Inspection of bridges, tunnels, and pavement by using cameras

West Nippon Expressway Shikoku Company Limited.

KURABO INDUSTRIES LTD.
West’s Japan highway business area Map

My company business area

West’s Highways in Operation
3,427km

- Expressways in operation: 3,427km
- Daily traffic volume: 2.82 million/day (fiscal 2013 results)
- Operating revenue: JPY 605.3 billion (fiscal 2013 results)
- Expressways under construction: 141 km
- Expressways under construction (section developed by the central government): 187 km

Development business:
- Service areas (SA): 98 locations
- Parking areas (PA): 200 locations
- Sales: JPY 151 billion (fiscal 2013 results)

Legend:
- Expressways in operation
- Expressways under construction
- Expressways under construction (Section developed by the central government)
- Other expressways

http://global.w-nexco.co.jp/
Budgeting for O&M Activities (West’s Japan highway)

Operation and Maintenance Costs: 15.6 bn. US$

(planned, in 2013 fiscal year)

Toll Collection Costs: 399 mn. US$
Maintenance Costs: 830 mn. US$
Repair Costs: 327 mn. US$
Inspection Costs: 84 mn. US$

【Note】Exchange Rate 1 USD = 115 JPY

http://corp.w-nexco.co.jp/corporate/disclosure/h25/
Inspection of Japan highway

Bridges

Tunnels

Pavement

J-System

L&L System

Analyzer with Laser & Line sensor
Ⅰ. Bridges Inspections

Ⅱ. Tunnel and Pavement Inspection

Ⅲ. Demonstration of the inspection technology implemented at Singapore
I. Bridges Inspections

II. Tunnel and Pavement Inspection

III. Demonstration of the inspection technology implemented at Singapore
Sounding inspection for prevention measure against flaking

Present method needs a lot of costs and time
Infrared inspection situation

Visible image camera

Infrared camera

Monitor

Battery

conventional sounding test (requires lane closure)

J-SYSTEM (does not require lane closure)
Basic Theory of Infrared Thermography

Inspection must be done when the temperature difference between air and concrete is large enough.

Temp. differences creates thermal anomalies

<table>
<thead>
<tr>
<th>view before break</th>
<th>Infrared image</th>
<th>view after break</th>
</tr>
</thead>
</table>

daytime: sound < flawed < air

night-time: sound > flawed > air
## Relationship between Inspection time, and bridge type or part

### Direction of heat flow and temperature in damage part

<table>
<thead>
<tr>
<th>Section</th>
<th>Surface to be inspected</th>
<th>Direct effect</th>
<th>Indirect effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>All bridges</td>
<td>Surface to be inspected</td>
<td>Sunlight</td>
<td>Temperature rises due to effect of sunlight</td>
</tr>
<tr>
<td></td>
<td>Surface to be inspected</td>
<td>Surface to be inspected is not directly exposed to sunlight</td>
<td>Temperature decreases due to effect of sunlight</td>
</tr>
<tr>
<td>Metal bridge</td>
<td>Surface to be inspected</td>
<td>Sunlight</td>
<td>Temperature decreases due to effect of sunlight</td>
</tr>
<tr>
<td>Box beam bridge</td>
<td>Pavement</td>
<td>Surface to be inspected is not directly exposed to sunlight</td>
<td>Temperature rises due to effect of sunlight</td>
</tr>
</tbody>
</table>

**Inspection time should be selected by bridge type or part**
Almost all bridge types and bridge sections can be investigated during night time.
Thermal images of different minimum detected temperatures (NETD) (Daily range = 10°C: photographed at 0 a.m.)

- 20mm inner Cavity
- 30mm inner Cavity
- 40mm inner Cavity
- 60mm inner Cavity

a) Thermal image photographed by Camera A
b) Thermal image photographed by Camera B

Temperature difference (°C)

- a) Temperature variation of Camera A
  - Standard deviation = 0.034 °C

- b) Temperature variation of Camera B
  - Standard deviation = 0.016 °C
Issues for accurate infrared inspection

- clarification of inspection depth
- quality guarantee and prevention of missing damage
- high efficient inspection work and cost performance
- efficient damage judgment and objectivity
- recording and reproductability

Camera performance
- resolving power
- detection wavelength region
- resolution
- detecting element etc

Inspection terms
- kind of bridge, part
- detection depth
- photographing distance etc

Inspection environment
- daily range
- solar radiation
- wind and rain etc

Feasible time
A new concrete inspection and assessment method with safer manipulating, higher performance, and lower cost based on infrared thermography technology.

J-SYSTEM

EM(S) Test-Piece
J Monitor
J Software
To ensure thermal condition of real structure for infrared testing before and during infrared inspection.
To obtain real temperature data under actual conditions element by element
Do we inspect at a suitable time?

