Corrosion of 30 Years Old Weathering Steel Bridges

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1.Abstruct

Atmospheric corrosion-resistant steel is unique in forming a tight and stable rust layer on its surface, which acts as a protective film that retards the corrosion of steel. Once stable rust forms, no coating is needed for many years, thereby reducing maintenance costs. However, on some bridges with such steel, stable rust has failed to form and the base metal has become corroded; as a result, the specification has been changed to painting. There are also cases where serious corrosion has required a bridge to be reconstructed. It is necessary to fully understand corrosion conditions through inspections or investigations and to conduct proper maintenance such as by removing and minimizing the causes of corrosion. Hokkaido Development Bureau is developing a technique for evaluating the deterioration of bridges built with weathering steel. The evaluation method is suited to the severe natural environment of Hokkaido. In 2003, this development program started with corrosion investigations on a corrosion-resistant bridge on Muroran Shindo (National Highway 36). This paper explores the extent of corrosion and factors of corrosion progress by comparing investigation results obtained in 2003 with those of 1987.

2.Introduction

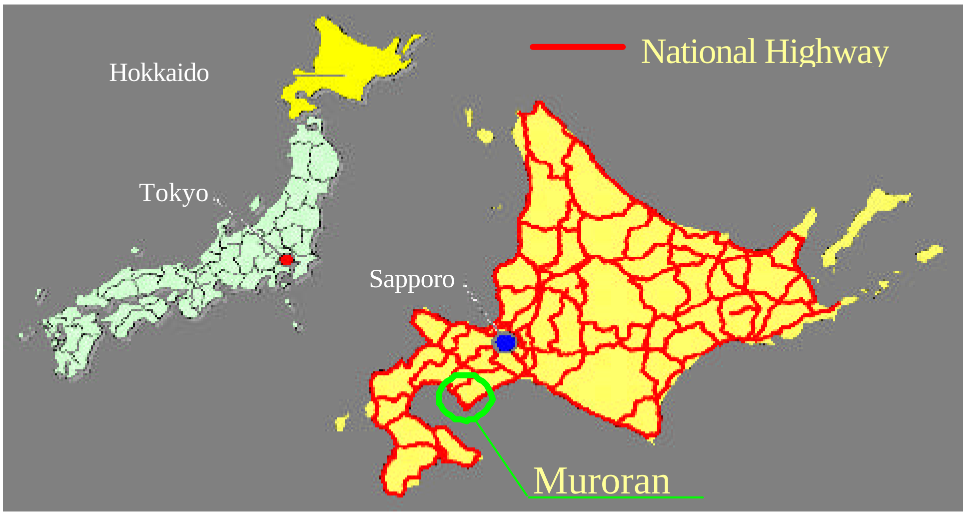

Figure 1. Location

Muroran Shindo in Muroran City is a section of National Highway 36. The section extends for 8.3 km and is used as a bypass to relieve traffic congestion in the city. Its construction began in 1970 and was completed in 1980.

The highway runs over eight bridges, which were built using about 7,800 tons of corrosion-resistant steel (Table 1). The bridges (Figure 1) are 0.5 to 3 km from the shoreline and are affected by windborne sea salt. In addition, the formation of stable rust is considered to be hindered by smoke from the factories found in this area, the largest industrial district in Hokkaido. The Weather Coat rust-stabilizing system was adopted for bridges toward reducing maintenance costs and preventing rust-containing water from splashing by promoting the formation of stable rust at an early stage.

