Defects and Remediation of Concrete Structures in Operational Metro Systems: Postprint

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Abstract

Concrete structures, after commissioning and operation, develop various deterioration issues of differing characteristics and severity during their service life, with certain defects presenting special, emergency, and exceptionally challenging circumstances. For instance, large-area air voids in the upper semicircle of mined tunnels, under the influence of vibration loads from train operation or external water pressure, cause crushing and spalling of the surface concrete, forming voids and cavities. Stabilizing the cracked concrete at cavity surfaces, repairing such void and cavity defects, while simultaneously ensuring normal and safe train operation, presents significant difficulty and requires emergency response. Emergency shrouds are employed to stabilize the fractured concrete surfaces, combined with EAA high-permeability hydrophilic epoxy material and a composite grouting process of cement grout—EAA high-permeability hydrophilic epoxy material, to perform penetration-filling-consolidation-strengthening repair treatments on void and cavity locations. For poor geological strata under flowing water conditions, such as muck, silty fine sand, medium sand layers, and silt, tunnels in operation experience differential settlement defects due to soil erosion. Based on the characteristics of such strata, stable single-slurry cement-sodium silicate materials are utilized to overcome the segregation and loss of cement grout under flowing water. The grout exhibits good self-stability, enabling drainage-filling-consolidation of soil in poor ground conditions, stabilizing the tunnel foundation, and controlling settlement.

This paper enumerates relevant defects in operational subway concrete structures. Based on the special, emergency, and difficult issues arising in operational subway concrete, correspondingly developed materials and construction techniques are employed to remediate damaged concrete defects, achieving certain effectiveness in the treatment.

Full Text

Problems and Treatment of Concrete Structure Defects in Operating Subway Systems

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Abstract
Concrete structures in operational subway systems develop various defects during their service life, exhibiting diverse characteristics and varying degrees of severity. Certain defects present special challenges that are particularly urgent and difficult to address, requiring innovative solutions that can be implemented without disrupting train operations.

One critical problem involves large air cavities in the upper semicircular sections of mined tunnels. Under train vibration loads or external water pressure, the concrete lining can crack and spall, forming voids and cavities. The challenge of stabilizing cracked concrete surfaces around these cavities while ensuring continuous safe train operation demands emergency measures. This study addresses this issue through emergency protective coverings to stabilize fractured surfaces, combined with high-permeability hydrophilic epoxy (EAA) materials and a composite grouting process using cement-EAA mixtures. This integrated approach achieves penetration, filling, consolidation, and reinforcement of the defective zones.

Another significant challenge arises in dynamic water environments with poor geological conditions, such as silt, fine sand, medium sand, and silty soils, where running tunnels experience differential settlement due to soil loss. To combat this problem, a stable single-slurry cement-sodium silicate material is utilized. This material overcomes the issue of cement slurry segregation and washout in flowing water, demonstrating excellent self-stability. It effectively drains, fills, and consolidates the soil mass, stabilizing the tunnel foundation and controlling settlement.

This paper systematically enumerates common defects in operational subway concrete structures and presents corresponding research-developed materials and construction techniques to address these special, urgent, and difficult problems. The proposed solutions have demonstrated effective and timely results in practical applications, providing valuable references for similar projects.

Keywords: Operation; Rail Transit; Concrete Structure; Defects; Treatment Measures

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