The thermal environment should be precisely obtained by an EM(S) device before any investigation.

IR Image
Central cavity is observed. → OK

IR Image
Cavity is not observed. → NG
J Monitor: A Display for IR images in Real Time

J-_SYSTEM

- EM(S) Equipment
- J Monitor
- J Software
J Monitor, inspection situation Movie
Temperature distribution is interpreted into damage ratings by using a comprehensive database of temperature patterns.

<table>
<thead>
<tr>
<th>Damage pattern</th>
<th>indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete surface</td>
<td><strong>Observation (Insignificant)</strong></td>
</tr>
<tr>
<td>Depth ≥ 4cm crack reinforcement</td>
<td><strong>Caution</strong></td>
</tr>
<tr>
<td>Concrete surface</td>
<td><strong>Critical</strong></td>
</tr>
<tr>
<td>Depth ≥ 2cm crack reinforcement</td>
<td>Emergency measures required</td>
</tr>
</tbody>
</table>

Visible image: EM(S) test-piece

IR raw image

IR Process image
J Software (analyzing) Movie
Comparison Between New and Conventional
Is it possible and easy to evaluate objectively?

Your resources can be focused on the areas that need the most work.
I. Bridges Inspections

II. Tunnel and Pavement Inspection

III. Demonstration of the inspection technology implemented at Singapore
System outline

**Width**: 2.180m  
**Height**: 3.140m  
**Length**: 6.320m  
**Weight**: 6t

**Detectable Items**
- Pavement
- Crack, Rutting
- IRI (International roughness index)
- Longitudinal Profile
- MPD (Mean Profile Depth)
- TN (Damage of cracks etc....)
L&L System

Visual image

Direction of movement

Line Sensor

Illumination area

Height image Width profile

Slit Laser

photographed with an area camera by a slant

The slit laser is situated in directions perpendicular.
Tunnel Inspection
Movie
Visual image (tunnel)
Zoom-up① visual image (Cracks)
Zoom-up② visual image (tunnel lighting)
Pavement Inspection
## Control Item

### Maintenance Target Values of Pavement (Expressway)

<table>
<thead>
<tr>
<th>Ruts (mm)</th>
<th>Difference in Level (mm)</th>
<th>Coefficient of Sliding Friction (μV)</th>
<th>Flatness IRI (mm/m)</th>
<th>Cracking Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Mounting</td>
<td>25</td>
<td>20</td>
<td>30</td>
<td>0.25</td>
</tr>
<tr>
<td>Crossing Structure Mounting</td>
<td>20</td>
<td>30</td>
<td>0.25</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>
Data Acquisition by Periodic Inspection

Road Surface Measurement (3 Elements)

Company-owned vehicle

- Cracks
- Ruts
- Flatness
Visual image (pavement)

Accuracy at a speed of 100km/h
~Detecting cracks~
Shooting width=4.5m (Color image)
Resolution 0.8mm x 0.8mm/pixel
Zoom-up visual image (Cracks checking)
Accuracy at a speed of 100km/h
~Rutting Measurement~
Shooting width=4.4m
Resolution 1.68mm (Transversal)
5.60mm (Longitudinal)
0.50mm (height; Depth)
Ruts

Height image (Black part is low.)

Ruts on the red line above
Flatness (Longitudinal profiling)

High-resolution allows us to accurately profile the longitudinal shape of a microscopic bump.

Result of longitudinal profiling (magnified)
Analyzing highly accurate longitudinal profile
Analyzing highly accurate longitudinal profile

Visual image  
Surface height image

Manhole Cover profile area

Scale 20cm
Pavement analyzing

To suggest a new pavement evaluation
Bumps Analyzing

Detecting cracks
Abstracting cracks from visual image

Visual image

Abstracting crack image

Detecting rutting
Abstracting rutting from visual image

Surface height image

Processed surface height image

Crack+Processed image
(red:bumps 5mm or deeper)

Depth of a rutting is contrasted through special software, called J-soft.
The form of partial damage such as blistering can be replicated.
(1) The degree of concrete corrosion and filling of fine materials can be identified.
(2) Small cracks in the protective post-placed concrete cover can be photographed.
The adhesion status of lane marking paint to the road surface can be confirmed.
Investigation using color images (Concrete Pavement)
Visualizing the state of subsidence in an embankment at the back of an abutment
Analyzing highly accurate longitudinal profile

Future: IRI can be measured thanks to no speed dependance
Contents

Ⅰ. Bridges Inspections

Ⅱ. Tunnel and Pavement Inspection

Ⅲ. Demonstration of the inspection technology implemented at Singapore
Plan and Photos of the Bridges
IR Scanning from the Ground
DTSS: a road surface on an earthwork
The End

J System

L&L System