EpsiMon
INFRASTRUCTURE MONITORING

CERN Super Proton Synchrotron tunnel TS16

Geneva, Switzerland

Long-term fibre optic monitoring of a repaired tunnel lining

The Super Proton Synchrotron (SPS) is an 8 km-long ring tunnel that houses one of the particle accelerators at the European Laboratory for Particle Physics (CERN). The tunnel has an inner diameter of 4.14 m and is situated approximately 40 m below ground, across the Swiss French border.

In 2023, a routine visual inspection revealed significant cracking in the concrete lining of tunnel section 16 (TS16) of the SPS, following which emergency investigation and remedial works were carried out to stabilise the lining. As part of the long-term mitigation measures put in place, Epsimon was commissioned to design, install and operate a permanent fibre optic (FO) monitoring system retrofitted to the tunnel intrados.

The monitoring, which started in April 2024, has enabled the CERN tunnel asset management (TAM) team to track the deformation of the lining remotely in real-time, ensuring that the tunnel continues to operate safely.

Challenges and solutions

Due to operational hazards related to nuclear radiation, the SPS is generally only accessible for a short period of time once a year for inspection and maintenance. Therefore, the FO monitoring system needed to be robust and reliable to enable **long-term, automated and uninterrupted operation**. It also had to provide a complete picture of the performance of the tunnel lining, between annual visual inspections. The key to achieve this was the **careful design of every detail of the system**.

The layout of the FO sensing cables was planned to provide the required information about both the circumferential and longitudinal deformation of the lining, at 58 locations in the repaired tunnel section.

The cables were anchored to the concrete lining using tailor-made aluminium clamps that were designed and tested by Epsimon. This enables reliable measurements to be taken, which can then be used to **identify and track movements in specific parts of the tunnel lining.**

Project highlights

- Instrumentation consisting of:
  - Eight rings of circumferential FO cables
  - Two lines of longitudinal FO cables
- Tunnel lining deformation tracked at 58 locations
- Automated monitoring with hourly readings
- Real-time data processing and visualisation

Technology used

- Distributed temperature & strain sensing (DTSS)
- Brillouin optical time domain analysis (BOTDA) spectrum analyser

Monitoring objectives and solution

The purpose of the FO instrumentation is to enable CERN's engineers to **monitor the performance of the SPS tunnel remotely, thereby ensuring that it continues to be operated safely and within serviceability limits**. The monitoring system is required to:

- record circumferential and longitudinal strains from the tunnel intrados at specific locations;
- operate continuously for several years without degradation, and without being affected by electromagnetic interference (EMI) generated by the particle accelerators;
- process the data automatically and make the results available to the project engineers in near real-time.

Distributed fibre optic sensing (DFOS) technology based on Brillouin optical scattering offers unique capabilities for monitoring strain and temperature with **high precision over long distances and in harsh environments**. FO cables are **immune to EMI and do not degrade over time**, making them ideal for long-term monitoring, especially in locations that are hard to access, like the SPS tunnel.

Since the FO cables were retrofitted to the surface of the tunnel lining, they are subjected to occasional ambient temperature fluctuations of a few degrees. A separate temperature-sensing FO cable was also installed in the tunnel, enabling the strain measurements to be **temperature-compensated during the data processing**. The Brillouin spectrum analyser, which is located outside the tunnel and is connected to the instrumentation via a FO extension cable, records hourly measurements. The raw data are **automatically uploaded to Epsimon's *Real-Time Monitoring System* (*RTMS*)** cloud-based software for processing and visualisation on a dashboard.

Project details

- **Client: European Organisation for Nuclear Research (CERN)**
- **Timeline: started January 2024**

Scope of services

- **Design of the DFOS monitoring scheme**
- **Production and installation of the fibre optic instrumentation**
- **Operation of the real-time monitoring system**

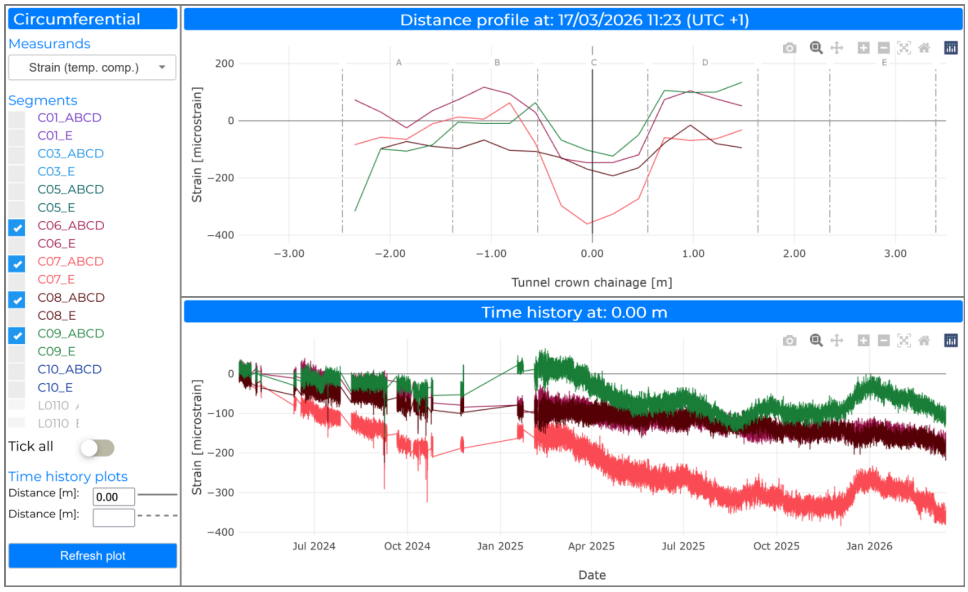
Key outcomes and benefits

The monitoring data indicate that, despite the repairs carried out on the tunnel lining, there is **ongoing development of forces and progressive displacement** at the tunnel crown in specific locations. This was corroborated with subsequent visual inspections.

The continuous monitoring from the DFOS instrumentation allows the tunnel engineers to keep watch over the performance of the SPS TS16. The **long-term trends** observed in the strain readings are particularly useful as these allow the asset owners to **plan ahead for additional inspections or further interventions** that may be deemed necessary, before they become critical.

The data are also being used to understand how **seasonal effects**, such as changes in ground water level, influence the tunnel structure.

Scan for digital version



Real-time visualisation of the monitoring data from the CERN SPS tunnel on Epsimon's RTMS dashboard.

"The FO monitoring system enables CERN to monitor the performance of our tunnel lining continuously, in areas which are difficult to access due to radiation constraints. Epsimon's expertise and collaborative approach ensures that we achieve the outcomes we aim for in meeting our critical infrastructure needs."

John Osborne
Senior Civil Engineer, CERN