A Discussion on the Adverse Geological Problems and Prevention Measures of the Foundation of the Yangtze River Overcrossing Transmission Tower in the Jingjiang River Section of the Yangtze River

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Abstract. The Yangtze River overcrossing transmission tower is the top priority for power transmission lines. For the foundation of overcrossing transmission towers in different geological regions, it is necessary to design based on specific local geological conditions. In recent years, most of the Yangtze River crossing projects have been distributed in Anhui and Jiangsu provinces in China. There is great potential for setting up new power transmission channels in Hubei province. Especially, the Jingjiang section is an extremely important waterway artery. Therefore, it is of great significance to conduct in-depth research and summarize the basic geological conditions of the Jingjiang River section in Hubei Province. This study investigated the Yangtze River's long-span overcrossing transmission tower and its structural type built in the past 20 years. The geological problems of the Yangtze River overcrossing transmission tower in the middle reaches of the Jingjiang River were studied. The landform, formation lithology, geological structure and earthquake, hydrometeorological characteristics, rainstorm flood characteristics and hydrogeological conditions of the Jingjiang River in the middle reaches of the Yangtze River were summarized. The unfavourable geological conditions of the project were clarified. To address these problems, the anti-seepage and anti-scour engineering measures of the tower foundation were discussed, which could provide a basis for the selection and design of new channels of the Jingjiang River section. This study reveals that for long-span overcrossing transmission towers and anchor towers, it is suggested to use drilled pile foundations. If the distance from the embankment is close, a certain anti-seepage treatment should be adopted around the pile cap of the tower foundation, and the foundation around the tower base should be reinforced.

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1 INTRODUCTION

In the stage of "the 10th Five-year Plan" in China, the "West-East Electricity Transmission" project has formed three transmission lines in the north, centre and south [1]. The central corridor is mainly used to send hydropower from the Three Gorges and the trunk and tributaries of the Jinsha River to East China. In this case, the transmission lines inevitably need to cross the Yangtze River. The long-span overcrossing transmission tower of the Yangtze River is technically complex and difficult to construct, thus it becomes the top priority of the transmission line [2]. This paper investigated the Yangtze River overcrossing transmission towers constructed in the past 20 years and their structural types. Table 1 shows the Yangtze River crossing projects in the past 20 years. It can be seen that most of them are distributed in Anhui Province and Jiangsu Province, while there are fewer in Hubei Province [3-6]. Therefore, there is great potential for setting up new transmission channels in Hubei Province.

Currently, there are three types of tower structures used for long-span river crossings, including the combined section angle steel tower, reinforced concrete tower, and steel pipe tower. The foundation types for these three tower structures are different, and the design needs to be based on the specific geological conditions of the area. Therefore, in-depth research and a summary of the foundation geological conditions in the Jingjiang River section of Hubei Province are important and can provide a basis for the selection and design of new long-span river crossings in the Jingjiang River section. The Jingjiang River section is located in the middle reaches of the Yangtze River, from Zhijiang in Hubei Province to Chenglingji in Yueyang County, Hunan Province. It is 347.2 km long [7], out of 1062 km of the Yangtze River in Hubei Province. As the Jingjiang River flows through the ancient Jingzhou area, it is commonly known as the Jingjiang River. The Jingjiang River section is an important waterway from Chongqing to Wuhan and Shanghai. Therefore, the main objective of this paper is to study the geological issues of long-span overcrossing transmission towers in the Jingjiang River section of the middle reaches of the Yangtze River, which can provide a geological basis for new long-span river crossings.

Table 1. The Yangtze River long-span project built in the last 20 years

Serial Number	Project	Voltage /kv	Longest Span Spacing/m	Tower height /m	Start-up Time	Structure type
1	Wuhan-Nanchang Line, Baojialin Yangtze River Crossing	1000kv	1728	325	2023	Steel Pipe Structure
2	Jiangsu Fengcheng-Meili Line, Jiangyin Second Yangtze River Crossing	500kv	2550	385	2023	Steel Pipe Concrete

