Case Study of Tunnel Monitoring Using Fiber Optic Sensors



Overview

Distributed fiber optic sensors for tunnel monitoring: A state-of-the. This study presents a state-of-the-art review of the DFOS applications for monitor.

Key Takeaways

Distributed fiber optic sensors (DFOS) enable continuous, high-resolution monitoring of tunnel deformation, strain, and temperature, providing real-time structural health insights.

Overview of Fiber Optic Tunnel Monitoring

Fiber optic sensors, particularly distributed fiber optic sensors (DFOS) or distributed optical fiber sensors (DOFS), are increasingly used for structural health monitoring (SHM) in tunnels. These sensors measure strain, displacement, temperature, and vibration along the entire length of the fiber, offering continuous, real-time data that surpasses traditional point-based monitoring methods like total stations or inclinometers.

DFO

S systems typically rely on Brillouin or Rayleigh scattering principles, and fibers can be embedded in tunnel linings or adhered to surfaces to capture distributed strain or point displacements.

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Key Implementation Considerations

Successful DFO

S deployment involves four critical aspects: Selection of sensing fiber: Choosing fibers compatible with the tunnel environment and measurement requirements. Measurement principle: Selecting Brillouin or Rayleigh scattering based on the desired resolution and range. Sensor layout design: Strategically placing fibers along longitudinal and transverse directions to capture structural behavior.

Field instrumentation: Ensuring robust installation and protection of fibers for long-term monitoring. Case StudiesHigh-Speed Rail Tunnel, Northern ChinaA high-speed rail tunnel was monitored using DFOS to track strain during concrete pouring, curing, and backfilling. The system provided spatiotemporally continuous data, revealing force-deformation characteristics at different tunnel positions.

This allowed engineers to dynamically adjust construction plans and implement early warning measures for potential structural issues.

CER

N Tunnel, GenevaDFOS was applied to a curved tunnel section to measure circumferential strain. An optimized data processing method converted strain profiles into tunnel convergence measurements, providing a more realistic representation of deformation than traditional point-based methods. Results closely matched conventional total station measurements, demonstrating DFOS's high accuracy and resolution.

London Crossrail, Royal Mail TunnelDuring the construction of a new platform tunnel beneath an existing masonry tunnel, DFOS cables were installed to monitor incremental strain. The sensors detected asymmetrical settlement patterns and provided continuous deformation profiles, confirming the effectiveness of DFOS for real-time monitoring in complex urban environments.

TM

B L-9 Metro Tunnel, BarcelonaDOFS were implemented to monitor potential impacts from nearby construction. The system enabled real-time strain monitoring, and innovative data post-processing techniques were developed to compare measurements with theoretical structural models. This case highlighted the reliability and practical applicability of fiber optic monitoring for urban tunnels.

Advantages of Fiber Optic Monitoring

Continuous, distributed measurements along the tunnel length. High sensitivity and resolution for detecting small deformations. Immunity to electromagnetic interference and corrosion.

Real-time monitoring for early warning and maintenance planning. Integration with smart infrastructure systems for automated SHM.

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Conclusion

Fiber optic sensors provide a robust, high-resolution solution for tunnel SHM, enabling engineers to monitor structural behavior throughout the tunnel's life cycle. Case studies from China, Europe, and CERN demonstrate that DFOS and DOFS can accurately capture strain, displacement, and convergence, support dynamic construction adjustments, and enhance safety and disaster prevention in tunnel engineering projects.

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