Mobile Measurement (MIMM)-Based Road Tunnel Soundness Evaluation Technology

1.Background

Over the past several years, infrastructure has suffered various types of damage associated with age-related deterioration, and several accidents have occurred in road tunnels (Cases 1 and 2). Road tunnels are usually inspected once every three to five years. For these inspections, roads or lanes are closed, and close visual inspections are conducted. However, given the difficulty of securing funds for maintenance and ensuring the necessary workforce, it has not been possible to inspect all tunnels. Soundness evaluation technology based on streamlined, low-cost inspection methods is drawing attention as a solution to these problems.

【Case1】

Ceiling panels falling onto an expressway (February 2012)

The main cause was said to be age-related deterioration of the hanging bolts that supported the concrete ceiling panels in the tunnel.

【Case2】

Concrete fragments falling onto a national highway (January 2013)

Concrete fragments from a sidewall fell onto the roadway as a result of age-related deterioration.

2. Challenges and purpose of tunnel maintenance

Challenges

- Difficulty identifying causes of damage and estimating the process of deterioration because the subject is surrounded by bedrock or comprises complex materials.
- Decisions about repairs and the like could be inconsistent because they are made based on inspectors' empirical judgments.
- Social loss associated with road/lane closures during surveys and inspections
- Insufficient funds for inspections and the like
- Worker shortage due to poor working environments (e.g. vehicle exhaust) during inspections and surveys.

Needs

- Inspections capable of properly identifying locations of damage
- Inspections conducive to objective judgments
- Inspections that do not require road/lane closures
- Safe, low-cost inspections
- Inspections with good working environments

Mobile measurement vehicle-based method of inspection

- Establish a method of evaluation based on image data
- Establish a method of evaluation based on laser data
- Establish an overall method of evaluation
- Establish a method of estimating causes of damage
- Establish specifications for mobile measurement

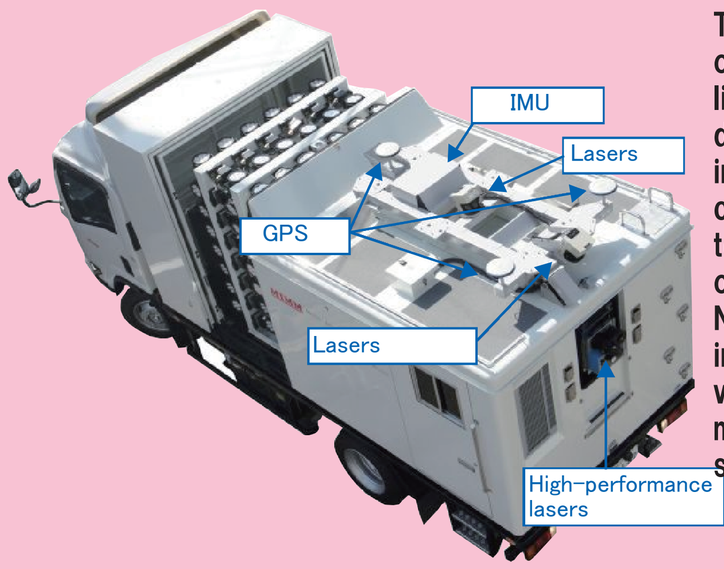
3. Mobile measurement system overview

The mobile measurement vehicle (MIMM) is capable of simultaneously gathering images of tunnel walls (Mobile Imaging Technology System (MIS)) and point cloud data (coordinates in three dimensions) with lasers (Mobile Mapping System (MMS)) on a single pass-through.

Mobile Imaging Technology System (MIS)

Video cameras capture and measure images of tunnel walls to objectively ascertain the locations of cracks, leaks, and material defects (honeycombing) on the surfaces of the lining concrete. The system features LED lighting as the source of the light needed for image measurement, and is outfitted with twenty 380,000-pixel cameras. (This enables the system to detect cracks as small as 0.2 mm)

Mobile Mapping System (MMS)



This system acquires data on the outlines of the inner surfaces of lining concrete through three-dimensional laser measurement in the form of three-dimensional coordinates to ascertain the texture and deformation modes of lining concrete surfaces. Notably, the laser apparatus installed on the rear of the vehicle has the capacity to measure 1 million points per second.

4. MIMM-based evaluation method

Images and laser data are combined to conduct 3D analysis and thereby evaluate tunnel walls.

