PERFORMANCE OF MAYARI R WEATHERING STEEL (ASTM A242) IN BRIDGES

EIGHT MILE ROAD

JOHN LODGE EXPRESSWAY

DETROIT, MICHIGAN

Printed by Bethlehem Steel Corporation

PERFORMANCE OF MAYARI R WEATHERING STEEL (ASTM A242) IN BRIDGES AT THE EIGHT MILE ROAD AND JOHN LODGE EXPRESSWAY IN DETROIT, MICHIGAN

by

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Report to be Submitted to the U. S. Bureau of Public Roads and Interested Personnel of State Highway Departments.

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ABSTRACT

Mayari R weathering steel was used in the construction of the Eight Mile Road Bridge and adjacent service bridges over the John Lodge Expressway in Detroit. Corrosion performance of the steel was based on results of a cooperative program by the Michigan Department of State Highways and Bethlehem Steel Corporation. The program, which has covered the period of 5-1/2 years since the bridges were opened to service, included periodic inspections of the weathering steel, x-ray diffraction and chemical analyses of soil and rust, as well as comparative studies of weathering rates of corrosion specimens.

As demonstrated by these inspections and tests, the major proportion of the weathering steel in the bridges has an excellent appearance and has developed the tight protective-oxide surface which is characteristic for Mayari R steel. A minor proportion now shows an accumulation of road dirt and some flaking of dirt and rust which is restricted to and presumed partially due to the confined configuration created by a combination of low overhang and high retaining wall in the two underpasses. With this type of configuration, road spray is easily carried up to the beams in considerable volume so that road dirt, deicers, cement dust and gypsum accumulate in layers that tend to remain wet, the resulting poultice-like action being conducive to higher corrosion rates.

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PERFORMANCE OF MAYARI R WEATHERING STEEL (ASTM A242) IN BRIDGES AT THE EIGHT MILE ROAD AND JOHN LODGE EXPRESSWAY IN DETROIT, MICHIGAN

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INTRODUCTION

To avoid the high cost and often hazardous and troublesome need for repainting highway bridges, engineers are increasingly using low-alloy weathering steels as a material of construction. These high-strength structural steels have a yield point considerably higher than that of ordinary structural carbon steel and have excellent corrosion resistance in many atmospheres. The weathering steels usually contain a total of 2 to 3% alloying elements such as Cr, Si, P, Cu, Ni and Mn. When allowed to rust naturally in the weather, these steels gradually develop a dark russet layer protective to steel.

Weathering steels have proved themselves in both general and industrial atmospheres. Prior to the present test program, however, there was little information on the possible effect of road sprays, road dirt, chloride deicing salts and traffic fumes on the corrosion resistance of weathering steels. During winter many maintenance departments frequently spread large amounts of sodium chloride to assist in the removal of ice and snow from the highways. In extremely cold weather calcium chloride or a mixture of calcium and sodium chloride salts is used. These chlorides as well as road dirt and dust could be carried up to the bridges by turbulent air and wet sprays from cars and trucks on expressways below the bridges, especially if the bridges were very low and in a confined area.

With the purpose of developing data on the effect of these substances on the long-term corrosion resistance of weathering steels, personnel from the Michigan Department of State Highways and the Bethlehem Steel Corporation jointly initiated a corrosion test program at the Eight Mile Road Bridge over the John Lodge Expressway in Detroit, Michigan. This is the first major bridge in which weathering steel was used, and in this case it was Bethlehem's Mayari R weathering steel. Our cooperative long-term test program was in keeping with the policy of the Federal Bureau of Public Roads in recommending regular inspection of highway bridges by state highway departments.

The program involved inspection of the Eight Mile Road Bridge and two adjacent weathering steel bridges, as well as the installation and periodic removal of Bethlehem's Mayari R corrosion test specimens beneath one of the adjacent low service bridges. For comparative purposes, corrosion samples were also located on the roof of a nearby building away from road salts, dirt, direct traffic fumes and the like. The bridges were opened to traffic in late 1964, about 5-1/2 years ago. Corrosion test specimens were installed about 1-1/2 years later and were removed after 1/2, 1, 2 and 4 years' exposure. A final eight-year removal is due in 1974.

DESCRIPTION OF WEATHERING STEEL BRIDGES

There are three adjacent weathering steel bridges that were under close examination and involved in the test. These are located at the complex intersection of Eight Mile Road (M-102) over the John Lodge Expressway in northwest Detroit. The center bridge, known as the Eight Mile Road Bridge, is a single high-rise plate-girder viaduct about 1,850 feet long, having a six-lane concrete highway with three lanes running east and three running west. The other two bridges, each adjacent to the center viaduct, are low service bridges having two lanes for one-way traffic. One will be referred to as the eastbound service bridge, the other will be referred to as the westbound service bridge. The west ends of the bridges are over the southbound lanes of the John Lodge Expressway with a clearance of 14 feet, 7 inches. The east ends are slightly higher in elevation and extend over the northbound lanes, a narrow medial strip and an exit lane of the expressway. There is a fourth bridge in the northeast corner of the complex, a short single span structure that separates the rampways.

The John Lodge Expressway has six high-speed concrete lanes, three running north and three running south. At the interchange it is entirely depressed below the adjacent land level, with a high concrete retaining wall along both shoulders that extends from the expressway to the service bridges. Alongside the northbound lanes there is an exit ramp and a medial strip. Further north is an entrance ramp. This arrangement leaves a more open area beneath the bridges over the northbound lanes and reduces the speed of the vehicles, at least in the exit lane. Figure 1 is a schematic diagram of the complex intersection, showing the areas described as well as the location of corrosion specimens (west end

FIGURE 1

COMPLEX INTERSECTION AT THE EIGHT MILE ROAD

AND THE JOHN LODGE EXPRESSWAY

Note location of corrosion specimens.

