Advanced Technology Solutions: Case Collection

Toward safer and more secure civil infrastructures driven by cutting-edge technologies

Cross-ministerial Strategic Innovation Promotion Program

Infrastructure Maintenance, Renovation and Management
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Exit Strategies
Introduction; The R&D Project of Infrastructure Maintenance, Renovation and Management

For Sustainable, Safe, and Secure Infrastructure Systems

The Cross-Ministerial Strategic Innovation Promotion Program (SIP) managed by the Council for Science, Technology and Innovation (CSTI) has been established to realize scientific and technological innovations. As a cross-ministerial and cross-field program, SIP is running forward with a focus ranging from basic research to commercialization/industrialization. One of its tasks is “Technology for infrastructure maintenance, renovation, and management” (hereafter referred to as “SIP Infrastructure”).

Infrastructure such as roads, railways, harbors, airports, and various disaster prevention facilities support our everyday life and social and economic activities. Many of them, however, were built during the high economic growth period. As they get older, the increase in maintenance and repair expenditure along with the possibility of a serious accident occurring during service have become serious social issues. This program aims at preventing accidents and reducing the burden of maintenance by constructing systematic infrastructure management that utilizes the world’s most advanced information and robotics technologies.

Unlike mass-produced products, such as vehicles and laptop computers, infrastructure consists of single products that are designed, constructed, and manufactured individually. The initial conditions of infrastructure vary depending on the time and condition they were built. As a result, in addition to the difference in deterioration actions under service, the rate of infrastructure deterioration also varies. Infrastructure that has been used for several tens of years may pose a higher risk of accidents due to material and structural degradation. To enable effective and efficient preventive maintenance management of infrastructure and to establish a safe and secure infrastructure system, it is therefore crucial to have technologies that can precisely diagnose and take appropriate measures, by closely examining a large number of items of infrastructure individually on-site. It is also important to minimize the hazards and risks associated with manual work on site.

For infrastructure managed by local governments, reduction of life cycle cost is also a particularly important viewpoint. Currently, infrastructure is being constructed across Asia; however, maintenance has already become a big issue there. In this program an asset management system is being developed and introduced to manage maintenance of many types of infrastructure on-site, in order to solve these problems. This asset management system integrates many types of technology such as technology for predicting the remaining life of infrastructure, technology capable of analyzing the state of degradation of infrastructure in a multi-faceted matter, systems that apply GIS to support the collection and analysis of infrastructure inspection data, robots that support or replace all or part of the inspection and monitoring work, support for diagnosis of infrastructure using AI technology, ultra high durability concrete, etc. The technologies developed in this project have superb performance, and we can recommend them with confidence.

The value of Japan’s infrastructure stock is estimated to be over 800 trillion yen. Infrastructure should function for several decades. Passing on to the next generation infrastructure that can be used with confidence is our contribution to the future. We believe that the widespread use of the results of “SIP Infrastructure” should contribute to the establishment of a sustainable, safe, and secure society.

Yozo Fujino graduated from Department of Civil Engineering, at the University of Tokyo in 1972. After completing his Master’s degree (Civil Engineering) at the University of Tokyo, he received the Doctor of Philosophy from the University of Waterloo in 1976. He joined the Earthquake Research Institute at the University of Tokyo; the Institute of Structural Engineering at the University of Tsukuba; and Department of Civil Engineering at the University of Tokyo. In 1990, he was appointed as a professor of Department of Civil Engineering at the University of Tokyo. In 2014, he joined the Yokohama National University, and has served in his current position from October 2014. He is a Professor Emeritus of the University of Tokyo. His expertise includes structures, vibration control and monitoring of civil infrastructures with emphasis on bridges. He was awarded the Medal with Purple Ribbon of Honor from the Emperor of Japan in 2007; and the 2015 Hitachi Hikari Award (The Hitachi Hikari Foundation), among others.

Sub-PD

- Hajime Asama (University of Tokyo, Professor)
- Yusaku Okada (Keio University, Professor)
- Yoshinori Sakamato (Kajima Corporation, Managing Executive Officer)
- Masaki Seki (Mitsubishi Electric Corporation, Senior Engineer)
- Kanji Kato (Mitsubishi Electric Corporation, Senior Engineer)

Project Promoting Council

Chair: PD

Research units: Universities, National Research and Development Agencies, private enterprises, etc.
Overall Plan

To minimize the opportunity loss of regional revitalization resources such as logistics, service, and tourism, it is vital to implement efficient and highly economical maintenance, renovation, and management. This is important considering that infrastructures such as roads, railways, harbors, and airports are public assets and domain whose functions should always be maintained.

The following points are important in achieving the efficient maintenance and management of infrastructures, which are estimated to be worth a total of 800 trillion yen.

- Cooperation with a wide range of advanced technology fields including civil engineering and ICT/robotics technologies
- Coordinating technologies based on adaptations on-site
- Technical specification menu based on the various different situations of end users
- Technical managerial viewpoint including organization management to utilize the technology appropriately
- Sustainable support system for technical development

Without relying only on the results of technical development at each ministry, national research institute, university, and private company, an unprecedented cooperation system is also needed to achieve the above goals.

Further, we believe that we must actively roll out a new viewpoint concerning infrastructure maintenance through the related ministries and local governments to various users and residents.

This includes providing the society with new values created by appropriate maintenance of infrastructures such as the safety of users and our reputation as judged by users, as well as directly solving issues regarding the current methods of infrastructure maintenance.

Exit Strategies

Since there is a diverse range of situations, targets, and technologies of infrastructure maintenance, we intend to implement infrastructure maintenance by optimally putting individual technical development together in the asset management phase. In the meantime, the development of IoT and other related technologies is remarkable, and construction of a platform that includes networked heterogeneous technologies, such as monitoring and sensing by robots and traveling vehicles, is rapidly becoming more of a real possibility. As a result, this has become a major strength that will allow us to drastically reform infrastructure maintenance. Therefore, we will advocate the promotion and cooperation with newly developed individual technologies by constructing an IoT platform to develop a scheme which will advance the integration of technologies through both asset management and the IoT platform.

