Construction Technology of Comprehensive Disposal for Shallowburied Section of Mountaintunnel

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Abstract—In this paper, the Wushi tunnel of Qingyun Expressway in Guangdong Province is taken as the engineering background, the shallow buried section of mountain tunnel is the area with frequent tunnel diseases, in order to solve the problems of poor self-stability of the excavation surface, destruction of supporting structure and water inrush caused by fully weathered surrounding rock in shallow tunnel, after integrating the treatment technology of the existing fully weathered surrounding rock shallow buried tunnel, pre-reinforcement treatment of fully weathered granite with cover grouting technology on deep surface, the working face is excavated after being pre-supported by a double-layer advanced small pipe and using a new type of self-adhesive waterproof membrane to ensure the waterproof effect of the lining, safe and efficient completion of shallow tunnel excavation, Then backfill the soil of the construction surface to carry out ecological restoration work. Through the study of this process, the construction process flow of the fully weathered surrounding rock shallow buried tunnel is summarized, and the key points of each construction stage are pointed out to ensure the construction quality and optimize the construction technology of the shallow buried section of the mountain tunnel, which provide a reference for other similar engineering problems.

1. Introduction
The “Belt and Road” strategy and the great project of the beautiful New China during the “Thirteenth Five-Year Plan” period have already sounded. Domestic infrastructure is in full swing; developed cities in the east and coastal areas are improving their transportation networks, while western regions and some backward mountain areas are moving towards The modernization process is accelerating; this also means that the expressway network and the (high-speed) railway network will intensively pass through the mountainous areas, and the construction of mountain tunnels will be inevitable. Many tunnels have safety accidents during the construction process, which brings many hidden dangers during the operation; how to complete the construction safely, efficiently, with high quality and green, a series of problems faced by the tunnel construction under complex geological conditions must be solved; the overlying layer of the tunnel is insufficient. The tunnel section with twice the span of the tunnel is a shallow buried section of the tunnel. Due to its shallow burial characteristics, the shallow buried section of mountain tunnels is often the area where the entire tunnel is prone to diseases, so the comprehensive treatment of shallow buried sections of mountain tunnels is of great significance. The key to the construction of the shallow buried section of the tunnel is to pay attention to the surface...
grouting treatment, strictly advance the support measures, control the excavation cycle length, and pay attention to the settlement inside and outside the cave. On the surface of the grouting treatment, Jiang Hongtao et al. [1] are introduced according to liao gong mountain tunnel at shallow buried section of poor geological conditions, large water volume, prevent liao home groove shallow buried in water hole and collapsed as the key part of this construction, liao gong mountain tunnel at the surface grouting adopts double fluid grouting pump slurry to carry on the back "hole card" of the grouting technology, blocked the groundwater seepage path, reinforcing the surrounding rock, improves the strength of surrounding rock, to eliminate the soil slip and flood water bursting accidents. Xu Zhanliang [2] system such as shallow buried tunnel section shows for the stockade hills, complicated geological conditions, buried depth, high underground water level, the karst development, the tunnel arch near earth stone line, under the condition of a high risk of engineering construction, tunnel processing in accordance with the "first after irrigation, ground irrigation combined with" principle, using the sleeve valve tube grouting process, the effective control of the stockade duty tunnel shallow tunnel in the early period of the supporting contamination limit, surface crack, etc. Zhao Yonghu et al. [3], based on the Shangge Village tunnel under construction by Yinxin High-speed Railway and the long-section shallow buried large-section loess tunnel at its exit, expounded that the slurry and soil combination formed by surface grouting has obvious "compaction effect" and supporting function, as well as engineering characteristics that can improve the structure of the original loess. [4] about forepole Tao Kun in combination with bearing the long highway tunnel as the shallow buried period of construction, this paper discusses the grew up pipe roof construction technology of large mechanical construction, main technical points and control difficulty, inaccurate positioning of the construction of common pipe run, borehole bending contamination limit, steel pipe connection is not reasonable, analysis to solve problems such as grouting is not full. Hui Cai [5] et al. took two-point anchor bolt reinforcement of shallow buried tunnel as the research object and regarded the anchor bolt as the same concentrated force of two interactions, and proposed an analysis method of point-anchor reinforcement of shallow buried tunnel. YZH [6] and so on in chongqing railway hub east loop new Bai Yangwan DK3 + 538 - DK3 + 588 blocks under close in highway tunnel project, using finite element analysis software MIDAS GTS - NX, for without advancing forepole, pipe roof support and a great screen forepole support form the three theoretical simulation based on its construction in the process of surface subsidence and deformation of surrounding rock and lining of internal force analysis, research, will reduce the screen supporting optimal conclusion in engineering practice. The new Baiyangwan tunnel, the hub of Chongqing Railway, underpasses The G5001 ring expressway, achieving the expected construction effect. About excavating shallow buried tunnel construction, Combining the simulated construction situation of railway tunnel engineering, Liu Yansong [7] is proposed that the construction technology of the shallow-buried section of the weak surrounding rock of the railway tunnel focuses on how to ensure its supporting effect, and the CRD construction method and large arch foot The two construction techniques of the step method are compared and analyzed, and the conclusion is that the construction effect of the step method with large arch feet is better than that of the CRD method. Xu Feng et al. [8] introduced that Shouyangshan tunnel adopts the three-step and seven-step excavation method to pass through the shallow buried section smoothly, which ensures the construction quality and progress, and has accumulated valuable experience for similar tunnel construction. Bao XianKai et al. [9] had based on the background of the construction of the shallow-buried soft rock small-distance tunnel in the Kufeng Mountain, through on-site measurement and Midas GTS numerical simulation, a comparative analysis of the double-side pilot method, the upper and lower steps method and the reserved core In soil method, it is concluded that for shallow-buried soft rock tunnels with small clear distance, the double-side heading method can more effectively reduce surface settlement, increase the stability of surrounding rock, reduce the settlement of the vault and level convergence.

