Identifying Structural Damage on the Fukuoka Expressway Using MCGPR

Advanced Subsurface Assessment with the GS9000 Multichannel GPR

Overview

- Nexco East need to evaluate the Fukuoka Expressway bridge to assess the condition after it had endured several seismic events.
- The GS9000 Multichannel GPR was used to scan the expressway in the selected bridge sections.
- The team collected valuable structural health data of the condition of the bridge, facilitating effective maintenance planning and ensuring the safety and longevity of the infrastructure.

The East Nippon Expressway Company Limited (Nexco East) is one of the main operators of expressways and toll roads in Japan, conducting construction, service area and expressway management business in the region.

Challenge

With Japan maintaining ownership of over 730,000 bridges, a substantial proportion (50%) of which are projected to exceed 50 years in age by 2030, the need for advanced assessment solutions becomes apparent.

Notably, the Fukuoka Expressway, located in Fukuoka and constructed in the 1970s, exemplifies a bridge requiring structural health diagnosis. Having endured significant seismic events, including multiple earthquakes, this bridge suffered substantial damage, prompting a month-long closure in April 2016. Nexco East collaborated with Screening Eagle Technologies to scan the expressway using the latest multichannel subsurface GPR (Ground Penetrating Radar) mapper, the GS9000.

The selected bridge sections for scanning were between expansion joints, with each section covering approximately 25 meters. A representative result is depicted in Figure 1, showing surface defects in a C-scan view overlaid in Google Earth.

Figure 1. C-scan view overlaid in Google Earth, depicting the analysis of surface defects obtained from GPR Insights data collected by the GS9000.

In the realm of Ground Penetrating Radar (GPR) technology, the prevailing design convention typically entails utilizing a spacing of approximately 7.5 cm between channels. This standardization persists across varying configurations, encompassing diverse frequency ranges and channel allocations. However, such a conventional setup often encounters limitations in effectively detecting surface defects such as cracks and deterioration defects in asphalt/concrete (A/C) layers.

Contrastingly, the GS9000 HF antenna introduces a pioneering design paradigm that deviates from the established norm. Notably, this innovative antenna design not only facilitates broader coverage across high-frequency spectra but also maintains a markedly reduced channel spacing of 2.5 cm. This departure from conventional spacing standards yields multifaceted advantages, profoundly impacting the capabilities and applications of GPR technology, as evidenced by this case study.

Figure 2 and Figure 3 show the GS9000 system operating on the bridge deck

Results

The scanning sessions yielded invaluable insights into the condition of the Fukuoka Expressway bridge. The advanced geo-positioning 'Free Path' feature of the GS9000 enabled engineers to record findings with centimeter-level accuracy, map lines on-site, and add geo-located data. They obtained a 3D map of the underground as they walked.

Detailed reports based on scanning data provided valuable information for structural integrity assessments and maintenance planning. Simultaneously, through its high-frequency array antenna, engineers were able to collect dense data, identify structural weaknesses, and assess the extent of asphalt damage, including major cracks, and patterns indicative of potholes (Figure 2 and Figure 6).

They could also detect defects between asphalt and concrete layers, such as delaminationn, and to identify the deterioration areas attributed to scaling and decomposition in concrete constituents (Figure 7); and to analyze the first rebar layer (Figure 8), to create a further insightful condition map (Figure 4), pinpointing areas requiring immediate attention or maintenance.

GPR mapping, particularly with extremely dense data collected by MCGPR GS9000, generates a Deterioration Map based on analysing amplitude degradation of the top reinforcement bars (rebar) within bridge structures. By emitting electromagnetic pulses and assessing the attenuation of reflected signals from rebar, GPR reveals insights into structural deterioration, aligned with ASTM D6087 standards. Traditionally, manual analysis of GPR data is labour-intensive and time-consuming. To overcome this, an AI engine autonomously detects rebar apexes, facilitating uninterrupted GPR application use.

The AI engine is designed to automatically detect the apex of hyperbolas associated with the top reinforcing steel in concrete. The search runs independently in the background, allowing the user to continue using the GPR application without interruptions. Once the AI engine completes its process, it generates two qualitative maps:

1. Likelihood of Deterioration Maps (Figure 4): These maps are computed following the ASTM D6087 standard, providing an assessment of the likelihood of concrete deterioration in bridge deck. This information helps in identifying areas that require closer inspection or potential maintenance interventions.
2. Condition Maps for Generic Reinforced Concrete Elements: These maps provide an overview of the condition of the generic reinforced concrete elements within the bridge deck. They offer valuable insights into the overall state of the infrastructure, enabling informed decision-making for maintenance and repair activities.