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Table 1 Overview of corrosion-resistant steel bridges

Bridge Name	Span #	Type of Bridge	Span Length	Completion
Washibetu Pedestrian	2	Box Girder	23.6+14.5	1974
Hinode OB	2	Box Girder	22.4+31.2	1975
Wanishi OB(1)	2	Box Girder	2×52.0	1977
Wanishi OB(2)	2	Box Girder	2×52.0	1977
Wanishi OB(3)	3	Open Girder	30.5+39.5+30.5	1977
Nakamachi OB(1)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(2)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(3)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(4)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(5)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(6)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(7)	3	Open Girder	30.5×23.2	1976
Nakamachi OB(8)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(9)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(10)	3	Open Girder	30.5×25.0	1976
Nakamachi OB(11)	3	Open Girder	30.5×25.0	1976
Mizunoe OB(1)	3	Open Girder	23.0+34.0+23.0	1978
Mizunoe OB(2)	3	Open Girder	3×26.5	1978
Mizunoe OB(3)	3	Open Girder	3×26.5	1978
Mizunoe OB(4)	3	Open Girder	3×26.5	1978
Mizunoe OB(5)	3	Open Girder	3×26.5	1978
Mizunoe OB(6)	2	Box Girder	53.65+43.05	1978
Mizunoe OB(7)	1	Open Girder	36.9	1978
Mizunoe OB(8)	1	Open Girder	36.9	1978
Mizunoe OB(9)	2	Box Girder	38.8+36.25	1978
Misaki OB(1)	2	Open Girder	2×35.0	1976
Misaki OB(2)	2	Open Girder	2×35.0	1976
Misaki Ramp(1)	2	Open Girder	33.0+23.0	1973
Misaki Ramp(2)	2	Open Girder	2×23.12	1973
Misaki Ramp(3)	3	Open Girder	3×23.12	1973
Misaki Ramp(4)	3	Open Girder	3×23.12	1973
Misaki Ramp(5)	2	Open Girder	2×23.12	1973
Misaki Ramp(6)	2	Open Girder	2×23.12	1973
Misaki Ramp(7)	3	Open Girder	3×23.12	1973
Misaki Ramp(8)	3	Open Girder	3×23.12	1973
Misaki Ramp(9)	2	Open Girder	2×23.12	1973
Bokoi OB(1)	2	Open Girder	22.0+28.0	1977
Bokoi OB(2)	2	Open Girder	2×35.0	1977
Bokoi OB(3)	3	Box Girder	40.0+50.0+40.0	1977
Bokoi OB(4)	2	Open Girder	28.0+22.0	1977