This article summarizes and introduces the safe, efficient, high-quality and green technology based on the example of the Wushi tunnel project on the Qingyun Expressway in Guangdong.
2. Project Introduction
Wushi Tunnel is located in Dongkeng Village, Antang Town, Yuncheng District, Yunfu City, Guangdong Province. The clearance of the cave is 11.00×5.0m. The tunnel type is a separate tunnel. The pile number is ZK129+730～ZK131+005, length 1275m; K129+730～K131+020, length 1288m; belongs to long tunnel. The tunnel area is a structurally denuded low-mountain landform, with large terrain fluctuations, developed gullies, and large water volume during heavy rains.

Among them, ZK130+100～355 and K130+210～300 sections have a ceiling elevation of 130.36m, a ground elevation of 142.76m, a stable underground water level of 130.36m, and a minimum buried depth of only about 11.0m. “fig. 1”.

Within 5m of the cave roof is fully weathered granite, brownish yellow, and the original rock structure has been basically destroyed. The core is mostly sandy with a small amount of weathered residual particles. The main component is quartz without viscosity, and rainwater disintegrates into sandy soil. The surrounding rock in this section is poor. During the excavation of the tunnel, due to the influence of the empty surface, a secondary stress field (ie, the stress redistribution of the surrounding rock) is generated, and the surrounding rock cannot form a natural arch during the stress redistribution process, resulting in deformation Or the force caused by the damage is greater than the bearing capacity of the initial support, which easily leads to the destruction of the initial support. Therefore, cave collapse, water and mud inrush are likely to occur during the excavation process, especially in the rainy season due to the porosity of the upper soil Too large will cause the surface water to seep into the broken zone, which will easily cause the surrounding rock to soften, swell, collapse, and may even cause roof fall.

![Figure 1. Longitudinal section of shallow tunnel](image1.png)

3. Disposal Plan For Shallow Buried Section

3.1. Overall disposal process

![Figure 2. The overall disposal process of the shallow tunnel](image2.png)
3.2. Deep surface grouting with cover
According to the principle that the stress redistribution caused by the excavation of the underground structure does not involve the surface, under the construction method of the mine method, the determination of the deep and shallow burial of the single-hole tunnel should be determined according to the equivalent height of the load, combined with the geological conditions, construction methods, etc. Buried in depth.

The empirical formula for the tunnel boundary depth $Hp$ is:

$$Hp \leq \left(2.0\sim2.5\right)ha$$

Where $ha$ is the vertical load height.

The empirical formula for equivalent vertical load of surrounding rock is:

$$Q = \gamma ha$$

$$Ha = 0.452S - i\omega$$

$$\omega = 1 + i\left(B - 5\right)$$

Where: $Q$ is the equivalent vertical load; $ha$ is the equivalent height of the load; $\gamma$ is the weight of the surrounding rock; $s$ is the surrounding rock grade; $\omega$ is the width influence factor; $B$ is the maximum excavation span of the tunnel $I=0.2$ when $B<5m$; $i=0.1$ when $B>5m$).

