The Future of Bridge Deck Assessments Leveraging AI and Multichannel GPR

Explore how mobile mapping GPR is revolutionizing bridge deck assessments with full resolution imaging in real-time

Maintaining the structural integrity of millions of aging bridges across the world presents a significant challenge. The limitations of traditional methods in detecting early-stage deterioration can lead to reactive maintenance, delays, errors, rework and increased costs. But things are changing, fast.

The latest technology developments present a more efficient way to detect even the smallest defects in bridge decks, with ultra-high efficiency and never-before-seen clarity.

This application note demonstrates how the integration of Artificial Intelligence (AI) with advanced Multichannel Ground Penetrating Radar (GPR) technology offers a powerful solution for rapid, accurate, and proactive bridge deck assessments that dramatically improves productivity, safety and resource allocation.

Challenge

The economic and operational efficiency of our transportation networks relies on the durability of bridge infrastructure. Bridge decks degrade over time due to rebar corrosion, moisture intrusion, and concrete decomposition. The effects of these issues directly threaten the service life and performance of bridge decks.

Early detection of any type of deterioration is critical for safe, cost-effective infrastructure management. Proactive, data-driven monitoring ensures safer bridges and smarter maintenance. Therefore, the key for predictive, not reactive, maintenance is mapping over time (monitoring) with an easy solution.

Solution

Monitoring is key for assessment of structural condition. Vehicle-mounted ground penetrating radars are becoming increasing popular to assess vast areas like large bridges and roads.

The GM8000, a mobile subsurface mapping platform that uses a combination of the latest generation of Multichannel GPR technology to achieve full-resolution imaging in real-time and cloud computing software together with AI analytics tools. Such platform aims to provide a scalable solution for continuous asset scanning representing a significant leap forward for smart bridge deck inspection and unique opportunity for structural health monitoring.

Apart from accurate imaging of the deck's reinforcement, GM8000 data can generate time-lapsed, georeferenced, full-resolution 3D measurements providing maps with critical information about changes related to deterioration of asphalt and concrete (cracking, debonding, moisture retention). Trends on how these maps change can be tracked over time for risk management assessment. This ensures the acquisition of comprehensive and actionable insights that can be combined with other sources of information for final decision-making into the structural health of the bridge deck.

High-Speed Data Acquisition

A key advantage of the GM8000 lies in its ability to operate at traffic speed, delivering full-resolution 3D imaging in real-time. This dramatically minimizes the need for extensive and disruptive road closures reducing the associated costs and safety risks associated with prolonged roadwork. Unlike traditional survey methods that often necessitate significant lane restrictions and traffic management, the GM8000 can collect critical subsurface information with minimal impact on daily traffic flow. This accelerates the assessment process making it more efficient. On the other hand, the unique real-time visualization significantly increases the efficacy during scanning, minimizing the risk of needing to go back to the field to collect more data.

Comprehensive and Rapid Wide Area Coverage

The GM8000 is designed to provide extensive and accurate data coverage across large bridge deck areas in an exceptionally short timeframe. Utilizing its advanced multichannel GX1 antenna, the system acquires a GPR data point cloud of unparalleled high density with each pass, offering images of unmatched clarity that provide far more comprehensive understanding of the subsurface compared to traditional GPR surveys. This rapid wide-area coverage allows for efficient assessment of entire bridge decks, identifying potential anomalies and areas of concern that might be missed by less comprehensive methods.

Integrated Positioning System

For effective structural health monitoring, scans need to be comparable over time and this requires repeatability in order to track the progression of bridge deck deterioration, evaluate the effectiveness of maintenance interventions, and make informed predictions about future structural performance.Therefore, accurate positioning, at all times, is a must, even in GNSS-denied areas.

The GM8000 a visual odometry-based positioning system leverages advanced sensor fusion, combining data from RTK GPS, camera with automatic feature tracking, inertial measurement units (IMUs), and other onboard sensors (e.g. accurate speed sensors) to provide accurate and dependable mapping. This deep fusion approach enhances location accuracy and, thanks to bundle adjustment algorithms, can compensate some drifting errors typically produced in urban canyons, ensuring that the GPR data aligns accurately with geographic coordinates, even in challenging environments (figure 6).