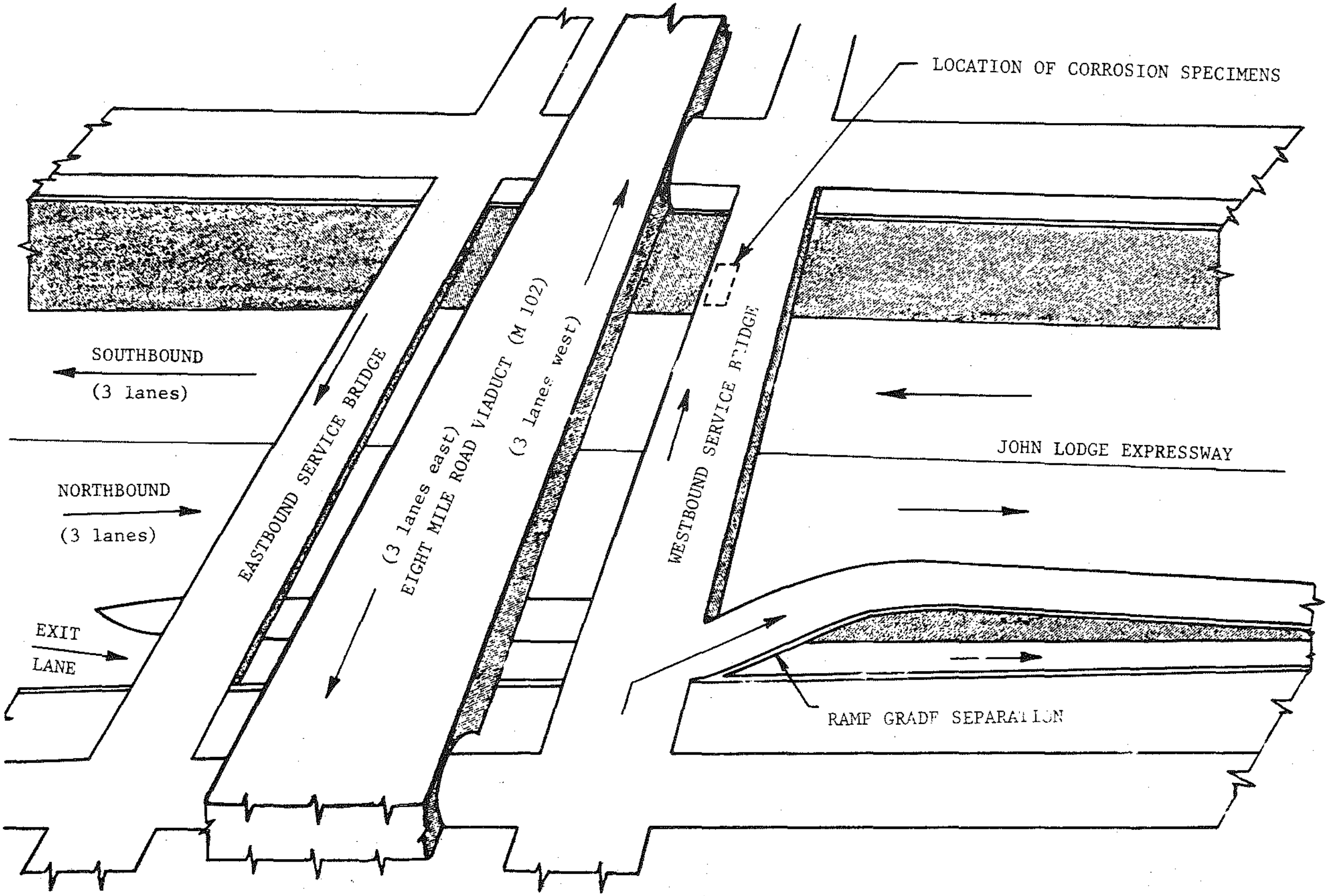

FIGURE 1. COMPLEX INTERSECTION AT THE EIGHT MILE ROAD AND THE JOHN LODGE EXPRESSWAY; NOTE LOCATION OF CORROSION SPECIMENS.

of the westbound service bridge over the southbound lane of the expressway).

Figure 2 is a photograph of the overall interchange looking north and illustrates the eastbound service bridge and high viaduct (Eight Mile Road Bridge) adjacent to and above the service bridge about a year after opening to traffic. Note the high concrete retaining wall along the edge of the southbound lane and the dirt accumulation along the shoulder of the lane and curvature of the road. Observe also the less confined area around the northbound and exit lanes. In the background and to the right can be seen the entrance ramp leading into the northbound lanes and, next to it, the continuation of the long exit lane. The westbound service bridge adjacent to the viaduct is not visible.

INSPECTION OF THE CONDITION OF THE BRIDGES AFTER 5-1/2 YEARS' EXPOSURE

Michigan Department of State Highways personnel have been inspecting the condition of the bridge complex periodically in accordance with the recommendations of the U. S. Bureau of Public Roads. The most recent inspection, with Bethlehem Steel Corporation personnel, was in April 1970. The inspection revealed that all steel bridge members above the northbound lanes and the exit lane had an excellent appearance and exhibited the normal dark protective rust layer typical of Mayari R steel. There was no noticeable accumulation of road dirt. An area typical of this steel surface is seen in Figure 3. The bridge beams shown in the figure are those on the eastbound service bridge above the northbound lane of the expressway.

