# Future vision for infrastructure maintenance: Innovation in inspection, monitoring, and diagnostic technologies

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## Categories of inspection, monitoring, and diagnostic technologies

Among the R&D topics of the SIP Infrastructure Program, technologies related to inspection, monitoring, and diagnostics are divided into four categories of technologies that can replace or support close visual inspection by inspection engineers: inspection support tools, screening, permanent monitoring, and detailed inspection technologies. In this paper, we will describe the changes that these technologies can bring to inspection practices and mention current challenges which need to be addressed for the diffusion and widespread adoption of these technologies. It is not possible to present all of the technologies in this journal, but more information is available on the website of the Japan Science and Technology Agency (JST).

## Inspection support tools

Tools that support inspection and diagnosis by engineers are technologies that can easily be brought into the field, are capable of recording inspection data as well as location information, and can function as high-precision sketch machines in the field.

Optical technologies include the latest image processing technologies for high-sensitivity camera images, and technologies using AI for high-precision detection of cracks in concrete surfaces. With technologies that use high-sensitivity magnetic sensors (small, portable superconducting quantum interference devices (SQUIDs) and magneto-resistive elements (MR)) to explore corrosion and cracking in steel, it is possible to inspect not only the top surface of a structure, but also the interior and back surface. This category also includes AI hammers, in which acoustic sensors are added to hammers used in hammering tests, and damage determination based on hammering sounds is supported by deep learning.

## Screening

Bridges, tunnels, and other infrastructure subject to inspection are scattered far apart, and it is extremely challenging for inspection engineers to thoroughly identify every location of damage by close visual inspection. Therefore, it is desirable to have technologies that can reliably discover deterioration and damage at a predetermined level of precision and perform automatic visualization and mapping with location information.

Therefore, technologies are being developed that will use advanced signal processing technologies to detect deterioration and damage while moving at high speed, using the latest sensors (high-sensitivity cameras, lasers, 3-D radar, synthetic-aperture radar, etc.) mounted on dedicated vehicles, aircraft, robots, or satellites. Examples include technology to detect surface properties, cracking, lifting, peeling, etc. in the covering concrete of a tunnel using vehicle mounted sensors (high-sensitivity cameras, radar, and lasers) while traveling through a tunnel at a speed of 60 km/h, technology to identify damage (crumbling and cracking) in the upper parts of reinforced concrete floor slabs of expressways while traveling at a speed of 80 km/h (3-D ground penetrating radar, Fig. 1), technology to measure 3-D data of riverbed topography by airborne laser bathymetry (ALB) and determine scouring of bridge piers with high accuracy, and technology to measure annual changes in the vertical displacement of revetments, dams, river and embankments, bridges, etc. from images distributed by satellite mounted synthetic-aperture radar (SAR).

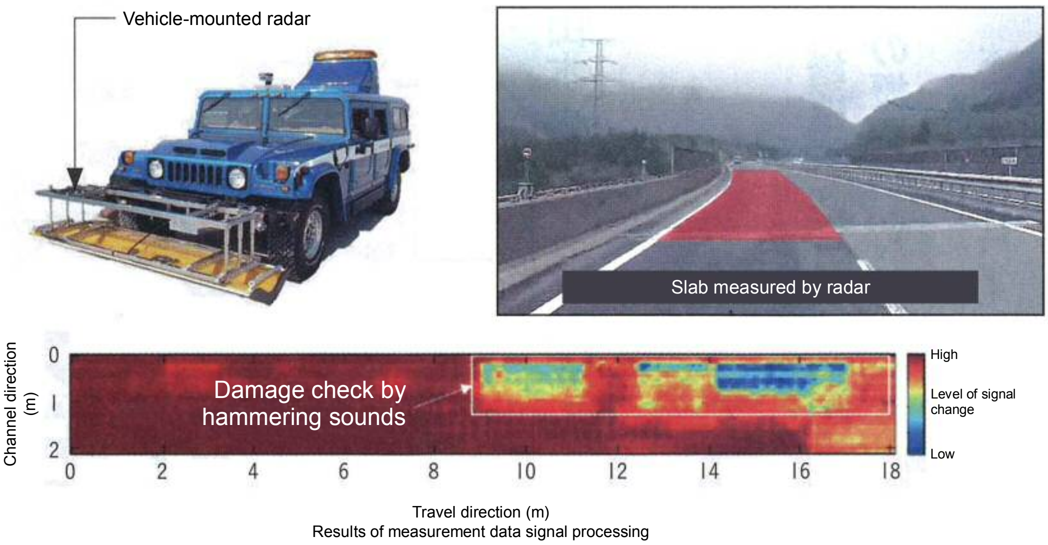


Fig. 1. Example of screening technology (3-D ground penetrating radar)

## Permanent monitoring

In permanent monitoring, large numbers of networked sensors are installed on the relevant kinds of infrastructure, including infrastructure with a high level of importance, large-scale structures (such as long span bridges and long length tunnels), and slopes expected to be at risk in disasters.

**Detailed inspection technologies**

When damage has been identified by inspections or screening, detailed data must be obtained in cases where an accurate determination is absolutely necessary because the safety of using a structure has been called into question, or to determine whether large-scale reinforcement and renovation is needed. For purposes such as these, development is underway on technology to visualize breakage of steel wire inside precast concrete bridges with high-precision transmission imaging devices using high-output X-ray sources (Fig. 2), and technology for detailed visualization of moisture, voids, crumbling, and other conditions inside concrete using compact neutron sources. Both of these are being developed for in-situ use in the field and will be mounted on dedicated vehicles.


Measurement inside a box girder


Visualization of internal steel wire and rebar

Fig. 2. Example of detailed inspection technology (high output X-ray)

**Future image of infrastructure maintenance and current issues**

Each of the technologies described above will make it possible to perform inspections with a high level of accuracy and efficiency through the use of cutting-edge technologies that did not exist in the past. Inspection support tools will help to improve inspection accuracy and reduce variability among the results of inspections performed by people. Screening may improve the efficiency of inspection work by narrowing the scope for close visual inspection. Permanent monitoring will make it possible to monitor the conditions of structures and provide early damage detection, based on suitable thresholds for sensor data. In addition, detailed inspection carries the potential for identification of deterioration factors and damage in the interior of structures, which has not been easily discoverable in the past.

Inspection information (deterioration and damage) obtained through screening and monitoring with advanced technologies will be mapped onto three-dimensional models of infrastructure with geographical location information, and this will be registered and stored in an infrastructure information database. This data will be used to compare past inspection records with current inspection records in order to determine the progress of deterioration and damage. In addition, damage mapping will be incorporated into structural analysis models by means such as data assimilation, and the performance deterioration curves of structures will be quantified through coordination with detailed remaining lifetime analyses. This will provide the basis for calculating the asset value and life cycle cost of infrastructure, facilitating effective infrastructure asset management.

However, when using advanced technologies to perform inspection, in many cases, some of the data that is gathered may not be necessary under the current inspection procedures and technical standards, etc. Therefore, at the same time that these technologies are being adopted and deployed, it will also be necessary to consider the handling of such data under these procedures and standards.

**Reference**

(1) Infrastructure maintenance, renovation and management technologies under the Strategic Innovation Promotion Program (SIP), website of the Japan Science and Technology Agency (JST), URL: http://www.jst.go.jp/sip/k07.html