

Construction Technology for Shallow-Buried Underground Excavated Tunnels Crossing Water-Rich Sand and Gravel Layers: Postprint

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Abstract

Underground excavation of tunnels in water-rich sandy cobble strata faces challenges of surrounding rock instability, water and sand inrush, and settlement control, while traditional shallow tunneling methods suffer from poor grouting effectiveness and low support efficiency. The sandy cobble layer, characterized by high porosity and large particle size, leads to difficult hole formation for advance support and non-uniform grout diffusion, which can easily trigger working face collapse, necessitating process optimization to enhance safety and construction efficiency. The underground tunnel in the connecting line section behind Xi'an East Station of Xi'an Metro Lines 5 and 21 has a length of 178.672 m, a cross-section of 13.4 m × 11.493 m, with its arch crown traversing water-rich sandy cobble strata (cobble particle size 20–200 mm) and a groundwater table depth of 12 m. The construction requires underpassing roads and shallow-foundation residential buildings, imposing stringent settlement control requirements. The original design employed 3 m small pipes and single-fluid grouting; however, difficult hole formation and insufficient grouting during construction resulted in schedule delays and safety risks. Addressing the characteristics of sandy cobble strata, this study proposes the following optimization scheme: optimization of advance support parameters—shortening small pipe length to 2 m, reducing circumferential spacing to 300 mm, installing one pipe per longitudinal frame, and adopting cement-sodium silicate double-fluid grout (grouting pressure 0.1–0.3 MPa) to enhance grout diffusion and consolidation efficiency; improvement of construction techniques—adhering to the principle of “short thin pipes, light disturbance, rapid solidification, and solid arch foot,” adding a 3–5 cm shotcrete sealing layer to stabilize the working face, and combining the bench cut method with the double side drift method for stepwise support to reduce surrounding rock exposure. Following optimization, construction efficiency increased to 2 m per day, monthly progress reached 60–70 m, and the construction period was shortened by nearly half. Surface settlement,

convergence, and building settlement all remained below warning thresholds, validating the technical reliability. This study establishes a rapid construction technology for shallow tunneling in water-rich sandy cobble strata, resolving the challenges of grouting and support efficiency while ensuring safe and efficient project implementation. The findings provide key technical references for metro construction in similar geological conditions, advance tunneling technology in complex strata, and deliver significant economic and social benefits.

Full Text

Construction Technology of Shallow Buried Tunneling through Water-Rich Sandy Gravel Strata

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Abstract

Tunnel construction in water-rich sandy gravel strata using shallow buried tunneling methods faces critical challenges of surrounding rock instability, water and sand inrush, and settlement control. The high porosity and large particle size of sandy gravel layers hinder advanced support hole formation and uniform grout diffusion, frequently causing face collapse. Conventional shallow buried tunneling techniques suffer from poor grouting effectiveness and low support efficiency, demanding urgent process optimization to enhance safety and productivity. The connecting tunnel behind Xi'an East Station for Xi'an Metro Lines 5 and 21 exemplifies these challenges. This 178.672-meter-long tunnel features a 13.4m × 11.493m cross-section, with its crown traversing a water-rich sandy gravel layer (cobble size 20–200mm) and a phreatic water table at 12m depth. Construction required undercrossing highways and shallow-foundation residential buildings, imposing stringent settlement control requirements. The original design utilizing 3m small pipes with single-fluid grouting encountered severe difficulties in hole formation and insufficient grouting, causing schedule delays and safety hazards.

Addressing the sandy gravel stratum characteristics, this study proposes: (1) Optimized advanced support parameters—reducing pipe length to 2m, circumferential spacing to 300mm, longitudinal spacing to one row per frame, and adopting cement-sodium silicate double-fluid grout (0.1–0.3MPa pressure) to enhance diffusion and consolidation; (2) Improved construction technology—following the “short thin pipes, light disturbance, fast setting, solid arch foot” principle, adding a 3–5cm shotcrete cover to stabilize the working face, and combining bench method with double-side wall pilot tunnel method for stepwise support to minimize rock exposure. These measures increased efficiency to 2m daily progress, achieving 60–70m monthly advance and nearly halving the schedule, while all settlement indicators remained within warning thresholds, confirming

technical reliability. This research establishes a rapid construction technology for shallow buried tunneling in water-rich sandy gravel strata, resolving grouting and support efficiency issues while ensuring safe, efficient implementation. The findings provide critical technical references for subway projects in similar geology, advance tunneling technology in complex strata, and yield significant economic and social benefits.

Keywords: subway tunnel; sandy gravel layer; strata grouting reinforcement; shallow buried tunneling construction technology

Note: Figure translations are in progress. See original paper for figures.

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