The steel girders on the high-rise viaduct were observed from the ground with field glasses. Regardless of whether the steel was above the

FIGURE 2

AN OVERALL VIEW OF THE NORTH SIDE OF THE COMPLEX
ABOUT A YEAR AFTER OPENING TO TRAFFIC

Note that the eastbound service bridge and the Eight Mile Road viaduct are clearly visible but not the westbound service bridge adjacent to the viaduct. Notice the accumulation of dirt along the southbound lane (left of photograph). Our corrosion specimens are located above the southbound lane of the westbound service bridge shown later in the report.


EXIT

FIGURE 3

CLOSE-UP VIEW OF THE STRUCTURAL BEAMS
ON THE EASTBOUND SERVICE BRIDGE ABOVE THE NORTHBOUND LANE
OF THE EXPRESSWAY AFTER 5-1/2 YEARS OF SERVICE

The area shown is typical of the appearance of bridge members above the northbound lanes of the expressway.

FIG. 3

north- or southbound lanes, the surface developed the good protective rust layer expected of weathering steel. The viaduct is 37 to 41-1/2 feet above the expressway and about 17-1/2 feet above the adjacent service bridges.

Figure 4 shows the viaduct and the westbound service bridge looking south. Though not visible in the photograph, our corrosion specimens are facing the southbound traffic and are located on the service-bridge beams near the concrete retaining wall. The area was considered to be the one most susceptible to corrosion, and this was later found to be the case. This type of area receives the most road spray, dirt and traffic fumes.

A study of Figure 4 shows why the bridge beams in this type of area receive more road spray and accumulate greater amounts of road dirt than other areas. In this area, seen in the right half of the photograph there is a confined, tunnel-like configuration resulting from a combination of low bridge-clearance and high retaining wall. These conditions intensify the effect of the heavy air blast produced by fast-moving trucks and cars passing under the bridge. In the partly contained space under the bridge, the air blast carries road spray and other substances up to the relatively low bridge beams as well as against the high concrete retaining wall from which the materials are deflected upward to the beams. These conditions prevail on bridge beams beneath the west end of the low service bridges facing southbound traffic of the expressway.

FIGURE 4

WESTBOUND SERVICE BRIDGE AND SOUTH SIDE OF VIADUCT

RIGHT HALF OF PHOTOGRAPH ILLUSTRATES THE
CONFINED, TUNNEL-LIKE EFFECT CREATED
BY A HIGH RETAINING WALL AND A
LOW BRIDGE CLEARANCE ABOVE AN EXPRESSWAY

Note: The corrosion specimens (not visible in the photograph) are located on the beams of the low bridge near the concrete retaining wall.

FIG. 4

Inspection of the beams three years after the bridge was opened to traffic showed some accumulation of road dirt but very little scaling as yet. The condition of these beams is shown in Figure 5.

An inspection of the same bridge beams after 5-1/2 years (4 years for the corrosion specimens) showed a considerable accumulation of caked roadway soil and rust, some of it flaking from the surface of the beams. Beneath the scaly rust and soil we often found small amounts of a white deposit consisting mainly of chlorides and carbonates. Figure 6, taken at the close of the 5-1/2 year period, shows the scaling condition on the rolled beams of the service bridges above the southbound lanes of the expressway. Figure 7 is a close-up view of the scaling road dirt and rust on the beams and on the corrosion specimens that had been on the structure for four years.

The top surfaces of the flanges have the heaviest flaking soil and rust, with the webs having the least amount. Scaling is heavier over the right lane, adjacent to the shoulder, than over the center or left lanes, but there is some scaling over all three lanes.

As will be explained in the ANALYSIS OF SCALY ROAD SOIL AND RUST section, the scales are caked road dirt and rust which have built up on the bridge-member surfaces until flaking initiated. This condition is not too noticeable from ground level, especially from vehicles, unless one is looking specifically for it. However, the condition is unsightly when viewed close-up, three or four feet away on a platform or scaffold, as was the case in Figure 7.

The build up of road dirt may be periodic, i.e., a caked mixture of soil and rust builds up over a period of years and then tends to flake off, after which a build-up begins again.

FIGURE 5

CONDITION OF BRIDGE BEAMS AFTER THREE YEARS OF SERVICE

Note this figure also illustrates the manner in which corrosion specimens are mounted.

