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Pile Capacity in Khulna Sub-Soil

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Abstract: This paper presents the results of pile capacity in tabular and graphical form from a field and laboratory investigation of sub-soil in khulna region. The sub-soil investigation reports of different sites of khulna were collected from crts (consultancy research & testing services), department of civil engineering, kuet and pile capacities at different depths were calculated. The analysis was made by using allowable skin friction and allowable end bearing capacity to determine pile capacity .a comparative study is made between pile capacities obtained by the conventional method and pile load test. Variation of pile capacity with respect to length of the pile obtained by conventional method differs from those obtained by pile load test. This difference can be considered reasonable from practical point of view. The results obtained from this study can be used for the design of pile in those cases where the owners are going to use pile foundation for small project without any sub-soil investigation. Moreover, for large projects pile capacity obtained by sub-soil investigation reports can be utilized for design with confidence by comparing with these results where pile load test is not performed.

Keywords: *Pile Capacity, Khulna Region, Conventional Method, Pile Load Test*

1. Introduction:

Khulna City is situated on southern region of Bangladesh. The soil in this region is formed by the alluvial deposits from different rivers (Rupsha, Vairab etc.). This region is also covered by deep forest of Sundarban. Due to tectonic forces at different times in the past, these deep forests were buried underneath. For these reasons, the soil is very soft, compressible having organic matter with low bearing capacity as well as pile capacity(Molla and Malik,1997).

Khulna City is expanding with large development projects including construction of high rise buildings, bridges and overhead water tanks etc. Since the bearing capacity of the sub- soil of Khulna is very low, pile foundation is used for the construction of high rise buildings and other important structures. For most of the projects other than a large project, the owner does not like to bear the cost of pile load test .In such cases the pile capacity obtained by conventional method can be used for the design of pile foundation confidently if any published paper is available on pile capacity of Khulna sub-soil. Unfortunately, such published paper is not available till now. Therefore, it is necessary to publish such a paper.

It is well known that the sub-soil of Khulna is of critical nature. The existence of organic layer is a very disadvantageous aspect of Khulna sub-soil. This organic layer is situated almost everywhere in Khulna City. In some places the thickness of this layer is 5ft to 20ft and in some places the thickness of this layer is much more. At south of Khulna the location of this organic layer is nearer to ground surface. At most of the places the top layer is composed of clayey silt or silty clay. The thickness of this clay and silt layer including organic layer is 35 to 40ft from ground level. Somewhere sand pockets are available within these 40ft.In most places the water table varies from 2-4ft.All the above mentioned factors have effects on the pile capacity in Khulna sub-soil. The main objectives of this study were to determine the pile capacity of Khulna sub-soil by Conventional method and to compare with the values obtained by pile load test.

2. Methodology:

In this study pile capacity is determined at fourteen different sites which are shown in figure-1. Details of the evaluation procedure are provided in the following sub-heading.

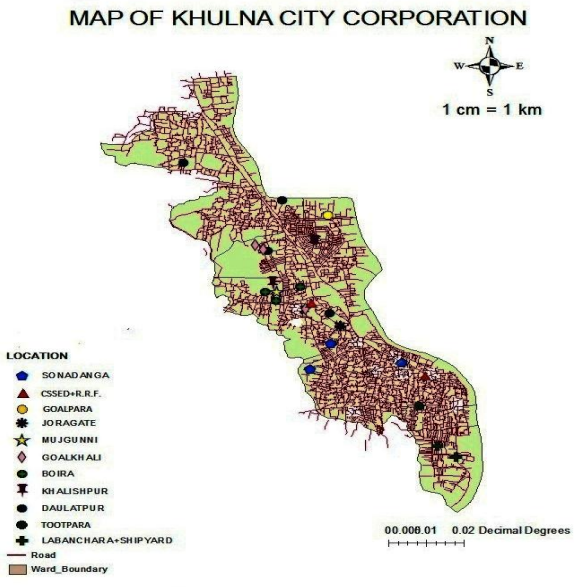


Figure-1: *Location map of Study Area in Khulna Region*

2.1 For Cohesive Soil

For soil under cohesive group i.e. for clay and plastic silt, the skin friction and end bearing capacities of pile may be evaluated by the following general formula:

