Case Studies of Failure of Cast-In-Situ Piles

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ABSTRACT

The paper deals with case studies of pile failure when cast-in-situ piling systems are adopted. The four commonly used methods of piling are the bailer, direct mud circulation, driven-cast-in-situ and rotary auger system. Failures in each of these cast-in-situ piling systems are discussed based on the failures noted in the initial testing or during execution. The causes for the failure are analyzed and the remedial measures adopted discussed.

INTRODUCTION

Even though pre-cast piling system allows better quality control, implementation of the system in many site conditions is difficult due to the problems of predetermining the exact length of pile. Jointed piles are not effective in some soil conditions. Driving through intermediatory obstructions causes problems in pre-cast piling. Due to these restrictions the commonly used system of piling is cast-in-situ. The construction systems normally adopted are bailer, direct mud circulation (DMC), driven-cast-in-situ and rotary auger. Failures have been noted in the initial tests or during execution of the piling in these systems. Typical case studies of each system are presented in this paper, analyzing the possible cause of the failure derived based on the test results or data from execution of pile.

CASE 1: FAILURE IN THE BAILER SYSTEM OF PILING

The soil profile in which this piling method was recommended is given in Fig. 1A. The pile foundation is recommended essentially due to the presence of soft silty clay layer present to nearly 10 m. With the bearing stratum present at a shallow depth of 13 m for economy of construction, bailer system of piling was initially adopted.

In the bailer system as shown in Fig.1B, the bore is made using a bailer with a flap at the bottom. The bailer is made to pound in the pile bore which is filled with bentonite slurry. The top 1 to 2 m of the pile bore is protected by a casing. When the bailer hits the bottom of the bore, the flaps open and the cut soil gets into the bailer, which gets trapped while the bailer is pulled out.

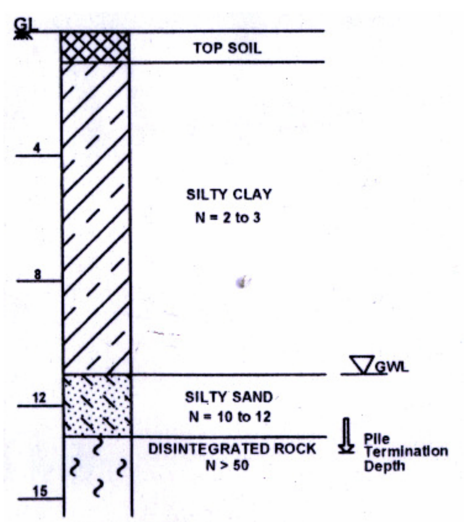

Fig. 1A. Soil Profile Bailer System Piling

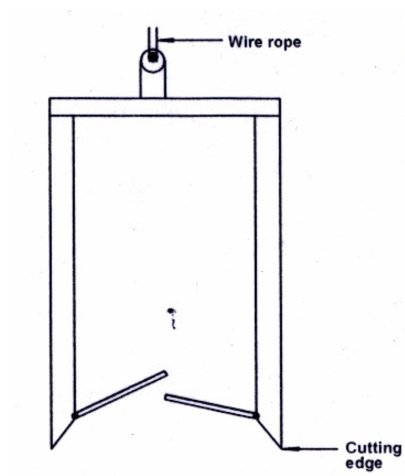

Fig. 1B. Bailer with Flap Door

Failure Analysis

The diameter of the test pile adopted is 56 cms, seated in the disintegrated rock layer for about 60 cms. The disintegrated rock layer being very dense, the allowable load determined by the structural capacity of the concrete, which is taken as 50 kg/cm^2 of M-20 concrete used, is 123 T. To allow for the negative drag calculated as 15 T, the initial load test was planned for 345 T with a factor of safety of 2.5. During the loading, total failure occurred at a load of 120 T which is 1/3rd the anticipated failure load. The cause for the failure is assumed as necking, which is likely to occur in the bailer system of piling passing through very soft clay layers because of the negative pressure generated when the bailer is removed for removing the cut soil. Extra care has to be taken to remove the bailer slowly, retaining the bore filled with bentonite to the ground level throughout. A reduction of the quantity of the concrete consumed was also noted in the pile. Hence it was concluded that the failure is due to necking. The piling system was changed from bailer to direct mud circulation, which retains positive pressure throughout and prevents necking. Using this method the second test pile gave the anticipated failure load with a settlement of only 6 mm.