3	Nanyang-Jingmen-Changsha Line, Luoshan Yangtze River Crossing	1000kv	2413	371	2022	Steel Pipe Structure
4	Baihetan-Zhejiang Line (Baizhe Line), Jiangjin Yangtze River Crossing	±800kv	1635	189.2	2022	Steel Pipe Structure
5	Baihetan-Zhejiang Line (Baizhe Line), Chizhou Yangtze River Crossing	±800kv	2354	345	2022	Steel Pipe Structure
6	Baihetan-Jiangsu Line (Baijiang Line) Jiangjin Yangtze River Crossing	±800kv	1511	148.8	2022	Steel Pipe Structure
7	Baihetan-Jiangsu Line (Baijiang Line), Wuhu Yangtze River Crossing	±800kv	2100	278.2	2022	Steel Pipe Structure
8	Dongzhou-Chongming Line, Shanghai Chongming Yangtze River Crossing	500kv	1690	204	2022	Steel Pipe Structure
9	Changji-Guquan Line (Zhun Dong-Hua Dong), Tongling Yangtze River Crossing	±1100kv	1790	225.2	2018	Steel Pipe Structure
10	Lingzhou-Shaoxing Line (Lingshao Line), Chizhou Yangtze River Crossing	±800kv	2269	280.2	2016	Steel Pipe Structure
11	Wan Dian Dong Song Huainan-Shanghai Line, Tongling Yangtze River Crossing	1000kv	1135	277.5	2013	Steel Pipe Structure
12	Jinping-Sunan Line (Jinsu Line), Hujiatan Yangtze River Crossing	±800kv	1639	190.4	2012	Steel Pipe Structure
13	Jinping-Sunan Line (Jinsu Line), Xinjiyang Yangtze River Crossing	±800kv	1931	223	2012	Steel Pipe Structure
14	Xiangjiaba-Shanghai Line (Xiangshang Line), Xinjiyang Yangtze River Crossing	±800kv	2052	242	2009	Steel Pipe Structure
15	Xiangjiaba-Shanghai Line (Xiangshang Line) Zhayinggang Yangtze River Crossing	±800kv	1733	204.3	2009	Steel Pipe Structure
16	Nanjing Sanchawan-Longwangshan Line Sanjiangkou Yangtze River Crossing	500kv	1770	249.5	2007	Steel Pipe Structure
17	Qianjiang-Xianning Line (Qianxian Line) Shijitou Yangtze River Crossing	500kv	1660	203.7	2006	Steel Pipe Structure
18	Chuzhou-Ma'anshan Line (Chuma Line) Ma'anshan Yangtze River Crossing	500kv	2050	257	2006	Steel Pipe Structure
19	Taixing-Doushan (Taidou Line) Jiangyin Yangtze River Crossing	500kv	2300	346.5	2004	Angle Steel

2 GEOLOGY OF THE JINGJIANG RIVER SECTION

2.1 Topography and Landforms.

The area along the Jingjiang River section of the middle reaches of the Yangtze River is mainly characterized by terrace landforms and primary river terraces. The terrace landform is undulating with gentle waves, and the top of the terrace is flat, with a ground elevation of 36-56 meters. There are broad and gentle gullies formed by erosion and scouring, and the area is mainly composed of dry land, paddy fields, and forests, with some ponds and shrimp ponds scattered around. The primary river terrace is flat with a ground elevation of 33-39 meters, with sporadic terrace land, mainly dry land and paddy fields, and ponds and shrimp ponds are often found in between.

(1) Geological Strata of Terrace Landform

The geological strata of the terrace landform are mainly alluvial cohesive soil, with a deep soil layer. If building a tower, the tower site is mostly distributed in paddy fields and dry land. The upper layer is mostly alluvial silt clay, with a yellow-brown or grey-brown colour, and is mainly plastic to hard plastic. There are also some slightly dense to moderately dense sand layers in some cohesive soil layers, and the thickness of the soil layer is generally greater than 20m.

(2) Geological Strata of Primary River Terrace

The geological strata of the primary river terrace are mostly alluvial cohesive soil, loess, and sand layers, mainly grey-brown and yellow-brown soft plastic cohesive soil, gradually transitioning downward to coarser particle soil layers, with a binary structure feature. The buried depth of the pebble and gravel layer is generally greater than 20m, and it is underlain by the third series of mudstone, silt sandstone, and Permian limestone. The buried depth of the bedrock is mostly greater than 30m.