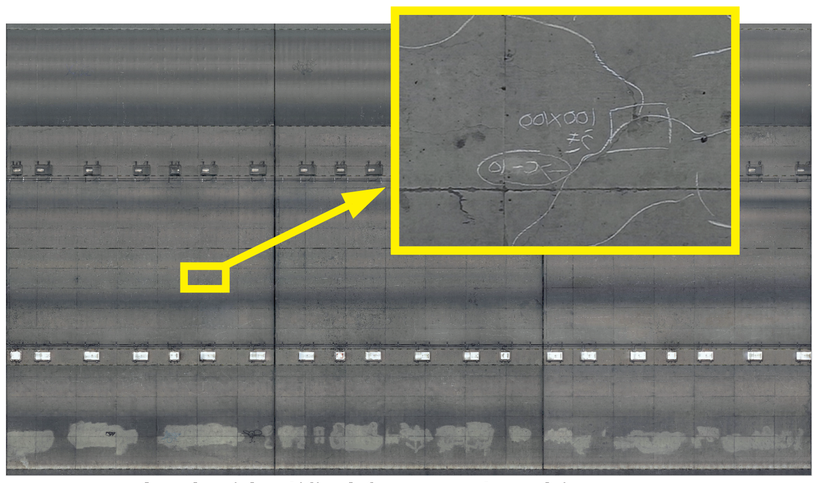
MIS image measurement

In the field

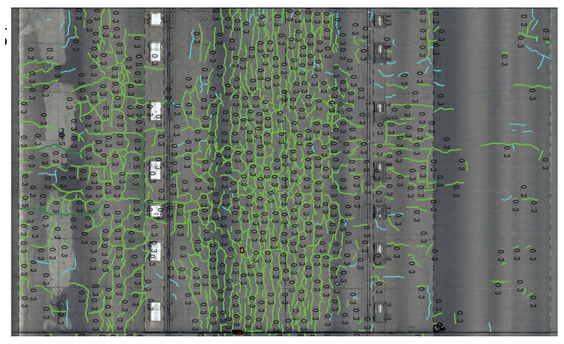
Create image analysis developments

Identify locations of damage

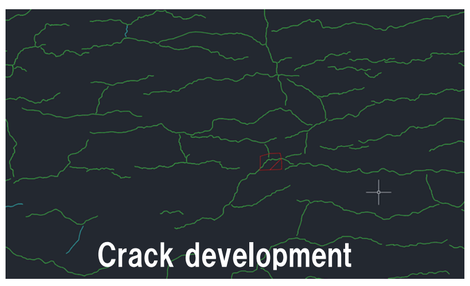
Cracks, leaks, honeycombing, discoloration, etc.



Leaks identified from captured images



CAD data image



Crack development

Data synthesis and evaluation

- Estimate causes of deformations
- Evaluate soundness
- Determine the need for detailed surveys
- Determine the need for countermeasures

MMS laser measurement

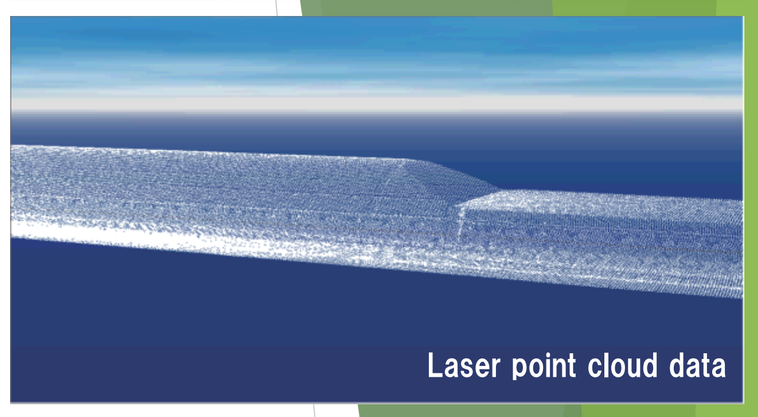
In the field

Laser analysis Create contour drawing

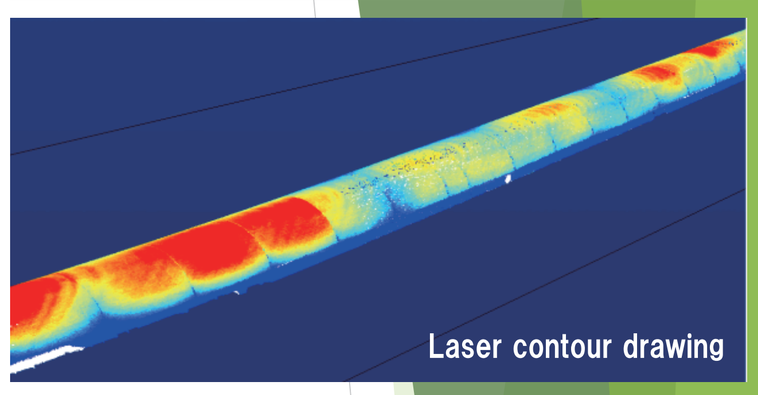
Identify locations of damage

Spalling, peeling, impact of external forces, etc.

