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PRESTESSED SPUN PILE IN SOFT SOIL: A CASE STUDY

S M Kamal Uddin*[1], D. Das[2] and Md Nowshad Ali[3]

[1]*Assistant Professor, Department of Civil Engineering, KUET, Bangladesh, e-mail: kamaluddin@ce.kuet.ac.bd*
[2]*Director, Poles and Concrete Ltd, Khulna, e-mail: debdas02@gmail.com*
[3]*Director, Poles and Concrete Ltd, Khulna, e-mail: amdnowshad@gmail.com*

***Corresponding Author**

ABSTRACT

Constructing a high rise building in the south-western region of Bangladesh is always challenging because of the very soft sub-soil profile. In this region, sometime foundation costing becomes the key factor for choosing the height of a structure. A study was carried out to examine the cost effectiveness of using Spun Prestressed Concrete (SPC) pile over bored situ pile for a real life structure in Khulna city. Foundations were designed for both situ pile and SPC pile.Both types of pile were then constructed and inserted to the depth 24m. Pile load tests were conducted to check the capacity of the SPC pile. Finally, the expenses that were required for the foundation was calculated and compared for both the situ pile and SPC pile.It has found that SPC pile can be a savior for the dweller who wants to construct high rises, and eventually construction industry will migrate to a new era.

Keywords:*Spun Prestressed Pile, Foundation in Soft Soil.*

1. INTRODUCTION

As per BNBC (2020) there is no particular definition of soft soil in terms of soil parameters, mineralogy or geological origin. Kamon and Bergado (1991) has defines soft clay as soils with large fractions of fine particles such as silty and clayey soils, which have high moisture content, peat foundations and loose sand deposits, located near or under the water table. It is however commonly understood that soft clay gives severe time related settlement problems due to compressibility and shear strength.

Standard Penetration Test (SPT) is one of the widely used and economical field tests methods for sub-soil investigation. The idea of softness of soil can be understood from the Standard Penetration Test (SPT) values. Table 1 shows the relation of soil condition with N-values given by Terzghai and Peck that is well accepted.

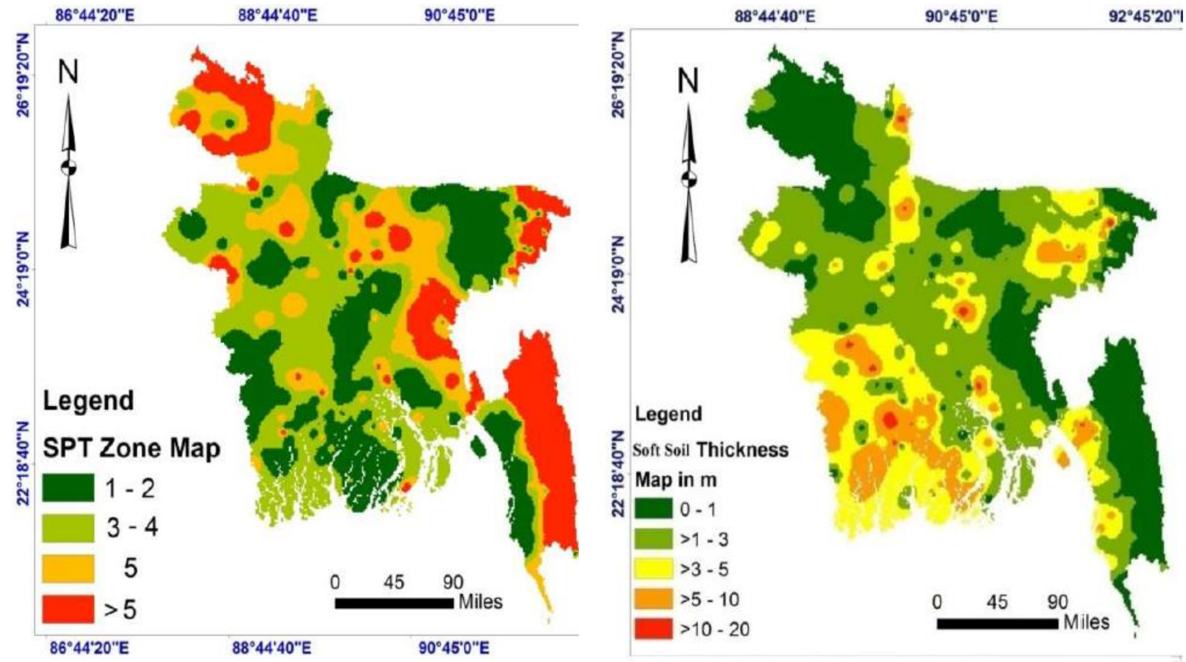
Table 1: Soil Condition with SPT value (After K. Terzhagi and R.B. Peck)