$f_{su} = \alpha C_u$

$q_{pu} = N_c C_u$

Where,

f_{su} =Ultimate skin friction

α = Adhesion factor

C_u= Undrained shear strength

q_{pu} =Ultimate end bearing of the pile

N_c = Bearing capacity factor for deep foundation (generally 9)

2.2 For Non-cohesive Soil

For non–cohesive soil of silt, firm to medium sand, the skin friction and the end bearing capacities of pile may be evaluated by the following formula:

$f_{su} = 4N/20$

$q_{pu} = 4N$

Where,

f_{su} = Ultimate skin friction

q_{pu} = Ultimate end bearing of the pile

N = SPT value

2.3 Pile Capacity By Conventional Method

Ultimate pile capacity = $A_s * f_{su} + A_b * q_{pu}$

Where,

A_s= Cross-sectional area of the surface of the pile = πDL (ft2)

f_{su} = Ultimate skin friction, tsf

A_b = Cross-sectional area of the base of the pile =$\pi D2$ (ft2)

q_{pu} = Ultimate end bearing of the pile, tsf

D = Diameter of the pile

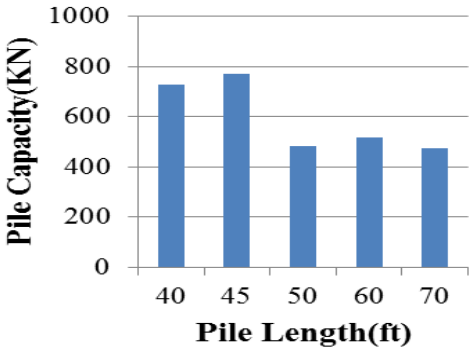
L= Length of the pile

(Bowels, 1997; Singh & Chowdhury, 1994; and Teng, 2012)

3. Results and discussion:

For each site pile capacity at different boreholes are determined and by averaging the pile capacities of all the boreholes the average pile capacity of that site is obtained. Finally averaging the pile capacities of all the sites the average pile capacity in Khulna sub-soil is obtained. Detail procedures of evaluation of two sites are presented in the following tables.

Site-1: An Infrastructure under Women Oppression Protection Project at Five Divisional Towns, Khulna



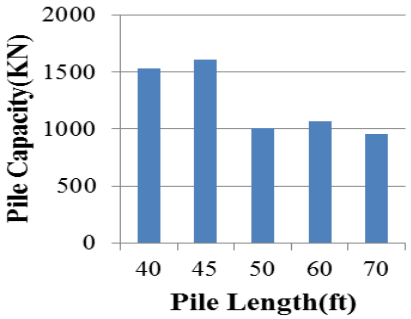


Figure-2: *Variation of pile capacity for site-1 of 12" diameter pile (Left) and Variation of pile capacity for site-1 of 18" diameter pile (Right)*

Table-1*: Ultimate Pile Capacity of Pre-cast Pile by Conventional Method*

Bore Hole(BH)	Length of the Pile(ft)	Ultimate Pile Capacity by Conventional Method(KN)		
		Dia(12")	Dia(18")	Dia(24")
BH-1	40	692.67	1457.95	2502.53
	45	756.63	1581.75	2704.75
	50	338.79	703.63	1198.76
	60	506.37	1038.78	1757.36
	70	475.93	965.20	1622.18
BH-2	40	646.58	1360.96	2336.07
	45	756.63	1581.75	2704.75
	50	338.79	703.63	1198.76
	60	354.43	727.09	1230.03
	70	475.93	965.23	1622.18
BH-3	40	646.58	1360.96	2336.07
	45	804.11	1681.03	2874.56
	50	484.02	1005.27	1712.67
	60	557.20	1143.11	1933.88
	70	528.72	1027.30	1802.05
BH-4	40	923.65	1944.14	3337.08
	45	756.63	1581.75	2704.75
	50	774.50	1608.56	2740.50
	60	658.31	1350.49	2284.68
	70	423.14	858.22	1442.31

Table-2*: Average Ultimate Pile Capacity of Pre-cast Pile by Conventional Method*

Length of the Pile(ft)	Average Ultimate Pile Capacity by Conventional Method(KN)		
	Dia(12")	Dia(18")	Dia(24")
40	727.37	1531.02	2627.94
45	768.50	1606.57	2747.45
50	484.03	1005.32	1712.67
60	519.07	1064.87	1801.49
70	475.93	953.98	1622.18

From the figure it is observed that pile capacities at 40ft and 45ft are greater than pile capacities at 50ft, 60ft and 70ft. Because at 40ft and 45ft the values of end bearing capacities are greater than the values at 50ft, 60ft and 70ft.

