National overview of the bridge condition and management: Japan

CAESAR
Center for Advanced Engineering Structural Assessment and Research, PWRI, Japan
## Road network in Japan

<table>
<thead>
<tr>
<th>Owner (Operator)</th>
<th>Highway length (km)</th>
<th># of bridges (15 m or more in total span)</th>
<th>Heavy truck travels</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Expressways (Toll roads)</td>
<td>Government (Designated corporations)</td>
<td>7,400 (0.6%)</td>
<td>6,402 (4.3%)</td>
</tr>
<tr>
<td>National Highways Designated sections</td>
<td>Government</td>
<td>22,200 (1.9%)</td>
<td>10,794 (7.3%)</td>
</tr>
<tr>
<td>National Highways Non-designated sections</td>
<td>Prefectures</td>
<td>32,000 (2.7%)</td>
<td>12,778 (8.6%)</td>
</tr>
<tr>
<td>Prefecture roads</td>
<td>Prefectures</td>
<td>128,700 (10.9%)</td>
<td>32,516 (21.9%)</td>
</tr>
<tr>
<td>Municipal roads</td>
<td>Municipalities</td>
<td>992,700 (83.9%)</td>
<td>85,733 (57.8%)</td>
</tr>
</tbody>
</table>

The government almost completely delegates prefectures and municipalities to operate and maintain their roads.
Most bridges are made of steel or PC.

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>RC</th>
<th>PC</th>
<th>Combo</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential NH routes</td>
<td>50.7%</td>
<td>8.6%</td>
<td>36.9%</td>
<td>3.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Prefecture roads</td>
<td>39.1%</td>
<td>17.9%</td>
<td>40.6%</td>
<td>1.9%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Municipal roads</td>
<td>36.7%</td>
<td>17.5%</td>
<td>41.7%</td>
<td>2.0%</td>
<td>2.1%</td>
</tr>
</tbody>
</table>
Recent traffic shutdowns because of bridge distress in essential NH routes in Japan

Many instances of damage such as fatigue cracks and corrosion have already appeared, some of which could have led to collapse.

Fatigue fracture in a steel main girder, Yamazoe Bridge, R25, constructed in 1971. (Traffic shut down for 2 days, ADTT 36,000)
Chloride-induced deterioration and ASR are also major distress.
Percentages of damage type for the bridges demolished due to deterioration of superstructure (1996-2006)

- Steel bridges:
  - Corrosion: 51.8%
  - Damage to deck slab: 30.4%
  - Others: 17.9%

- PC bridges:
  - Chloride ingress: 51.5%
  - Corrosion of reinforcement: 12.1%
  - Damage to deck slab: 9.1%
  - Cracks and spalling of girder: 9.1%
  - Others: 18.2%

Fatigue distress of RC deck slab is also a serious concern.
US bridges vs Japanese bridges in Year built

### # of constructed bridges

- **Became older than 50 years in 1980’s**
- **Will become older than 50 years in 2010-2025**

**Construction Year**

- 1901-05
- 1911-15
- 1921-25
- 1931-35
- 1941-45
- 1951-55
- 1961-65
- 1971-75
- 1981-85
- 1991-95
- 2001-04

**15 m or more in length**
Percentage of bridges 50 years or older

Bridges on national essential highway routes

FY2006
- 6% (8,900)

FY2016
- 20% (8,900)

FY2026
- 47% (66,300)
Preventive maintenance initiatives

A preventive maintenance initiative was raised in 2003.

The Ministry notified and mandated a new-every-five-year inspection program for their bridges on essential NH routes in FY2003. (Previously (since 1988): Just a recommendation; Interval < 10 years)

<table>
<thead>
<tr>
<th>Damage</th>
<th>Remedial work urgency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check every element of every member to track the time evolution of damage</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>E1</td>
</tr>
<tr>
<td></td>
<td>E2</td>
</tr>
<tr>
<td></td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>S</td>
</tr>
</tbody>
</table>

Damage rank:

- a: Small
- b: c: d: e: Large

Now we’re in the middle of the second 5-year term of the new program.
Hands-on, Visual inspection for all members
Remedial work urgency increases with increasing their age.

Remedial work needs increase as bridges approach their 30th year.
Prioritized remedial works

A high priority of detailed inspection and remedial work on the bridges that needed urgent remedial work for these types of distress for a three-year period of FY2005-2007.

A BMS algorithm was also developed and now it’s been used as a trial in some highway offices by referring when they make budget.
We still don’t know about local bridge conditions.

Local highway administrators, especially community governments, did not inspect their bridges.

Have you ever inspected your bridges? (as of September, 2007)

Main reasons (Questionnaire survey):

65% of local governments admit they are not good at technical issues.
62% admit budget is deficient.
50% admit the lack or shortage of in-house engineers.
Recommendations for the outline inspection of bridge condition

Aim:
Inspect all bridges as immediately as possible while avoiding the critical misunderstanding of a bridge condition as much as possible.

The amount of collected data reduces 50% of that of the government every-five-year inspection based on the statistical analysis for damage data collected in the government inspection.