The surrounding rock of the shallow buried section of the Wushi tunnel is fully weathered granite, grade V surrounding rock, and the surrounding rock weight $\gamma=19kN/m^3$. The excavation span is designed to be 13.53 meters. Considering the over-excavation value, $B=13.8m$. The critical depth coefficient is taken as 2.5.

Calculated: $ha=13.536m$;  
$Hp=2.5\times13.536=33.84m$.

Therefore, it is judged that when $H<33.84m$, the tunnel is shallow buried; when $H<15.536m$, the tunnel is super shallow buried. According to the geological profile of the Wushi tunnel, the shallow buried section on the left line is ZK130+100~ZK130+355, of which ZK130+215~ZK130+278 are ultra-shallow buried sections, with a minimum buried depth of 10.86m and a maximum buried depth of 27.067 m; the shallow buried section of the right line is K130+100~K130+150 and K130+205~K130+335, of which K130+258~K130+278 ultra shallow buried section, the minimum buried depth is 10.995m, the maximum buried depth is 25.68m. See “Fig. 3” for a schematic plan of the shallow buried section of the tunnel.

![Figure 3. Schematic diagram of the scope of the shallow buried section of the tunnel](image)

(2) Ground surface grouting reinforcement measures

According to the actual situation of the project, combined with the geology of the site and the hydrological conditions during the construction period, comprehensive consideration is given to the selection of deep surface covered grouting for pre-reinforcement treatment.

The surface of the weathered granite area at the top of the cave is reinforced with steel pipe grouting on the surface, as shown in “Fig. 4”. Reinforcement adopts $\Phi42mm$ grouting small pipe, length $13\sim20m$, shallow buried section spacing $2.0\times2.0m$, plum-shaped arrangement, ultra-shallow buried section spacing $1.2\times1.2m$, plum-shaped arrangement; small pipe end exposed $20cm$, pouring
30cm thick C25 Plain concrete. A Φ12 reinforced steel mesh is set in the concrete, and small pipes are welded to the reinforced mesh. Pour 20cm thick C25 concrete to seal the ground along 8m on both sides of the ditch to prevent groundwater from seeping.

![Figure 4. Typical cross-sectional view of small grouting pipe in shallow buried section](image)

The starting pile number of Wushi tunnel ground grouting is ZK130+200, and the ending pile number is ZK130+290. The grouting width is 4m on each side of the outer side of the tunnel's main tunnel excavation profile, a total of 21.31m, which forms a 90m×21.31 The rectangular grouting area of m has a grouting area of 1918m². The grouting depth needs to be 0.5m within the excavation contour line, and the grouting hole length is 13-20m.

The grouting slurry is mixed with 42.5R ordinary portland cement, and the water-cement ratio is 1:1; the grouting pressure is maintained at 0.5 ~ 1.0MPa, and lasts for more than 15 minutes, and intermittent grouting is used when necessary.

Surface-draining grouting is less expensive than curtain grouting and advanced pipe sheds, and the construction period is short; it can more effectively strengthen the soil body than shallow surface grouting, and the reinforcement range is deeper to prevent the encounter of non-cohesive sand-like fully weathered granite. The water collapsed and collapsed.

3.3. Surface treatment of shallow buried section
According to the actual terrain on site, combined with engineering geology-related data, surface shallow drainage treatment and grouting reinforcement were adopted for the shallow burial section. After the construction was completed, the surface reinforced concrete in the grouting area was destroyed and backfilled with cultivated soil to level the green For ecological restoration. The surface treatment method of the shallow buried section of the tunnel is shown in “Fig. 5”.

![Figure 5. Schematic diagram of the surface treatment plane in the shallow section](image)

(1) Surface interception drainage measures for shallow buried sections
Surface interception drainage measures mainly include surface interception, drainage ditches and ground hardening measures for ultra-shallow buried sections.
The net cross section of the ditch A is designed to be 2.0×0.8m (width × height), the net cross section of the drainage ditch B is designed to be 2.5×1.2m (width × height), the bottom of the ditch is 30cm thick C25 reinforced concrete, and the side wall is 30cm thick C25 plain concrete. Formwork construction.

(2) Restoration of green surface and ecological restoration

After the excavation and support construction of the shallow buried section passed smoothly, the hardened parts of the concrete on both sides of the drainage ditch were chiseled, backfilled with planting soil, the collected topsoil was spread out, the terrain was renovated, and the grass seeds were re-greened.

