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Case Histories of Bored Pile Foundations

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SYNOPSIS A kind of bored pile with large diameter is being used in civil engineering in China. The maximum length in earth of the pile is greater than 100m. This pile may be built in rock. In the paper, the constructing methods of the bored pile foundation of a bridge and a grade separation are described. Relating the result with its cause, the failure of the bored pile in construction, the cause of the failure and the treatment methods are related.

INTRODUCTION

From the 60s on, a kind of solid bored pile with large diameter have developed in Chinese bridges and buildings. It isn't pier foundation. Its desigh and calculation are according to the principe of pile foundation. The size being various, the diameter is usually 1. 0m to 1. 5m and the length usually is less than 100m. The maximum diameter is greater than 3m and the maximum length in earth is 107m. It may be built in rock. The length that some piles were built in rock are 10m～15m. The constructing methods of the bored pile are as follows:

Embedding Pile Casing

The pile casing is embedded in earth only a few metres. Its functions are protecting the top of drill-hole and maintaining the inside water-level or slurry-level of the drill-hole higher than the outside 1～2m. Another part of the drill hole is without any casing except the upper class a few metres hign.

Drilling Hole in Pile Casing

Drilling hole is carried out in the pile casing and there must be drilling slurry in the drill-hole. The pressure of the slurry in the hole to the wall of the drill-hope can maintain stability of the hole wall. The mud membrane formed on the wall of the hole profits stability of the hole wall, too. Another function of the slurry is to float off the drill residue and exclude it from the drill-hole. The clay made the drilling slurry is usually local clay. For economic reasons, it doesn't usually use bentonite for the constructor to make the slurry, so that the specific gravity of the slurry is usually very big. The specific gravity of the slurry can be 1. 6 in some construction.

Present main methods drilling hole are two types:

1. Rotary Drill Among them normal-circulation rotary drilling can be used in soils or in soft rocks. It is used very extensive in Chinese engineering. It is this drilling that have drilled 8 holes with depth 107m and with diameter of 1. 5m in soils, using a SPJ-300 Type rotary drilling rig. Another kind of rotary drilling, reverse circulation rotary drilling, is used less in Chinese engineering.
2. Percussion Drilling Cross shot bit winched can be used in soils or in rocks to form the drill-hole, but it is mainly used in rocks if the pile must be built in the rocks.

Cleaning out Drill-Hole

After drilling hole is finished, the cuttings of boring, namely the drill residues, must be cleaned up. It is to change from the slurry with cutting of borings to net slurry for friction pile and change from slurry with cuttings of boring to clean water for bearing pile. When the drill-

hole is being cleaned, the inside water-level of the drill-hole must be higher than the outside for maintaining the hole wall self-supporting.

Placing Underwater Concrete with Tremie Method

The reinforcing cage having been placed into the drill-hole, the underwater concrete, whose slump is usually 16 ~ 22cm, is placed in the drill-hole from the bottom to the top with tremie method. Thus the construction of the pile is finished. The following is real examples of this pile foundation.