As the base of this exit strategy, we will actively cooperate with key universities, regional universities, national research institutes, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Land, Infrastructure, Transport and Tourism, and local governments to create a unique framework for infrastructure related research. Specifically, we are considering the following business deployment patterns: "unique technological developments that have an individual theme," "deploying business to local governments through regional universities," "deploying business to the state administrative system through national research institutes," "establishing a permanent organization system to support industries," and "exporting and globally deploying technology;"

Of these patterns, we place greatest importance on "custom-made technical implementation support that suits regional characteristics," and investigate a technical support system from the base institutes, a fund support system, and the establishment of various technologies and sustainable support in local governments. In addition, we plan to implement a business model that will both help regional revitalization, and prepare an environment for business, by establishing a technical strategy plan based on reputation management.
01 High Output X-Ray and Compact Neutron Source Visualization Technology

Like medical radiography

Soundness of concrete bridges can be diagnosed by visualization of the inside of them. It enables decisions on repair and strengthening methods.

-Diagnosis of Soundness of Concrete Bridges by Fusion of Advanced X-ray and Neutron Visualization Technology with Civil Engineering-

Visualization using high output portable X-ray sources

- Enable visualization of the internal structure of PC beams
  Insufficient grout filling and rupture of steel wires inside PC beams can be visualized.
- Transmission images of thick concrete structure can be obtained.
  High X-ray energy sources while maintaining their portability were realized by linear electron accelerators. The high X-ray energies enabled on-site X-ray imaging of thick concrete structure which was not achieved with conventional X-ray tubes.
  950-keV source: Maximum thickness of approximately 40 cm
  3.95-MeV source: Maximum thickness of approximately 80 cm

Visualization using Neutron Beams

- The world’s first reflective (backscattered) neutron imaging
  • Two-dimensional visualization of degradation and stagnant water inside slab samples
  • The inside can be checked without removing the pavement.

Results of Use

Demonstration of on-site X-ray inspection of real bridges using high output X-ray sources

FY 2015 PC Box Girder Bridge (National road)
- Installation of X-ray source
- X-ray image
- A mesh model for structural analysis
- Structural analysis based on visualization results

FY 2018 PCT Girder Bridge (Managed by Local Government)
- Installation of X-ray source
- X-ray image
- Good grout filling
- PC tendons
- Sheath

First in Japan

Towards on-site diagnosis of real bridges

Working towards development of a transportable neutron source for diagnosis of bridges on site.

Media coverage

- NHK Science ZERO 30th July 2017
- Nikkan Kogyo Shimbun 26th February 2018 (6 sides)
- Nikkei Construction 12th March 2018

Inquiries

Center for Advanced Engineering Structural Assessment and Research, Public Works Research Institute
(Masahiro Ishida, Yoshinobu Oshima) TEL: 029-879-6773 Email: caesar@pwri.go.jp
**02 Portable magnetic inspection equipment**

Detection of hidden corrosion of underground and underwater steel structure

**Feature 1**
Detection of thin wall thickness caused by corrosion

**Feature 2**
Quick inspection without surface treatment

**Feature 3**
Underground and underwater corrosion detection (light poles in the roads and underwater steel piers)

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**Overview, Specification**

Newly developed an extremely low-frequency eddy current testing (ELECT)

**Device body**
- Portable (Easy used for field inspection)
- Rechargeable (Operable in one day)
- Measurable thickness (< 20 mm)
- Measurable depth under ground level (< 50 mm)

**Waterproof magnetic sensor probe**

- A sensor probe for detection of underground steel corrosion

**Results of Use**

- **Detection of steel thickness directly from rust and painting in seconds**
- **Portable** (Easy used for field inspection)
- **Rechargeable** (Operable in one day)
- **Measurable thickness** (< 20 mm)
- **Measurable depth under ground level** (< 50 mm)

- **Detection of underground steel corrosion**
  - Initial development of inspection equipment that can inspect underground corrosion without excavation
  - Non-digging
  - Simultaneously possible

- **Thickness measurement of bridge girder**
  - By rapid inspection
  - Proximity visual inspection for thickness

- **Detection of thin wall thickness caused by corrosion**
  - Directly from rust and painting in seconds

---

**Graduate School of Interdisciplinary Science and Engineering in Health Systems, Okayama University (Keiji Tsukada)**

TEL:086-251-8129 E-mail:tsukada@cc.okayama-u.ac.jp HP:http://www.ec.okayama-u.ac.jp/~sense/index.html
Remote imaging of surface and internal defects of tunnel!

Vehicle-mounted laser surface measurement system
High-speed laser imaging detection and ranging at high time and spatial resolution
Reliable detection of cracks extended more than 0.2 mm in width Continuous measurement from a vehicle traveling at 30 km/h

Laser hammering device
Introduction of high power lasers
Operation at 50Hz (Stop-and-Go measurement) Internal concrete defects (depth 50 mm or less/distance 10 m or less # under evaluation)

Feature 1 Remote inspection
- Secure and reliable remote imaging from a distance of about 5 m.

Feature 2 Up to 0.2 mm spatial resolution at 30 km/h
- 0.2 mm crack is detectable while vehicle is in motion.

Feature 3 Easy 3D mapping of acquired images
- 3D mapping of acquired images with easy operation.

Verification Tests

- Laser surface inspection
  January 30-31, 2018
  Japan Construction Method and Machinery Research Institute
  Full-scale tunnel
  July 26-27, 2018
  National Institute for Land Infrastructure Management
  Full-scale tunnel
  May 29, 2018
  Shizuoka Prefectural Route 416 on Yaizu City
  Hamatome tunnel and Obama Zuido tunnel

Potential of an integrated system
Detection of defects in thorough inspection of inner wall surface
Combination of image measurement and laser hammering measurement

1st step Sensing of the internal defects
2nd step Precise and automatic inspection

Tunnel diagnosis technology

- Laser hammering test
  June 2017 Japan Construction Method and Machinery Research Institute Mock Tunnel
  May 2018 Narasaka Tunnel, Nara City
  June 2018 Tenno Tunnel on National Route 173, Osaka Prefecture
  Open verification test (see below)

It is expected that this technology is ready for practical use and commercialization.

