Road Talk

Ontario's Transportation Technology Transfer Digest

Ministry of Transportation

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Ontario

Discovering the Invisible: Using Ground-Penetrating Radar

The Ministry of Transportation tests 3D imaging to evaluate pavement conditions

Ontario's Ministry of Transportation (MTO) recently tested three-dimensional (3D) ground-penetrating radar (GPR) on Highway 417 to identify deteriorating pavement joints.

What is GPR?

GPR locates underground objects and sub-surface conditions to assess roads, bridges, airport runways, railway tracks and tunnel walls, among other applications.

3D GPR, such as the 3D-RADAR system, collects data from a wide frequency range, typically from 100 MHz through 3 GHz. This provides optimal resolution at any given depth, ensuring accurate and detailed subsurface imaging.

Users can tailor the system to their specific needs. To capture details near the pavement surface, a high-frequency antenna is used. If deeper penetration is required, a lower-frequency antenna may be more suitable.

3D GPR technology has several advantages over the traditional methods of assessing pavement conditions. For example, visual assessments are inadequate for detecting premature freeze-thaw damage. Surface cracks may not always align with cracks underneath the asphalt. 3D GPR can provide detailed information about pavement layers, helping MTO evaluate and maintain highway infrastructure.

Figure 1: Conventional single-antenna GPR

Figure 2 : Boring into pavement is a traditional pavement investigation method.

Figure 3: A falling weight deflectometer is also a traditional pavement investigation method.

MTO's 3D GPR trial

3D GPR allowed MTO to collect and analyze data quickly, reducing the time required for pavement assessments.

In 2013, a 10-km section of Highway 417 started to show signs of joint distress eight years after construction. Pavement cores taken from the highway revealed damage below the joint sealant that were not visible on the surface. These findings prompted investigations on other MTO highways to assess the extent of the problem and provide solutions.

Additional trial investigations

MTO extracted cores from two additional sections of pavement on Highway 401 near Windsor and Highway 410 in Brampton. The results also revealed signs of premature joint deterioration, suggesting the issue extended beyond a single highway and warranted broader investigation.

Highway 417

MTO's 3D GPR study was carried out on a 3.2-km stretch of Highway 417 near the Town of Vankleek Hill in Eastern Ontario to identify underlying pavement damage and distressed pavement joints.

Collecting and assessing data

MTO collected GPR data using an air-launched array with a surface range of 1.8 metres. The array collects 21 pavement readings every 75 mm, allowing for detailed 3D measurements.

Figure 4: Rear-mounted 3D GPR unit shown in the lower right of the photo.

Figure 5: 3D GPR trial section on Hwy 417.

Figure 6a: Concrete with underlying joint distress visible from the surface .

Figure 6b: Concrete with underlying joint distress not visible from the surface.

The assessment was performed at three different pavement depths: 20 mm below the surface, 50 mm below the surface and at the bottom of the concrete pavement layer. The array travelled at an average speed of 100 km/h and was able to capture the data from the highway in a few minutes.

To assess the data, a software called Examiner generated a combination of pavement cross-sections and overview images from various depths, offering information on variations and distress patterns in different visual formats, including heat maps.

The data revealed areas where surface distress had not yet occurred despite distress in the subsurface – crucial information for the ministry to identify potential future areas of surface distress and make informed maintenance and rehabilitation decisions.

Highway 417 recommendations

The GPR data analysis for Highway 417 recommended focusing on the 50 mm depth and the bottom of the concrete layer to accurately assess the pavement condition. MTO suggested intrusive testing at 20 locations to further investigate distresses detected in the GPR data.

Impact on pavement specifications

Based on the investigations, the ministry made significant updates to improve its concrete pavement specifications. Changes were made to ensure concrete is more durable in a saturated freeze-thaw environment. Joints were redesigned to minimize the degree of concrete saturation.

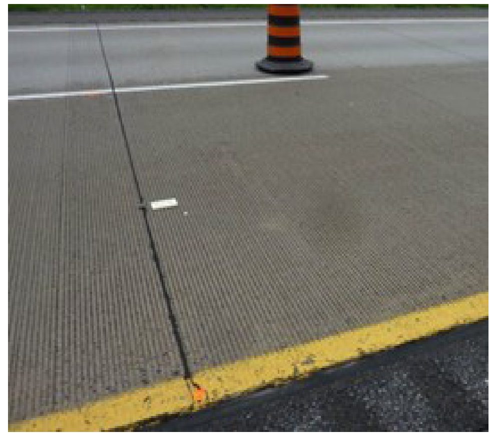

Figure 7a: Concrete joint deterioration without surface signs.

Figure 7b: Concrete joint deterioration shown in core sample.