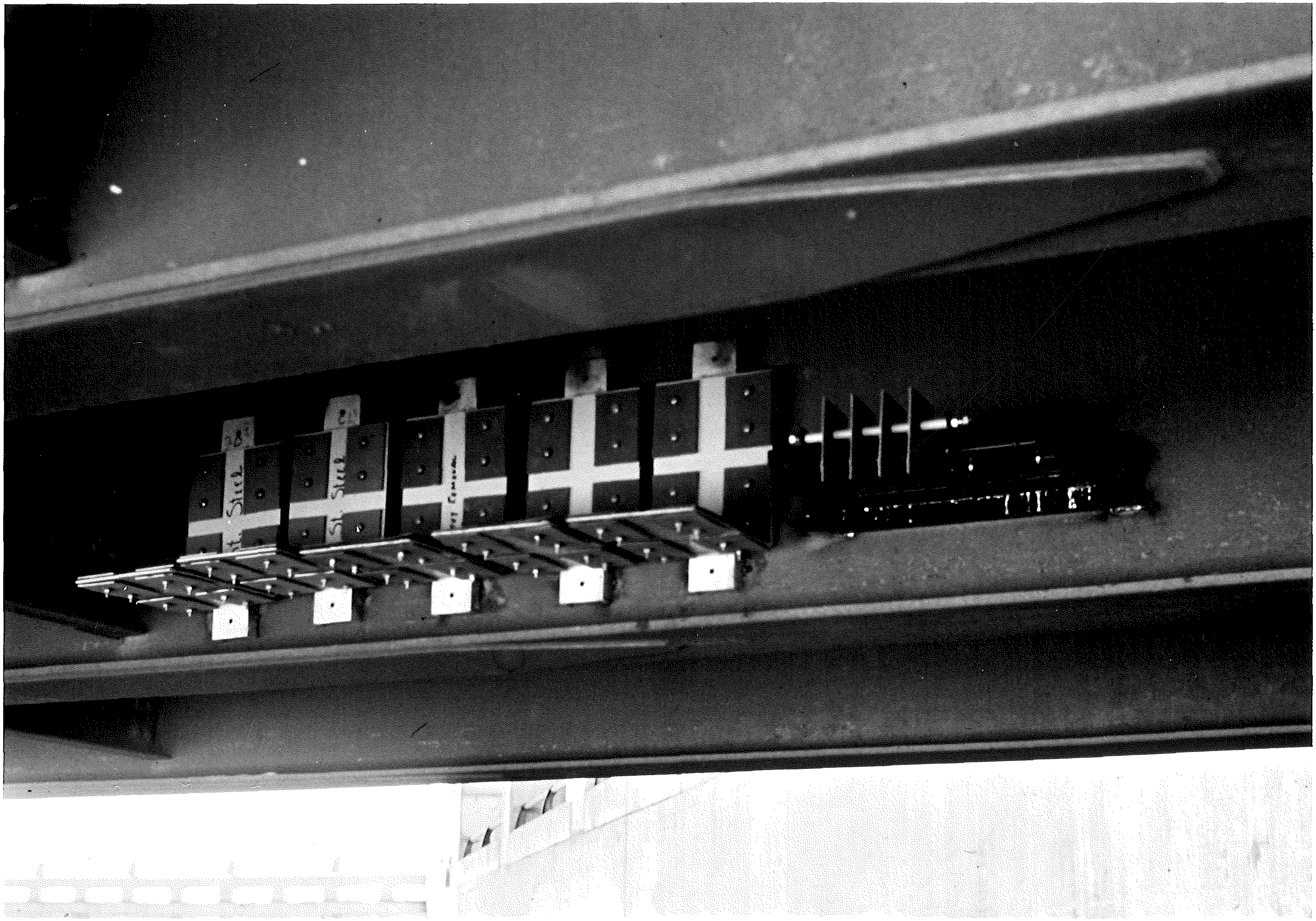

FIG. 5

FIGURE 6

FLAKING SOIL AND RUST ON STEEL MEMBERS

OF THE WESTBOUND SERVICE BRIDGE

AFTER 5-1/2 YEARS OF SERVICE

Note that the most extensive flaking appears on the steel closest to the concrete abutment, and the beams most affected are the innermost ones. Corrosion specimens can be seen in the lower left-hand corner of the photograph.