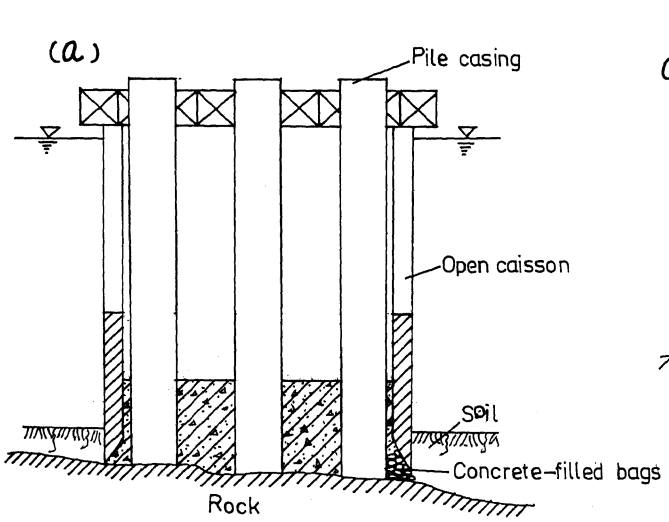
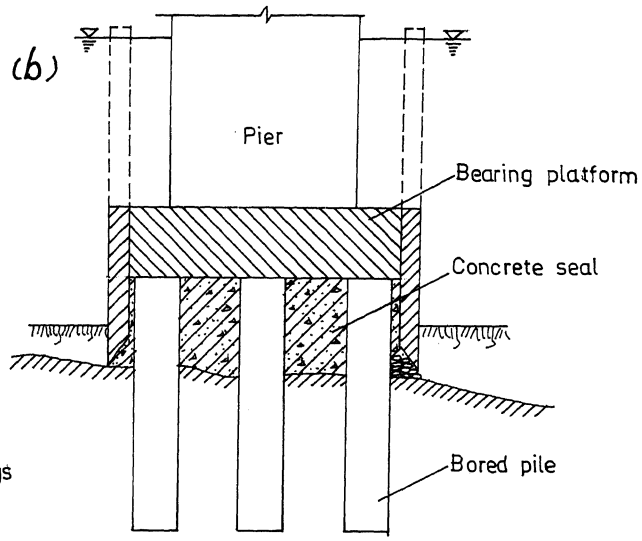


Fig. 1 Construction of Composite Foundation.

A BRIDGE PILE FOUNDATION

The Changde Bridge over the Yuan River was built in the 80s in Chngde, Hunan, China. Its total length is 1408m and there are various spans with 52 spans. The superstructure of the main bridge is prestressed coucrete continuous box beam and its spans are $1\times84+3\times120+1\times84$m with four piers. The piers are all reinforced concrete hollow pier with the height of 17. 4~19. 8m. The foundations were constructed with float open caisson of one dredge well. Among them No. 1 and No. 2 open caissons through overburden layers 10m think were sunk on to the rock stratum, and No. 3 and No. 4 open caissons, for thin overburden layer (1m) and deep water (13 ~ 18m), a method to add some bored piles building in the rock to the open caisson was adopted. There are 7 bored piles with desigh diameter of 2. 5m in each open caisson and the depths building in the rock are 15m or 11m. The foundation to add bored piles building in rock to the open caisson is entitled composite foundation (see Fig. 1). The bored piles are the main part bearing forces in the foundation, and the open caisson with one dredge well behaves like a cofferdam in the construction of the bored pile and the bearing platform.



The constructing methods of the foundation No. 4 are as follows (see Fig. 1):

Making and Floating Open Caisson

The depth of the foundation No. 4 water is 18m, so the floating open caisson which has double steel skin plates is 18. 7m high. Its outside diameter is 16m and the inner diameter is 14m and thickness of the hollow wall is 1m. There are 8 atternate bays in the hollow wall. The floating open caisson were divided into three sections with horizontal planes, the upper section, the middle section and the bottom section, with the height being 4. 5m, 4. 5m and 9. 7m respectively. All weight is 153. 3t.

The floating open caisson was made in a shipyard by the river. It is about 6 kilometres from the bridge to the shipyard. The bottom section was slided into the water at the shipyard slipway and then was floated out to the foundation No. 4 site. Placing concrete in the hollow shoe 1. 5m high and then pumping water into the alternate bays, the caisson bottom section sunk in the water 7. 2m deep and revealed

2. 5m high above the water surface. Then the middle section was put on the bottom section with the cable crane. After Checking, the two section were welded on. The upper section was joined with the same method.

Pumping water into the alternate bays, the open caisson sunk to the river bottom. Then the water in the alternate bays was changed for concrete to design height, as shown in Fig. 1, The floating caisson had become gravity type.