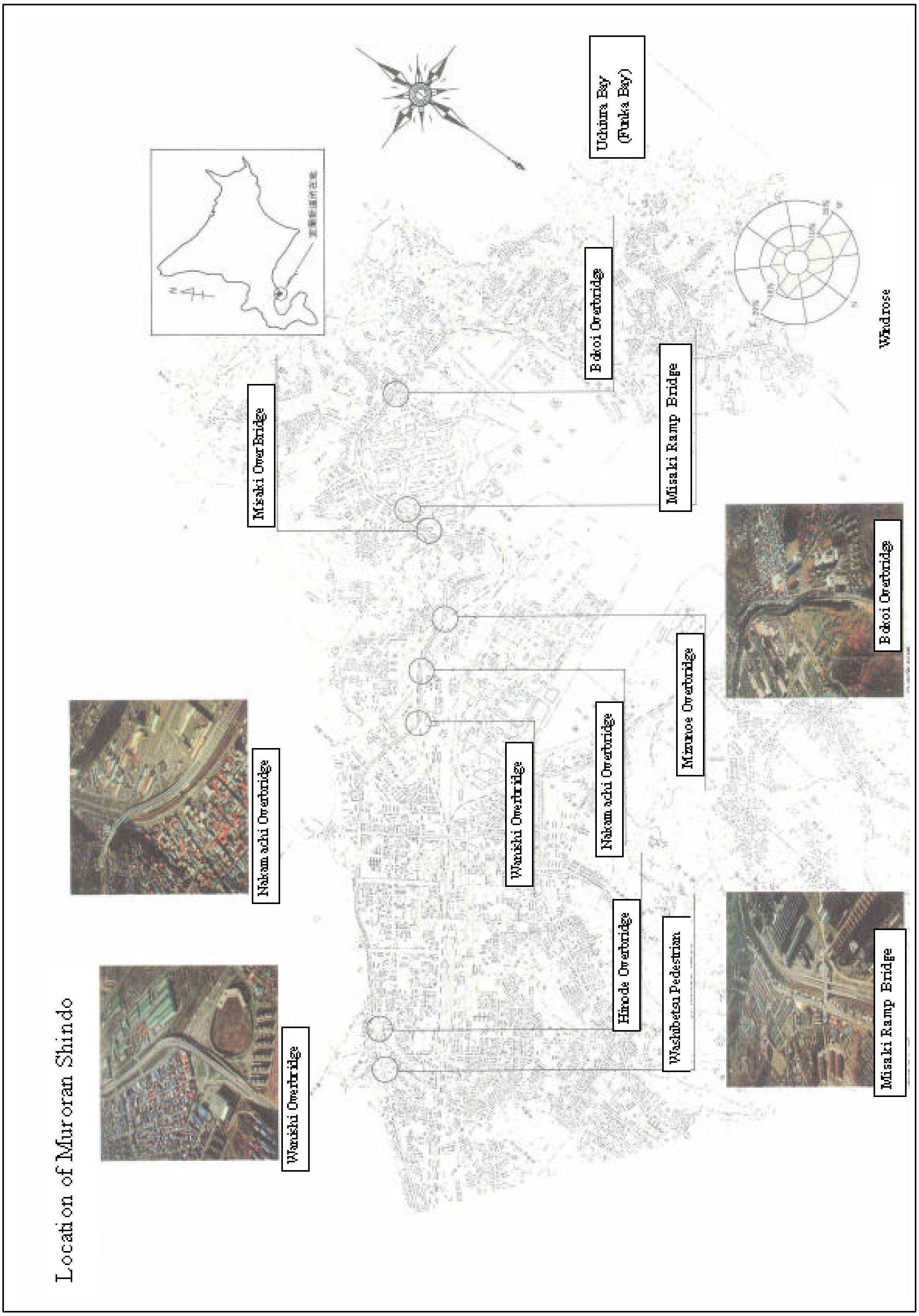


Figure 2 Sites of corrosion-resistant steel bridges on the Muroran Shindo

2. Investigations on corrosion-resistant steel bridges on Muroran Shindo

To identify the condition of surface rust on the bridges, investigations were made at predetermined fixed points.

(1) Examination of appearance

Surface rust condition was observed and color tone was examined by photograph.

(2) Examination of film thickness

Total thickness of film (thickness of Prepalen acrylic coating ＋ rust thickness) was measured to investigate the corrosion progress.

(3) RST measurement (ion permeation resistance)

Ion permeation resistance was measured to investigate the progress of steel-corrosion protection afforded by rust film and rust-stabilization film.

(4) Measurement of salt deposition

Salinity on the steel surface was measured using electrical conductivity, to investigate the influence of salinity.

3. Investigation Results

3.1 Hinode Overbridge

The observation location in this study was on the A1 abutment (Hinode A1) and the outer side of the main girder on the A2 abutment section (Hinode A2). Both locations were chosen as observation points at the beginning of construction. The results, along with the results of previous film thickness investigations, are shown in Figure 3.