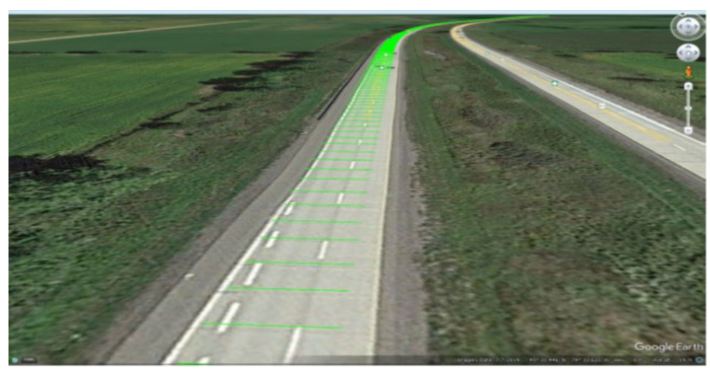

Figure 8: Joints of concrete pavement annotated by green horizontal lines on Google Earth image.

How 3D GPR may be used for highways:

- **Preliminary project design field assessment:** Assess the subsurface conditions of a site prior to construction. This can help inform the design process and avoid potential issues
- **Post-construction quality assurance:** Assess the quality of newly constructed pavement and other structures to ensure they meet design specifications and are free from defects.
- **Pavement forensic studies:** Investigate the cause of pavement distress or failure by mapping subsurface layers and detecting anomalies.
- **Post-flood pavement structure condition:** Assess the condition of pavement structures following a flood by detecting changes in subsurface layers and identifying potential damage.

3D GPR allowed for a comprehensive and precise assessment of pavement conditions. By using 3D GPR, engineers located distresses without causing damage to the pavement, unlike more invasive techniques.

3D GPR is proving effective at detecting and assessing premature joint deterioration. This contributes to informed decision-making for maintaining and repairing highways, thereby extending their lifespans and reducing overall costs.

Figure 9: Amplitude variation display as a heat map.

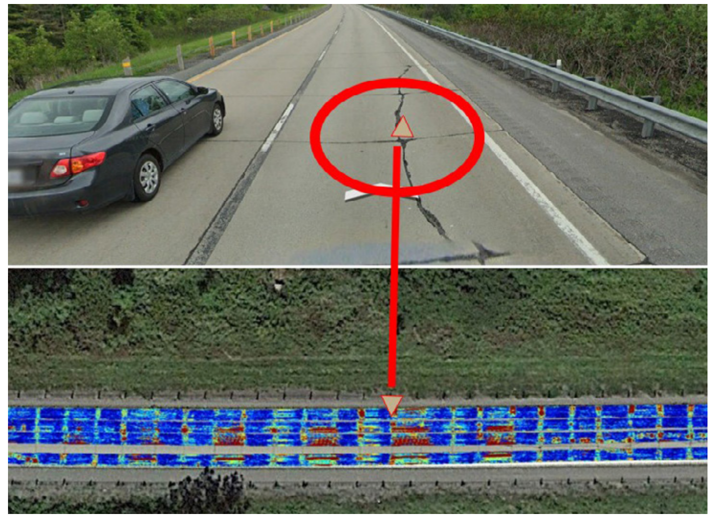

Figure 10: Area of distress confirmed by heat map location.

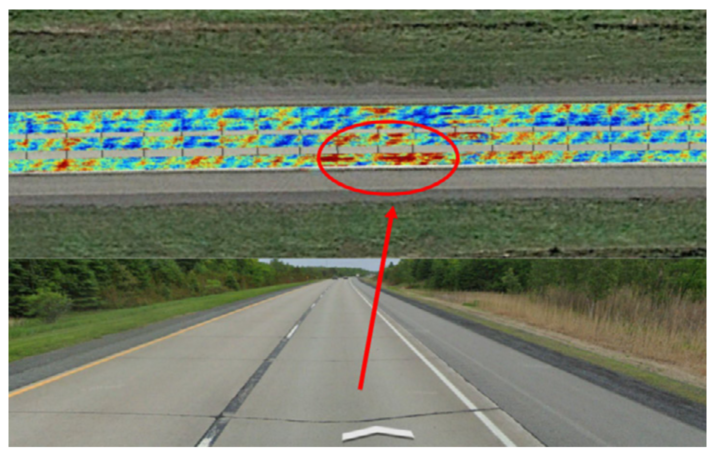

Figure 11: Distress area in 3D GPR heat map is not clear from surface observation.

Table 1: Joint damage rating data

Joint ID	Joint amplitude response - 20 mm surface offset	Joint amplitude response - 50 mm surface offset	Joint amplitude response - Bottom of concrete	Latitude	Longitude
Westbound Joint 6	Low	Medium	High	45.54575259	-745.53759537
Westbound Joint 32	Low	Low	High	45.54518679	-74.5387183
Westbound Joint 60	Low	Medium	High	45.544449044	-74.53981964
Westbound Joint 68	Low	Low	High	45.54423762	-74.54006301
Westbound Joint 71	Low	Medium	High	45.54416014	-74.54017591
Westbound Joint 99	Low	Low	High	45.54341343	-74.54120036
Westbound Joint 134	Low	Medium	High	45.54240067	-74.54244129
Westbound Joint 176	Low	Low	High	45.54121889	-74.54378658
Westbound Joint 343	Low	Medium	High	45.53640652	-74.54929162
Westbound Joint 604	Low	Low	High	45.52866111	-74.55741029

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