Remote imaging of surface and internal defects of tunnel!

- Media coverage
  - Nikkei Shimbun (July 1, 2017)
  - Science ZERO (July 30, 2017)
  - Asahi Shimbun (June 23, 2018)

- Consolidated operation

Overall responsibility: RIKEN (Kiawamu Kase)
TEL:048-467-9846 E-mail:kiwamu@riken.jp HP:http://www.riken.jp/research/labs/rap/photon_ctrl/
Inquiries regarding implementation: Photon Labo Co., Ltd. (Shigeru Kogure)
TEL:03-6214-2529 E-mail:info@photon-labo.jp HP:http://photon-labo.jp/law.html

03 High-performance, non-destructive infrastructure diagnosis technology using lasers
04 Integrated diagnostic system for pavement and embankment

Diagnose road soundness by visualizing pavement and the inside the embankment

**Overview, Advantages (Features), and Specification**

- Measure shear wave velocity (by 2 dimensional surface wave velocity logging) and electric resistivity (by towed electric logging) simultaneously
- Automatic in-situ analysis of measurement result
- Possible to log to deep soil layer by carrying out simultaneous FWD measurement
- Perform a diagnostic of pavement and embankment at a speed of 500 m/h or more

**Results of Use**

- Perform the diagnostic for 26 national and prefectural road sections
- Evaluate the embankment stability based on shear wave velocity and electric resistivity
  \[ F_s = \frac{V_s \cdot R}{20000} > 1.0 \] stable
- Confirm the relationship between unstable points and trace of road repairs
- Perform an initial diagnostic before opening of the expressway
  → Evaluate embankment materials and stability of the embankment in the vicinity of the structure
- Perform a diagnostic during large-scale renovation
  → Diagnose the influence of seepage water in the embankment
- Propose a repair method to extend the life of pavement by evaluating the cause of pavement deterioration

**Inquiries**
Department of Civil Engineering, Gifu University (Principal Investigator: Atsushi YASHIMA)
TEL:058-293-2438 E-mail:yashima@gifu-u.ac.jp

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Department of Civil Engineering, Gifu University (Principal Investigator: Atsushi YASHIMA)
TEL:058-293-2438 E-mail:yashima@gifu-u.ac.jp
Tunnel Inspection and Synthetic Soundness Diagnostic System using High-Speed Scanning Non-contact Radar

High Speed Inspection of Cavities and Inner Defects at Speeds of 50 km/h and Higher

Feature 1: Traffic restrictions unnecessary! (No impact on traffic flow due to high-speed scanning)
Feature 2: Simultaneous measurement of cracks in lining, damage, delamination, back cavities, etc., in one scan
Feature 3: Applicable to almost tunnels! (As the distance from radar antenna to wall is about 3 m)

Overview, Specification

- High precision laser (1 million points/sec)
- 3D measurement of lining shape
- Non-contact cavity detection radar
- 20 video cameras over whole circumference
- Non-contact inner defects detection radar
- Developed in SIP
- Lining thickness and back cavities
- Inner defects, honeycombing
- Image scanning of cracks and damages

Results of Use (Inner defect detection)

- Measurements in a tunnel within Gifu Prefecture: Verification was carried out compared with contact type radar, and the same good results were obtained. The synthetic diagnostic system using a combination of laser and radar was able to effectively support soundness diagnosis.
- Mock internal cavity appropriately detected in new bridge at Nagoya University *2
- Experience has been gained on more than 1,000 km of traveling measurement.

Users' voices

- It is effective for obtaining information on cavities, etc., prior to carrying out conventional inspection.

Inquiries

Pacific Consultants Co., Ltd. Infrastructure Management Dept. Tunnel Section (Hideki Yamamoto)
TEL: 03-6777-4763 Email: tn-mimm@ss.pacific.co.jp HP: https://www.pacific.co.jp/service/infrastructure/tunnel/close-up/mimm-r/
06 AI-aided hammering test system

Artificial intelligence (AI) assists a hammering test for inspection, improving efficiency!

**Feature 1**
Detects float or exfoliation without relying on experience or know-how of hammering echo inspector!

**Feature 2**
Inspection is possible without being affected by noise even in an environment with running vehicles!

**Feature 3**
Flags hammering points and anomaly points in real-time and improves overall accuracy by additional inspection!

### Overview, Specification

Hammering test of infrastructure

- On-market inspection hammer
- Sensors unit
- Anomaly alarm
- Hammering echo data
- Wireless communication
- Visualizes anomaly points
  - Vertical position (m)
  - Horizontal position (m)
  - Automatic generation of an anomaly map

### Applicable targets
- Type of structure: Concrete structure
- Inspection location: Flat structures (lower structure (abutment, pier), retaining wall, tunnel wall, etc.)

### Results of Use · Schedule etc.

- **2017/7-12**
  - Demonstration test at seven actual bridges in Toyama City
- **2018/11**
  - Demonstration test at tunnel maintained by Metropolitan Expressway
- **FY 2019**
  - Scheduled for inspection of Metropolitan Expressway and municipality.
- **FY 2020**
  - Planned rental sales of equipment

### Media coverage

- Nikkan Kogyo Shimbun 2017.6.2 (page 21)
- Japan Chemical Daily 2017.6.2 (page 10)
- Kotsu Mainichi Shimbun 2017.7.13 (page 2)
07 System for airport pavement surface monitoring

Recognizes damage and records location with high accuracy. Improves pavement inspection efficiency!

Feature 1
Stereo line sensors capture the damage condition of the pavement with high accuracy!

Feature 2
Driving course guide system indicates the damaged parts and points the locations precisely!

Feature 3
Detects cracks with width of 1 mm or more and pot holes with a depth of 1 cm or more!

Feature 4
Improves efficiency of inspection including measurement, analysis, data accumulation and visualization!

Overview, Specification

Driving course guide system (a view from the driver’s seat)
Displays how far the current position deviates from the driving lane

Information required by user, such as driving lane, is projected onto the road surface

Measures the position and direction of the vehicle by using high precision GPS and G-sensor, and displays driving route guide.