Site-2: Fabrication Shed at Khulna Shipyard, Khulna

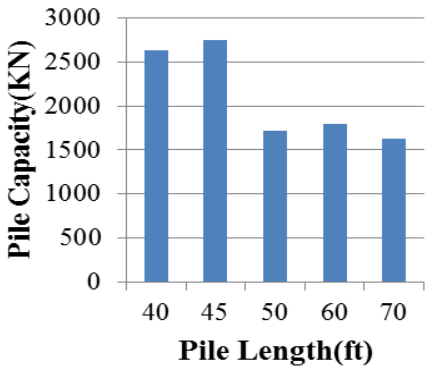
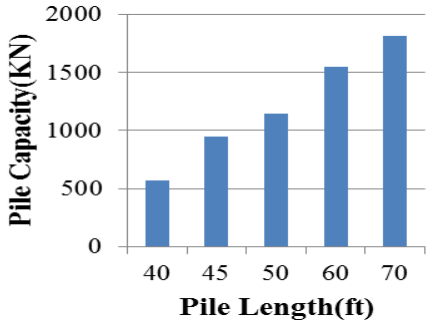


***Figure-3**: Variation of pile capacity for site-1 of 24" diameter pile*



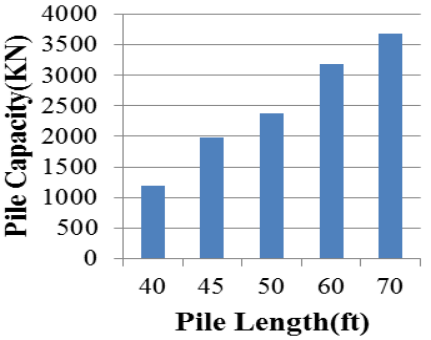


***Figure-4**: Variation of pile capacity for site-2 of 12" diameter pile (Left) and Variation of pile capacity for site-2 of 18" diameter pile(Right)*

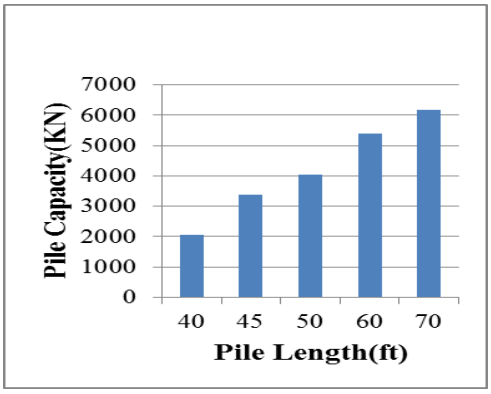


***Figure-5**: Variation of pile capacity for site-2 of 24" diameter pile*

***Table-3**: Average Ultimate Pile Capacity of Pre-cast Pile by Conventional Method*

Length of the Pile(ft)	Average Ultimate Pile Capacity by Conventional Method(KN)		
	Dia(12")	Dia(18")	Dia(24")
40	168.31	274.45	395.27
45	240.48	391.38	562.74
50	295.56	477.94	690.88
60	566.09	1129.90	1880.92
70	740.31	1501.48	2523.31

***Table-4**: Ultimate Pile Capacity of Pre-cast Pile by Conventional Method*

Bore Hole(BH)	Length of the Pile(ft)	Ultimate Pile Capacity by Conventional Method(KN)		
		Dia(12")	Dia(18")	Dia(24")
BH-1	40	128.20	208.0	298.30
	45	232.66	376.43	538.50
	50	254.44	409.11	582.06
	60	658.31	1350.49	2284.67
	70	634.57	1287.02	2162.90
BH-2	40	128.20	208.0	298.30
	45	205.0	331.18	473.14
	50	275.11	444.09	634.02
	60	658.31	1350.49	2284.67
	70	846.0	1715.81	2883.50
BH-3	40	228.47	374.12	540.73
	45	174.56	281.53	401.63
	50	298.57	483.26	691.55
	60	709.14	1454.81	2461.20
	70	846.0	1715.81	2883.50
BH-4	40	128.20	208.0	298.30
	45	273.44	445.55	641.27
	50	324.83	526.62	754.67
	60	348.85	558.67	792.09
	70	740.43	1501.72	2523.75
BH-5	40	228.47	374.12	540.73
	45	316.73	522.22	759.14
	50	324.83	526.62	754.67
	60	455.82	935.09	1581.95
	70	634.57	1287.01	2162.90