FIG. 6

FIGURE 7

CLOSE-UP VIEW OF THE FLAKING SOIL AND RUST

ON THE BRIDGE BEAMS AND ON THE CORROSION SPECIMENS

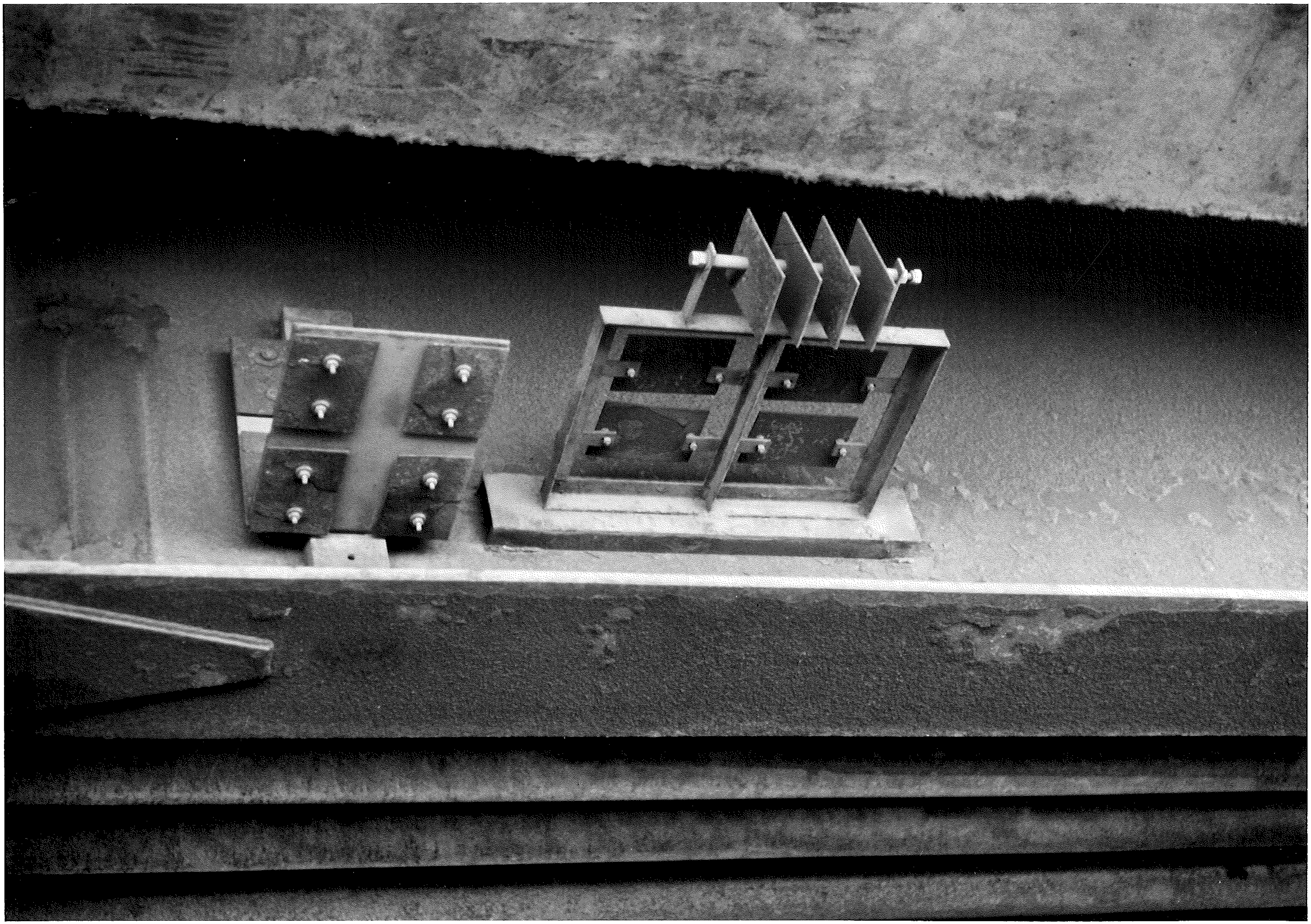

FIG. 7

EVALUATION OF THE CORROSION BEHAVIOR OF WEATHERING STEEL SPECIMENS DURING FOUR YEARS' EXPOSURE

To evaluate the corrosion behavior of Mayari R weathering steel, 4 by 6-inch specimens were mounted on racks and installed on the north side of the interior structural beams of the westbound service bridge. This location was over the southbound lane next to the shoulder of the expressway with the specimens facing the southbound traffic. This type of location was considered to be representative of areas most subject to road spray and therefore indicative of maximum weathering rates on bridge members. Figure 5, previously shown, shows how the specimens were mounted and the appearance of the specimens as well as the appearance of the bridge beams at that time, i.e., about three years after the bridge was opened to traffic. Notice the absence of flaking soil and rust.

The specimens were bolted to racks using insulating washers and the racks welded to the bridge beams. Quadruplicate specimens were mounted vertically to simulate web surfaces, horizontally to simulate the top side of flange surfaces, and horizontally to simulate the bottom side of flange surfaces. The under sides of the sheet samples were protected from weathering by painting. Some deterioriation of the paint was observed after about one year of exposure, and the under sides were further protected with Scotchrap vinyl tape (10 mils thick). The specimens were initially grit-blasted and weighed to the nearest milligram before painting of the under sides and exposure of the specimens as a whole. Removals of specimens for each position were made after 1/2, 1, 2 and 4 years' exposure, only the eight-year specimens remaining on exposure. When the specimens were taken down, the tape was stripped from the under sides and the amount of chloride on the exposed surfaces measured by leaching the panels in distilled water and chemically analyzing the leachings for chlorides. The specimens were then cleaned in a sodium hydride descaling bath, which removes the paint on the under side and rust on the exposed side without significant loss of the steel base. The weight percent composition of the base steel was as follows:

C	Mn	P	S	Si	Ni	Cr	Cu
0.09	0.73	0.077	0.030	0.24	0.75	0.56	0.24

This composition is representative of Mayari R weathering steel for light plate and structural sections. Heavier structural sections, such as were used on these bridges, may have slightly higher alloy contents to meet required mechanical properties and may therefore have slightly greater corrosion resistance.

In order to measure the weathering rates of this steel in the atmosphere away from road spray and also subject the steel to the normal washing action of rainfall, a similar set of specimens was mounted on the roof of the Northland Towers Building nearby. After 1-1/2 years' exposure, the specimens were moved to the National Guard Armory roof close by. Figure 8 shows the specimens on the corrosion stand on the armory roof.

Table 1 shows the weathering data obtained after 4 years' exposure beneath the westbound service bridge. These data, plotted in Figure 9, show that after four years beneath the bridge the weathering steel has not yet shown

FIGURE 8

CORROSION SPECIMENS ON THE NATIONAL GUARD ARMORY ROOF

FIG. 8

TABLE 1. WEATHERING OF MAYARI R STEEL SPECIMENS BENEATH THE WESTBOUND SERVICE BRIDGE, DETROIT, MICHIGAN

Position		Weathering Loss, mils			
		6 Months	1.0 Year	2.0 Years	3.9 Years
Vertical (Web)		0.48	0.81	1.54	2.49
		0.48	0.85	1.68	3.00
		0.50	0.86	1.78	3.51
		0.51	0.89	1.81	*
	Average	0.49	0.85	1.70	3.00
Bottom of Horizontal (Flange Bottom)		0.51	0.81	1.44	3.35
		0.52	0.84	1.58	3.43
		0.53	0.86	1.62	4.33
		0.54	0.89	1.77	*
	Average	0.53	0.85	1.60	3.70
Top of Horizontal (Flange Top)		0.36	0.73	1.70	4.05
		0.37	0.75	1.85	4.41
		0.43	0.75	2.20	4.84
		0.45	0.83	2.73	*
	Average	0.40	0.77	2.12	4.43
	Overall Average	0.47	0.82	1.81	3.71

* In each case, one specimen was not cleaned but was kept as is to show the surface appearance.