Display supported by in-vehicle tablet guidance
Displays the driving lane from a bird’s eye view
Displays damage locations around the current position on compass

Guide information projected on road surface

Automatic detection of cracks and irregularities from line sensor images

Line sensor images
Long and wide images
Binarization
Crack detection
Crack rate evaluation
Mesh position
Level
3360, -66
1230, -72
2190, -21
B
B
C

Usage Results - Schedule

Periodic inspections
Daily inspections

Periodic inspections/Daily inspections(Pavement inspection1, 2)

Discovered damaged parts and recorded (field work)
Recorded by driving guide and monitoring system.
Repair assessment.

Analyze damage and compile into a database (office work)
Automatic detection of cracks and irregularities.
Visualize effective information for pavement surfaces management.
Assess distribution of deterioration condition, confirm change over time.
Output inspection report.

Utilize for the next pavement inspection
Pass information on to next day members.

[Effect of system introduction]
1. Reduction in measurement time
   - Conducted visual and impact-echo inspection on foot.

2. Improvement of office work efficiency
   - Recorded by driving guide and monitoring system.
   - Repair assessment.
   - Automatically detect cracks and irregularities.
   - Visualize effective information for pavement surfaces management.
   - Assess distribution of deterioration condition, confirm change over time.
   - Output inspection report.

3. Monitoring of damage status
   - Aggregate data recording of inspection information.
   - Improvement of work efficiency by simplifying manual work.

4. Sharing of inspection data
   - Accumulation of analysis data

Inquiries
PACIFIC CONSULTANTS CO., LTD. Aviation Department (Contact: Isao UENO, Naoto FUTAMATA)
TEL: 03-6777-1868 E-mail: isao.ueno@ss.pacific.co.jp
Related information from the University of Tokyo HP: http://advancedinfra.org/archives/1536
Map the shape of entire riverbed three-dimensionally from the sky!

**Feature 1**
No need to work in a river channel!
The laser measuring device is mounted on an airplane or helicopter and 3D measurement of scouring area is performed with a green laser from the sky.

**Feature 2**
High measurement accuracy
Measurement accuracy is comparable to that of echo sounding used for scouring survey.

**Feature 3**
Wide area measurement in a short time
Measurable at a maximum speed of 200 km/h (in case of airplane). By measuring several times, it is also possible to grasp the variation in wide riverbed topography.

**Overview, Advantages (Features), and Specifications**

- **System controller**
- **Data recording device**
- **Laser measurement device (including GNSS/IMU device)**
- **Installed sensor (inside airplane)**
- **Mounted sensor (lower fuselage)**

**Provision of easy-to-understand measurement results**

- **3D data from near scouring**
- **Cross section display of scouring**
- **State of pier foundation riverbed change**

- Confirmation of pier foundation scouring in 3D.
- Confirmation of cross section shape of scouring.
- Scouring progress understood using measurement results from different times.
- Estimate the influence of extensive river bed change on pier foundation scouring.

**Usage Results**

- Kansai University SIP project team conducted field experiment.
- From the results of river survey using ALB, confirmed that scouring of the pier foundation was accurately captured.
09 Bridge Inspection Robotic Camera

Capable of measuring crack widths in locations where a person cannot easily go!

Feature 1: Safety operation ---- The inspection survey can be carried out from the top of the bridge or a distant location.

Feature 2: Excellent camera performance ---- Optical zoom 30, contrast correction, shake correction.

Feature 3: Easy operation ---- Remote operation of pan, tilt, zoom, and taking photo/movie with a tablet PC.

Feature 4: Portability ---- Weight (13 kg), installation time of the device is about 5 minutes.

Feature 5: Wide range of applications ---- Can be applied not only to bridges, but also to road lighting columns, signage columns, tunnels, tanks, jetties, and buildings.

Applied Use Case

I. Within box girder with large depth
II. Pedestrian bridge at the side of a bridge
III. PC stress ribbon bridge

Results of Use

- Field test by the SIP Local Implementation Support Team
- Participated in on-site verification and trial introduction by "Next Generation Social Infrastructure Robot Development and Introduction Study Group.*

1. Through type steel truss bridge
2. PC Finback bridge
3. PC hinged long span bridge
4. Steel plate girder bridge

Inquiries

Sumitomo Mitsui Construction Co., Ltd. (Yasuhisa Fujiwara)
TEL: 03-4582-3060 Email: information@smcon.co.jp HP: https://www.smcon.co.jp/topics/2014/09309778/

Hitachi Industry & Control Solutions, Ltd. Social Infrastructure Sales Division (Yoshitaka Chiba)
TEL: 03-3251-7245 Email: www.ml.hitachi-ics.co.jp HP: http://info.hitachi-ics.co.jp/product/kyouryou/index.html

Remarkable performance

Tool for measurement of crack width and object dimensions

The crack scale, measurement scale, and L-type scale are displayed on the operation terminal screen.

- L-type scale
- Crack scale

Automatic image taking function of low magnification

(When taking zoomed in images, zoomed out images can be automatically taken at the same time)

Continuous automatic image taking

(When taking zoomed in images, zoomed out images can be automatically taken at the same time)

Very practical, and the technology is mature.

Measurements can be taken with the crack scale, and it is considered that the performance is equal to that of measurements taken close up visually.

The operability of the digital camera using the tablet and the visibility of the inspection images are good, so the inspection work is efficient, and can be used for advanced purposes.
Highly accurate monitoring of uneven settlement / subsidence of infrastructures in a wide area!

- **Target:** Bridge, Slope, Residential Area, Port Facilities, Power Plant, Bank/Dam, Volcano, etc.

**Feature 1** Wide area and high-density measurement
- Number of measuring points in urban area: approx. 500,000 points/4 km square.
- Measures a wide area at once (e.g.: 40 km square)

**Feature 2** Highly accurate measurement
- Measures a displacement rate of a measuring point in mm

**Feature 3** Ground deformation measurement
- Visualizes ground deformation in a wide area through man-made structures

**Feature 4** No on-site work
- Completely no-contact measurement. No equipment installation or traffic control required.

