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Application of Waterproofing Construction Technology for Concealed Passages

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Abstract. Leakage issues, as a key concern for the quality of underground works, have been influencing construction decisions in engineering practice. Most projects still count leakage on site after a leakage problem has occurred and use this to develop a plugging plan, and as leakage is usually assessed after the overall closure, this leads to insufficient attention being paid to leakage in the preliminary work. In this paper, we take the pursuit of economic benefits as the core and safety and quality as the bottom line for the waterproofing project of the concealed channel of the Ecological Centre project. Before construction, we combine the geological and hydrological situation of the site, conduct statistical analysis of the possible leakage risks and finally focus the waterproofing project on the prevention and treatment of deformation joints, construction joints and concrete cracks. Design from the aspects of waterproof structure design, raw material selection, construction personnel capacity, on-site construction process, etc., to reduce the risk of leakage of underground passages and ensure the normal use of underground passages.

Keywords. Concealed passage, waterproofing, Wuhan

1. Background to the Leakage Study

Waterproofing has always been a perennial problem in building construction. As urbanisation in China continues to advance, traffic problems in central urban areas are becoming very serious and a common method currently used is to use underground passages for inter-building traffic. In areas where underground passageways are needed to ease traffic, the traffic in the passageway section is inevitably very important, so open excavation should not be used for the main body of the passageway. The common construction methods for access roads are open excavation, cover excavation and concealed excavation. For this project, it was decided to use the shallow buried concealed excavation method for construction due to traffic considerations.

The aim is to use the shallow buried concealed excavation method. It takes as a prerequisite the reinforcement and treatment of soft ground, uses a composite lining structure, uses a rational excavation method and applies information-based feedback design and construction methods to ensure construction safety and to control ground settlement. In the cut-and-cover tunnel construction, the cross-section of the tunnel construction is basically a horseshoe section, and the tunnel structure is composed of

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the initial support, the sandwich waterproofing layer and the secondary lining from the outside to the inside. The initial support consists of shotcrete and steel grids, the interlayer waterproofing layer can be made of different waterproofing materials to suit the specific project context, and the concrete used for the secondary lining is waterproof reinforced concrete.

Leakage is mainly concentrated in the construction joints, induced joints, the main body and channel connection parts, concealed tunnel construction joints, deformation joints parts [1]. A statistical analysis of a number of tunnels revealed that leakage occurred in basically every tunnel, the difference being only in the degree of leakage. The survey results show that nearly half of the tunnels have concentrated water gushing points in the arch and side walls when there is no pressure; half of the tunnels have concentrated water gushing points in the arch and side walls when there is pressure, and most of the tunnels have some leakage in the arch and side wall areas [2]. The severity of leakage in the tunnel is closely related to the effectiveness and durability of the waterproofing measures used in the tunnel.

Waterproofing project quality problems, not only the quality of materials or construction problems, more important root cause is that China's construction industry management model can not train and inspire construction enterprises to pay attention to the development of technology and quality management, enterprise tendency to profit factors and market supervision is not strict, resulting in a long-term low level of waterproofing market [3].

2. Project Design Overview

According to the survey results, combined with the site stratigraphic characteristics, site conditions and Wuhan area experience, the design water level for floatation resistance was taken to the design ground elevation, and the safety factor for floatation resistance was taken as 1.1 (without considering the sidewall friction). After calculation, the concealed channel cladding + self-weight floatation resistance meets the specification requirements. Anti-floating design of basement: T1 building even channel location is divided into two types of anti-floating water level, the northwest anti-floating design water level is 28.8m, the southeast anti-floating water level is 26.7m. T2 building basement anti-floating design water level is 28.2m. The structure self-weight and building practices (including cladding) are included in the anti-floating load, and part of the anti-drawing piles are used to meet the anti-floating design requirements.

