Beyond a Century:
Advanced and Smart Maintenance Technologies for Extending the Service Life of Tunnels

EAST JAPAN RAILWAY COMPANY

○ Characteristics of one of the largest and oldest railway tunnel maintained by JR East

- Many aging tunnels, particularly on conventional lines, the oldest approximately 140 years in service as shown in Fig. 2
- Tunnels in conventional line: approx. 490 km, about 1,000 tunnels, average age 80 years
- Tunnels in Shinkansen: approx. 440 km, about 200 tunnels, average age 35 years

○ Tunnels constructed by diverse methods and a wide range of materials

- Maintenance of all major types: mountain tunnels, shield tunnels, cut-and-cover tunnels, immersed tunnels
- Mountain tunnels constructed using different methods: Timbering support methods, NATM
- Timbering support tunnels with historically diverse materials of linings: brick, masonry, concrete block, concrete (unreinforced), reinforced concrete

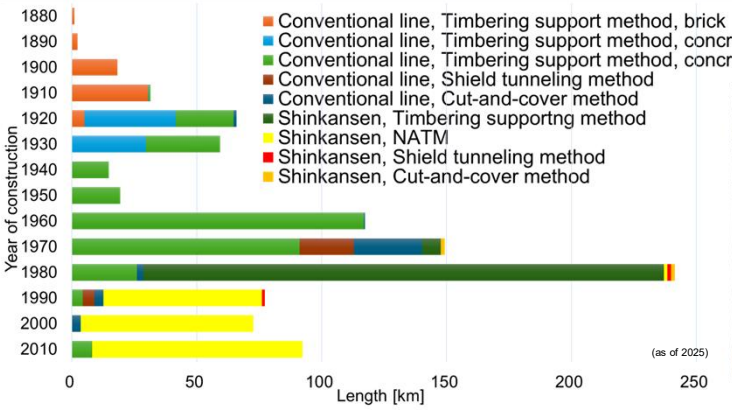

Fig. 1 Representative transitions in construction methods and materials

Fig. 2 Legacy Tunnel (Left side tunnel), approximately 140 years in service

Fig. 3 Close inspection of tunnel linings by in-house engineers

○ Accumulated and advanced maintenance technologies for inspection

- Accurate evaluation of tunnel condition through periodic inspections by in-house engineers (Fig. 3)
- Integrated support by expert tunnel engineers for deep consideration into cause of defects and damage, and developing maintenance strategies

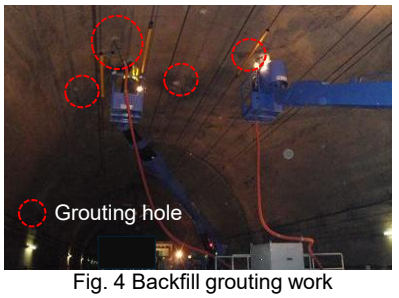

Fig. 4 Backfill grouting work

○ Development and long-term on-site verification of repair and reinforcement technologies for defects and deterioration

- In-house development of repair and reinforcement technology addressing mechanism such as earth pressure, settlement, and heaving
- In-house development of repair materials such as backfill grouting (JETMS) and repair technologies for structural stabilization (Fig. 4)
- Long-term on-site verification of effectiveness of countermeasures, including installation of rock bolts against earth pressure, based on periodic measurement data for more than 30 years [Fujita et al. WTC2022]
- Sustaining tunnel performance through continuous and proactive repair works such as pointing (Fig. 5) and dredging of drainage systems in roadbed
- ✓ **These maintenance technologies have demonstrated proven long-term performance in sustaining legacy tunnels under complex ground conditions and severe climatic conditions in Japan.**

Fig. 5 Pointing of concrete block lining

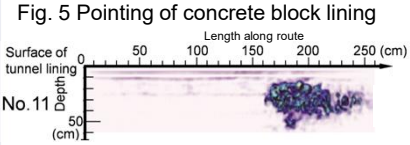

Fig. 6 Example of results of inspection by CLIC

○ Digital smart solutions for advanced and efficient maintenance

- Quantitative and high-precision evaluation of subsurface and surface defects in tunnel linings using dedicated inspection vehicles
- CLIC (Concrete Lining Inspection Car): Evaluation of subsurface defects and deterioration in linings such as honeycomb as shown in Fig. 6, using electromagnetic wave radar [Matsunuma et al. WTC2012]
- TuLIS (Tunnel Lining Scanning car): High-precision scanning of surface defects in tunnel linings such as cracks, and drawing of digital plan to support periodic inspection by in-house engineers
- Development of automated technology for crack extraction on the surface of linings, as shown in Fig. 7
- Development of automated technology for comparative analysis of crack conditions and quantitative evaluation of crack progression, as highlighted by red lines in Fig. 7
- Advanced inspection and evaluation of tunnel roadbed based on three-dimensional point cloud data [Kajiyama et al. WTC2026]
- ✓ **Digitalization technologies enhance — rather than replace — engineering expertise and strengthen decision-making in complex and aging tunnels.**

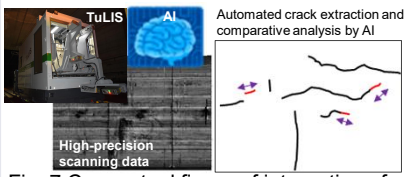

Fig. 7 Conceptual figure of integration of high-precision data by TuLIS to support in-house engineers

○ Development and implementation of seismic retrofit of mountain tunnels

- Development of technologies based on analysis of seismic damage to prevent similar heavy damage in preparation of future strong earthquakes (Fig. 8) [Mizuno et al. WTC2014, 2025]

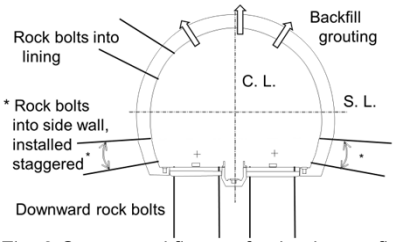

Fig. 8 Conceptual figure of seismic retrofit

Keeping tunnels safe, functional, and sustainable beyond 100 years.

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