Sunking Open Caisson

Having been dredged in the well, the caisson sunk down through the thin overburden layer on to the rock. Because the rock stratum was uneven, concrete-filled bags for the open caisson stability were installed under the cutting edge by divers.

Installing Steel Pile Casings

A constructing platform of Bailey trusses and woods was installed on the open caisson top. The steel pile casings with diameter of 2. 7m were installed in the open caisson well (see Fig. 1). Its upper part was fixed in the hole of the platform and the lower part was fixed in the concrete ring installed on the rock by the drivers.

Placing Tremie Concrete Seal

At that time there was water in the open caisson well. The tremie concrete seal of 656m^3 was placed with 8 tremies in the well in 20 hours in order that the open caisson and the pile casing was fixed and sealed. The concrete seal was 5. 5m thick.

Constructing Bored Pile

The cross shot bit winched continuously punched the rock in the pile casing. A hole with diameter of 2. 5m or more large was formed on the bottom in the pile casing. The cuttings of boring rock was dredged with suction dredger once a day. The drilling hole 11m deep can be formed in 10～20 days.

The following works were: Cleaning the drill-hole with suction dredger, placing the reinforcing cage in the hole, placing underwater concrete in the drill-hole and the pile casing with tremie method. Thus the pile built in the rock with diameter of 2. 5m was formed.

Constructing Bearing Platform and Pier

Having pumped out the water from the open caisson well, the pile casings above the tremie seal were dismantled and carried away. As above, up to that time the open caisson had behaved like a cofferdam. The reinforcing concrete bearing platform was constructed in the well, namely in the cofferdam, then the pier was constructed. Having finished these works, the hollow wall of the steel open caisson above the bearing platform was dismantled and carried away with underwater cutting and the cable crane.

The above mentioned composite foundation of the Changde Bridge pier No. 4 was used in overburden layer which is thin (about 1m). It can also use in overburden layer which is thick, for example the Yangtze River Bridge in Luzhou, Sichuan, China. Its foundation No. 4 adopted composite foundation, where overburden layer formed by sands and gravels is 23m thick. The depth of the water is 11m. The floating open caisson sunk into the soils 4. 7m deep with 11 bored pile of diameter 2. 3m of building in the rock 11m deep.

This composite foundation can overcome various obstructions in soils and the difference of elevation of rock. It avoids the shortcoming of open caisson and have the advantage of pneumatic caisson. There are some case histories to treat uneven settlement and overcome the difference of elevation of rock. For economic and caisson disease reasons, pneumatic caisson haven' t usually used in China up to now.

When the tremie conerete of the pile of the Changde Bridge foundation No. 4 was being placed, some unusual phenomena were found, for example the tremie once leaked and blocked. According as the past experience, this is an omen having underwater concrete shortcomings. Therefore concrete cores of the bored pile were taken out with core drill at four bored piles (No. 1, No. 3, No. 4, No. 6) among the 7 bored piles. Some shortcomings and breack of the piles were proved to exist. Some engineers, professors and lecturers held a meeting in the site in order to find out the cause and treatment method. After analysis and investigation we knowing the causes to produce the shortcomings and breack of the piles were the tremie to leak and to be blocked in placing the underwa-

ter concrete. The tremie consisted of many sections which were jointed with flange joints. If the flange joints is loosed by suspended force of the ropes in the construction placing, the water can leak into the tremie by water head pressure. The water into the tremie washed off the cement paste and the coarse aggregate still remained in the tremie, so that the coarse aggregate blocked tremie. Up to that time, the tremie bottom must be raised to the surface of the concrete in the drill-hole to poke the blocks in the tremie with a long reinforcement, for the concrete was bathed. This sections of the bored piles must be some shortcomings.