The length of the underground passage is 15.2m, the width is 7.9m, the height is 5.1m, and the depth of the passage is 18.4m. The waterproofing level of the underground passage structure is Grade I: no water seepage is allowed, and the surface of the structure is free from wet stains.

3. Engineering Hydrogeological Conditions

The groundwater in this site can be divided into three types, which are upper layer stagnant water in the upper fill layer, pore pressure water in the sandy soil layer and bedrock fracture water in the bedrock.

1) Upper layer stagnant water: mainly stored in the fill (1) layer of soil, no unified free water surface, by atmospheric precipitation, surface water and production,

domestic water infiltration recharge, fill thickness of the larger sections have a certain amount of water, the water table depth of 0.8 ~ 4.7m measured during the survey, corresponding to the elevation of 21.63 ~ 29.47m.

2) Pore pressurized water: this layer of water is distributed below the channel, the site is close to the ancient river channel, its water level and water quantity are directly influenced by the ancient river channel water level, the overlying clay layer and the underlying bedrock are the relative water barrier top and bottom. During the survey, the burial depth of the pressurised water level in Hole 5 at this site was measured to be 13.60m, and its corresponding elevation was 14.06m. The annual variation of the pressurised water head height was 2.0~3.0m. There is no hydraulic connection with the upper layer of stagnant water because it is blocked by the layer.

3) Bedrock fracture water is mainly stored in the bedrock fractures of the site, its permeability and water-richness have anisotropy and heterogeneity, etc. The bedrock fractures of the site are developed, and the bedrock has a strong weathering layer, and the strong weathering is basically weathered into soil, and the permeability is poor, the main source of recharge may be the fracture connection between the bedrock of the site and the ancient river area, but most of the bedrock fractures of the site are closed, and during the drilling process individual During the drilling process, individual boreholes showed leakage of water and slurry, and the overall amount of water in the fissures was small and uneven, which may have adverse effects on the pile construction and should be taken seriously. In the survey process, a detailed geological investigation was carried out on the site and its surrounding area. The area is not built with polluting factories and mines, nor is it polluted by pollution, the soil has no odour, the groundwater is very shallow, the plants on the ground are also very good, the environmental class belongs to class II. 2 water samples were collected for this survey to do a simple water quality analysis, and 2 soil samples were collected to do a dissolved salinity experiment, according to the According to Article 12 of the Code for Geotechnical Investigation (GB50021-2001, 2009 Edition), the groundwater and foundation soil in the area have a slight corrosive effect on the underground concrete and the reinforcing steel in the reinforced concrete structure.

The site is basically stable, the topography is undulating, there are many types of geotechnical soils and the distribution is uneven, the influence of groundwater on the construction is not significant, the surface drainage conditions are good, so the suitability of the site is graded as more suitable.

4. Analysis of Potential Leakage Problems in the Project

The standard for selecting waterproofing subcontractors is "lowest bid", this bidding system to a certain extent, the project has hidden quality problems [3]. At present, the cost of waterproofing works account for about 3% of the total project cost [4], resulting in construction units, contractors on waterproofing works do not pay enough attention.

Before the concrete is poured, there is no control over its raw materials, matching ratios, etc., resulting in the concrete itself easily producing gaps and thus leaks. Waterproofing membrane, waterstop steel plate into the field without acceptance or re-inspection, resulting in its tensile properties and durability is not qualified, construction is completed less than the working life of the waterproof structure was destroyed, thus producing water leakage.

In the concrete pouring construction process, due to inadequate vibrating, or in the same location twice the interval between concrete pouring is too long, at the construction joints waterstop steel plate or waterstop, the concrete is not closely combined with the waterstop components, resulting in groundwater under the influence of pressure, through the gap between the waterstop and concrete, infiltration into the underground works. Secondly, the improper treatment of deformation joints has prevented them from meeting the durability requirements in areas such as settlement joints and expansion joints. Therefore, it is important to standardise and control the construction of the project during the construction process [5].