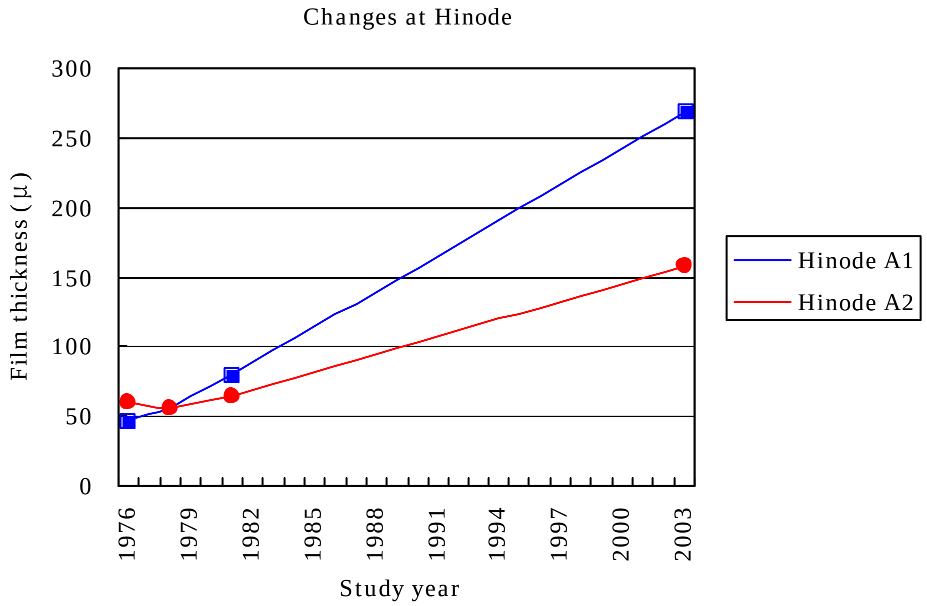


Figure 3 Temporal changes in film thickness

Investigations at A2 found a thickness increase of 6.5 μ/year from 1976 through 1981, and 8.6 μ/year after 1981. Investigations at A1 found increases of 0.8 to 4.3 μ/year. Our study found thickness of 158 μ at A1 and 268 μ at A2. This is probably due to the bridge's proximity to the frontage road and the low clearance (Figure 4). Use of anti-icing agents began to increase from the 1980s, and we suggest that anti-icing agents were spattered on the overbridge by passing cars. Investigations on salt deposition were made in 2001 and 2003. Deposition was 562 mg/cm^2 in 2001 and 620 mg/cm^2 in 2003, i.e., salt deposition increased. It is judged that surface rust has not yet reached a stable state.

Figure 4(a) Hinode A1

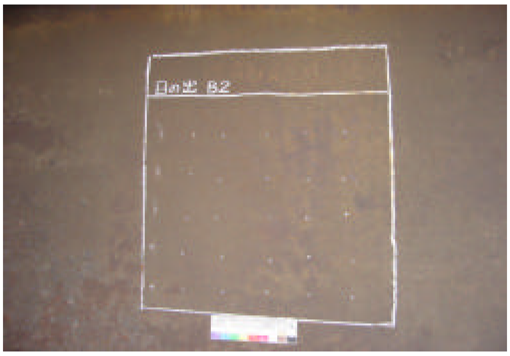
Figure 4(b) Hinode A2

Figure 5 shows temporal changes in appearance.

1976 Hinode A1

1978 Hinode A1

1981 Hinode A1



2003 Hinode A1

Figure 5(a) Appearances of Hinode A1

1976 Hinode A 2

1978 Hinode A 2

1981 Hinode A 2

2003 Hinode A 2

Figure 5(b) Appearances of Hinode A2

Figure 6 shows the corrosion characteristics of Hinode Overbridge. Figure 6(a) shows corrosion at the girder end section that resulted from water leakage from the expansion joint. This corrosion seems to be progressing. Figure 6(b) shows layer-by-layer rust exfoliation on the upper surface of the main girder bottom flange. Corrosion is probably progressing due to deposits such as salt-containing dust on the upper surface of the flange.