The treatment method was pressure grouting. As above, there had been a drill hole with diameter of 11cm in each bored pile for taking out the pile concrete core. Using the hole with diameter of 11cm, the cement curtain grouting was adopted in the treatment and the net cement grout was pressure into the bored piles. The condition of pressure grout of the

TABLE I. Condition and Consuming Cement of Pressure Grout of Bored Pile Foundation No. 4

Pile Number	Grout Hole Depth (m)	Grout Section Length			Water Cement Ratio of Grout		Consuming Cement			Grouting Time (hour)
		From (m)	Up to (m)	Length (m)	Start	End	Total (kg)	Net (kg)	Unit Value (kg/m)	
No. 3	21.99	21.99	1.21	20.78	3 : 1	0.5 : 1	1650	754.7	36.3	7.5
No. 4	20.36	20.36	1.25	19.11	1 : 1	0.5 : 1	700	137.0	7.2	3.83
No. 1	21.58	21.58	1.30	20.28	1 : 1	0.5 : 1	1050	445.0	21.9	3.67
No. 6	21.90	21.90	8.96	12.94	1 : 1	0.5 : 1	550	188.7	14.6	2.0
Total							3950	1525.4		

foundation No. 4 are tabulated in table I. It is 1525. 4kg to convert the cement grout to squeeze into the piles into cement. It indicates two points:

1. The bored piles were again proved to exist some shortcomings.
2. The bored piles were reinforced.

The practice have proved the pressure grout correct. From open to traffic on, settlement observation to the pier have indicated that the pier is normal. The treatment is successful

SOME BORED PILE ON A FREEWAY

The Guangzhou-Shenzhen-Hongkong superhighway is a freeway. It is being constructed now. There are a lot of bridges, grade separations and interchanges on the freeway and their foundations usually adopted the bored piles, there being thousands bored piles with diameter of 1. 0m, 1. 2m and 1. 5m. The most deep pile in the soils is 70m, building in the rock 1. 5m

The Shangchuanlu simple grade separation over the freeway have two spans (2×25m) The piers are pile bents of friction pile. The length of the piles with diameter of 1. 2m is 20m or 30m. A VRM-1500 type driller that made in Germany was used in the construction of these piles. There are all steel casing from the top to the bottom in the drill-hole.

The steel casing is given a continuous semi-rotary motion to keep it sinking as the borehole is advanced. The diller is a grab and percussion-type rig. Some cross shot bit are provided for rock conditions.

The drill-hole having finished with the driller, there Were some water in the hole, so that the underwater concrete was placed with tremie method. Quality of the pile concrete was once examined with small strain dynamic method and its instruments. The couclusion is that" the piles can be used". But according as the past experience, there must be some shortcomings in the pile concrete and can't be used.

Therefore concrete cores of the piles were taken out with core drill. The photos in Fig. 2 area part of the concrete cores of the bored pile No. 4. The photos show us the most poor section, the poor section and the good section of the