FIGURE 9

WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS

BENEATH THE WESTBOUND SERVICE BRIDGE, DETROIT, MICHIGAN

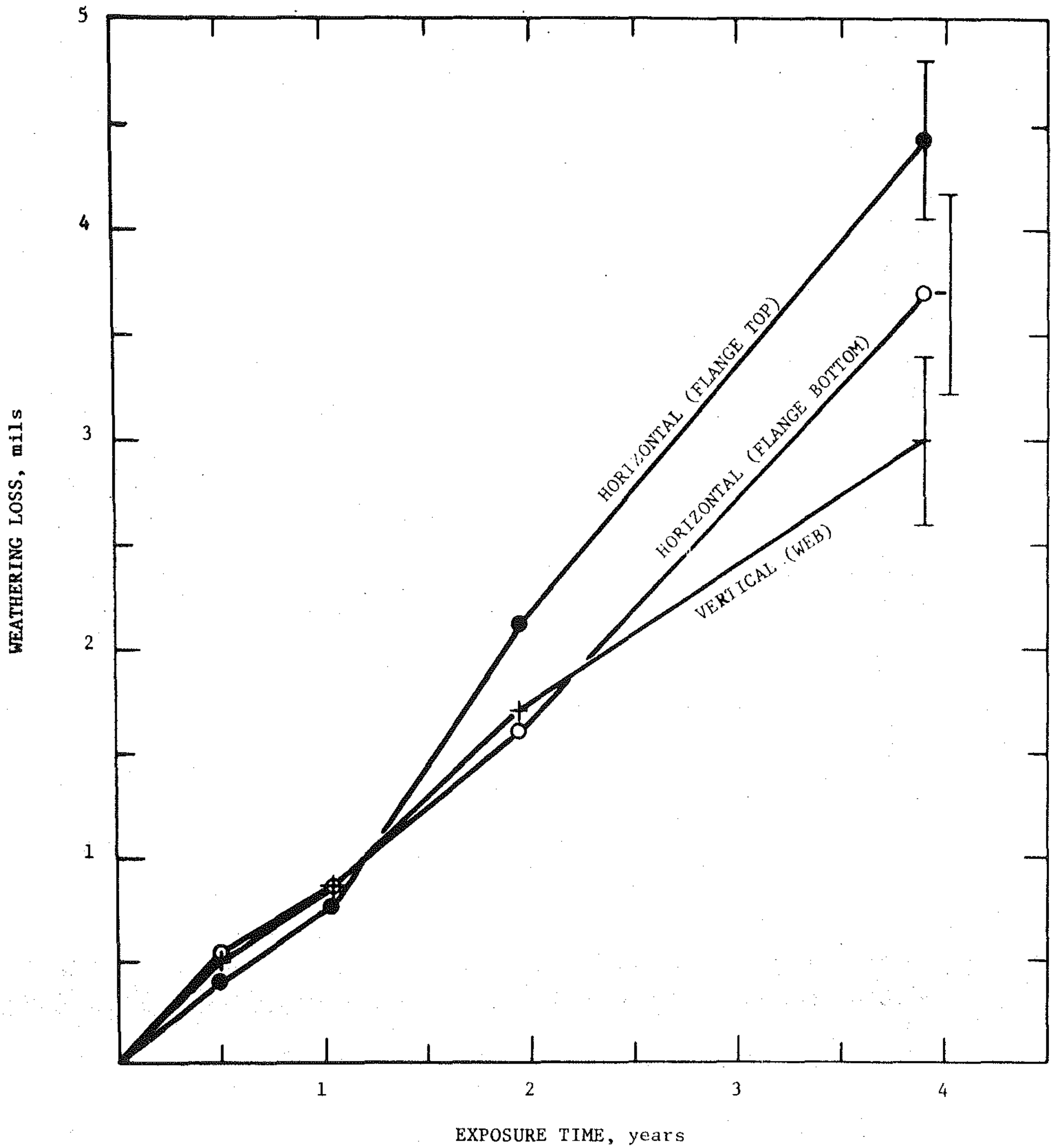

FIGURE 9. WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS BENEATH THE WESTBOUND SERVICE BRIDGE, DETROIT, MICHIGAN

Error bands are $\pm$ 1σ (standard deviation) the expected degree of turnover of the weathering rate. In other words, the slopes of the weathering-time curves have not decreased with time as much as expected.

Based on Table 1 and Figure 9, a comparison of corrosion of the vertical surface representing webs and the horizontal surfaces representing the top and bottom of flanges show that the vertical samples corroded less than the horizontal samples. Furthermore, the horizontal top panels, representing the top surface of the flange and ledges that tend to accumulate the most soil, showed the most corrosion. The total time of wetness may be significant here in that beam flanges which accumulate more caked dirt and rust, may not dry as readily as the webs. If the flanges remain wet for a greater proportion of the exposure time, they would be expected to corrode more. After 4 years' exposure, the weathering loss of the horizontal specimens was about 25 to 50% greater than that of the vertical panels.

Figure 10 shows the condition of the four-year specimens beneath the bridge and on the roof before cleaning. Although the bridge specimens had an unsightly scaliness, when this was removed, the surface was smooth and proved to be free of any significant pitting.

Table 2 shows the amounts of chloride which accumulated on weathering steel specimens beneath the westbound service bridge. There has been a marked increase in the amount of chlorides with increasing time of exposure. Viewing Figure 9 shows that there is a linear increase in corrosion or weathering, but no sharp and abrupt increase in weathering with time even though there has been a marked upturn in accumulated chloride with time.