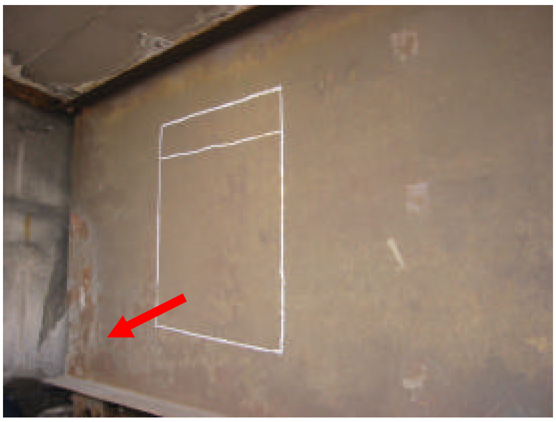


Figure 6(a) Corrosion at the girder end section

Figure 6(b) Layer-by-layer rust exfoliation on the flange upper surface

3.2 Wanishi Overbridge

Figure 7 shows temporal changes in film thickness at this bridge. The film thickness investigation found that the film thickness has been gradually increasing. The thickness increase was 3.1 μ/year between 1978 and 1981. Since 1981, the thickness increase has stabilized at 1.4 μ/year. The surface condition is favorable. Compared to the other bridges studied, the salt deposition was small, which is favorable for corrosion-resistant steel. Figure 8 shows the temporal changes in appearance.

