# Comparison of dewatering schemes for foundation pits under complex hydrogeological conditions

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**Abstract.** With the advancement of urbanization in China, more and more urban utility tunnel are being constructed in complex geological and hydrogeological environments. Dewatering during the construction of tunnel pits is often a big technical problem. Taking the construction of a utility tunnel in Sanya, Hainan Province, China as an example, this paper compares several technical methods of coral stratum and silty sand stratum dewatering in this area. The characteristics of the methods and their advantages and disadvantages were analyzed. One of these methods has been implemented by engineering dewatering, and the effect is remarkable.

## 1. Preface

With the development and rapid progress of urbanization, we have brought about convenient living conditions and superior quality of life. At the same time, there must be problems with the expansion of urban space and the promotion of infrastructure construction. In recent years, with the contradiction of insufficient infrastructure capacity brought about by the rapid advancement of urbanization, the intensive construction of municipal pipelines and the improvement of pipeline construction standards have become problems that we must solve [1]. The construction of the integrated pipe corridor becomes the major trend of the integrated layout of municipal pipelines.

The geological structure of coastal sites in Sanya is mainly composed of marine formations, which often develop coral reef formations of with different thickness and coral reefs are a kind of special engineering construction sites, which are influenced by geological genesis, biological action, marine hydrodynamic environment and geological environment evolution. This kind of site has complex hydrogeological conditions, high groundwater level and abundant water level content. During the excavation of the integrated pipe corridor in this area, it is unavoidable to carry out the foundation pit dewatering.

## 2. Project overview

The utility tunnel project is located at Shengli Road in Sanya City, north from the Yingbin Road, south to the Jianang Road, with a total length about 3.3 km (figure 1). The design elevation is about -4.5 m to -3.5 m (excavation depth is approximately 7.0 m). Cover soil thickness is 3.0 m. Due to the large amount of water inflow into the foundation pit, traditional bored pile supporting measures and the well point dewatering cannot meet the corresponding requirements, which has great influence on the project schedule and construction safety.


**Figure 1.** Project location.

## 3. Engineering geology

### *3.1. Stratum*

The total length of the tunnel is about 3.3 km, and the whole section of geomorphologic unit is marine sedimentary terrace. The foundation soil layers are sands and clays of the Quaternary Holocene and Pleistocene. Along the line there are low-to-high-rise buildings (structures) and underground pipelines distributed .The ground elevation (orifice) is about 3.05 m to 4.41 m, the terrain is relatively flat, the whole is low in the south and high in the north; the west is about 180 m from the South China Sea.

The strata of the area are divided into 10 geological units, mainly marine sedimentary clay and sand, which are described as follows:

(1) Miscellaneous filling: Poor particle size distribution, uneven soil quality, surface thickness of about 0.3m of concrete.

(2) Silt: There is a lot of distribution along the line and partial loss. Poor particle size distribution, with a small amount of coarse sand, a small amount of powder cohesive.

(3) Coral Debris: Part of the borehole was revealed. The soil is uneven, containing fine quartz sand and silt, corals are crushed and light, visible shell debris.

(4) Silty clay: Part of the borehole exposed. Occasional shell debris, organic content of 6.5% ~ 9.6%.

(5) Silty clay: Distributed in some area, toughness is low, dry strength medium, with a small amount of fine sand.

(6) Silt: The soil is homogeneous, the particle size is uniform, the particle size distribution is poor, and a small amount of powdery clay particles are contained.

(7) Sand: Distributed in some area. The soil is homogeneous, the sorting is general, and the subangular shape contains a small amount of powdery clay particles.

(8) Silty clay: relatively uniform soil, the cutting surface is smooth, toughness, dry strength medium.

(9) Silt: the soil is relatively uniform, the particle size is relatively uniform, and contains a small amount of powder and clay particles.

(10) Silty clay: Most boreholes uncovered. The soil is more uniform, the cutting surface is smooth, toughness and dry strength are high.