2.2 Stratigraphic Lithology

Along the Jingjiang River section of the middle reaches of the Yangtze River, the rock and soil layers are mainly composed of Quaternary Holocene (Q4ml) arable soil, Quaternary alluvial (Q4al+pl) silt clay, silty clay, fine silt sand, and Upper Cretaceous Runmagan Formation (K2p) sandstone, siltstone, and Cambrian limestone. The specific descriptions from top to bottom are as follows:

1. Layer of fill soil and arable soil (Q4ml): brownish-yellow, slightly moist, loose, with a surface containing a large number of plant roots, with a thickness generally of 0.3-0.5m. This layer is mainly distributed on longitudinal and transverse levees and is mainly cohesive soil. The layer thickness is generally less than 3.0m.

2. Layer of silt clay (Q4al+pl): brownish-yellow, slightly moist to wet, soft and plastic, with local thin layers of silt and fine sand, and abundant mica. The thickness is generally 1.0-2.0m and buried at a depth of 0.3-0.5m. In some valleys, fish ponds, and river sections, this layer is in the form of silt clay.

3. Layer of silty clay, silty clay with fine silt (Q4al+pl): grey-brown or grey, saturated, with flow plasticity close to soft plasticity, with local thin layers of loose fine

sand or interbedding. The thickness of this layer varies greatly, generally ranging from 1.0 to 8.0m.

4. Layer of silt clay (Q_4^{al+pl}): grey-brown, moist, mainly soft plastic, with a smooth section, high dry strength and toughness, with a thickness generally of 3.0-5.0m.

5. Layer of clay (Q_4^{al+pl}): grey-brown, moist, plastic, with local clay-like areas, thin layers of fine sand, or interbedding, with a thickness generally of 2.0-4.0m.

6. Layer of silt clay (Q_4^{al+pl}): grey-brown, moist, soft and plastic, with local thin layers of silt and fine sand or interbedding, with a thickness generally of 1.0-3.0m.

7. Layer of fine sand (Q_4^{al+pl}): grey, mainly grey-black, slightly dense, with local loose areas, containing a small amount of silt and clay lumps, with a thickness generally of 2.0-4.0m.

8. Layer of fine sand and silt (Q_4^{al+pl}): grey, mainly grey-black, slightly dense, locally moderately dense, containing a small amount of silt and clay lumps, with a thickness generally of 3.0-10.0m, and the top buried depth generally at 8.0-16.0m.

9. Layer of fine sand (Q_4^{al+pl}): grey, mainly grey-black, moderately dense, containing a small amount of silt and clay lumps, with relatively good sorting and relatively uniform particle size. The thickness of this layer is generally greater than 20.0m, and the top buried depth is generally at 15-23.0m.

10. Layer of broken stones (Q_4^{al+pl}): grey, mainly grey-black, slightly dense, containing a small amount of cohesive soil and sand filling, underlying the bedrock.

2.3 Geological Structures and Earthquakes

According to the GB18306-2015 Seismic Ground Motion Parameter Zoning Map of China [8], the basic seismic intensity of the Jingjiang area is level VI and the peak ground acceleration corresponding to a 10% exceedance probability in 50 years for type II sites is 0.05g [9]. Historically, there have been no records of destructive earthquakes in the Jingjiang section of the Yangtze River, and it is considered a relatively stable block. However, due to geological movements, the Jianghan Plain has unevenly subsided, showing a multilayered ring-shaped zoning pattern [10] between the plain and the surrounding terrain, which changes from north to south. The terrain in the area is diverse, including mountains, hills, hillocks, and plains, with the elevation gradually decreasing from northwest to southeast, transitioning from low mountains to plains in stages. Although there have been no records of destructive earthquakes in the area, geological movements may affect the seismic risk in the region, and earthquake safety should be taken into consideration.

2.4 Hydro-meteorological Characteristics

The middle and lower reaches of the Yangtze River belong to the subtropical region, with distinct four seasons, abundant sunshine, and plentiful rainfall. The rainy season and hot season occur simultaneously, with long frost-free periods. The average annual precipitation in the area ranges from 1120 to 1620mm, gradually decreasing from upstream to downstream. The distribution of rainfall within a year is extremely uneven, with more than 70% of the annual rainfall occurring during the flood season. The maximum rainfall of 2337mm occurred in the Poyang Lake area, while the minimum rainfall of only 713mm occurred in the Jingjiang area.