The cleared concrete and other construction waste must be cleaned up and transported to the waste slag yard. It is strictly forbidden to backfill the soil with stone slag. The average thickness of the backfill soil is 2.0m, and the topsoil is flattened to facilitate the vegetation to restore its original appearance.

3.4. Advance support measures in the cave

Advanced support with double-layer small catheter, as shown in “Fig. 6”. The small pipe grouting adopts Φ42mm hot-rolled seamless steel pipe with a wall thickness of 4mm and a pipe section length of 4.0m. The inclination angle of the first row of small pipes is about 30°, and the second row of small pipes is about 12-15°.

(a) Longitudinal section view of double-layer small duct reinforcement on excavation surface

(b) Cross-sectional view of double-layer small pipe reinforcement on the excavation surface

The steel pipe is not opened within 0.5m of the nozzle section. The rest of the grouting holes are staggered at 15cm intervals. The hole diameter is 8mm. The cement slurry has a water-cement ratio of 1:1. The grouting pressure is recommended to be 0.5-0.75MPa.

The excavation adopts three steps and seven steps excavation method to strengthen the support and timely implement the closed arch in a loop.
3.5. Lining waterproof treatment
The original design of the second lining of the cave body uses 1.2mm EVA waterproof board + 350g/m² non-woven fabric, combined with a circular and longitudinal drainage blind pipe to form a drainage system.

In order to ensure the waterproof effect, PMH-3040 high-density polyethylene (HDPE) self-adhesive film waterproof coiled material is used to replace the conventional EVA waterproof board in the shallow buried section. HDPE self-adhesive waterproof membrane, with high-density polyethylene sheet as the bottom film, one side covered with polymer self-adhesive film layer, the surface of the film layer is covered with anti-sticking weather-resistant coating and isolation layer (PET isolation film protection).

The membrane self-adhesive film can have physical and chemical reaction with the newly poured concrete. The adhesion between the polymer self-adhesive and the concrete can improve the waterproof effect. At the same time, it has a unique self-healing ability for minor construction damage and efficiently solves the second liner seepage. Problems, to ensure driving safety after completion of the inspection.

4. Construction technology for shallow buried section disposal

4.1. Construction process
See “Fig. 7” for details of the construction process of the shallow buried section.

4.2. Construction preparation and clearance
(1) Before construction, ensure that all materials are submitted for inspection, construction plans and technologies are in place, and work, materials, machines, and construction access roads are ready.

(2) Loft accurately according to the drawings, remove the surface shrubs and weeds, and level the ground basically. Pay attention to the collection of topsoil for post-work greening and ecological restoration.

(3) Carry out the canalization of the original ditch according to the drawings and the topography of the site. Ensure smooth drainage and no leakage at the bottom of the ditch.

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施工准备
测量放样
清表 表土收集
地表渠化
钻孔,安装钢花管
地表加盖
钢花管制作
注浆
洞内双层小导管超前支护
三台阶七步开挖、初期支护
浆液制备
加强监控量测
加强地质预报
HDPE防水板施工
二次衬砌施工
地表复绿
检查验收

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4.6. Grouting treatment with deep surface cover

(1) Drilling and clearing

Use down-hole drilling to drill holes at the grouting point, adjust the angle before drilling, and often check during the process to prevent deviations. Scan the hole in the backward mode. After the hole is cleared, insert the drill rod into the bottom of the hole and repeat the hole sweep once.

(2) Install steel flower tube

Figure 7. Construction process of shallow buried section of tunnel
① The front end of the steel pipe is made into a tapered shape to facilitate the installation of the small catheter jack; 8mm grouting holes are drilled around the pipe wall, and there is no grouting hole in the range of 0.5m at the tail.

② Adopt manual matching excavator for small pipe intubation construction. During the installation process, small pipe should be perpendicular to the ground. If the resistance is too large, use excavator for construction. The top of the pipe is exposed 20cm, which is used to embed in the closed concrete.

③ Ensure that the steel flower pipe joint is reliable and the length of the steel flower pipe is ensured to penetrate into the reinforced contour of the tunnel.

3) Ground hardening and capping
① Bind the reinforcement mesh according to the drawings, effectively connect the reinforcement mesh and the steel flower tube, and install a grouting valve.
② Pouring the hardened concrete of the ultra-shallow buried sealing layer.
③ Make sure that the grouting valve is not clogged when exposed.

The surface construction effect is shown in “Fig. 8”.