Waterproofing membrane in the construction of follow-up work after the completion of the paving, easy to produce

As the site's groundwater and foundation soil on the ground concrete and steel has a slight corrosive effect, and double-sided adhesive waterproofing materials work in a corrosive underground environment, and the corrosive environment is strongly acidic, it will have an impact on the material's tensile properties, the greater the acidity, the faster the material's tensile properties are reduced [6]. Waterproofing projects may not reach the waterproofing design working life.

5. Technical Measures for Waterproofing of Concealed Passages

5.1. Application of Waterproofing Technology for Concealed Passages

Underground channel structure waterproofing measures for three, the first for 3mm thick polymer cement waterproofing coating, the second for the pre-paving 1.5mm thick polymer self-adhesive membrane coil, the third for the structure of self-waterproofing.

Arch, side wall waterproofing layer using 50mm thick M30 rigid waterproofing layer and leveling layer protection, back arch waterproofing layer using 50mm thick fine stone concrete protection. All shaded corners should be made 50mmX50mm chamfered or rounded.

5.2. Waterproofing Measures for the Main Structure

Concealed excavation section structure bottom waterproofing structure: C35 moulding waterproofing (P8) reinforced concrete, 50mm C20 fine stone concrete protection layer, 15rm thick polymer self-adhesive membrane waterproofing membrane, 3mm thick polymer cement waterproofing coating, 300mm thick C25 early strength injection concrete [7].

Concealed excavation section top waterproofing structure: 300mm thick C25 early strength shotcrete, 50mm thick waterproof mortar levelling layer, 3mm thick polymer cement waterproofing coating, 15mm thick polymer self-adhesive membrane waterproofing membrane, C35 moulding waterproofing (P8) reinforced concrete. The waterproof section of the concealed excavation is shown in figure 1.

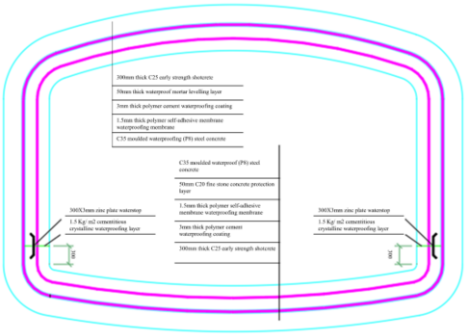

Figure 1. Waterproof section of concealed section structure.

5.2.1. Waterproof Concrete Construction Measures

The slump of waterproof concrete must be checked before placing, and when the test results do not meet the construction requirements, the relevant quality control personnel should add cement slurry with the same water/cement ratio or add water-reducing agents to the concrete for mixing. It is strictly forbidden for any person to add water during the entire pouring process.

High frequency mechanical pounding should be used to ensure that the waterproof concrete is dense. When air-entraining agents or air-entraining water-reducing agents are added, a high-frequency insertion-type vibrator should be used for pounding. Construction personnel should be pounding time in 10 ~ 30s, pounding standards is waterproof concrete pulp, and no longer out of the bubble, while there should be someone in the side supervision, so as to avoid leakage vibration, under-vibration and over-vibration.

In waterproof concrete structures, the protective layer of reinforcement should be fully qualified and should not be in direct contact with the mould frame [8]. When anchors in the formwork system need to pass through the concrete structure, appropriate water stopping measures should be taken, anchors with welded square stop rings, anchors that can be tested using tools, anchors or anchors with plugging method. Demoulding is carried out when the strength of the concrete meets the requirements for demoulding and the recesses left by the bolts are coated with waterproofing paint or other reasonable reinforcement measures are taken. Maintenance must be carried out immediately after the final setting of the waterproof concrete and must not be less than 14 days. After pouring the waterproofing concrete, no holes are allowed and various pre-buried parts and holes must be buried in the ground in advance.

5.2.2. Waterproof Material Acceptance and Construction Requirements

Waterproofing membrane selection 1.5mm thick double-sided sticky type wet laying volume material than single-sided sticky type material material has better tensile properties, in the concealed excavation channel, more suitable as a concealed excavation channel initial lining and second lining between the flexible waterproof layer.

