Study on Targeted Retrofitting Technology for Dual-Mode (EPB-Slurry) Shield Machines: Post-print

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Date: 2025-08-20T00:00:00+00:00

Abstract

This project is based on a subway project in Shenzhen, which is constructed along the coast and mainly traverses sand layers, silty soil, completely weathered granite, upper-soft lower-hard strata, and rock-fill layers, featuring lateral crossing of bridge piles, high water pressure, and large burial depth. This paper addresses the challenges of shield tunneling construction under complex geological conditions and sensitive construction environments in coastal areas through systematic modification of existing shield machines: (1) Upgraded composite cutter head: adopting a six-spoke composite cutter head with an opening ratio of 33%, welding 6+6mm composite wear-resistant plates on the cutter head panel, embedding alloy wear-resistant blocks on the outer periphery of the cutter head, adopting a zoned tool layout, and configuring shell cutters and overbreak teeth; (2) Added cutter head freezing system: installing three-inlet three-outlet freezing circulation pipelines covering the entire cutter head inside the cutter head, forming a frozen soil curtain by circulating -30°C brine to freeze the moisture in the soil ahead of and around the cutter head, enabling atmospheric pressure tool change under conditions where pressurized tool change is not feasible; (3) Optimized 10bar sealing system: the main drive seal comprises two internal and external sealing systems consisting of face polyurethane lip seals + axial polyurethane lip seals + axial rubber seals, which, through automatic continuous grease injection of EP2 grease without back pressure, can withstand working water pressure greater than 10bar; (4) Improved slurry mode muck volume statistics system: installing flow meters and density meters on the slurry circulation pipeline, through an intelligent excavation management system that calculates the actual muck volume per ring in real time and conducts comparative analysis to avoid ground settlement caused by over-excavation. Through the above modifications, key technical challenges such as adaptability to complex strata, safety of adjacent construction, and high water pressure tunneling

were successfully solved. The research results not only ensured the safe and efficient implementation of the project, but also provided a generalizable technical solution for shield machine selection and construction under similar geological conditions, promoting the application and development of composite tunneling modes in urban rail transit construction.

Full Text

Preamble

Discussion on Targeted Modification Techniques for Dual-Mode (EPB/Slurry) Shield Tunneling Machines

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Abstract

This study examines a coastal metro project in Shenzhen characterized by tunneling through complex geological formations including sand layers, muddy soil, completely weathered granite, upper-soft lower-hard strata, and boulder fill layers, while contending with adjacent bridge piles, high water pressure, and substantial burial depth. To address the challenges of shield tunneling in such complex geological and sensitive environmental conditions, systematic modifications were implemented on existing shield machines.

Four key technical improvements were made: (1) The composite cutterhead was upgraded to a six-spoke design with a 33% opening ratio, featuring 6+6mm composite wear plates welded on the cutterhead face, alloy wear-resistant blocks embedded around the periphery, a zone-based tool layout, and the configuration of shell cutters and overcutting bits; (2) A cutterhead freezing system was added, incorporating a three-inlet/three-outlet freezing circulation pipeline covering the entire cutterhead, which freezes moisture in the soil ahead of and around the cutterhead by circulating -30°C brine to form a frozen soil curtain, thereby enabling atmospheric pressure tool changes where pressurized interventions are not feasible; (3) The 10bar sealing system was optimized with dual inner and outer sealing systems for the main drive, comprising face polyurethane lip seals, axial polyurethane lip seals, and axial rubber seals, which through continuous automatic grease injection enables EP2 grease to withstand working water pressures exceeding 10bar without requiring back pressure; and (4) The muck volume statistics system for slurry mode was enhanced by installing flow meters and density meters on the slurry circulation pipeline, enabling an intelligent excavation management system to calculate actual muck volume per ring in real time and perform comparative analysis to prevent surface settlement from over-excavation.

These modifications successfully resolved key technical challenges related to complex strata adaptability, close-proximity construction safety, and high-pressure

tunneling. The research outcomes not only ensured safe and efficient project implementation but also provide a replicable technical solution for shield machine selection and construction under similar geological conditions, advancing the application and development of composite tunneling modes in urban rail transit construction.

Keywords: dual-mode shield; coastal environment; large burial depth; adverse geological conditions

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