Figure 5. Visual odometry-based system for data positioning.

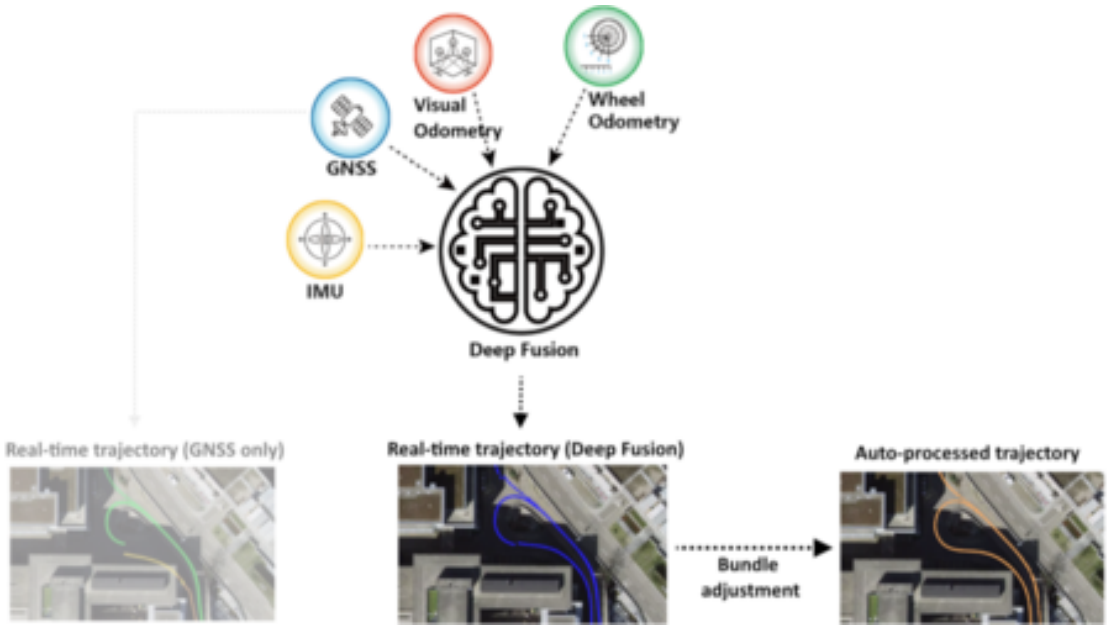


Figure 6. Advanced sensor fusion for accurate trajectory calculation

The accuracy of this positioning system ensures that subsequent data acquisitions can be precisely referenced to previous surveys. This is crucial for repeatable, long-term monitoring programs.

Advanced, High-Resolution Insights into Concrete Integrity

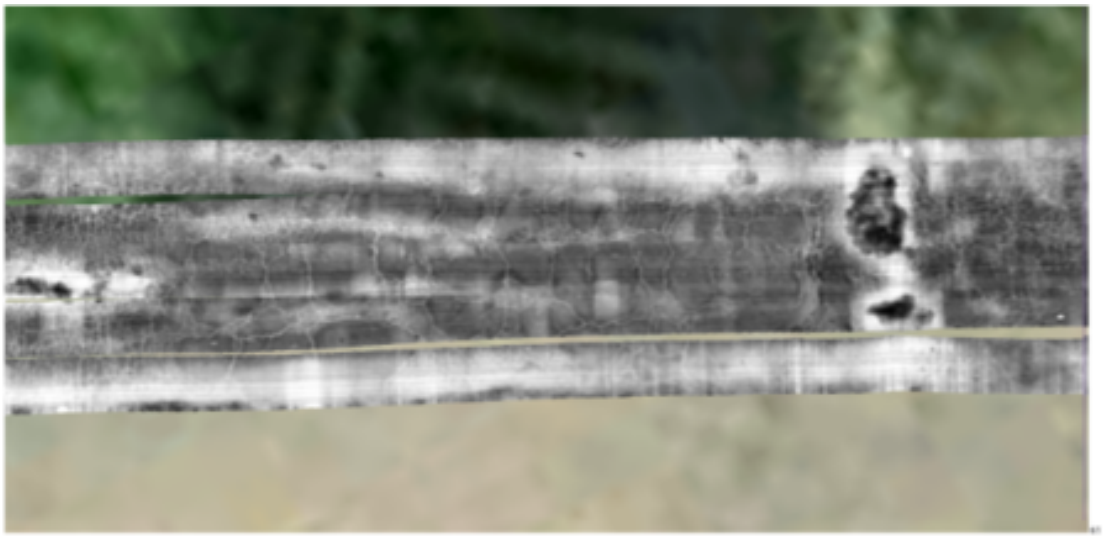
Powered by GPR Insights software, the GM8000 provides unparalleled, high-resolution imaging of the bridge deck. The detailed subsurface information allows for the precise identification of various defects (e.g., cracks, debonding, voids). Furthermore, reading signal responses and attributes across the whole deck, can provide qualitative information related to early stages of rebar corrosion, cover thickness or the extent of moisture intrusion.