Theoretically, the entire underground channel can be linked into a whole through measures such as waterproofing membranes, thus avoiding leakage, but in the

construction process, under the influence of various factors, the theory will deviate from the actual to a certain extent.

In order to prevent damage to the waterproofing layer caused by the reinforcement work, a protective layer of C20 fine sand concrete with a thickness of 50 mm is poured over the waterproofing layer. During this period, the lap width of the waterproofing membrane must be ensured. Therefore, the material provider should be adjusted accordingly to the actual project situation to ensure lap quality and reduce construction difficulties. In the process of laying, the quality of the waterproofing membrane should be launched to check the quality of the waterproofing membrane, re-examine the gaps and cracks in the waterproofing membrane, and if necessary, take timely measures, while checking whether there are any bad spots or leaks in the laps.

According to field measurements of groundwater and foundation soil is not strongly acidic, but still slightly corrosive, so require material suppliers to provide appropriate adjustments to waterproofing materials to enhance durability and increase service life.

A variety of waterproofing materials performance indicators should be in line with national and industry specifications: deformation joints embedded materials should be in line with the "waterproofing technical specifications for underground construction" GB50108-2008 requirements, rubber water stops performance indicators should meet the "waterproofing technical specifications for underground construction" (GB50108-2008), page 43, 5.1.8 B-type requirements, polyurethane sealant seal Performance indicators should meet the "underground engineering waterproofing technical specifications" (GB50108-2008), page 44, section 5.1.9 requirements. Waterproof coating should meet the "spraying rubber asphalt waterproof coating" (JC/T2317-2015) and "underground engineering waterproofing technical specifications" (GB50108-2008) section 4.4.8 of the requirements. Polymer self-adhesive waterproofing membrane performance should meet the "polymer waterproofing materials" (Part 1: sheet) (GB18173.1-2012), "waterproofing membrane with self-adhesive layer" (GB/T23260-2009) and "waterproofing technical specifications for underground engineering".

5.3. Waterproofing of Special Areas

Detailed waterproofing measures at the construction joints of the concealed section structure are shown in figures 2 and 3.

Construction joints using high-quality cement-based crystalline waterproofing coating + 20mmX10mm water expansion rubber, longitudinal joints set 300mmX3mm steel plate waterstop, ring joints set steel edge rubber waterstop.

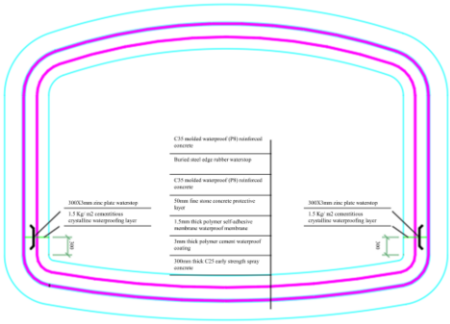

Figure 2. Waterproof section of construction joints in concealed excavation section.

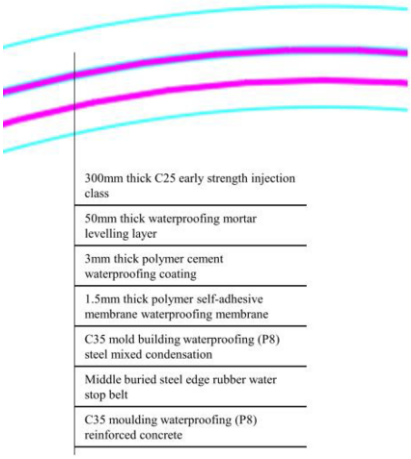

Figure 3. Waterproof section of construction joint in concealed section structure (top).

Concealed excavation section ring construction joints waterproof structure: initial support, waterproof mortar leveling layer, waterproofing coil, waterproofing coil reinforcement layer, waterproof coating, external rubber waterstop, cast-in-place reinforced concrete second lining.