<table>
<thead>
<tr>
<th>Government program</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All element</td>
<td>e.g. Girder ends for corrosion</td>
</tr>
<tr>
<td>Hands-on</td>
<td>e.g. hands on are not necessary for substructures</td>
</tr>
<tr>
<td>26 damage types × 5-tier ratings = 130</td>
<td>12 damage types × 2-5-tier ratings = 33</td>
</tr>
</tbody>
</table>
A new subsidy program for local governments

A subsidy program for local governments to inspect their bridges and establish their long-term bridge maintenance program was invented in FY2007, ending in FY2011.

- A half of the cost to make up a long-term maintenance program for the longevity of bridges
- A half of the cost to inspect the bridges that will be taken into account in the expected long-term maintenance program

After FY2012, as for a damaged bridge, if its rehabilitation plan is not listed in their long-term bridge maintenance program, the local government cannot obtain the subsidiary to repair from the Ministry.
Municipalities will get the inspection of 50.5% of their bridges achieved by the end of FY2009. (Formerly, almost none!)

However (or, deep down, as we suspected), …..

the number of weight-restricted or closed bridges increases as the inspection progresses.

<table>
<thead>
<tr>
<th></th>
<th>FY2006</th>
<th>FY2007</th>
<th>FY2008</th>
</tr>
</thead>
<tbody>
<tr>
<td># of closed</td>
<td>83</td>
<td>138</td>
<td>193</td>
</tr>
<tr>
<td>bridges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of bridges with</td>
<td>510</td>
<td>724</td>
<td>1002</td>
</tr>
<tr>
<td>weight limitations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>or lane closures</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(The program started)
Towards the second stage of bridge management:

Strategic management

At the first stage

The top priority is to know and analyze the current structural status of all stocks.

However, it is not sure that they will continue to inspect and take care of all bridges under this cash-strapped situation.

At the second stage --- Strategic management

1. Rationalization of inspection items and frequencies
2. Coordination of in-house and outsourcing responsibilities
Rationalization of inspection items and frequencies

Two major aims in inspection

A structural safety inspection is needed to confirm if there is little expectation to reach a fatal failure. --- All bridges

A thorough inspection such as the government inspection program is needed to predict the deterioration rate and life cycle cost for a bridge. --- Is this kind of thorough inspection really necessary for all bridges?

We are seeking different inspection frequencies and items for both aims, respectively, based on earlier experience and statistics.
Empirical approach by CAESAR: Fracture critical structures

Learning from earlier experience in bridge failure or structural safety issues

Need to know an expected failure process with changing its appearance
Probalistic approach by NILIM: # of spans not having or having cracks in steel girder & box-girder bridges

Inspection for fatigue in steel girders and box girders may not be necessary if a bridge does not carry heavy traffic and is younger than 30 years old.

Average daily large vehicles (in thousands)

<table>
<thead>
<tr>
<th>Age</th>
<th>0-2</th>
<th>2-4</th>
<th>4-6</th>
<th>6-8</th>
<th>8-10</th>
<th>≥ 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>350</td>
<td>425</td>
<td>344</td>
<td>300</td>
<td>39</td>
<td>3343</td>
</tr>
<tr>
<td>10-20</td>
<td>337</td>
<td>592</td>
<td>599</td>
<td>318</td>
<td>93</td>
<td>306</td>
</tr>
<tr>
<td>20-30</td>
<td>363</td>
<td>572</td>
<td>485</td>
<td>296</td>
<td>71</td>
<td>309</td>
</tr>
<tr>
<td>30-40</td>
<td>5726</td>
<td>498</td>
<td>400</td>
<td>258</td>
<td>18</td>
<td>406</td>
</tr>
<tr>
<td>40-50</td>
<td>184</td>
<td>97</td>
<td>158</td>
<td>58</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>≥ 50</td>
<td>72</td>
<td>29</td>
<td>18</td>
<td>84</td>
<td>5</td>
<td>34</td>
</tr>
</tbody>
</table>

No cracks
With cracks
One other example of statistics: Corrosion in steel girders

Different inspection frequency may be able to set for girder-ends and other parts, respectively, in terms of corrosion in steel girders.
Which way should we go?

Questionnaire survey for local governments on why they could not carry out bridge inspection:

65% of local governments admit they are not good at technical issues.
62% admit budget is deficient.
50% admit the lack or shortage of in-house engineers.

Probably, we’ll face some questions of which way we should go to:

A. Outsourcing to industry
B. Hiring and educating in-house engineers

Need to coordinate in-house and outsourcing responsibilities
Excerpts:
``HA is an executive agency of DfT.”
``The inspection and maintenance activities are undertaken by managing agents and contractors appointed by HA.”
``Inspections are carried out by staff employed by the maintaining agents.”
``The maintaining agents are required to consider potential work programs.”
``The Agency uses a risk-based approach for the prioritization of maintenance needs.”

Who is responsible what if a bridge fell down because of irrelevant diagnosis, HA or agents?

How do in-house engineers check and approve the relevance of the remedial work programs and the prioritization suggested by BMS (or the accuracy of BMS prediction for individual bridges)?
Thank for listening

Center for Advanced Engineering
Structural Assessment and Research (CAESAR)