Leveraging AI for quick, automated, preliminary analysis of massive data sets using GPR Insights software to generate actionable deliverables for predictive maintenance:

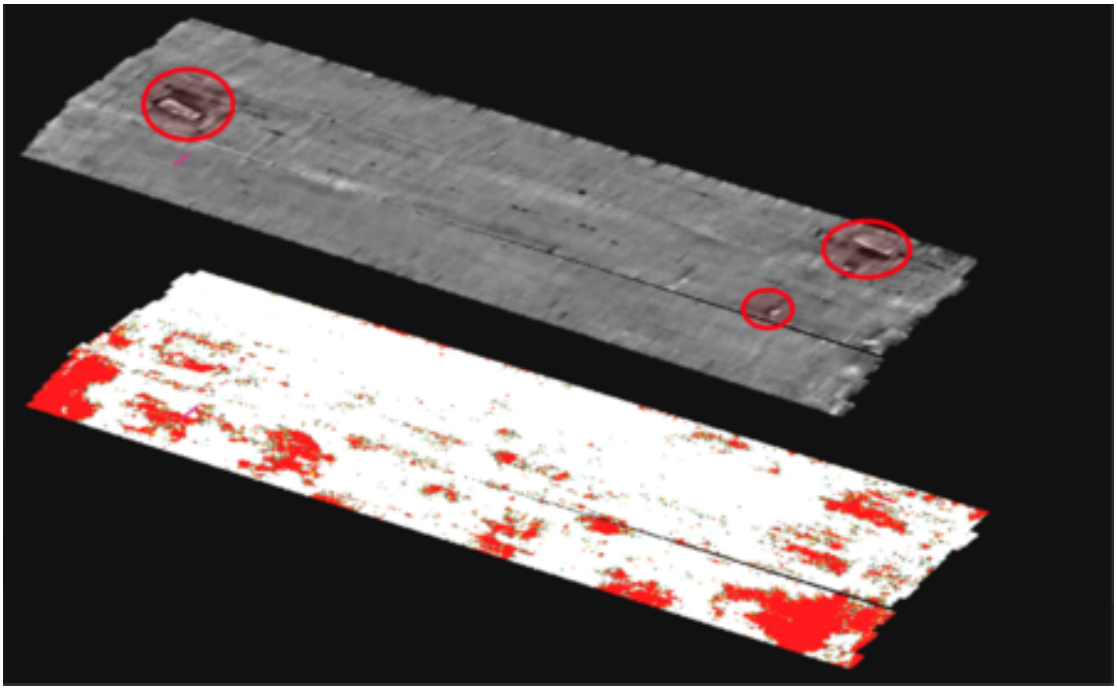
- Fast computing to achieve unmatched image resolution showing centimeter size cracks on asphalt.
- Top Rebar Detection: Automatic mapping of the first layer of reinforcement
- Deterioration Maps: ASTM D6087-compliant condition visuals
- Dielectric/Velocity Maps: Indicators of likelihood of moisture presence above first layer of rebars
- Concrete Cover Maps: Visualize protection depth over steel