**Results of Research and Development**

- **Bridge monitoring.**

- FY2014-2015: Participated in demonstration experiment
  - Verification comparing result of image analysis and field survey (leveling & close visual inspection).
  - Correctly detected displacement rate of bridge.
  - Detected abnormal part with temperature/earthquake and displacement rate correlation analysis
  - Selected points of interest by close visual inspection.

- Effective for screening before close visual inspection in infrastructure monitoring

**Usage Results**

- Monitored ground deformation over utilities.
- Monitored ground deformation in landfill.
- Monitored uneven settling of plants in port area.
- Monitored structures in a restricted area.
- Monitored ground deformation in a natural gas underground storage area.

- Providing services mainly to private companies.

- It can limit people’s exposure to dangerous areas.
- Points of interest can be seen at a glance because ground deformation is intuitively observed in an entire region compared to leveling. It also cuts costs.
- Use of this technology nationwide will be more cost effective. We look forward to cooperating with the government.

**Inquiries**
- NEC Corporation
- Radio Application, Guidance and Electro-Optics Division
- Contact: Takakazu Ishii, Hideya Tomita
- TEL: 042-333-1183
- E-mail: sspo@rgd.jp.nec.com
11 An EWS for slope failure and landslides.

Disaster prevention of slope and landslide by using multipoint measurement technology

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Feature 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy installation</td>
<td>Easy maintenance</td>
</tr>
<tr>
<td>Easy to install at lower cost.</td>
<td>Run over one year with C-size battery x 4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature 3</th>
<th>Feature 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically viable system</td>
<td>Efficiency of remote monitoring</td>
</tr>
<tr>
<td>Prediction of slope deformation by multipoint measurement.</td>
<td>Establishes a stable and highly accurate EWS for slope failure.</td>
</tr>
</tbody>
</table>

**Results of Use**

- A successful case of road slope failure detection in Kyushu district
  - Successfully avoided secondary disasters in advance.

- Cut slope failure induced by rainfall accompanied by typhoon.
- Installed equipment to prevent secondary disaster.
- Successfully detected a secondary slope collapse due to rainfall.

**Users' voices**

- The alarm standards help keep our construction sites safe. (Major general contractor)
- Recommended for monitoring slope along the railway (Major railway company)
- Successfully avoided secondary disasters on a highway slope (Major general contractor)
- We prevented a waste slope failure during torrential rain. It's simple and effective! (Bureau of Environment, Tokyo)

**Regional implementation and cooperation**

- Nagasaki University: applied to a slope in Sasebo city, confirmed the movement of slope.
- Hiroshima Institute of Technology: applied to disaster prevention on slope in Hiroshima.
- RAIMS: created guideline for monitoring the stability of cut and natural slopes.

**A case study of landslide monitoring in Australia**

- Monitoring a slope stability in real time
- Monitoring landslide deformation in real time
- Visualizing slope movement.
Large weeding machine × Sensing technology

A simultaneous embankment monitoring and weed cutting

Using ICT to detect deformations that are visually hard to spot!

**Feature 1**
Acquire high-resolution terrain data while weeding!
Can be easily attached to the back of a large weeding machine, and collect ground data!
It is not disturbed by the grass, you can see the surface ground of the embankment!
Quantitative data helps to evaluate the condition of the embankment!
Possible to inspect and evaluate without relying on inspector’s experiences

**Feature 2**
Acquire unprecedented high-resolution terrain data.

**Feature 3**
Possible to inspect and evaluate without relying on inspector’s experiences

### Technical Overview
- **CalSok**
  - GNSS/IMU
    - Horizontal: 8cm, Vertical: 15cm
    - IMU located in data storage unit
  - Digital camera
    - Ortho mosaic resolution 1mm
  - Laser scanner
    - Point density: 10,000 points per sq. meter

### Results and Uses
- **Gifu University’s SIP project**
  - Demonstration experiment in Ibigawa River (H28-H30)
- **Toyooka River and National Highway Office**
  - Demonstration experiment in Maruyamagawa River (H28-H30)

**Results of Verification Test etc.**

**Steep slope embankments (February)**
Measured the same slope (1:0.9) as river charts and confirmed there was no major change since then.

**Steep slope embankments (June)**
Measured same slope after typhoon season, and found several deformation locations other than the deformation listed in river chart.

**Others**
- Contracted by weeding and inspection companies etc.
- Contracted by government research institute and public organizations.

**Future Activities**
- Participate in NETIS themed-technology public offering.
- Receive required performance certification, expand to government-controlled river offices.
- Produce prototype that can correspond to hand guided weeding machine, expand to smaller rivers.

**Media coverage**
- Nikkei Construction
  - Published on June 25, 2018, feature article
- Construction Management Technology
  - Published on August 1, 2018, feature article

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Aero Asahi Corporation, Product Planning Department (Correspondence: SHIRAI)
TEL: 049-256-7862  E-mail: masataka-shirai@aeroasahi.co.jp  HP: https://www.aeroasahi.co.jp/

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Inquiries

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High corrosion–resistance rebar

Very high corrosion resistance and deformability was achieved with low cost

Feature 1
Excellent corrosion resistance

Feature 2
Easy to bend and weld

Feature 3
Low cost

Excellent material

Excellent corrosion resistance verified by 2 years exposure tests under tropical weather at Miyako-jima island in Okinawa.

Conventional steel rebar was heavily corroded leading to cracking in concrete, while developed rebar did not corrode, and cracks did not form in concrete.

There is no crack by the thermal cycle same level of the expansion coefficient with that of concrete.

Low cost

No use of expensive pure metals, only cheap material
- steel scraps
- metals containing iron (ferro-chromium)

Comparison of production cost for each rebar
Carbon steel: stainless steel: coated steel: developed steel

Excellent deformability

Easy to handle. Developed steel rebar shows good deformability. Easy to bend on site.

Good weldability

Possible to weld by conventional method
Possible to weld by gas pressure welding

Inquiries
National Institute for Materials Science (NIMS). Research Center for Structural Research (NISHIMURA Toshiyasu)
TEL: 029-859-2127  E-mail: NISHIMURA.Toshiyasu@nims.go.jp
14 Precast products with high-durability concrete

Highly durable against salt damage, freeze/thaw attack and wheel load!