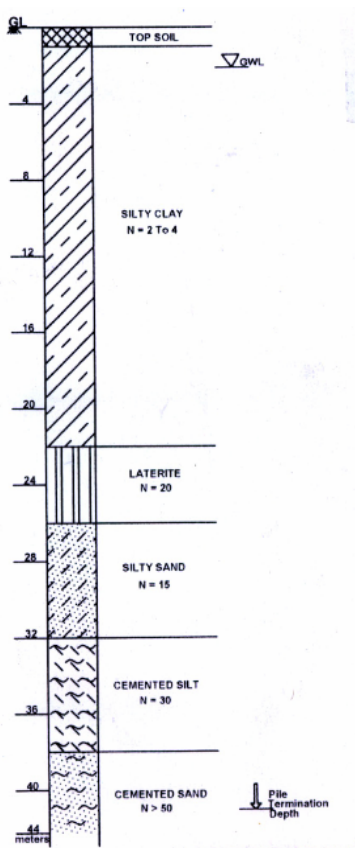

Fig. 2A. Soil Profile DMC Piling

Conclusions from the Results

The conclusion to be made from this is to not use the bailer system of piling if piles have to pass through very soft and loose soil layers. The DMC method of piling has to be adopted in such cases.

CASE 2: FAILURE IN THE DMC PILING SYSTEM

In the direct mud piling system (DMC), a chisel as indicated in Fig 2B is used. The chisel cuts the soil and the bentonite slurry pumped through the nozzles at the base of the chisel pushes out the cut material, maintaining positive pressure in the bore throughout. This system is generally adopted when the length of pile is more than 25 to 30 m and the diameter of the pile is more than 60 cms. The DMC method of piling was adopted for the profile indicated in Fig 2A. The area has very soft silty clay upto 22 m, followed by a fairly stiff lateritic clay with underlying layers of silty sand, cemented silt and the bearing stratum appearing at 38 m. The 75 cms diameter piling was adopted in this case with the pile terminated with 2-m seating in the cemented sand layer. The initial pile test load was fixed, including the negative drag of 30 T and allowable end bearing load of 220 T as 625 T with a factor of safety of 2.5. The test pile failed at a load of 315 T. The calculation of the pile capacity based on its skin friction alone, considering the soft silty clay also contributing to positive skin friction, indicated that no end bearing has developed.

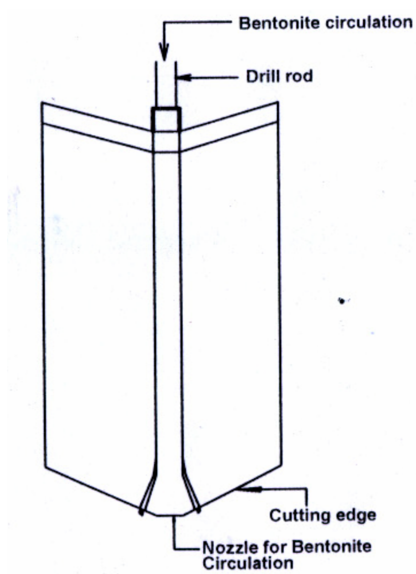

Fig. 2B. DMC Chisel

Failure Analysis

The cause for the failure was presumed as poor cleaning of the cut material from a depth of 40M. This was confirmed by further analysis of the pumping system capacity adopted in cleaning the pile bore prior to concreting. The second test piling was done improving the pump capacity and also increasing the duration of the pumping of bentonite slurry through tremmie pipe prior to concreting. The test gave the required results with settlements of the order of only 8 mm.