MIMM measurement in action



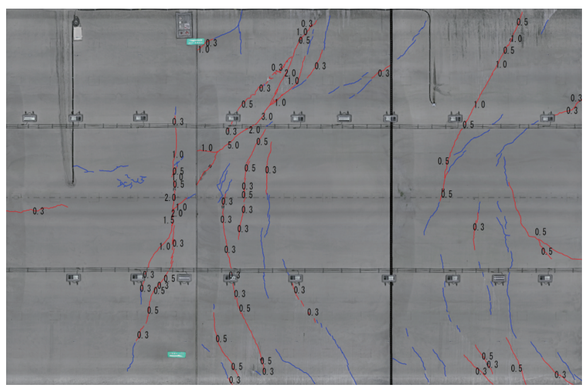
Laser point cloud data



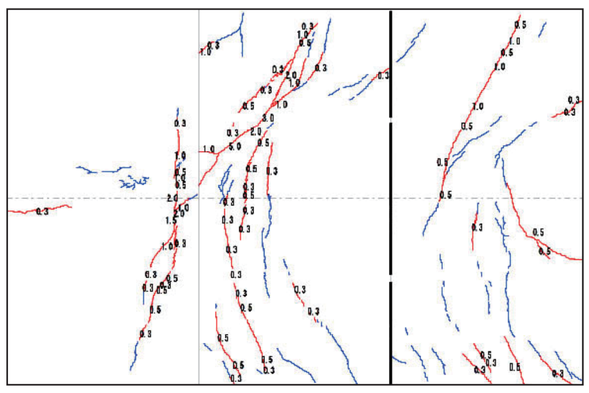
Laser contour drawing

5. Example of MIMM-based evaluation

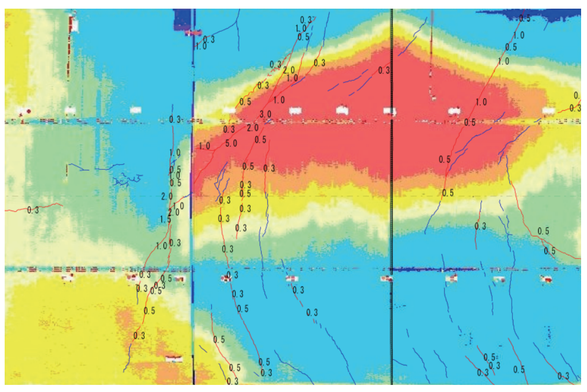
Below are the results of an MIMM measurement conducted in a tunnel. We knew that deformations were occurring on the inner surfaces where clusters of cracks were identified by the MIS, so we checked for consistency in the field. Consequently, we identified some diagonal unevenness in the tunnel and confirmed that it was due to external forces.



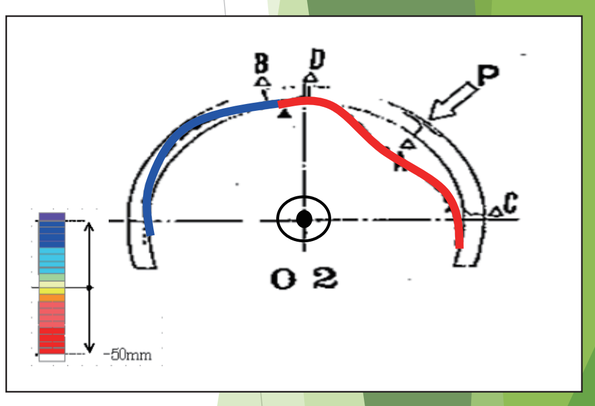
Mobile image (MIS)



Crack development



Contour drawing (MMS)



Deformation mode drawing

6. Outcomes and challenges of evaluation

MIS evaluation

① Spalling is highly likely in locations of peeling, leaks, free lime, honeycombing, and joint deterioration/discoloration.

② Similarly, spalling is highly likely where cracks close, intersect, or cluster (hexagonal).

③ Spalling is highly likely when cracks extend longitudinally or where there is unevenness.

④ The system is capable of detecting cracks as small as 0.3 mm at a speed of 40 km/h.

⑤ When the aforementioned types of damage are confirmed on images or CAD, it is necessary to verify by conducting close visual inspections or hammering tests in the field.

MMS evaluation

① Contour drawings can be used to estimate the impact of external forces or the causes of cracks.

② Laser analysis can be used to determine the progressiveness of deformations.

③ The system is capable of detecting unevenness as small as 0.5 mm at a speed of 40 km/h.

④ Taking measurements when tunnels are constructed and confirming subsequent differences enables more advanced management.

⑤ It is necessary to save measurement data for use in subsequent maintenance.

Contact for inquiries

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