### 3.2. Hydrogeological conditions

The main aquifers in the area that may affect the construction of the pipe gallery are the (2), (3), (6), (7), (9) layer pore dive, which is a strong permeable layer; the (4) layer, the (5) layer, the (8) layer and the (10) layer are weak permeable layers. The (1) layer is water-permeable and water-free. According to the comprehensive analysis of the engineering geological profile and measuring the water depth in the borehole, the groundwater of this section is not completely cut off by aquiclude, and the layered aquifer may have a hydraulic connection. The groundwater level varies from 1.2 m to 4.0 m, and the excavation depth of the foundation pit varies from 7 m to 10 m. It is difficult to fully seal for the dewatering due to the influence of sub-construction, exit of tunnel, current pipeline, and traffic organization. The hydrogeological conditions in the entire site are complex.

To sum up the above preliminary analysis, the work of dewatering and water stoppage is one of the important engineering technical issues that cannot be avoided in the implementation of this project [2].

## 4. Main dewatering scheme

Foundation pit dewatering is an important step to ensure the quality of the foundation. There are many common methods for foundation pit dewatering. There are:

### *4.1. Water well dewatering in open ditch*

Open Ditch is a kind of drainage method for dewatering water wells (figure 2). It mainly excludes unconfined water, construction water and precipitation. In areas with rich groundwater, if this method is used alone, it will be more difficult to support the construction of anchorage and shotcrete network because of the large amount of seepage water in the slope of foundation pit. Therefore, this method is not applied to the support of foundation pit slope in high water level area [3].

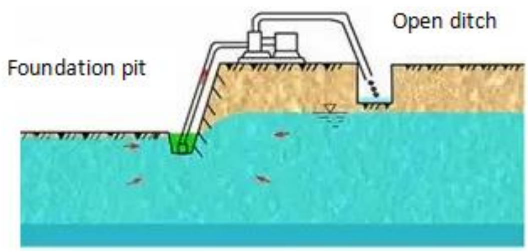


**Figure 2.** Water well dewatering in open ditch.

### *4.2. Mildtype well point dewatering*

Mildtype well point dewatering is suitable for places with small pit area and low water level (figure 3). This method generally reduces the water level between 3 and 6 meters. If the dewatering depth is more than 6 meters, a multistage well point system can be adopted in theory [4].

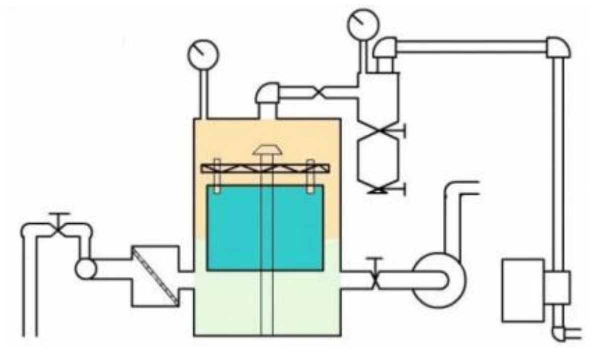

**Figure 3.** Mildtype well point dewatering.

*4.3. Electric seepage well points dewatering*

Electric seepage well points are suitable for fine granular soils with low permeability, such as clay, subclay, silt and silty clay. The permeability coefficient of these soils is less than 0.1 m per day, and it needs to be applied in combination with light or spray wells (figure 4).

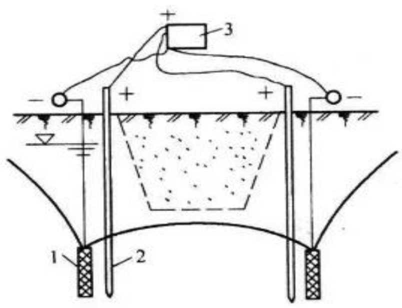


**Figure 4.** Electric well point dewatering (1, wellpoint 2, electrode 3, DC power supply).

*4.4. Spray well point dewatering*

The injection well point system can produce the vacuum degree of 250 mm mercury column at the bottom of the well point. The permeability coefficient of soil layer is the same as that of light well point, which is generally 0.1~50 meters per day. However, the pumping system and injection well pipe are very complex, the failure rate of operation is high, and the energy loss is high, and the cost is higher than other well point methods [5].