Conclusion from the Results

The conclusion to be made from this is that when large diameter deep piles are adopted, the capacity of the cleaning pump used and the duration of cleaning should be adequate to achieve proper flushing out of all cut materials. This is essential to generate the end bearing based on which the pile is designed.

CASE 3: FAILURE OF DRIVEN-CAST-IN-SITU PILES

The soil profile in which the piling was initially adopted indicated very dense cemented sand at a depth of 20 m as indicated in Fig.3A. During the soil exploration, boring was terminated after drilling for 1 m into the refusal stratum. The soil exploration thus was terminated at 21 m. Based on the result, 50 cms driven-cast-in-situ piling of length 20 m was adopted presuming that the required set value would be obtained in the disintegrated rock layer with N value over 50. In the driven-cast-in-situ piling as given in Fig 3B, the casing is driven with a dispensable shoe. During the piling operation, for the first few blows seating resistance was noted at 20 m as given in the soil exploration report. However, during further driving the pile casing penetrated without achieving the adequate set value. The pile casing achieved the set value only at a depth of about 24 m.

Failure Analysis

Further soil exploration indicated that below the layer of cemented sand a layer of cemented clay of N value only of the order of 5 was present. The thickness of the cemented sand taken as refusal stratum was only 2 m, which was punctured by the casing while drawing. The piles terminated at 24.5 m gave the required capacity.

Conclusion from the Results

The conclusion to be made from this case is that for the piling to be terminated at any specific depth, adequate depth of boring has to be done below the suggested termination depth in the soil exploration work. This is to ensure that the bearing stratum of required thickness is present below the pile base. In the case of seating in cemented sand and disintegrated rock a minimum of 5 m depth below seating level has to be explored.

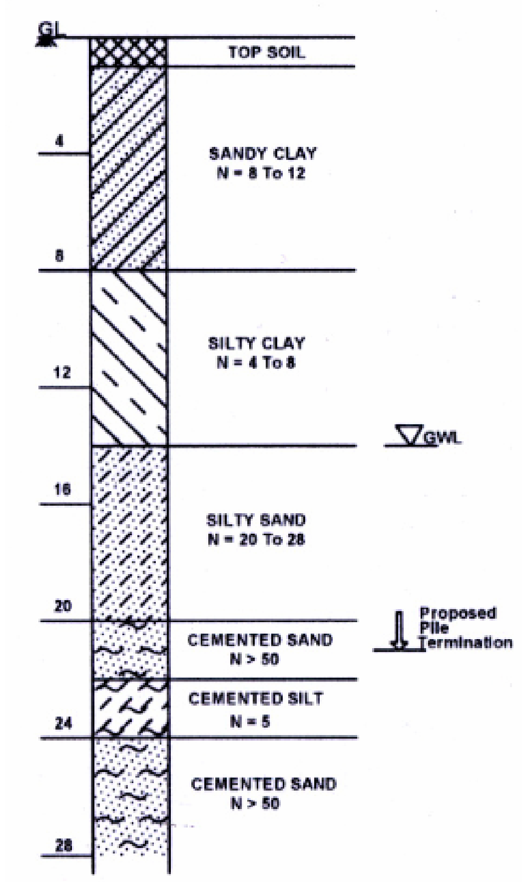

Fig. 3A. Soil Profile Driven Piling

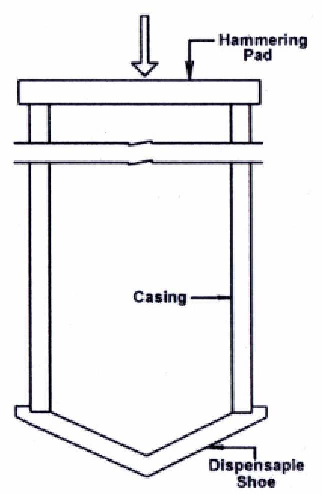

Fig. 3B. Driven Pile System

CASE 4: FAILURE OF THE ROTARY AUGER SYSTEM OF PILING

The rotary auger system of piling is extensively used in many areas. The piles were designed with a length of 25 m, terminating the pile in the very dense cemented sand for the soil profile given in Fig.4A. In the rotary auger the bore is advanced by the auger as given in Fig 4B. The pile diameter adopted is 60 cms. The initial test pile failed at a load nearly equal to the skin friction indicating that the end bearing has not been generated.