Non-Cohesive Soil		**Cohesive Soil**	
N-values	Condition	N-values	Condition
0 -4	Very loose	0-2	Very Soft
4-10	Loose	2-4	Soft
10-30	Medium	4-8	Medium
30-50	Dense	8-15	Stiff
Over 50	Very Dense	15-30	Very Stiff
--	--	Over 30	Hard

Besides the soil characterization, SPT value or N- values are also being extensively used for designing foundations of different types of structures (Dung and et. al), especially, for the calculation of bearing capacity of piles (Meyerhof, 1976; Shioi and Fukui, 1982; Decourt, 1995; Robert, 1997). Thus, many codes or manuals including the BNBC uses SPT-based methods (FHWA, 1996; CFEM, 2006; AASHTO,2007).

Hore and et. al. (2019) carried out a study to prepare a zonation map based on soft soil regarding clay of Bangladesh. Sub soil investigation data were collected from different district and were analysed and presented using ArcView GIS. The figure 1 shows the presented result which shows that, most of the district needs deeper foundation for constructing high rise structures.

In Bangladesh cast in situ pile are widely used and believed as the cheapest method for pile construction. This is because of the availability of equipment and technique. But the capacities of cast in situ pile are comparative very low than the driven pile. Precast piles are now a days used but in limited application. In recent times, Pre stressed High Strength Concrete (PHC) piles have become popular in China, India, Thailand, Malaysia, Japan, Indonesia and German; and are getting attention to other countries like Bangladesh. Compared to other pile (bored pile, RCC precast pile, timber pile etc), PHC have some advantages. For example i) Because of higher young modulus, it can be driven to deeper depth even in dense sand and decomposed rock layers ii) it requires less concrete when made as Spun Pre stressed Concrete (SPC) pile ii) it can provide higher capacity to bear vertical loads. In this paper a case study is presented to draw a relative study in terms of cost of cast in situ and SPC pile



a) Zonation Map using SPT value

b) Thickness Map of Soft Soil

Figure 1: Soft Soil zonation and thickness map of Bangladesh (Hore et al, 2019)

2. DETAILS OF THE CASE STUDY

2.1 Background

The case study is about a private property. A six storied building was designed and prepared for construction at Goalkhali, Khulna (22°51'11.32"N, 89°32'6.14"E). The total land area was 6000 sqft and the foot print area of the structure was 4400sqft. The sub-soil investigation was