**Feature 1** High resistance to chloride penetration!
**Feature 2** High resistance to freezing and thawing!
**Feature 3** Resistant to over 100 years of highway fatigue!

### Overview, Specification

- **Reaction between BFS and cement paste improves the interfacial adhesion.**
- **No cracks are generated in BFS concrete due to improved interfacial adhesion.**
- **High freeze/thaw durability in salt environment is achieved.**

![Graphs and diagrams showing chloride diffusion suppression, interfacial adhesion improvement, and freezing/thawing test results.](image)

- Chloride diffusion is suppressed by adhesion of BFS and cement paste.
- Achieve a high corrosion-resistance steel performance in severe salt environment.
- Confirmation of high-resistance against fatigue through three kinds of wheel load running tests.

### Results of Use

- **Application to ocean structures**
  - Box culvert, precast pier
  - Kanmon sea route (West district) gravel disposal site revetment construction work

- **Application to products used in cold region**
  - Overhanging road block, overhanging sidewalk block, sidewalk/roadway boundary block.
  - Highway No. 53 Kouen sidewalk maintenance work

- **Application to prestressed concrete**
  - Precast prestressed concrete slabs, prestressed concrete girders.
  - Precast prestressed concrete branch girders for the superstructure construction of the Furumichi Bridge (two spans continuous prestressed concrete T-shaped girders bridge) for realigning the municipal road of the Oitagawa River Dam

**Many products have been adopted by the Ministry of Land, Infrastructure and Transport (LANDES Co., Ltd.)**

As a result of three kinds of wheel load running tests using specimens with joints, it was confirmed that the performance was equivalent to or better than monolithic ones (Oriental Shiraishi Corp.)

**Inquiries**

PC: Oriental Shiraishi Corporation - Technical Division (Contact: Kyoji Niitani)
RC: LANDES Co., Ltd.-Director of technical development group (Contact: Kazuyoshi Hosotani)

TEL: 03-6220-0637 TEL: 086-287-7373
E-mail: kniitani@orsc.co.jp E-mail: k-hosotani@landes.co.jp
HP: http://www.orsc.co.jp/tec/con01_2.html HP: https://www.landes.co.jp/product/111
Smartphone-based Road Condition Evaluation System

Detect road surface damage simply and inexpensively!

**Overview, Advantages**
Achieves cost reduction by a factor of 20 and high accuracy compared with the conventional method! Enables wider ranging and more frequent surveys.

The smartphone is simply fixed to a special case, and the vehicle response is accurately measured.

Anyone can take measurements in any car using a single smartphone.

**Results of Use**
- Within Japan verification tests are being carried out in Ibaraki Prefecture (Ibaraki Prefectural Public Corporation of Constructional Technology), as well as in Chiba City, Katori City, Asahi City, Toyonaka City, Beppu City, and in the Kinki and Shikoku Regional Development Bureaus of the Ministry of Land, Infrastructure, Transport and Tourism.
- Overseas, operation is scheduled to start in Kenya in FY 2018

**Users’ voices**
- Just carry your smartphone, handling is simple.
- The results are also consistent with the evaluation opinions of patrol staff.

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Inquiries
JIP Techno Science Corporation. (Yasuaki Hirose, Muneaki Takahashi)
TEL: 03-5614-3206  Email: drims_project@jip-ts.co.jp  HP: https://www.jip-ts.co.jp/highlights/sip.html

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*1. IRI: International Roughness Index
*2. iDRIMS applies IRI “Class 2”
*3. iDRIMS “Measurement”: An iOS app that measures the vehicle vibrations using acceleration/angular velocity sensor, etc. mounted on iPhone/iPodtouch
*4. There are also successful test results confirming the performance of the road surface properties automatic measurement device on a vehicle on which iDRIMS is mounted.
16 The Variable Guide Frame Vehicle for Tunnel Inspection

Vehicles can pass under the frame during an inspection.

This system automatically detects concrete spalls and cracks of an entire tunnel!

Feature 1
Vehicles can pass under the frame during inspection, minimizing traffic restrictions!

Feature 2
Automatic detection of concrete spalls by machine learning, and concrete cracks by light section! Quantitative inspection results are obtained!

Feature 3
Image and hammering data of the entire tunnel can be recorded, and it is possible to grasp the change with time of the deformation!

Overview, Specification

Variable Guide Frame
Deforming the guide frame to fit the tunnel shapes and obstacles.

Protected Frame
Protect vehicles traveling under the frame during inspection.

LCC Management system
Show the optimal repair methods based on inspection result.

Crack Measurement Unit
Detecting cracks using images and depth data.

Hammering Unit
Detecting concrete spalls from hammering sounds.

Examples of Results

• Experiment inspection while passing the vehicles.
• Automatic detection of cracks and spalls in actual tunnel.

Niraone tunnel (Sagamihara City)
Vehicle passing during inspection

Hirasawa tunnel (Minamiboso City)
Vehicle passing at normal traffic condition (no inspection)

Inspection result example

<table>
<thead>
<tr>
<th>Inspection result item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack Measurement Unit</td>
<td>Spalls, Cracks</td>
</tr>
<tr>
<td>Hammering Unit</td>
<td>Detecting concrete spalls from hammering sounds</td>
</tr>
<tr>
<td>LCC Management system</td>
<td>Show the optimal repair methods based on inspection result</td>
</tr>
</tbody>
</table>

Results of Use

Periodic inspection of road tunnel
(Recording the cracks and spalls)

Final inspection before completion
(Recording initial data of lining concrete, only use the automatic detection of spalls function)

The Variable Guide Frame Vehicle for Tunnel Inspection: Tokyu Construction Co., Ltd. (Satoru NAKAMURA)
Machine Learning for Inspection: The University of Tokyo (Atsushi YAMASHITA)
Tel: 042-763-9533 E-mail: nakamura.satoru@tokyu-cnst.co.jp

Inquiries
17 Bridge inspection system using UAV with passive rotational spherical shell (PRSS)