According to meteorological data from the Jingjiang area, the annual average temperature is 16.4°C, the average highest monthly temperature is 28.4°C, and the average lowest monthly temperature is 4.0°C. The highest and lowest temperatures in history were 39°C and -14.9°C, respectively. The maximum annual wind speed is 19m/s, and the maximum flood season wind speed is 14m/s, corresponding to a north wind direction. The average flood season wind speed ranges from 10.8 to 10.95m/s.

According to meteorological data from the Chenglingji area, the annual average temperature ranges from 16.5 to 17.0°C, with the highest recorded temperature being 43.6°C (Yiyang, July 24, 1961) and the lowest being -18.1°C (Linxiang, January 31, 1969). The average number of rainy days per year is 147 in the Dongting Lake area and 132 in the Honghu area. The average annual wind speed ranges from 2.5 to 2.7m/s, with the highest wind speed of 28.0m/s (Yueyang, July 21, 1965) corresponding to a westerly wind direction. The annual evaporation is 1291mm, and the annual sunshine hours are 1703h.

2.5 Characteristics of Heavy Rain and Floods in the Dongting Lake Area and Jingjiang River Section

The floods and sediment of Dongting Lake are derived from two sources: the Xiang, Zi, Yuan, and Li Rivers, and the Yangtze River at the Songzi, Taiping, and Ouchi outlets, and the Dongting Lake area. Due to the multiple sources of floodwater and the different flood characteristics of the Yangtze River main stream and the four rivers, the composition of floods in the area is complex.

Floods in the Yangtze River basin are mainly caused by heavy rainfall, while floods in the Jingjiang River section come from the upper reaches of the Yangtze River. The floods of the Xiang, Zi, and Yuan rivers in Dongting Lake generally occur from April to July, while those of the Li and Qing rivers occur slightly later, from May to August [11], along with the flood season of the Wujingang River, a tributary on the south bank of the upper reaches.

Floods in the Jingjiang River section are characterized by frequent high water levels, long durations, and large peak flow rates. According to the measured data from the Shashi station, which has been recorded for 102 years since 1903, the water level exceeded the warning level of 43.00m for 43 years, with the highest level of 45.22m in 1998, followed by 44.74m in 1999 and 44.67m in 1954. Since 1951, the Shashi station has measured peak flood flow rates exceeding 50,000m3/s for 7 years, with the highest flow rate occurring on July 12, 1998, at 55,200m3/s [12].

According to measured hydrological data, the maximum flow rate at the Caowei station on the Caowei River was 5,080m3/s, which occurred on July 24, 1998. The maximum flow rate at the Luowenyao hydrological station at the eastern branch of the Ouchi River on the Ouchi River was 5,290m3/s, which occurred on June 27, 1955. The maximum flow rate measured at the Chenglingji outlet station at the exit of Dongting

Lake was 43,900m3/s, which occurred in 1996, and the highest water level of 35.94m occurred in 1998.

2.6 Hydrogeological Conditions

On the north bank of the Yangtze River in the Jingjiang area, there are four major lakes: Changhu Lake, Sanhu Lake, Bailu Lake, and Honghu Lake, hence the name "Four Lakes Basin". On the south bank of the Yangtze River in the Jingjiang area, the four rivers of Songzi River, Huduo River, Ouchi River, and Tiaoxian River converge into the Yangtze River and flow into Dongting Lake, collectively known as the "Four Rivers of Jingnan"[13].

Dongjing River is a seasonal river that connects the Han River and the Yangtze River, with a total length of about 173.7 kilometres. It flows through Jianli City and Honghu City and is a typical plain river.

In the first-level terrace and hill sections of the river, there are mainly two types of groundwater: upper stagnant water in the shallow viscous soil layer and confined water in the deep sand or rounded gravel layer. The latter has a certain pressure-bearing capacity. The upper stagnant water is mainly affected by atmospheric precipitation and agricultural irrigation supply, and the main way of discharge is evaporation and downward infiltration; the deep confined water is hydraulically connected to nearby rivers. Groundwater in the first-level terrace section of the river is generally abundant, with a depth of 1.2-4.0 meters, analyzed as the water level of the upper stagnant water. In some areas, the groundwater depth is deeper than 10 meters and is analyzed as the water level of the confined water.