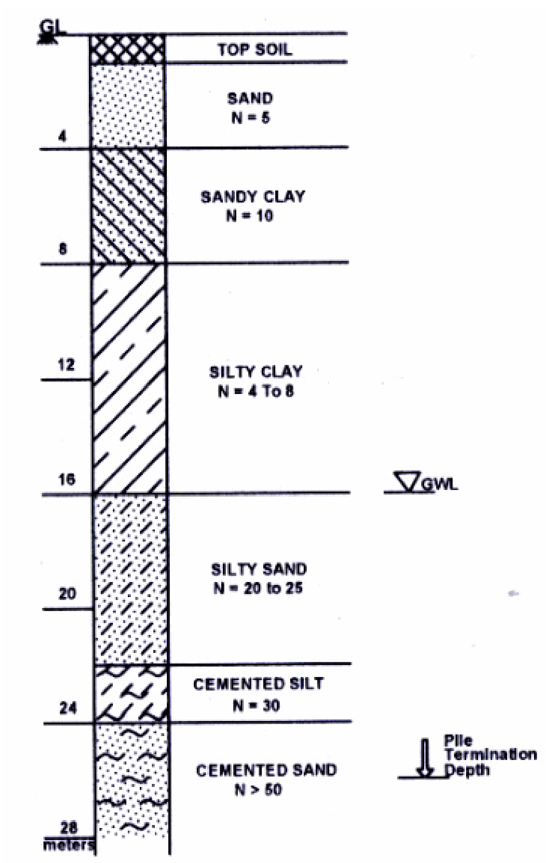

Fig. 4A. Soil Profile Rotary Piling

Failure Analysis

Further boring was done using the same rotary system. To verify the bearing stratum, a Standard Penetration Test was conducted inside the pile bore at the seating depth. The results showed loose soil for nearly 20 to 25 cms at the bottom of the pile bore. It was concluded that in this system of piling, particularly while terminating the pile in layers like cemented sand, loosening of the bottom could take place resulting in non-development of end bearing capacity. This disturbance is caused by the augering process and the suction created while pulling out the auger. The rotary piling system with pile terminated in cemented sand layer of bearing stratum would not be effective.

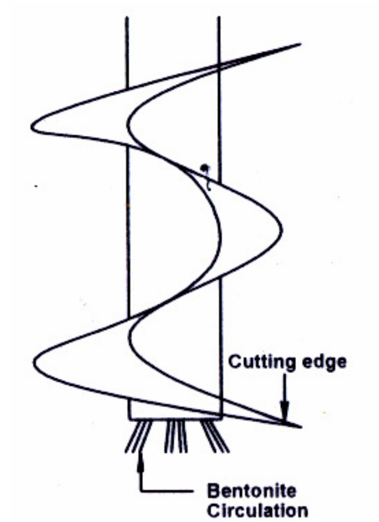

Fig. 4B. Rotary Auger System

Conclusion from the Results

The conclusion to be made in this case is that even though the rotary auger system is efficient and fast, it should be adopted only in areas where the termination layer of the pile is like disintegrated rock/medium/hard rock, which will not be disturbed by the system of piling.

CONCLUSIONS

The failures noted in the various methods of cast-in-situ piling were analyzed in the paper. The likely cause of the failure was studied based on test results and conclusions were made leading to suggestions for adopting the suitable method of piling for each soil condition. The precautions to be adopted in each method of piling have been indicated.