54 Research and Development of Infrastructure Structures and Inspection Devices for Advanced Inspection of Civil Infrastructure

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Collaborative Research Groups: Public Works Research Institute, Japan Bridge Engineering Center, Japan Construction Machinery and Construction Association

R&D Objectives and Subjects

R&D Objectives

- Aging social infrastructures (bridges, tunnels) require reliable maintenance for people to be able to use them safely and securely. However, concerns are being expressed about a labor shortage in the construction industry and a technician shortage in public organizations, etc., due to the declining birthrate and aging population.
- This research looks at inspecting social infrastructures (bridges, tunnels) safely, efficiently, and economically. In addition to examining the structuralization of infrastructures that better suit inspection work, this research also proposes an optimal inspection system where infrastructures, robots, and people work together to clarify concerns about the design of structures in order to introduce equipment, such as robots, more efficiently.
- As a target to be reached by the end of FY2018, taking the development and dissemination of robotic technologies into consideration, we will work toward the early realization of “support and efficiency improvement of our existing close visual inspection” using robotic technologies on the precondition that existing control standards and techniques are used as a base.

R&D Subjects

- We will work on the following support (research and development) to achieve the early introduction of robotic technologies on-site in order to realize “support and efficiency improvement of our existing close visual inspection” using robotic technologies. Target sites for introduction include locations where we expect the introduction of robotic technologies to produce effects, such as “hard-to-inspect spots” (according to the needs of infrastructure administrators, etc.).

  (1) Examine the structures of infrastructures (new and existing) that take inspection into consideration.

  (2) Prepare procedures for installing additional equipment.

  (3) Establish performance requirements for robotic technologies to solve "hard-to-inspect spots," etc.

  (4) Develop operation guidelines for location sensing technology (markers), examine methods to deliver damage diagrams.

  * The main objective of (1) and (2) is to take measures against "hard-to-inspect spots".

Current Accomplishments (1/2)

Bridges

Main hard-to-inspect spots and proposed countermeasures (proposal to improve work efficiency and improving hard-to-inspect spots)

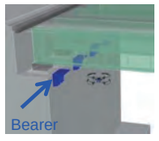
<Classification of hard-to-inspect spots (classified in the previous years)>
Cases of about 120 typical hard-to-inspect spots were extracted and analyzed in order to classify hard-to-inspect spots based on data from about 23,000 bridges across national roads under direct control of Ministry of Land, Infrastructure, Transport and Tourism by conducting field surveys on Honshu-Shikoku Bridges and the Tokyo Bay Aqua-Line, etc. Measures which contributed to improving the inspection efficiency, etc. were examined and proposed based on the relevant classification.

(1) Examine the structures of infrastructures (new and existing) that take inspection into consideration

Proposals to improve girder edges and a bridge collapse prevention unit

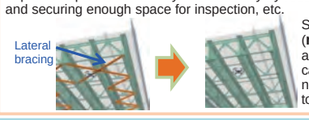
[Hard-to-inspect spots] Shielding condition using a bridge collapse prevention unit

E.g. Adopted a bearer method (upsizing, etc.), instead of a block type and wire type



Examination and proposal to remove lateral bracing

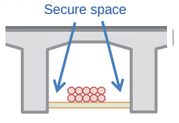
Improve inspection efficiency and accuracy by reducing the number of inspection targets and securing enough space for inspection, etc.



Safety needs to be secured (**reinforcement using stiffeners,** etc. as necessary) through structural calculations, etc., since lower lateral bracing needs to be installed in principle according to the Specifications for Highway Bridges.

(2) Prepare procedures for installing additional equipment

[Hard-to-inspect spots] Shielded by additional equipment



E.g. Proposal to secure space of 50 cm of width or wider around the additionally installed equipment to facilitate inspection by robots, etc. Created "Guidelines for installation of additional equipment (draft)" (planned for 2016)

(3) Establish performance requirements for robotic technologies to solve hard-to-inspect spots, etc.