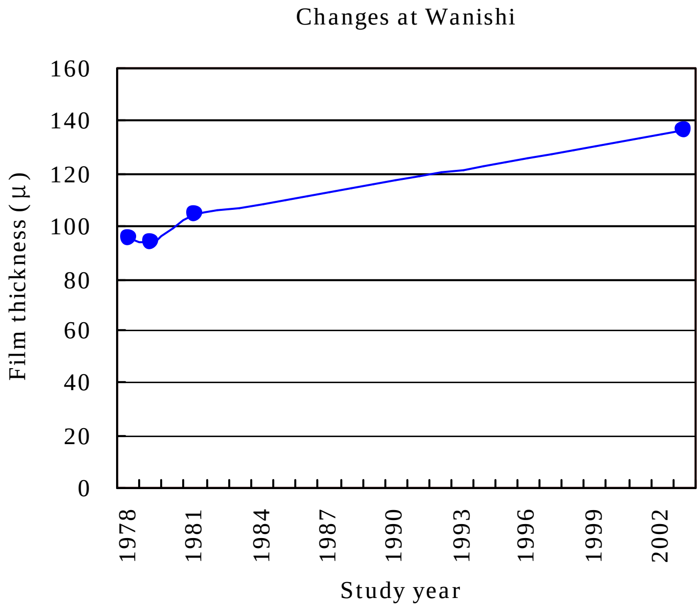


Figure 7 Temporal changes in film thickness at Wanishi Overbridge

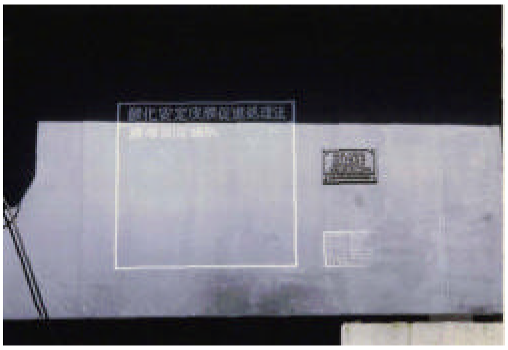


Figure 8 (a) 1978 Wanishi OB

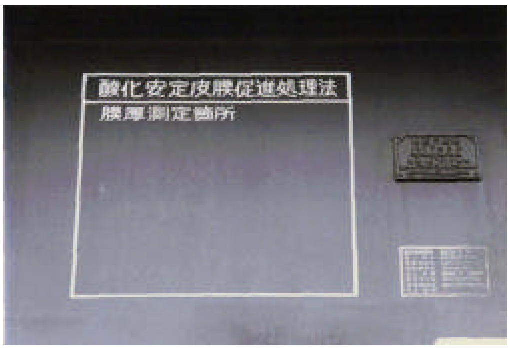


Figure 8 (b) 1979 Wanishi OB

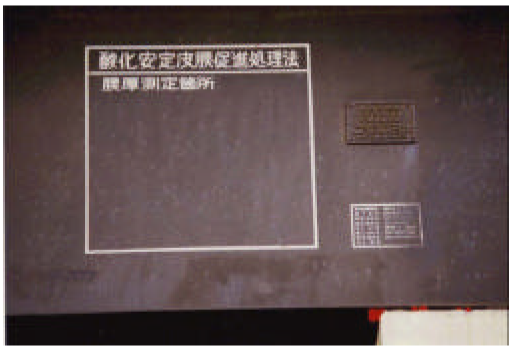


Figure 8 (c) 1981 Wanishi OB

Figure 8 (d) 2003 Wanishi OB

Figure 8 Temporal changes in appearance of Wanishi Overbridge

3.3 Misaki Overbridge

Figure 9 shows the temporal changes in film thickness at this bridge. The investigation from 1975 to 1982 found the thickness to fluctuate around the value of 60 μ. Since 1982, the thickness increase has been 5 μ/year. At the surface, stabilizer remains at some parts and rust is present at other parts. This suggests that stable rust is still being formed. Corrosion here is characterized by marked corrosion resulting from water leakage from the expansion joint, as with the other bridges.

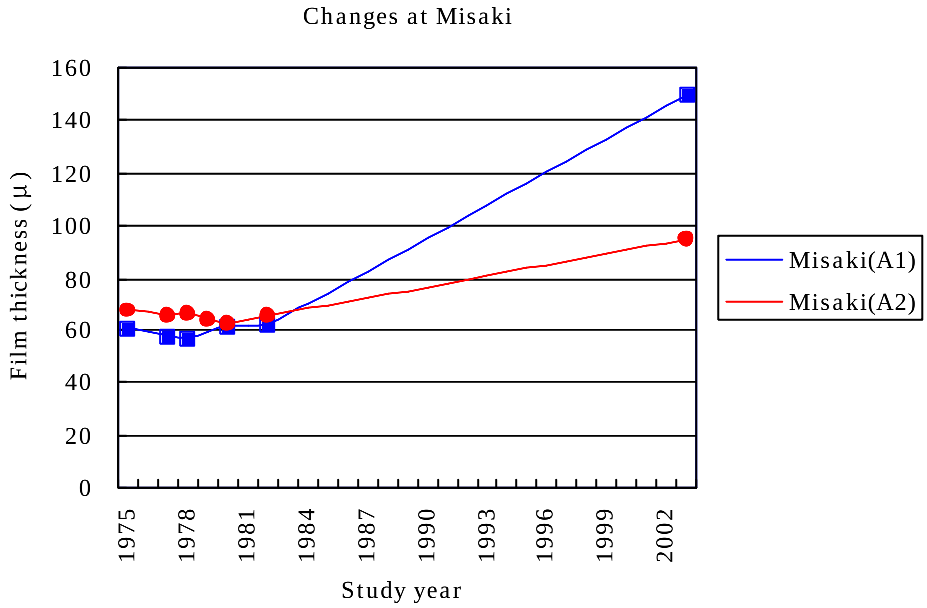


Figure 9 Temporal changes in film thickness at Misaki Overbridge

Figure 10 (a) 1978 Misaki OB

Figure 10 (b) 1979 Misaki OB

Figure 10 (c) 1982 Misaki OB

Figure 10 (c) 2003 Misaki OB

Figure 10 Temporal changes in appearance of Misaki Overbridge

3.4 Bokoi Overbridge

Figure 11 shows the temporal changes in film thickness at this bridge. The investigation from 1975 to 1982 found that the film thickness fluctuated between 80 and 90 μ (0.4 μ/year). Since 1982 the film thickness increase has been 2.4 μ/year. Stable rust seems to have formed on the surface, but it does not seem thick enough to serve as a protective film. Corrosion is characterized by marked corrosion resulting from water leakage from the expansion joint, as with the other bridges.