Variation of pile capacity with respect to pile length is shown in the above figure. The figure shows that pile capacity increases with the increase of diameter and length of pile.

The values of average pile capacity of Khulna sub-soil are shown in the following table:

***Table-5**: Average Ultimate Pile Capacity of Pre-cast Pile in Khulna City by Conventional Method*

Length of the Pile(ft)	Average Ultimate Pile Capacity by Conventional Method(KN)		
	Dia (12")	Dia (18")	Dia (24")
40	571.07	1185.51	1870.28
45	589.52	1203.36	1926.44
50	660.49	1319.39	2146.07
60	668.52	1352.95	2241.15
70	738.67	1514.40	2456.80

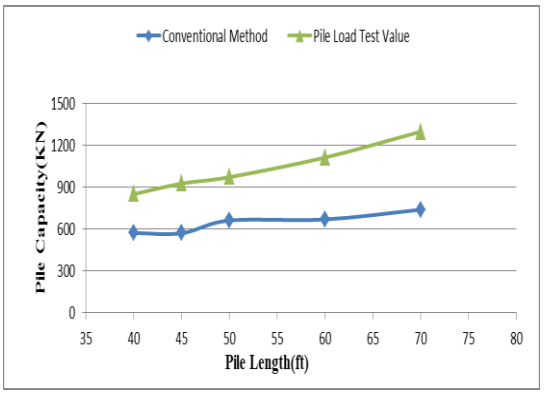


***Figure-6:** Comparison of Pile Capacity Obtained by Conventional Method and Pile Load Test for 12" diameter pile*

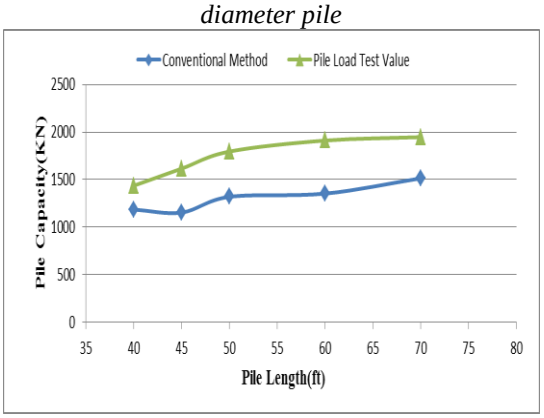


***Figure-7**: Comparison of Pile Capacity Obtained by Conventional Method and Pile Load Test for 18" diameter pile*

It is observed that variation of pile capacity with respect to length of the pile obtained by Conventional method differs from those obtained by pile load test(Rahman,2001). This difference can be considered reasonable from practical point of view. From figure-6 and figure-7, it is observed that Conventional method gives lower value than pile load test.

The results obtained from this study can be used for the design of pile in those cases where the owners are going to use pile foundation for small project without any sub-soil investigation. Moreover, for large projects pile capacity obtained by sub-soil investigation reports can be utilized for design with confidence by comparing with these results where pile load test is not performed.

4. Conclusions:

The critical feature of the Khulna soil is the existence of thick compressible organic layer (the thickness of this layer varies from 10 to 40 ft) located at a depth 5 to 20 ft from ground surface in most of the places which affects the pile capacity to a great extent. Generally the pile capacity increases rapidly at about 40ft depth from the ground level. Below this depth the pile capacity generally increases with increase of depth and sometimes pile capacity decreases with the increase of depth because of the fact that the end bearing of pile sometimes decreases at higher depth. The results obtained from this study can be used for the design of pile in those cases where the owners are going to use pile foundation for small project without any sub-soil investigation. Moreover, for large projects pile capacity obtained by sub-soil investigation reports can be utilized for design with confidence by comparing with these results where pile load test is not performed.

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