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Case History on Dewatering Problems in Shanghai

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SYNOPSIS This paper deals with the dewatering problems in soft soils; it also describes the historical review of the dewatering work in the Shanghai region. In some cases, the measures taken in preventing the settlement of the neighbouring buildings have been introduced.

INTRODUCTION

It is very difficult to carry out the dewatering work in the complicated soft soils of Shanghai, especially to guarantee the stability of the foundation pits and trenches under the ground water table. The author has investigated the geological conditions of soft soil of Shanghai and with the domestic equipment, designed a set of vacuum dewatering system suitable for the Shanghai region and other districts. After many trials, much improvement has been made. These procedures are used not only in Shanghai but also in other soft soil districts. This paper introduces some case histories of performance and consulting work of many projects by author's own experience.

GEOLOGICAL CONDITION OF SHANGHAI

Shanghai is the largest industrial city in China. It is situated on the east coast of the China Sea, at the front edge of Yantse Delta. The elevation of the flat-lying city area is 3 - 4 m above the sea level. The Huangpu River and Suzhou Creek, both being the outlets of Taihu Lake, are the two chief tide waterways of the city.

In the Shanghai area, unconsolidated materials, about 300 m thick, of alternating marine and continental facies were deposited on the bed rock during the Quaternary Period. The upper portion of 150 m is composed of clayey soil and sand of littoral and fluvial delta facies; the lower portion of 150 m consists of alternating sand layers of fluvial facies and variegated lacustrine facies.

This paper only concerns the soil layers of 30 m under the ground surface. In urban district of Shanghai, it can be roughly devided into two types: (1) along the banks of the Huangpu River and Suzhou Creek and the northeastern part. There is a layer of sandy silt of 3 - 12 m thick under the surface layer (the thickness may be 2 - 3 m), and the underlying layers are the typical Shanghai soft silty clay and soft clay; (2) in the other districts, especially in the southwestern district, the soft silty clay of 10 - 12 m thick is directly underneath the surface layer, but laminated with thin layers of finest sand. The soft clay layer is about 10 - 30 m thick, and its thickness varies with different districts. There is a dark green stiff clay layer about 2 - 3 m thick and stiff brown silty sand about 2 - 3 m thick which is the bearing layer of the pile foundation, Probably 20 - 50 m underneath the ground surface.

THE HISTORY OF DEWATERING WORK IN SHANGHAI

Before liberation (1949), when trenches for installation of sewer lines were excavated, the timber piling was generally used for shallow excavation and the steel sheet piling for deep excavation, but owing to the high ground water table, quicksand was usually discovered. It is very difficult to excavate to expected depth, as the workers performed uneasily and even sank their feet into the soil. Sometimes, the short sheet piling sank together with the bank. These facts effected the quality and schedule of construction. When constructing the sewerage pumping stations, we had the same difficulty of excavation in quicksand. The cracks of neighbouring buildings often occurred and the pumping station could not conform to the designed depth.

After liberation, in order to improve the labourers' working condition, the Party and Shanghai Municipal Government have determined to reform the construction method in excavation. The wellpoint system was investigated to cope with the difficulty in quicksand by the Technical Department of Public Works Bureau. After studying the foreign information, a small test was carried out on May 16, 1951. The size of the test pit was 3.7 m X 3.7 m. When the pit was dug to 46 cm from the ground surface, seepage occurred. The pit was protected by wood shoring at 1.5 m deep, but the ground water came out rapidly and continuously. Next day, only 15 cm of sloughing soil was dug manually, and it took 4 hours and 19 minutes. It was discovered that the finest sand moved slowly too. Fissures were shown on the surface of the ground outside of the pit, surely quicksand encountered, and so digging work stopped. The heave of the bottom was 5 cm. In order to test the possibility of dewatering by wellpoints, a 1.2 m X 1.8 m small test hole was made by driving 3.66 m steel sheet piling in the previous pit, three 5 cm ø 5.2 m riser 1.8 m long wellpoints were installed on the three corners of the small test hole. The coarse sand was carefully filled around the wellpoints connected by a 76 mm header pipe from which the water was pumped out by a 5 cm ø self-priming centrifugal pump. Before pumping, prior to digging to the depth of 1.5 m, the sloughing soil occurred again. Then digging stopped and the heave was still 60 cm. Next morning, pumping and digging 1.5 m started again. It proved that wellpoints were effective in quicksand district.

An intermediate test was carried out in the construction of a sewerage pumping station in October 1952, the construction area was 342 m^2, a depth of 5 m from ground surface must be excavated. To prevent the quicksand by our previous experience acquired in Shanghai, more than 10 m steel sheet piling must be driven in. There was an enclosing wall in the vicinity of the construction site. Inside the enclosing wall there is a two-storey building. In order to guarantee the safety and process of the project, two layers of sheet piling are used. The first layer is a timber sheet piling of 8 X 20 X 300 cm, to excavate 1.83 m of top soil; the second layer is a steel sheet piling of 6.1 m in length. Between these two layers of sheet piling, a ring of wellpoint system is installed. The distance between them is 1.52 m and is pumped by two 7.5 cm ø self-priming centrifugal pumps. This project was successfully constructed by method described above.