Bridge deck condition map

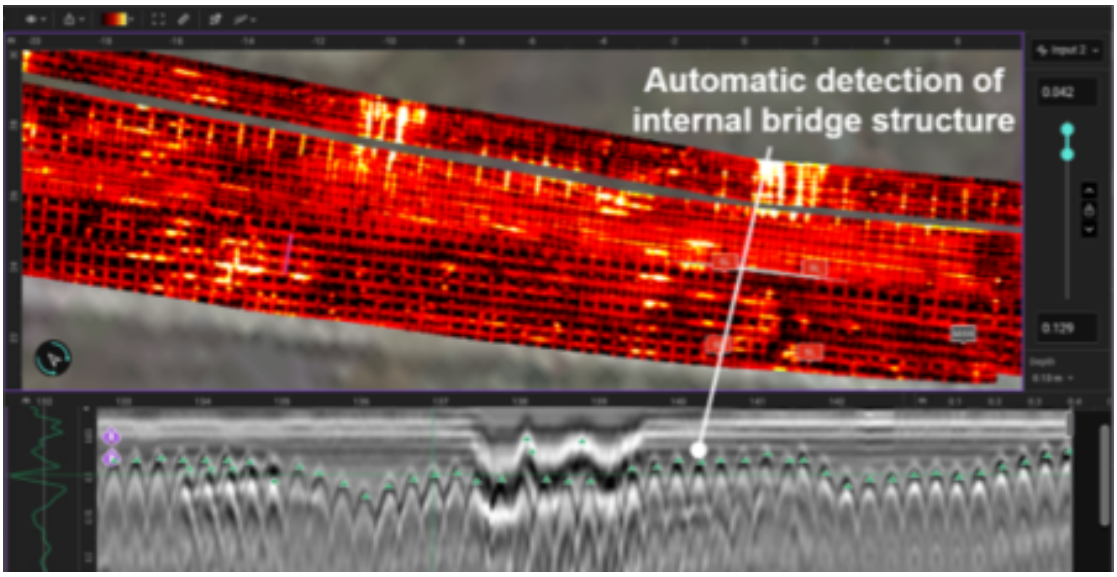
This analysis starts from the surface looking for defects like cracking:



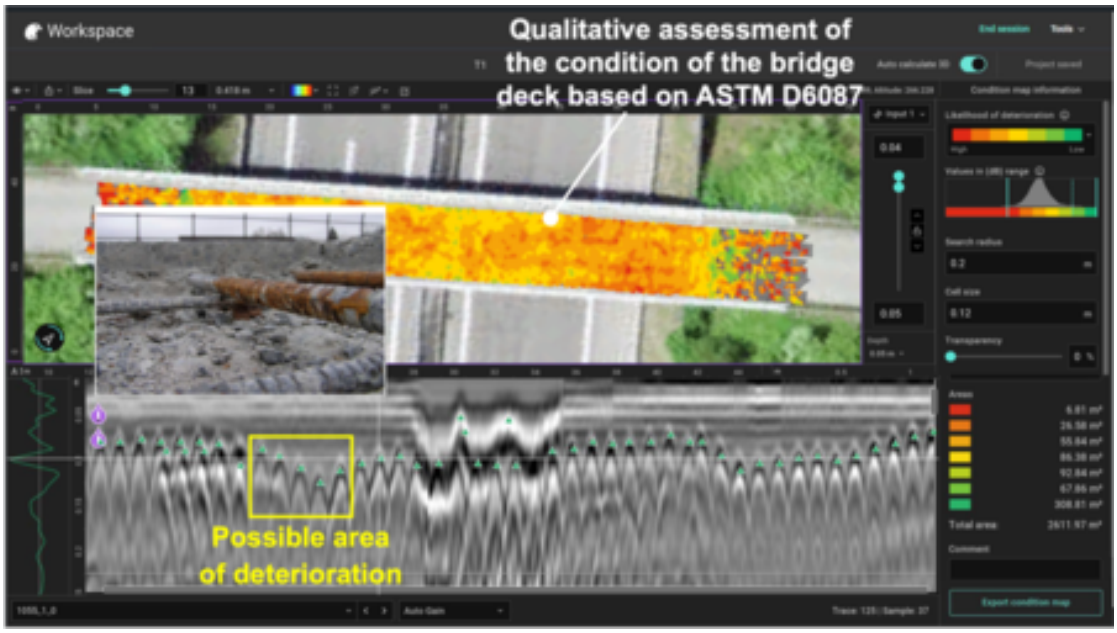
Other defects as potholes (upper image) or debonding at the asphalt concrete interface (red color areas on the bottom image)