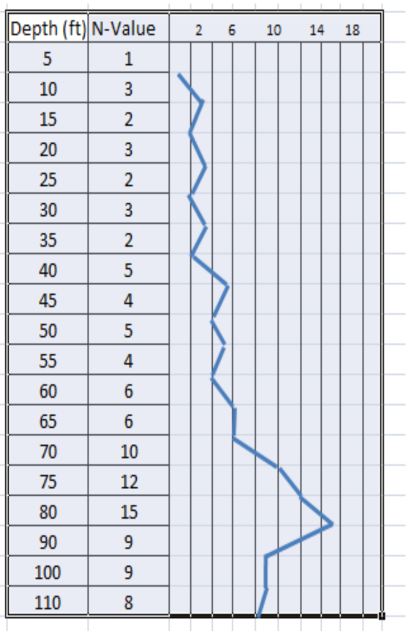


Figure 2: SPT value of Bore hole 1

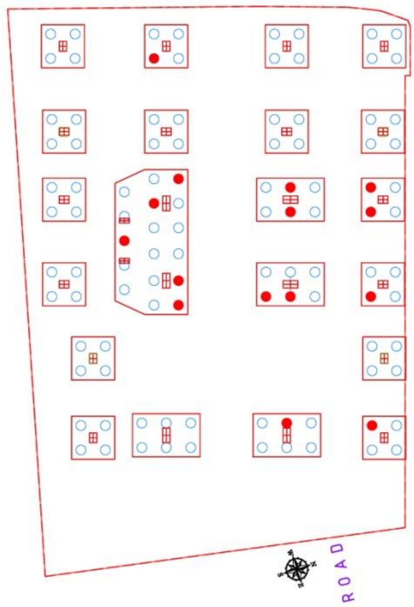


Figure 3: Pile layout plan for cast-in-situ pile

done with three bore holes. From the bore log data, it can be seen that the soil profile is almost similar which was presented by Hore et al (2019). The representative bore log for SPT values is shown in figure 2. It can be seen that up to 65 ft the soil SPT value is 6 up to which soil was mainly clay type, after trace sand were presented in the soil deposition. Which means the top soil up to 65 ft was soft and afterward medium strength layer existed as per table 1. The subsoil report suggested the capacity of bored situ pile as shown in table 2. Designer then selected a 20-inch dia pile for a depth of 80ft. The capacity of the pile is approximately 30 tons. It was counted that a total number of the 105 piles were required for the building foundation. The pile layout plan is shown figure 3

Table 2: Pile Capacity at different depth for various sizes in tons

Length	70'-0"	70'-0"	70'-0"	80'-0"	80'-0"	80'-0"	90'-0"	90'-0"	90'-0"
Bore Hole	16"dia	18"dia	20"dia	16"dia	18"dia	20"dia	20"dia	20"dia	24"dia
BH-1	17.53	19.91	22.33	22.49	25.58	28.73	31.60	34.94	38.33
BH-2	18.00	20.44	22.91	23.89	27.21	30.61	32.87	36.34	39.85
BH-3	21.19	23.96	26.76	27.92	31.77	35.71	37.91	41.89	45.90

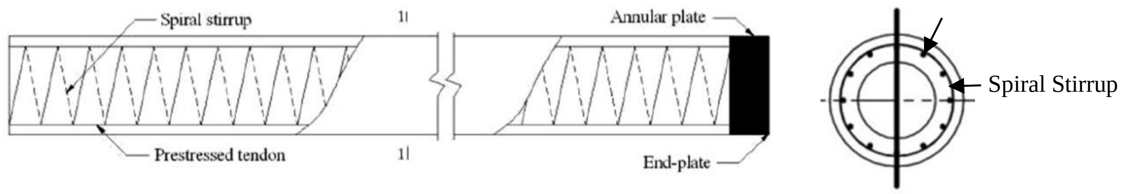
The land owner hired a pile driving group for casting of the pile. The actual capacity of the pile was supposed to find out with a test pile, but nothing was done as it is accepted for the whole lot of pile. The costing of the pile including driving cost was estimated about 70 lakhs BDT. After driving of 15 piles (solid piles in figure 3) the land owner found that the average costing was running more than the estimated one, which annoyed him.

2.2 A Revision

For cost minimization, land owner return back to the designer for a revision and asked the reason of the issue. The designer made a PIT test and found that the situ piles were irregular which was a sign of collapse of inside wall of borehole; meaning consumption of larger amount of materials than it was expected. Such issue may occur due to soft top soils and the poor quality of the Bentonite slurry. The designer then decided for driven pile. At that time a local manufacturer offered SPC pile which looks costly when compared individually with other RCC driven pile. The pile manufacturer offered for a free pile load test to show up the capacity of the pile rather than calculation based on traditional equation. The manual of JIS A-5335-1987 was supplied to the designer for better understanding of the

Prestressed tendon

phenomenon. There was not much in BNBC though. The designer studied the Japanese standard and agreed for a trial test of SPC pile for the first time.



a) Long section

b) Cross sectional view (1-1)

Figure 3: Details of SPC Pile

A test pile was driven in the project site within a week after clearing the old cast-in-situ driving machine with the help of hydraulic pushing machine (figure 4). It was a segmental pile of 40ft (12m) long with 16inch (400mm) dia. Two segments were welded together to reach a depth of 80ft. The pile was manufactured with 8000psi (55MPa) concrete, 12 numbers of 7mm high tensile wire, and spiral shear reinforcement was with 5mm wire with two different spacing along the length. During the pile driving process it was observed that a total load of 160tons was required to drive it to that depth. Afterwards pile load test setup up was prepared shortly and the test was completed within the week. The load-settlement graph is shown in figure 5.