FIGURE 10

MAYARI R STEEL SPECIMENS AFTER FOUR YEARS' EXPOSURE
BENEATH THE BRIDGE AND ON THE ROOF, DETROIT, MICHIGAN

APPEARANCE OF MAYARI R STEEL AFTER FOUR YEARS' EXPOSURE AT DETROIT, MI

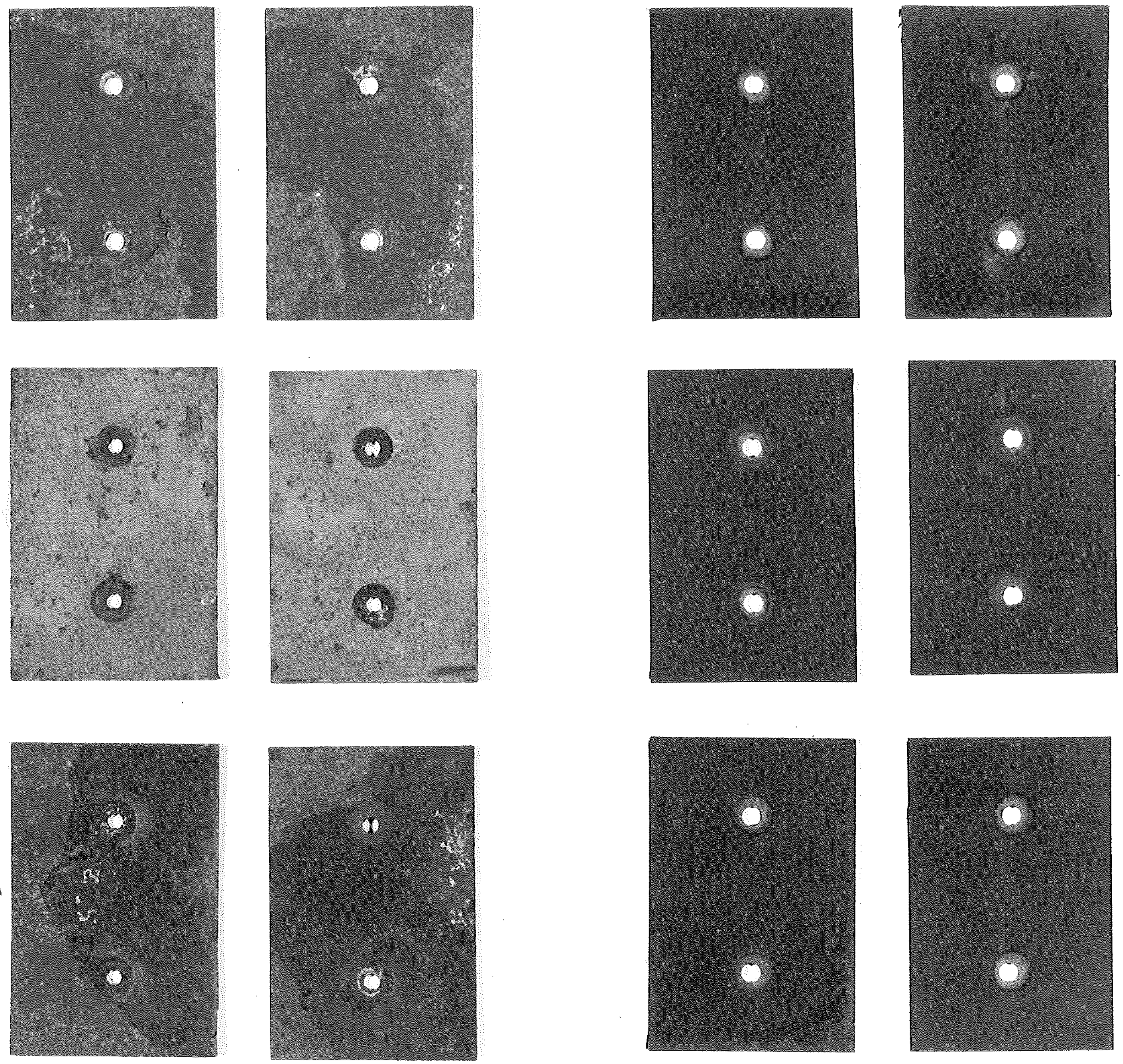

FIG. 10

TABLE 2. CHLORIDE ACCUMULATION ON MAYARI R WEATHERING STEEL SPECIMENS BENEATH THE WESTBOUND SERVICE BRIDGE

Position	Amount of Chloride on 4 x 6-inch Specimens mg/sq.in.		
	1.0 Year	2.0 Years	3.9 Years
Vertical (Web)	1.8	5.5	6.4
Bottom of Horizontal (Flange Bottom)	2.3	4.6	16.1
Top of Horizontal (Flange Top)	5.0	12.8	18.7

Table 3 gives the weathering data for specimens on the roof of a building in the vicinity of the Eight Mile Road Bridge. Figure 11 shows these data plotted as weathering-time curves. For all positions the curves show the typical turnover of the weathering rate with time. There is no flaking, only the usual dark russet layer seen on the right hand group of roof specimens in Figure 10.

We also studied the effect of specimen orientation on the corrosion behavior of Mayari R steel specimens on the building roof. The data are shown in Table 3 and in Figure 11. The effect of specimen orientation was somewhat less in case of the rooftop specimens than those beneath the bridge. The vertical specimens on the roof, that represent the web of beams, still have the least corrosion as was the case for specimens beneath the bridge. However, the order of superiority for horizontal top and bottom specimens on the rooftop was reversed as compared with those beneath the bridge, with the horizontal bottom rooftop specimens having the most weathering loss. After 4 years' exposure, the weathering loss of the horizontal specimens was about 15 to 35% greater than that of the vertical panels.

Total time of wetness may still be an important parameter as in the case of the bridge specimens. However, the washing action of rain as well as lack of caked soil and chloride accumulation, which tend to retain moisture and increase corrosion, could account for the smaller effect of orientation on the rooftop specimens and the reversed order of superiority of the horizontal panels.