UAV with PRSS can fly in narrow spaces under bridges and take close-up images

**Feature 1**
UAV with PRSS can fly in narrow spaces and handle collisions!

**Feature 2**
UAV with PRSS can take close-up images from about 50cm!

**Feature 3**
Labor-saving creation of bridge inspection reports using ortho-image and semi-automatic crack tracing!

**Inquiries**

Kazunori Ohno, NICHe Tohoku University JAPAN
TEL:022-795-7025  E-mail:kazunori@rm.is.tohoku.ac.jp

Masakazu Yokoe, Chiyoda Engineering Consultant Co.,Ltd. JAPAN.
TEL:03-5974-5161  E-mail:m-yokoe@chiyoda-ec.co.jp

**Overview, Advantages (Features), and Specifications**

- Protection of UAV using a rigid spherical shell
- Lightweight UAV (weight:3kg & size:1m) that can be carried by one person
- Tether is used for safety measures when flying close to overhang of concrete floor slabs and third-party properties
- Lighting and camera that can take clear images under various flight conditions

**Examples of Results 1**

Software for creating bridge inspection reports

**Examples of Results 2**

Semi-automatic crack tracing and its width measurement

**Examples of Results 3**

Spherical shells in images are removed in real-time

**Results of Use**

- Minamitaharai Bridge in Fukushima (steel truss bridge: NEXCO)
- Chidori Bridge in Gifu (steel plate girder bridge)
- Takasago Bridge in Sendai (steel plate girder bridge)
- Side road of Akihira Bridge in Saitama (steel plate girder bridge)
- Many others.

News of Sendai City’s bridge inspection using UAV with PRSS was aired all over the country (NHK, TBS, Fuji TV, TV Asahi, Nippon TV). Many other newspaper articles featured UAV with PRSS.

90% of users said they want to use this bridge inspection system. (Gifu SIP) It allows easy inspection without an inspection vehicle. (Nexco-Engineering Tohoku)
18 Hammer-tapping and close observation systems on UAV

The Flying Inspection Robot that can tap and observe bridge structures

**Feature 1**
Realizing detection of peeling and delamination independent of hammer tapping power

**Feature 2**
Realizing self-location acquisition and autonomous movement by laser measurement

**Feature 3**
Detection of defects such as crack from digital images

**Inspection objective**
Concrete bridge/ slab, member, etc...

**Hammer-tapping mechanics**
Hammering test can be conducted up to 80cm width by using four hammering mechanics

**Hammer-tapping sound analysis**
Automatic detection distribution display

**Driving wheel**
Continuous inspection with travelling movement

**Measuring region sensor**
Autonomous movement with self-location recognition

**Power-supply unit**
Efficient inspection with wired power supply

**Camera**
Acquire high-resolution images by capturing them from a fixed distance

**Image analysis**
Crack detection, shape measurement, wide area imaging

**Advanced Technology Solutions**

Shin-Nippon Nondestructive Inspection Co., Ltd. (Officer: Hideki Wada)
TEL: 093-581-1256  E-mail: h-wada@shk-k.co.jp
Bridge inspection system using two-wheeled multicopter

Efficient recording of close-up bridge images and 3D digitalization of inspection records!

Feature 1: Moving along a surface at 50cm distance enables continuous shooting of high-resolution images that can identify a 0.1mm width crack.

Feature 2: 3D model is generated from sequential images, and 3D shape and position of the damage is recorded on 3D model.

Feature 3: Inspection results are handled in international standard IFC extension data format and can be used by the web applications independent of platform.

Inspection objective: Concrete bridges / high piers, floor slabs, bearings, etc.

System outline:
- Realizing a system that generates a 3D model from close-up images by SfM (Structure from Motion) technology, detects and records damage in a large area orthographic image, and manages damage data on 3D-CAD model.

Results of Use:
- A series of technology from shooting close-up images to making and visualizing 3D inspection data was verified in a real bridge, and the performance that can create 3D sketch of a 0.1mm width crack is proven.

Inquiries
Fujitsu Limited, Systems Unit IV (Contact person: Naoyuki Sawasaki, Kazuya Nagatani)
TEL: 044-754-2577 E-mail: sawasaki.naoyuk@fujitsu.com TEL: 044-433-0927 E-mail: nagatani.kazuya@fujitsu.com
Ultra high speed measurement at 80 km/h! Sees abnormalities inside bridge decks!

**Overview, Advantages (Features), and Specification**

- Automatic analysis of very small changes in complex radar data by Digital Signal Processing and AI
- Detects cracks in the order of 0.1 mm containing water and Segregation damage inside bridge decks
- Is capable of large-scale analysis of about 100 km in one day
- Supports efficient inspection by road managers using the integrated management system (ROAD-S System) that maps the diagnosis results on maps on the web

**Results of Use**

This is already being introduced on a trial basis by three local governments, and at present measurement and analysis is scheduled to be carried out by a further 2 local governments.

- It is not possible to observe degradation of the interior of the deck from above the pavement. This system that enables diagnosis of the internal condition on-destructively is useful.
- At present surveys of whole roads have not been conducted because of financial limitation. Regarding price aspects, the effect of introduction of the system is large.

**Users’ voices**

- Advanced Technology Solutions

**Media coverage**

- NHK “Science ZERO” (broadcast 30th July 2017)
- Nikkei Construction (12th March 2018)
Overview, Advantages (Features)

- Fatigue lives under heavy traffic conditions can be calculated with advanced FEM scheme by inputting current damage conditions
  - Well-validated fatigue model based on various past experiments
  - Logarithmic integral method for the efficient
  - Data assimilation method with the inputs of current damages (i.e., crack distributions) enables assessment of the remaining fatigue life
  - Can integrate material deterioration (ASR, freeze-thaw cycles, salt attacks)

Analysis case

- Remaining fatigue life can be assessed from the bottom surface crack patterns! (Simulated results are well-matched with the real-scale moving load fatigue tests)

Comparison with test (live load deflection)