Processing a large-scale GPR dataset in GPR Insights software involves utilizing the software's capabilities to analyse and interpret the collected data. By leveraging the AI engine and advanced algorithms within the GPR Insights, the GPR data from the bridge deck can be efficiently processed and transformed into meaningful maps and visualizations. These outputs provide valuable information for assessing the condition of the reinforced concrete elements in the bridge deck, prioritizing maintenance actions, and ensuring the safety and longevity of the infrastructure.

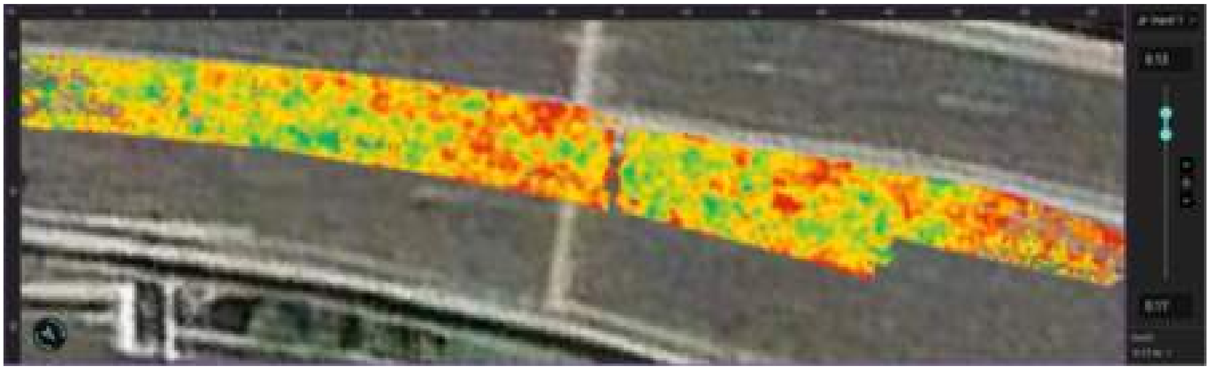

Figure 4. The most significant output of GPR mapping results is the Deterioration Map, based on the amplitude degradation of the top rebar.

Figure 5. Major surface defects at asphalt layer (cracks)

Figure 6. Extended surface layer defects were found at depths of 4 to 6 cm within the asphalt layer.

Figure 7. Interface defects between Asphalt-to-Concrete (A/C) layers (Delamination.)

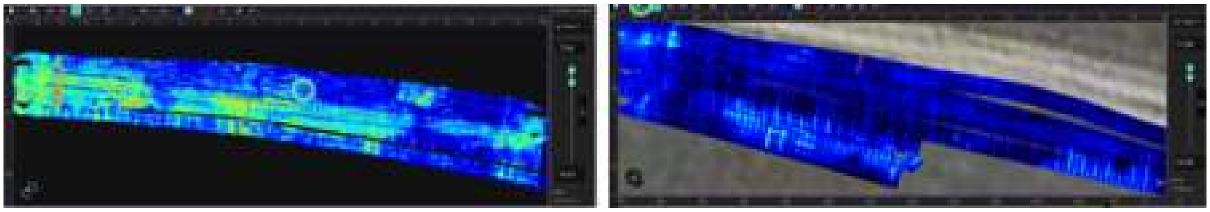

Figure 8. Live-Slice view of the first layer rebar mesh.

Validation

Based on the GPR data collected, a portion of the scanned area was chipped off for validation, revealing a high correlation between the GPR data and actual conditions observed. The identified structural weaknesses and defects corresponded closely to those detected by the GPR scans.

The validation process confirmed the accuracy and reliability of the GPR mapping conducted using the MCGPR GS9000. The advanced technology provided valuable insights into the condition of the bridge, facilitating effective maintenance planning and ensuring the safety and longevity of the infrastructure.

Visit our Tech Hub for more real case studies and application notes for geomatics and subsurface mapping.