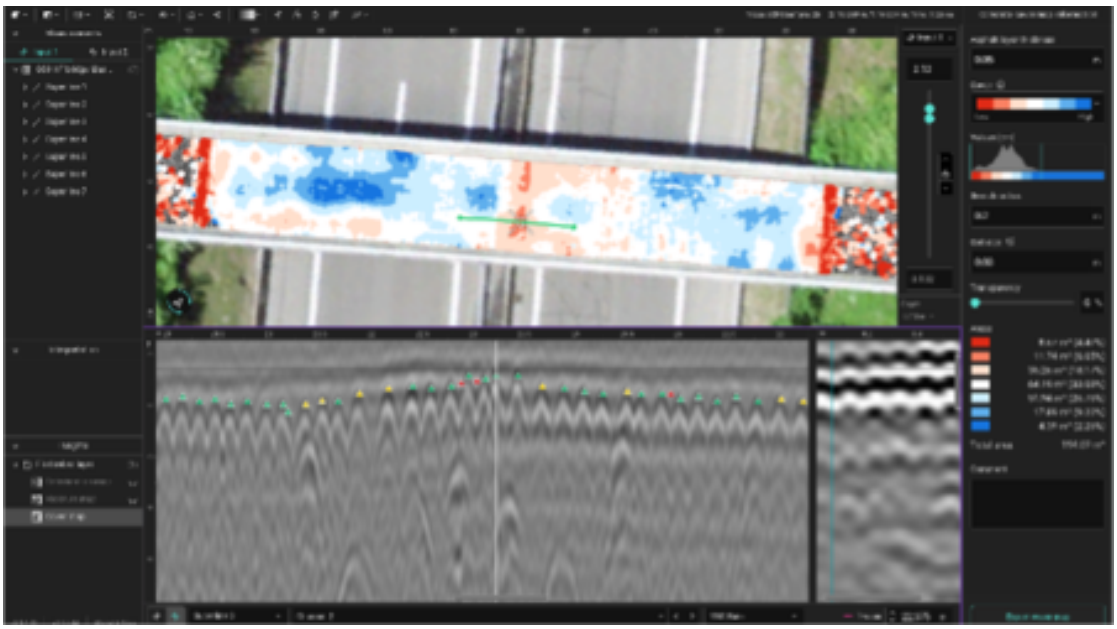
The next level is the top reinforcement. Accurate imaging with passes in just one direction.



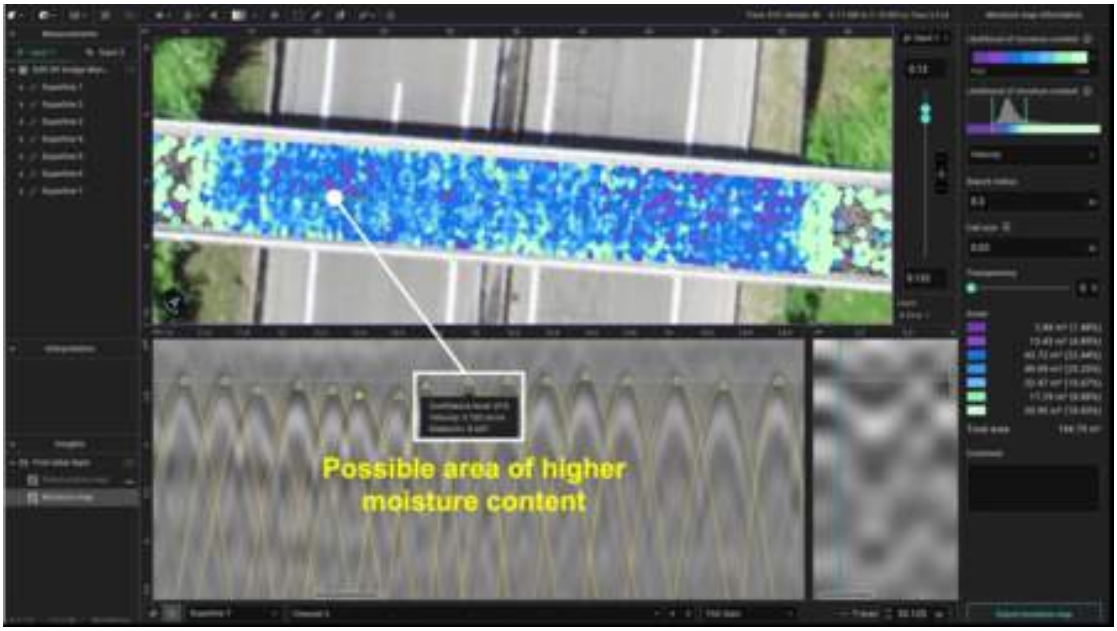
And qualitative heatmaps for fast preliminary condition mapping of the first layer of rebars and concrete above it.