In April 1955, an improved equipment of self-jetting vacuum wellpoint system was used in the pier of a bridge, the equipment was co-designed by the Chang Jiang River (Yantze River) Water Conservation Committee. The capacity of the vacuum pump was increased to 4.4 m^3/min and the air-water separator was used in order to fit the Shanghai's geological condition .

The excavated area of the pier was 400 m^2, excavating depth was 4.5 m, along the river a cofferdam was constructed, and the other sides were excavated by an open cut with the vacuum wellpoint system in the silty soil. No steel sheet piling was used. The slope of the excavation is almost vertical. The bottom of the pit was dry, and the labourers worked in dry condition, so the efficiency of excavation was greatly enhanced as compared with the old method.

Then the equipment was set up as a pattern called the Shanghai Wellpoint System, and has been widely used since then.

Eductors with small diameter were developed in 1960's and also proved to be effective. In saving energy, water-jet pumps and auto-diaphram pumps were developed in 1970's, mainly used in sewerage lines and pumping stations. Electro-osmosis was used in some projects with well-point system or eductors.

SOME CASE HISTORIES ON DEWATERING

Sewerage Engineering -- the construction of sewerage lines, including pumping station are associated with many quality problems before wellpoint system is used, such as the crack of sewer base; could not be reached to the designed depth by ordinary methods of excavation; or by open caisson, the extra-sinking of open caisson often occurs. These problems are solved after dewatering has been adopted.

Lock Engineering -- during the excavation of a lock, quicksand occurred before the designed depth of 20 cm, rubble stones were poured into the foundation pit and was quickly accomplished. Three months after the operation, the wing wall collapsed due to piping, so seepage isolation method was used by dewatering for repair. It has proved that the quality is still good for more than 20 years.

Drydock Engineering -- a drydock was constructed alongside the Pearl River in the suburb of Guang Zhou in 1963. The bottom of excavation was 215 m long, 44 m wide and 11 m deep, and its top was 260 m long and 120 m wide. The construction procedure was building a cofferdam, excavating under water with a dredger, and dewatering by vacuum wellpoints because of soft cohesive soil. The key points of this dewatering work were: (1) using a 30 cm casing with water jet toward the expected depth, then decreasing the jet water pressure, inserting wellpoints in the casing, filling sand strictly according to recommendation, then pulling up the casing and sealing the top of wellpoint with clay. Actual practice proved that there were no clogging of wellpoints during operation for more than one year; (2) increasing the capacity of vacuum up to 11 m^3/min in order to prevent air leakage in the system. The vacuum dewatering kept the stability of the slope, measurement showed that the strength of every layer of soil had increased. The average settlement of the ground surface was 33 cm and average displacement was 10 cm.

Civil Engineering -- numerous foundation pits of industrial and domestic buildings are now excavated in dry with dewatering without any protection sheet piling and the stability of the pits are maintained.

MEASURES SHOULD BE TAKEN TO PREVENT THE SETTLEMENT OF NEIGHBOURING BUILDINGS

It had been found in Shanghai that the demage of building was caused by excavation with dewatering, but now measures are commonly taken as follows:

1. The foundation pit of an ice storage in the vicinity of a standing 6 storey building was only 7.45 m; the bottom of the ice storage was 3.1 m underground level. A blind creek passed through part of the pit, and digging of the peat of the blind creek was done before excavation, but when the digging reached to 3.0 m, subsidence of the ground occurred. The creek was filled so as to protect the 6 storey building and then a dewatering system was used. On one side of the building, the intervals of the wellpoints were enlarged and even some of the wellpoints were shut. The storage was raised and preloaded by water in the storage reservoir. All of these measures guaranteed the safety of the building. During pumping, the settlement of one side wall base of the building was 2.5 mm and another side was 1.0 mm; after grout of reservoir of the storage and filling of water, the corresponding settlement was 50 mm and 40 mm respectively. Because of even settlement, no fissure can be found in the building.

2. A sewer line was required to dig 4 - 4.5 m, 2 rows of wellpoints were adopted, the distance between the header pipe and the side wall of two residential buildings was only 2.0 m. In order to protect any damage to the buildings, pumping was also choosed to prevent the grains of soil carrying out by pumping. Longer riser pipes were used in order to flatten the drawdown curve and incresed the influence scope, consequently, there was no fissure found during three months'pumping. If sewer lines passed through an important building, recharging method usually has to be adopted in order to guarantee the safety of the building.

3. a 5 storey office building of 1930's, of raft foundation which was 68 X 36 m at the depth of 1.52 m under ground surface, a 7 storey store was built nearly in 1982. The distance between the excavated pit and the old raft foundation was only 12 m, the depth of the pit was 3.5 - 4.3 m. In dewatering, a row of wellpoint was used along the old building and recharged with water, a 44 ton, 4.3 m wide back-crawler crane was used. The pressure on the crawler was 10 tons. Attention was paid to the dewatering and recharging, so the settlement of the old building was very small.

CONCLUSION

Dewatering engineering has started in Shanghai since 1950's it experienced a lot of engineering work. Practice proved that the vacuum dewatering was effective in Shanghai.

The experience of dewatering in soft soil are: (1) increasing the capacity of vacuum and handling the vacuum in the system; (2) choosing suitable screens and filters in order to prevent clogging.

The recharging technique developed in 1970's now are adopted widely. Water-jet pumps are also used to the sewerage lines and pumping stations to save energy. The dewatering technique also experienced some large, deep and important projects and played a great role in 1980's.

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