Groundwater in the hill section is generally weak, with a depth of 6-10 meters. In some areas, the groundwater depth is deeper than 10 meters. The annual variation range of groundwater level is about 1.0 meters, and the overall burial depth of groundwater is shallow. Due to the characteristics of shallow burial and large water volume of groundwater, the influence of groundwater on the foundation should be fully considered in the design, and the impact of groundwater on foundation construction should also be taken into account during construction.

3 RECOMMENDED VALUES FOR PHYSICAL AND MECHANICAL PARAMETERS OF VARIOUS SOIL LAYERS

Foundation design requires a thorough understanding of the physical and mechanical properties of soil layers. Based on the testing regulations and standards, the indoor physical and mechanical properties of each soil layer are statistically analyzed. The statistical average value of the parameters is taken as the basis, and some parameters are adjusted based on regional experience. The main physical and mechanical characteristics of the foundation soil for ordinary transmission line sections are comprehensively presented in Table 2. Among them, the silty clay is soft and plastic. It has a well-developed micro-fine layer structure and low shear strength. The fine sand layer has poor erosion resistance.

Table 2. The main physical and mechanical properties of foundation soil in ordinary line reach

Stratum number	Soil	Unit weight /kN.m^{-3}	Direct shear test		Elastic modulus	Bearing capacity
			Cohesion c /kPa	Friction angle φ /°	E_s /MPa	F_{ak} /kPa
1	Gravelly soil	17.5	10-15	10-12	2.0-3.0	60-70
2	Silty clay	18.0-18.5	18-25	10-15	4.0-6.0	100-120
3	Silty clay with mud	17.0-17.5	10-18	10-12	2.0-3.5	70-90
4	Silty clay	18.0-18.5	20-28	10-16	5.0-7.0	80-100
5	Clay	18.0-18.5	30-40	10-15	6.0-8.0	150-180
6	Silty clay	18.0-18.5	18-20	10-12	4.0-5.0	80-100
7	Sandy silt	18.0-18.5	5-10	20-28	6.0-9.0	100-120
8	Fine sand	18.5-19.0	5	20-25	6.0-8.0	120-140
9	Fine sand	18.5-19.0	5	25-30	8.0-10.0	140-200
10	Sand and gravel	20.0-21.0	0	34-36	/	250

4 POOR GEOLOGICAL CONDITIONS OF THE FOUNDATION AND ENGINEERING MEASURES

For long-span overcrossing transmission towers and anchor towers, a drilled pile foundation is generally used. The foundation adopts the scheme of pile caps and four independent foundations with concrete beams between the pile caps [14]. Considering the load of the elevator shaft and the construction landing pole, a foundation platform is arranged at the centre of the tower position, which takes into account both temporary construction foundations and later elevator shaft foundations.

(1) When using the drilled pile foundation scheme, for the fine sand and medium sand layers, considering that they are locally slightly agglomerated and locally mixed with a small amount of gravel, suitable construction machinery and measures should be considered to ensure construction progress. The key to ensuring the quality of the pile foundation project is to do a good job of mud protection wall and avoid quality problems such as collapse and necking of the pile body. At the same time, the bottom sediment removal work should be done well to avoid adverse consequences such as insufficient bearing capacity of a single pile due to excessive sediment at the bottom of the pile.

(2) If the pile body needs to pass through soft soil layers such as silt and silty clay, the effect of negative skin friction on the pile side should be considered when calculating the bearing capacity of a single pile [15-16]. When calculating, take the side friction above the neutral point as zero, and take the depth of the neutral point as the depth of the lower limit of the soft soil layer around the pile (depth of the bottom of the soft soil layer) calculated from the top of the pile.

(3) The main geological hazards along the Jingjiang River section are seismic liquefaction [17], karst, and sudden surges during the excavation of foundation pits. The line passes through an area with a dense river network, and the flood season has a certain scouring and erosion effect on the riverbank slope, which can cause the slope to collapse [18]. A small number of slope collapses were found in the field investigation. Therefore, the location of ordinary river overcrossing transmission towers should be a safe distance from the riverbank slope, and corresponding protective measures should be taken to ensure the stability of the tower position [19].