GPR Insights software showing Condition Map of bridge deck

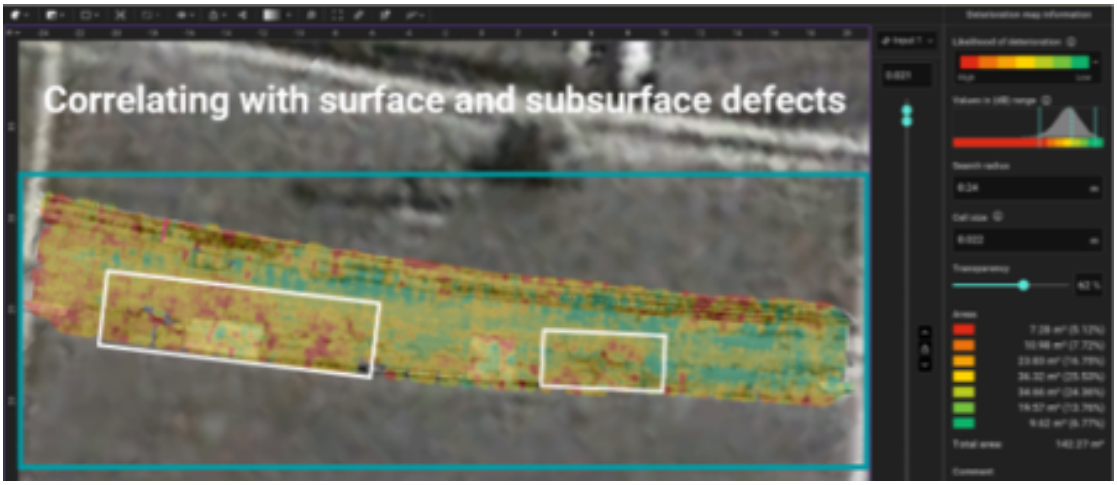


GPR Insights software showing Concrete Cover Map of bridge deck



GPR Insights software showing Moisture Map of bridge deck

For a more detailed analysis, all this information should be supervised and interpreted using all the information provided. For example, combining the information from shallow cracks and likelihood of deterioration:



Key Benefits of the GM8000 & GPR Insights

✅ Fast, non-destructive bridge monitoring

✅ Scalable to regional/national infrastructure networks

✅ Automated, data-driven condition maps

✅ Actionable results for predictive maintenance planning

The Future of Bridge Health Monitoring

The power of the Proceq GM8000 and GPR Insights represents a major shift in bridge deck assessment. By delivering rapid, comprehensive data acquisition coupled with AI-driven analysis, this integrated solution empowers infrastructure managers to move beyond reactive repairs towards proactive, predictive maintenance strategies.

Identifying even subtle early-stage deterioration with unprecedented speed and accuracy translates directly into enhanced safety, optimized resource allocation, minimized disruption, and ultimately, the extended lifespan of critical bridge infrastructure.