Longitudinal construction joints in concealed excavation: initial support, waterproof mortar levelling layer, waterproofing membrane, waterproofing membrane reinforcement layer, waterproof coating, cast-in-place reinforced concrete second lining

Underground channel deformation joints 30mm wide, using closed-cell polyethylene foam board embedded joints, buried rubber waterstop, external waterstop and polyurethane sealant sealant to strengthen the waterproofing treatment.

5.3.1. Measures to Avoid or Reduce Water Leakage through Deformation Joints and Construction Joints

Choose a suitable slump; to control the anti-diffusion performance of commercial concrete, usually the second lining in the construction process, the delamination height will exceed the specified range, when the second lining reinforcement density is large,

if the concrete anti-diffusion performance is not good, will have a great impact on the quality of concrete placement;;

To control the concrete vibrating off well, in the process, usually used is the combination of inserted vibrating and attached vibrating.

in the design of the lining trolley, the position of the window plate and the hanging plate should be reasonably arranged; the concrete should be poured continuously as far as possible, leaving no or few construction joints, and before continuing to pour at the construction joints, the surfaces of the joints must be chiselled, the scum removed and the water stops affixed;

The placement of the waterstop should be precise, with no gaps, and the waterstop (tape and tape) should be bonded by the hot-melt method with a tight bond to avoid damage to the waterstop when the mould is removed;

Concrete for deformation joints and construction joints should be vibrated tightly, but the vibrations should ensure that the waterstop is correctly positioned.

The concealed channel overburden and self-weight buoyancy resistance have met the code requirements, but Building T1 is still in the main structure construction phase. However, the floating design shows that the structure of the self-weight and building practices (including cladding) into the floating load, so there will be a difference in height due to buoyancy in the deformation joint parts, will produce damage to the deformation joint parts of the waterproofing, so all rubber flexible waterproofing in this part of the optimization for rigid waterproofing, and for waterproofing steel plate below the concrete is not easy to vibrate, resulting in the pouring is not dense, it is recommended to use self-compacting for pouring, but also or to strengthen the pounding in this area.

5.4. Drainage

The main objective of waterproofing works is to 'plug', but waterproofing works at the deformation joints, as a concentrated area where leakage occurs, should be prevented for possible risks. To ensure that leakage does not affect the normal use of the access road once it has entered the use phase, a water interceptor was installed in the design of the deformation joints in the concealed excavation interval, allowing a small amount of seepage to be diverted via the interceptor to the central drainage ditch in the access road and then discharged into the municipal network by the waste water pump room in the interval. The design of the waterproof box construction is shown in figure 4.

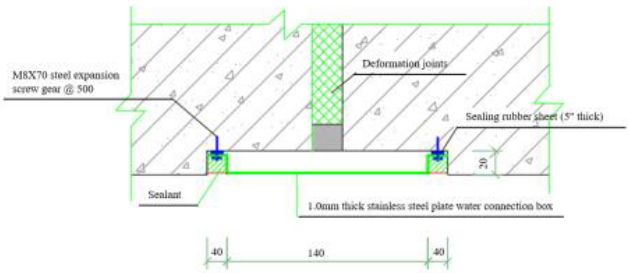

Figure 4. Detail of stainless steel plate water connection box.

6. Conclusion

As a result, high demands are placed on the watertightness of access roads during construction. Due to differences in hydrogeological and engineering conditions, the requirements for impermeability measures also vary considerably, so that impermeability measures have to be flexible. At the same time, it is also necessary to strictly follow the provisions of the specifications. The cost of quality should be fully taken into account at the bidding stage, and both the government and enterprises should increase their efforts to control the quality and carry out self-inspection and self-inspection throughout the construction process, and should constantly carry out self-monitoring, improve and summarise in order to achieve the aim of improving the quality of construction.

Author in Brief

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