5 ANTI-SEEPAGE AND ANTI-IMPACT MEASURES FOR TOWER FOUNDATION

5.1 Methodology

The tower foundation is located near the embankment. If the drilled pile foundation penetrates a weak and permeable layer, there may be concentrated leakage channels around the drilled pile foundation and pile cap when the water level outside the embankment is significantly higher than that inside the embankment during the flood season. Once there are dangerous situations such as soil flow or pipe burst, it will seriously threaten the flood control safety of the river embankment. Therefore, certain anti-seepage and anti-impact measures must be taken to reinforce the foundation around the tower base.

The anti-seepage treatment around the tower foundation and pile cap is generally carried out by using clay backfill combined with a composite geotextile membrane. The composite geotextile membrane is set in the middle of the backfill clay layer, and grass or Reno cushion is placed on the top of the backfill soil to protect against erosion. The structural diagram of the anti-seepage measures for the tower foundation and pile cap is shown in Figure 1, and the detailed diagram of the connection between the geotextile membrane and the tower foundation and pile cap is shown in Figure 2.

If a geotextile membrane is used, it is necessary to strengthen the anti-filtration protection of the soil around the pile foundation. A layer of geotextile membrane should be laid around the base of the tower foundation, and after the geotextile membrane is laid, a 20cm thick fine sand layer, a 20cm thick coarse sand layer, and a 20cm thick gravel layer should be set up from bottom to top as an anti-filtration layer. Then, sand loam could be backfilled as a protective cover layer. The overlap of the geotextile membrane at the joint and the edge of the pile cap should be 50cm, and a special adhesive can be used to bond the geotextile membrane and the pile cap.

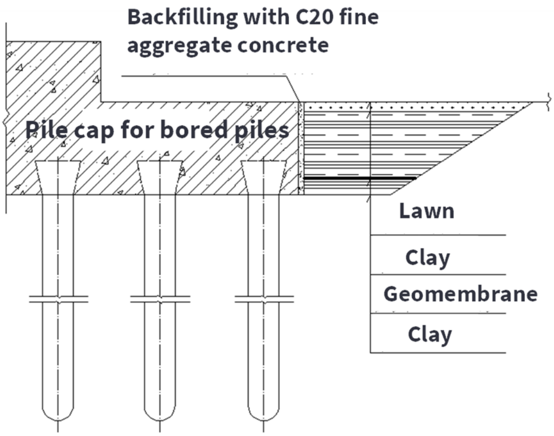

Fig. 1. Cross-sectional view of anti-seepage and anti-impact measures for tower foundation plinth.

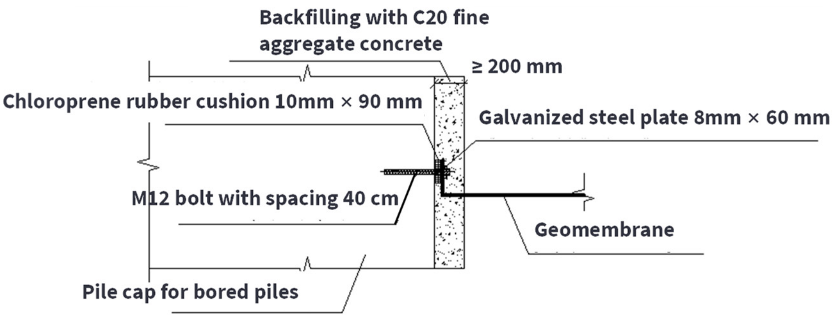

Fig. 2. Detailed diagram of the connection between geomembrane and tower foundation

5.2 The Result and Data

The quality of infiltrated water of geomembrane with different pressure was plotted, as shown in Fig. 3. It can be seen from the results that the permeability of geomembrane showed a gradual increase with the increase of pressure, but the rate of change was extremely uneven. The rate of increase was larger at 1.2 MPa, and the rate of increase in the rest of the water pressure range is relatively small. The test results show that if the geomembrane undergoes large deformation, its permeability coefficient will increase significantly. However, compared with the traditional seepage control material, it still has significant advantages in terms of seepage control performance.