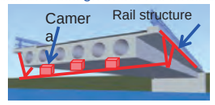
○ Proposal of a new inspection system (no equipment development)
Confirm whether or not hard-to-inspect spots, etc. can be inspected with the outline design

[Hard-to-inspect spots] Narrow area with the water surface under the girder

Design of float type inspection equipment

[Hard-to-inspect spots] Narrow area under the girder

Suspension type inspection robot system and design of the rail structure



○ Establish robotic technology performance requirements (planned for 2016)
- Classify inspection work that is applicable to robots
- Classify the robotic technologies that are expected to be utilized for inspection work

(4) Develop operation guidelines for location sensing technology (markers), examine methods to deliver damage diagrams

Examine markers, propose installation

Survey the visibility of robotic technologies, targeting about 5 types of markers (planned for 2016)

Effects of introducing markers
- Prevent misunderstanding of inspection sections
- Improve work efficiency when making a photomontage (about 40%)

Current Accomplishments (2/2)

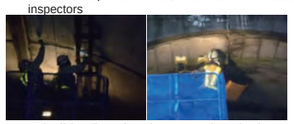
Tunnels

Develop inspection support equipment (platform)

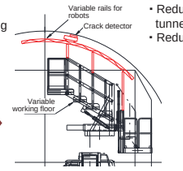
Inspection work issues (according to the interviews)
- Reduced inspection efficiency due to pain or exhaustion, etc. caused by work in an overhead position (unnatural posture),
- Relocation of working floor of trolley is time consuming

Countermeasure: Develop a platform where the working surface angle can be changed freely in accordance with the shape of the tunnel section (design phase in 2016)

[Expected effect 1] Support the introduction of robotic technologies
- Get robots closer to conduct the inspection by installing rails which can be equipped with crack detectors, etc.
  → Substitute inspection works, and reduce the number of inspectors



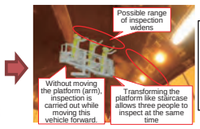
Chalking/beating (current situation)



- Conduct inspections using robots
- Reduce the number of inspectors

[Expected effect 2] Countermeasure against hard-to-inspect spots
- Reduce inspection works in an unnatural posture by having a working surface that suits the shape of the tunnel section.
- Reduce the trolley working floor relocation work during inspections to shorten the inspection work time.

Replacing the platform (current situation)



Assumed the effect of shortening the inspection time by about 10 to 20% (according to test calculations based on the field survey)

- Omit replacement work for shoulder inspections
- Shorten the work time by conducting shoulder inspections concurrently

Examine location sensing technology (markers)

Inspection work issues, usage of robots (according to the interviews)
- Difficult to understand the location information since no identifiable characteristics can be found in the tunnel.
- Diagnostic work during the inspection can be more accurate if construction information is provided in the tunnel.

Countermeasure: Carry out a basic examination of the various information required for human and robots, and of the marker specifications that will make the information recognizable to improve tunnel inspection efficiency.

[Expected effect 1]
- Robots can recognize their own locations even under conditions where GPS radio waves cannot reach and no identifiable characteristics can be found inside the tunnel.
- Markers can be used as identifiable characteristics when merging images obtained by the robot.

[Expected effect 2]
- Human inspectors can identify the construction information, etc. that is used to understand their own locations and used as a reference for diagnosis.

- Reduced inspection time or reduced office work time can be expected.
  ⇒ Specific effects of this reduction will be examined by future demonstrations, experiments, etc.

A mark that enables inspectors, etc. to recognize information during construction of the tunnel

A marker that can be recognized using camera, radar, etc.

Representation of the lining span No.

A mark for other additional information (such as coordinate information)

Marker (draft), currently under consideration

Goals

The following table summarizes the results in order to introduce robotic technologies for infrastructure maintenance to realize “support and efficiency improvement of our existing close visual inspection” as an exit strategy at the end of FY2018.

Issue	Final result
(1) Narrow inspection space (measures against hard-to-inspect spots)	・Proposal of structures (new and existing) that take inspection into consideration ・Design of an inspection support equipment (system)
(2) Hard to inspect visually due to obstacles (measures against hard-to-inspect spots)	Preparation of Guidelines for installation of additional equipment (new and existing)
(3) Infrastructure inspection using robotic technologies	・Clarification of a utilization method and performance requirements for robotic technologies on-site ・Design of an inspection support equipment (system)
(4) Improve inspection efficiency and accuracy	Development of operation guidelines on location sensing technology (markers)

[R&D Objectives and Subjects]

○Support measures for introducing robotic technologies on-site
(Structures of infrastructures, inspection support facilities, etc.)
(1) Examine the standard of infrastructure structures (new and existing) that takes inspection into consideration
(2) Prepare procedures to install additional equipment (system)
(4) Develop operation guidelines on location sensing technology (markers), examine standards to deliver damage diagrams

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○ Clarify the utilization method and performance requirements of robotic technologies on-site
(3) Establish performance requirements for robotic technologies that are utilized for infrastructure inspection

[Outcome]

Improved efficiency in infrastructure maintenance by introducing robotic technologies, etc.

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Promoted development of required robotic technologies, etc.