*4.5. Pipe well point dewatering*

Pipe well point is suitable for high permeability stratum, ground water rich stratum and light well point. The water discharge per pipe well can reach 50~100 cubic meters per hour. The permeability coefficient of soil is within 20-200 meters per day (figure 5).

**Figure 5.** Pipe well dewatering.

*4.6. Deep well point dewatering*

Deep well point dewatering is a method that is widely used in foundation pit support. Its advantages are large displacement, large precipitation depth and large precipitation range. For the cases where the permeability coefficient of sand and gravel layer is large and the thickness of water permeable layer is large, light well point and injection well point are generally not effective, and this method is most suitable.

## 5. Dewatering scheme of this project

In this project, the underground aquifer has a large permeability coefficient, shallow groundwater burial and large water discharge. The fifth of the above methods is adopted.

### *5.1. Groundwater pumping test*

In the project, a well test and trial pumping experiment was carried out. The local sand is medium and coarse sand, the lower layer (3~7 meters below the ground surface) is about 4~5 meters, the layer underwater self-stability is poor, the well is easy to collapse and shrink. Some operation technology is required to control Well construction. Three wells were drilled, two wells were completed, one of them was not in place, and one of the two wells was successful (only 3.5 meters).

In the case of pumping experiments, the underground hydraulic connection is very close. There are two conditions to be paid special attention to: 1, the horizontal supply of vertical water runoff in the direction of the vertical section; 2, the external plentiful recharge at the opening of the unclosed section of the tensile steel sheet pile. The drop in the well in the pumping water and the water supplement in the pipe well are very good, but due to the high water head difference (3~4 m) of the clear water runoff and the opening , the dewatering effect of the single well is not obvious, but the water level of the pumping water is obvious.

### *5.2. Water pumping measures*

It is difficult to determine the displacement of a single well accurately according to the pumping situation of a single well. According to the analysis of the soil geological report, the water submersible pump of a single well needs to be between 3.0 and 5.5 kw (considering that the cross-sectional cutoff well and tensile steel sheet pile are not closed).The layout of single well should be decided after pumping water from continuous working surface in the later stage. In addition, drainage channels (or drainage pipes) should be provided outside the tensile steel sheet pile, which can effectively discharge the drainage of the lift in the pit and ensure effective drainage

### *5.3. Other special solutions*

- The vertical section interceptor must be encrypted, or double-row, multi-row dewatering scheme;
- If the steel sheet pile is not closed (or leaking section), it needs to be increase the density of dewatering wells or add drain wells on the outside or an external water stop curtain;
- To ensure the stability of the construction precipitation power supply in the pumping operation process, the backup power supply scheme should be considered if the power is used.
- Other emergency plans for groundwater (safety emergency plan).

## 6. Dewatering effect evaluation

After the formation of the enclosure structure in the deep foundation pit of this project, by adopting the artificial high-pressure punching and well-spotting technology, the construction of the structural floor was completed in only 20 days, and the expected construction schedule requirements were achieved. The change of water level outside the pit has been controlled within the allowable range of the design, indicating that the on-site pumping is very effective and the groundwater level is controlled. The hydrological parameters were calculated by a professional technique and the model was verified to make the software simulation close to the dewatering under actual geological and hydrological conditions. The layout of the wells is optimized to ensure that the dewatering time and dewatering space meet the specifications in effect. There is no leakage or piping in the entire process of foundation pit construction, which satisfies the construction requirements of the structure, and truly realizes the concept of construction management based on pre-control.

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