2013) "Bored pile capacity by direct SPT methods applied to 40 case histories", Civil and Environmental Research,Vol. 5, pp. 118- 122.

[17] Hamid Alielahi and Mohammad Adampira (2016) "Comparison between empirical and experimental ultimate bearing capacity of bored piles—a case study", Arabian Journal of Geosiences.

[18] Yudhi Lastiasih and Indra Djati Sidi (2014) "Reliability of estimation pile load capcity methods", J. Eng. Technol. Sci., Vol. 46, No. 1, 1-16.

[19] Wojciech Koz owski and Dariusz Niemczynski (2016) "Methods for Estimating the Load Bearing Capacity of Pile Foundation Using the Results of Penetration Tests - Case Study of Road Viaduct Foundation", Procedia Engineering 161, pp. 1001- 1006.

[20] Ahmed Majeed, Olla Haider, (2018) "Simulation of bearing capacity of bored pile", MATEC web of conference 162, 01004, BCEE3- 2017.

[21] Fatema Sultana, Nusrat Khanum Zinia, Farjana Akter and Md. Motiur Rahman Khan (2016) "Pile Load Testing & Determining Bearing Capacity of Cast in Situ Pile: A Case Study", Global Journal of Researches in Engineering: E Civil And Structural Engineering, Volume 16 Issue 4 Version 1.0.