Figure 8. Ground treatment construction in shallow section

(4) Grouting
① The order of grouting should be four weeks, then middle, deep first, shallow first, low first, and high high. It is not allowed to arbitrarily inject randomly, causing "sandwich" phenomenon.
② The grouting pressure is maintained at 0.5 ~ 1.0MPa. When the grouting pressure gradually increases and reaches about 1.0MPa, and the amount of grouting decreases significantly and continues for 10-15 minutes, the grouting can be terminated.
③ Observe the amount of grouting and surface changes at any time during grouting, adjust the slurry concentration appropriately according to the situation, and use intermittent grouting if necessary.

4.7. Excavation, support and lining construction
(1) Advance geological forecast
① When the tunnel is constructed to a distance of 50m from the beginning of the shallow buried section, TRT6000 is used to predict the geological structure in the range of 0-120m in front of the palm face.
② When approaching the dark hole in the shallow buried section, the geological radar is used to further verify the geology in the range of 0-30m in front of the palm face.
③ In the process of construction of the shallow hole in the shallow buried section, the method of deepening the blasthole and the geological survey intuitively judge the surrounding rock in front of the palm face.
④ Confirm the geological surrounding rock in front of the palm face through various geological prediction methods, analyze and feedback in time, and guide the next step construction accordingly.
⑤ Geological forecast must be used as a process and the next step of construction can be carried out after completion.

(2) Monitoring and measurement
1. Observe inside and outside the cave during construction.
2. Monitor the surface settlement of the tunnel.
3. Carry out tunnel headroom convergence monitoring.
4. Monitoring the tunnel arch subsidence.
5. Each observation point and reference point must be buried in strict accordance with the requirements and unified numbering; pay attention to the protection in the process and ensure the continuity of the observation data.
6. Observation data is sorted and analyzed in time; charts are formed to facilitate intuitive analysis.
7. Establish monitoring, measurement, early warning and feedback mechanisms.

(3) Advanced support
1. Strictly follow the disposal plan to set up the advanced double-layer small catheter. Ensure the length, angle and fullness of the small pipe.
2. Ensure the reliable connection and overlap between the small pipe and the arch.

(4) Tunnel excavation and initial support
1. The excavation method of the three-step reserved core soil is preferentially used for the excavation of the cave body. At any time, according to the surrounding rock changes, the relevant construction method is used to convert the plan. Single side wall, double side wall method conversion.
2. According to the construction sequence, the upper, middle and lower steps are divided into sections for excavation. The upper step has a height of 4.0 meters and the middle step has a height of 3.45 meters. The lower steps are directly excavated to the top of the filling surface, and finally the tunnel bottom is excavated.
3. Strictly control the looping footage and the length of the steps. The length of each step should be controlled at 5~10 meters; the looping footage should be controlled at 0.5~1.0m, and no more than two arches should be closed in time to form a loop.
4. Weak blasting must be used during excavation to reduce the impact of blasting vibration on the surrounding rock (including reinforced soil).

(5) Secondary lining
1. According to the monitoring and measurement data, determine the timing of the second liner.
2. Using nail-free laying of PMH-3040 high-density polyethylene (HDPE) self-adhesive film waterproof coiled material, the degree of slack.
3. Pay attention to protect the waterproof coiled material during the construction of the steel bar. After the construction is completed, remove the protective film of the coiled material to expose the back adhesive layer.
4. The trolley is formed by molding two lining concrete at a time.

5. Surface ecological restoration
1. Concrete and other construction waste must be cleaned up and transported to the waste slag yard.
2. The average thickness of the backfill soil is 2.0m, and it is strictly prohibited to use the backfill of soil with gravel.
3. Use the clear topsoil to spread out to help the vegetation restore its original appearance.

6. Conclusion
At present, the project has been successfully completed and opened to traffic, with good results after construction.
1. The use of deep grouting in the shallow buried section of the Mountain Expressway has a good effect on the consolidation of undesirable soils. It is characterized by a larger reinforcement range than shallow grouting, and the overall stability of the shallow buried layer is improved. To ensure that the excavation of the tunnel can be carried out by the three-step construction method of reserving the core
soil with three steps; the temporary measures such as temporary arches and side wall guide pits are avoided, which reduces the investment and speeds up the construction period.

②The use of (HDPE) self-adhesive film new waterproof membrane in the shallow buried section of Mountain Expressway has almost no leakage points, which ensures the safety and comfort of driving during operation, reduces the maintenance cost, and reflects the people-oriented concept.

③After the construction, the land was reclaimed and greened, and ecological restoration was carried out, which did zero damage to the environment and ecology.

It is hoped that this article can provide a certain reference for the construction treatment of the shallow buried section of the mountain tunnel in the future.

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