Figure 4: Hydraulic pile pressing machine

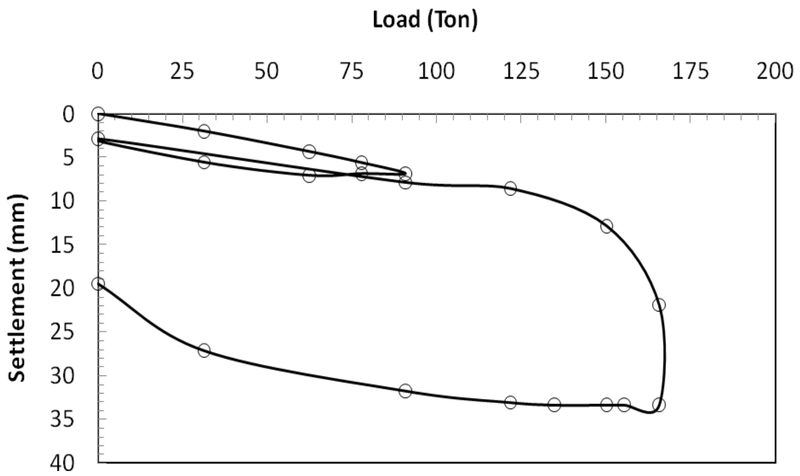


Figure 5: Load-settlement curve of test pile

3. Results and Discussion

From the load settlement curve, it was seen that the capacity of the test pile was surprisingly large enough than situ pile. The maximum load was found 168tons for a settlement of 0.8 inch (22mm). The resistance of the pile increases rapidly and reaches to its maximum value at this small movement. The designer considered the capacity of the test pile for two-third of the load for which 12mm of settlement occurred, which was around 90ton. Clarke (1993) and Bogard and Matlock (1990) conducted field measurement studies in which it was shown that the time required for driven piles to reach ultimate capacity in a cohesive soil can be relatively long—as much as 2–3 years. Besides,it is worth mentioning that there is a significant strength increase in a short period after installation of pile and this happens due to the strength rate gained rapidly after driving directly, and this rate decreases during the dissipation process (El Reedy M. A. 2020). Hence the designer went more conservative and considered the pile capacity half of the load for which 12mm settlement were occurred, which is 70 ton.

The whole design was then revised considering the SPC pile capacity of 70tons. And it was 50 numbers of 16ich dia. SPC pile of length 80ft (24m) blended with the previously installed cast-in-situ pile of larger diameter (20inch). Finally, the cost was revised to 45lakh BDT, which was much lower than the initial budget.

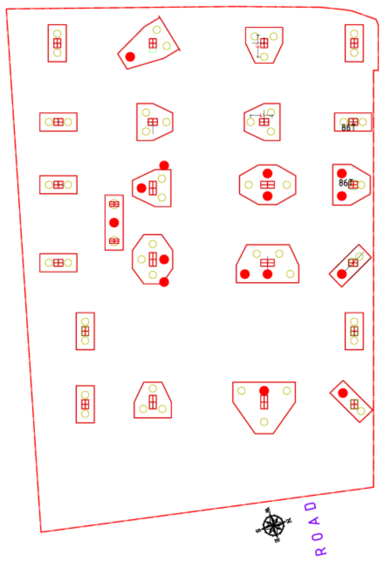


Figure 6: Revised footing plan with SPC pole

4. CONCLUSION

It is evident that the cost can be reduced by using the driven pile as the bearing capacity of is higher than the bored situ pile. There were some disadvantages of driven pile in consideration to vibration generation. But in this project a hydraulic pushing machine was used which does not create any noticeable vibration. In Khulna, people have to spend a significant amount of money on footing. The scenario is same for the whole country as most of our area is composed of deltaic sedimentation. From this case study, it can be concluded that use of SPC pile can reduce the substantial amount of foundation cost. It will be good if the design detail of foundation using SPC pile is included in BNBC after a careful revision of all existing codes of Japan, Malaysia and China.

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