<table>
<thead>
<tr>
<th>Number of loading cycles</th>
<th>Deflection (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 million cycles</td>
<td>Deflection at fatigue limit</td>
</tr>
<tr>
<td>2.94 million cycles</td>
<td>Deflection success</td>
</tr>
<tr>
<td>0.1 million cycles</td>
<td>0.1 million cycles</td>
</tr>
<tr>
<td>23.06 million cycles</td>
<td>23.06 million cycles</td>
</tr>
<tr>
<td>70 million cycles</td>
<td>70 million cycles</td>
</tr>
</tbody>
</table>

Expeditied evaluations by AI

- AI model was created to reduce the time for fatigue simulation of FEM.
  - Instantaneous evaluations of remaining fatigue life from crack patterns on bottom surface

Future developments

- Accuracy validation of the model for freeze-thaw cycle (FTC) will be conducted to apply the model to FTC-damage cases
- AI model planned to be applied to real structures

Inquiries

Department of Civil Engineering, The University of Tokyo (Contact: Tetsuya Ishida)
TEL: 03-5841-7498 E-mail: tetsuya.ishida@civil.t.u-tokyo.ac.jp
HP: http://concrete.t.u-tokyo.ac.jp/mem/ishil/
Remotely Operated Vehicle (ROV) equipped with camera system for visual inspection of concrete pier superstructure

**Advantages**
- Positioning system under superstructure where GPS is not available
- Applicable to inspection in narrow and dark spaces
- Remote control available

**Feature 1**
- Shortens inspection time.

**Feature 2**
- Reduces inspection cost.

**Feature 3**
- Provides 3D model from captured images.

**Results of Use • Schedule etc.**
- Demonstration tests were performed at Nagoya, Shimizu, Kawasaki, Onahama and Chiba.
- The diagnosis support system, including documentation of the inspection and diagnosis report with 3D image data, was developed in this project.

**Dimensions:** L1210 x W800 x H925 mm
**Weight:** Approx. 100 kg

**Media coverage**
- The daily engineering and construction news, Jan. 27, 2017.

Enquiries
Toshinari TANAKA, Port and Airport Research Institute (PARI), National institute of Maritime, Port and Aviation Technology (MPAT)
TEL: 046-844-5062  E-mail: tanaka_t@pari.go.jp  HP: https://www.pari.go.jp/unit/lcm/sip.html
**Overview**

- Database (DB) system construction, introduction, and support for local governments, based on the DB system for the East Nippon Expressway Company Limited (NEXCO EAST) developed from SIP research project.

**Issues at Local Governments: ex. YAMAGATA**

- Very large stock of infrastructure to be managed
- Inspection data has already been obtained for 10,000 cases in prefectures, cities, towns, and villages
- This will increase by 1,600 cases annually
- Searching for and preparing the necessary information or documents is difficult!
- Delay in implementation of measures by local governments, especially cities, towns, and villages
- The key to measures against the aging bridges is the cities, towns, and villages

**Results of Use - Schedule etc.**

- Service commenced in Yamagata Prefecture in 2016
- In 2017 all 35 cities, towns, and villages within Yamagata Prefecture introduced the “Yamagata Prefecture Road Bridge Maintenance Integrated Database System (DBMY)”

**Joint operation of DBMY**

- Charge
- Joint operation of DBMY

**Merits of Introduction**

- Time required for preparation of bridge diagnosis document for 1 bridge
- About 3 hours
- About 3 minutes

**Integrated database system**

- Integrated data management of bridge inspection for time-saving and economic advantage!
- Realization of advanced inspection and diagnosis, efficiency, and proper repair plan and budget control

**Inquiries**

Center for Infrastructure Management Research, Tohoku University (Makoto Hisada, Ko Kamata, Chie Nakagawa)

6-6-11 Aoba, Aramaki, Aoba-ku, Sendai

TEL: 022-721-5503 Email: inquiry-imc@tohoku-imc.ac.jp HP: http://imc-tohoku.org/
Robotic Technology to Support Periodic Inspection of Bridges in Local Governments

Achievement of Advanced and Efficient Bridge Periodic Inspection, with Greatly Shortened Traffic Restrictions!

Overview of initiatives and results

Utilization of robotic inspection technology for inspection of bridges
- Implementation of inspection on bridges where inspection is difficult (large bridges having large cross-sections, etc.)
- Major shortening of traffic restrictions on the bridge (efficiency due to the combination of robotic technology and large-size inspection vehicle)  
  Example: 10 days → 4 days
- Acquisition of detailed inspection information (information useful for future inspections)

Initiative of Gifu University SIP Team
- Development of Guidelines for application of robotic inspection technology to local government bridges
- Performance requirements for robotic inspection technology and performance evaluation
- Examples of optimum combination of robotic inspection technologies

Future development

- Application to Kakamigahara Bridge periodic inspection
  - First inspection in 2018
- Proposals for improvement of inspection robot
  - From the viewpoint of the user
- Collection of damage AI teaching data
  - Cooperation between the robot developer and the road administrator, with the aim of improving the accuracy of detection of damage by the robot

Preliminary Surveys with Optimum Combination of Robotic Technologies

Confirmation by close visual inspection

Ultra large bridge inspection vehicle

Inquiries: Center for Infrastructure Asset Management Technology and Research, Gifu University (Keitetsu Rokugo, Hideaki Hatano)
TEL: 058-293-2436  Email: gifusip@gifu-u.ac.jp  HP: http://me-unit.net/
Exit Strategies

Business on Infrastructure Maintenance and Management (mainly related to Public Orders/Public Works)

**Business model on Infrastructures maintenance and management**


New Technical Certification system (Collaboration with MLIT*)

Technical certification is an “essential step” for safely using new technologies on site

1) Setup of requirements for needs on site.
2) Setup of inspection standards for new technology.
3) Revision of inspection procedure.
4) Realization of “Technical Certification” and “Visualization of Technology”.

**Expansion of New Technologies in public works**

**Promoting Regional Implementation of New Technologies (Network based upon Regional Universities)**

Proposal of a regional custom-made symbiosis society with infrastructure based on an asset management system that can realize durable and long life infrastructure.

*MLIT: Ministry of Land, Infrastructure, Transport and Tourism*