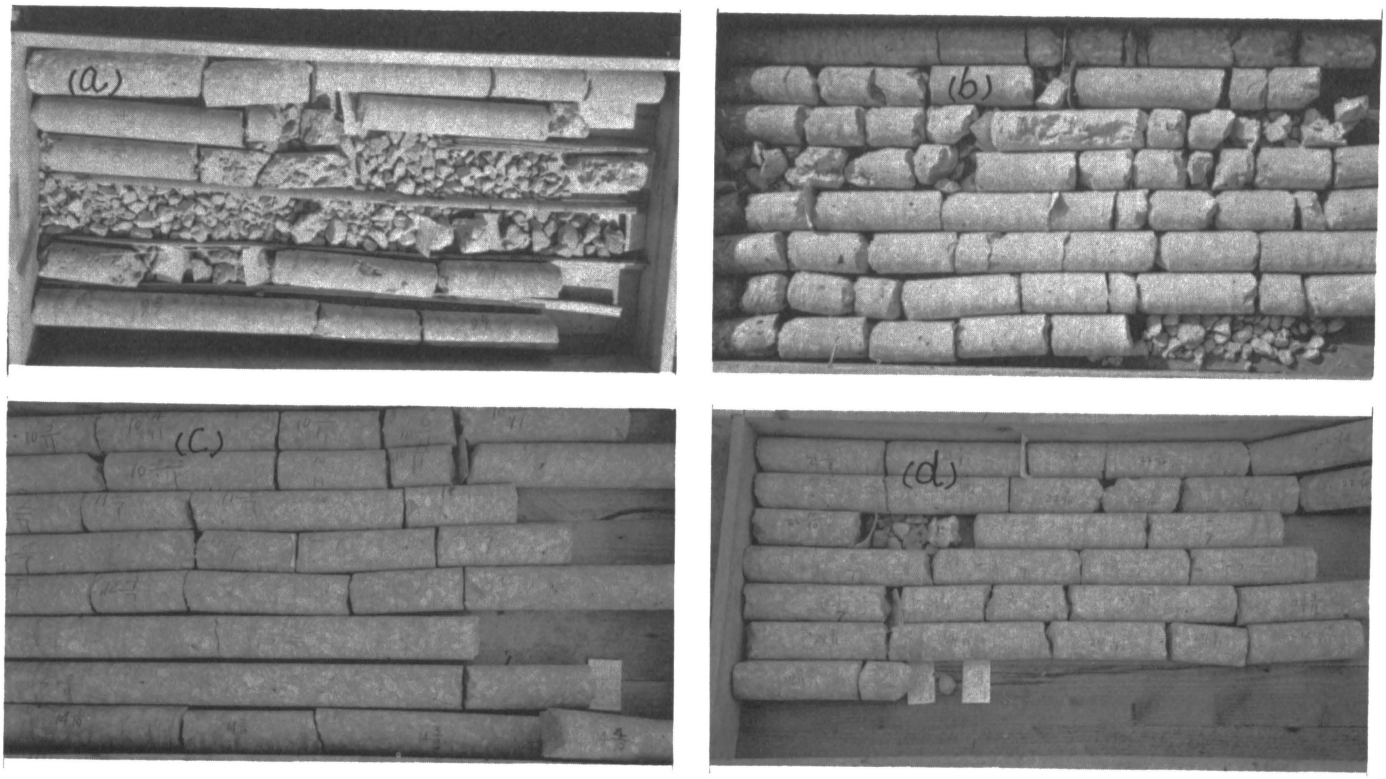


Fig. 2. Part of Concrete Cores of Bored Pile No. 4

pile. From photo (a) we know that the ecncrete quality of some sections of the pile No. 4 were such bad that there weren't any cement paste. The bored pile No. 2 isn't better than pile No. 4. Other two piles is better, but there are some shortcomings, too.

What's the cause of these piles failure? As is known to us, to place underwater concrete must be careful, experienced and the equipments must be in good condition. The tremie concrete was usually finished for the pile of 30m long in 2 to 3 hours. Being carried to the site from abroad, the driller was used at the simple grade separation at once. The people weren't familar with the advanced driller. The workers had no skill in using its some part. It took them 11. 5 hours to place the tremie concrete in the pile No. 4 of 29. 67 long, once stopping three times for 60 , 90 and 125 minutes. For the economic reasons, some parts of set of the driller, such as the equipment to place concrete, hadn't bought from abroad and was self-made. It made the work slow, too. The pre-setting concrete blocked the tremie, then the tremie must be raised above the surface of the concrete to clear away the blocks, so that the concrete was bathed and the remains of the concrete were only the coarse aggregate. The treatment method will be pressure grouting. After treatment, the supervising engineers will check once again. Having been qualified, the bored pile can be used.

CONCLUTION

The bored pile with big diameter in China have the advantages of big bearing capacity, goo stability, no casing construction and low cost. Its main defect is that there are concrete shortcomings in approaxmate 1% to 2% pile as subaqueous concreting. Supervision and check having severely been carried out, the shortcomings of the bored pile can usually be found. The bored pile having shortcoming can be reinforced and used. Therefore the Chinese engineers still like to adopt it in civil engineering.