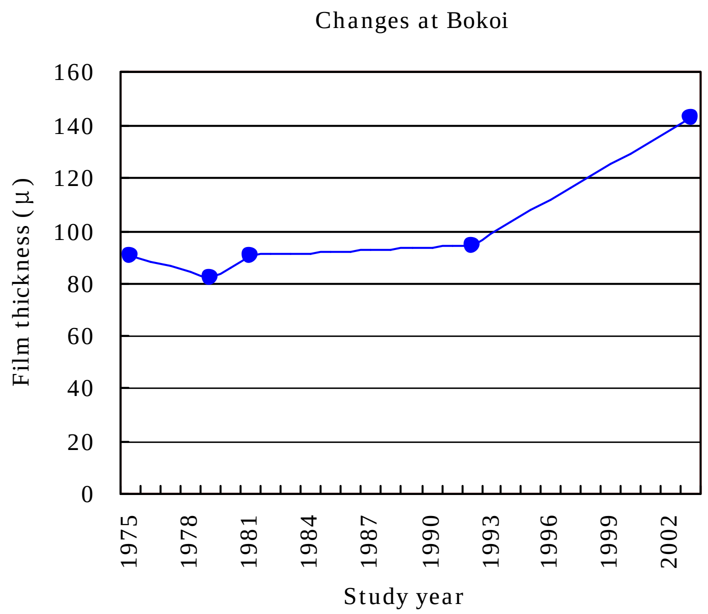


Figure 11 Temporal changes in film thickness at Bokoi Overbridge

Figure 12 (a) 1979 Bokoi OB

Figure 12(b) 1981 Bokoi OB

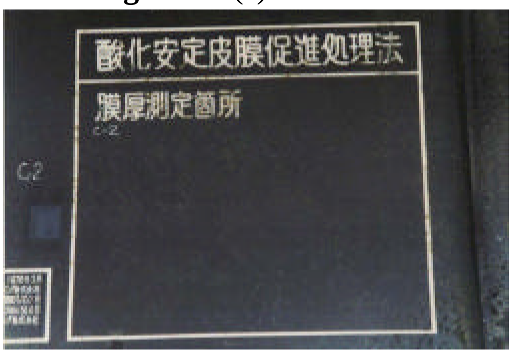


Figure 12 (c) 1985 Bokoi OB

Figure 12 (d) 2003 Bokoi OB

Figure 12 Temporal changes in appearance of Bokai Overbridge

4 Summary

1) The investigations on appearance and film thickness conducted at fixed points on the four bridges found the following.

- o As a whole, the surface rust was basically in a condition to act favorably as a protective film. However, corrosion progressed due to water leakage from the expansion joint and the deck. Some portions of steel members were observed to have corroded away.
- o Given the trends of film thickness increase, a protective film of stable rust is considered to be in the process of forming.
- o In some places other than fixed points, serious corrosion was seen at the sections connected in situ. This is probably because rainwater or runoff flowed out and collected at the connected sections, which generated wetness, and because dirt and dust were easily deposited around bolts and connection plates.

2) It is necessary to take measures against water leakage from the expansion joint and deck.

3) The investigations on appearance and film thickness did not show significant corrosion. However, it is necessary to make further investigations (at span mid-section, cross beam, etc.) in order to evaluate the overall condition of a bridge, as the investigations in this study were carried out at fixed points for the purpose of continuous observation.

4) The film thickness of surface rust tended to increase. It is necessary to evaluate whether surface rust will perform well as a protective film. Investigations are also necessary to see whether film thickness will show further increase.

5) Based on these findings, we are planning to do sampling on existing bridges, and to develop a soundness evaluation method for atmospheric corrosion-resistant bridges through measurements of surface condition, rust thickness, plate thickness, deposition salinity, roughness of rust and others.