Fig.4 and Fig.5 shows the effects of pressure on the permeability coefficient with 40% and 60% elongation, respectively. The change of permeability coefficient with the increase of water pressure basically shows the characteristic of increasing and then decreasing, and reaches the maximum value when the water pressure is 1.2 MPa, and then decreases rapidly.

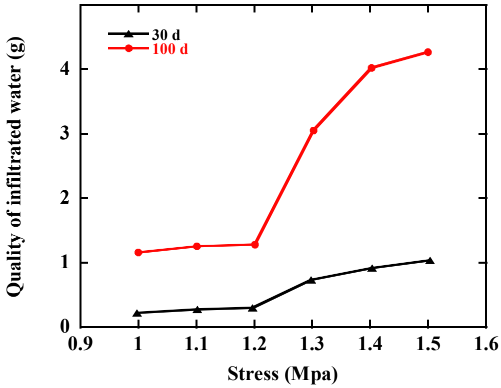

Fig. 3. Effects of stress on the quality of infiltrated water

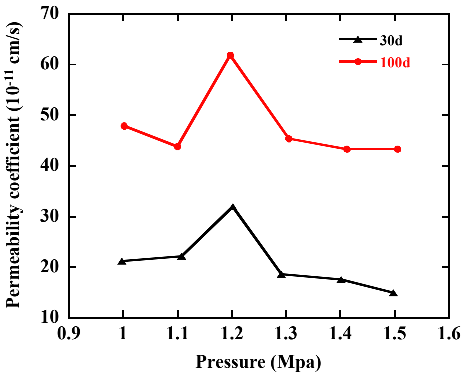

Fig. 4. Effects of pressure on the permeability coefficient of geomembrane with 40% elongation

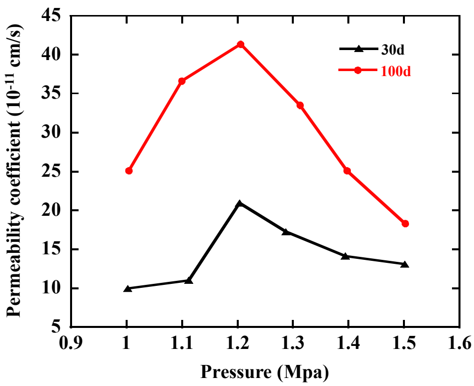

Fig. 5. Effects of pressure on the permeability coefficient of geomembrane with 60% elongation

6 CONCLUSIONS

This paper summarizes the topography and geomorphology, lithology, geological structure and seismicity, hydrological and meteorological characteristics, storm and flood characteristics, and hydrogeological conditions of the Jingjiang River section in the middle reaches of the Yangtze River. The exposed strata in the exploration range of the Jingjiang River section are mainly the Quaternary alluvial layer (Q4al), which can be divided from top to bottom into (1) plain soil; (2) silt; (3) silty clay with silt; (4) silty clay; (5) clay; (6) silty clay; (7) silt; (8) fine sand; (9) fine sand; (10) sand and gravel layer. This paper presents the main physical and mechanical properties of the soil in the common line section of the Jingjiang River section in the middle reaches of the Yangtze River. The silt has a developed micro-lamination and has a low shear strength. The silty sand layer has poor erosion resistance. For long-span overcrossing transmission towers and anchor towers, drilled pile foundations are generally used. The foundation adopts a pile cap scheme, with four independent foundations and concrete beams between the pile caps. If the pile body needs to pass through a soft soil layer with silty clay, the negative friction resistance of the pile side should be considered when calculating the single pile bearing capacity. If the distance from the embankment is close, a certain anti-seepage treatment should be adopted around the pile cap of the tower foundation, and the foundation around the tower base should be reinforced.The anti-seepage treatment around the tower foundation and pile cap is generally carried out by using clay backfill combined with a composite geotextile membrane.The composite geotextile membrane is set in the middle of the backfill clay layer, and grass or Reno cushion is placed on the top of the backfill soil to protect against erosion. It should be noted that if the geomembrane undergoes large deformation, its permeability coefficient will increase significantly. However, compared with the traditional seepage control material, it still has significant advantages in terms of seepage control performance.

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