TABLE 3. WEATHERING OF MAYARI R STEEL SPECIMENS ON THE NATIONAL GUARD ARMORY ROOF NEAR THE WESTBOUND SERVICE BRIDGE

Position		Weathering Loss, mils			
		6 Months	1.0 Year	2.0 Years	4.0 Years
Vertical		0.46	0.72	1.18	1.36
(Web)		0.49	0.77	1.22	1.64
		0.53	0.83	1.43	1.72
		0.61	0.85	1.50	*
	Average	0.52	0.76	1.33	1.57
Bottom of Horizontal		0.66	1.11	1.84	1.88
(Flange Bottom)		0.67	1.12	2.02	1.92
		0.79	1.23	2.12	2.52
		0.90	1.26	2.22	*
	Average	0.76	1.18	2.05	2.11
Top of Horizontal		0.56	1.02	1.55	1.64
(Flange Top)		0.71	1.03	1.59	1.76
		0.69	1.13	1.65	2.16
		1.01	1.22	1.94	*
	Average	0.74	1.10	1.68	1.85
	Overall Average	0.67	1.01	1.69	1.84

All specimens were exposed on the Northland Towers roof for 1-1/2 years before removal to the armory roof for remainder of exposure.

* In each case, one specimen was not cleaned but was kept as is to show the surface appearance.

FIGURE 11

WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS

ON THE BUILDING ROOF IN DETROIT, MICHIGAN

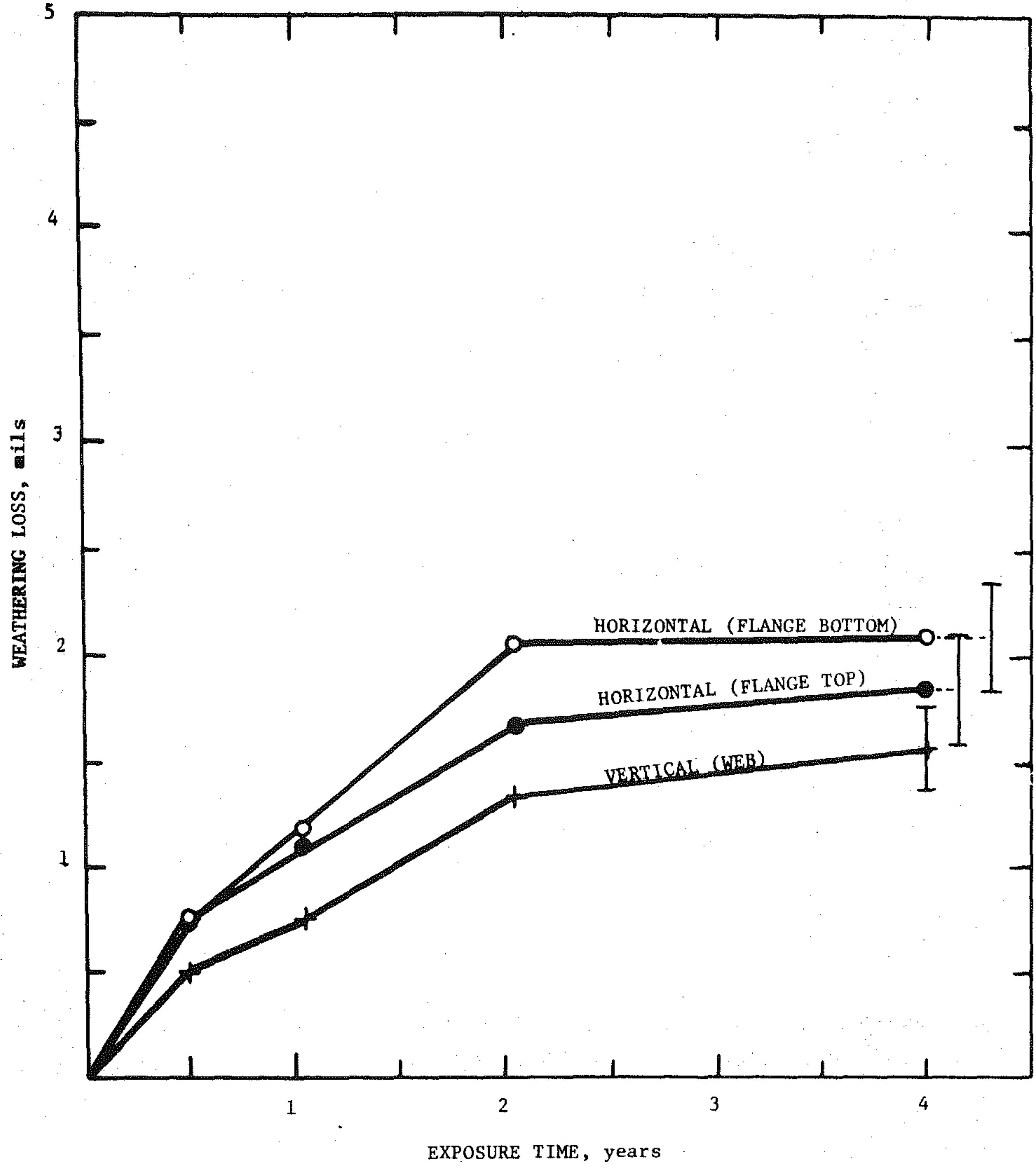

FIGURE 11. WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS ON THE BUILDING ROOF IN DETROIT, MICHIGAN

Error bands are $\pm$ 1σ (standard deviation)

Table 4 compares the weathering rates of specimens beneath the bridge and on the armory roof. For the four-year period, the average weathering rate for the specimens beneath the bridge was about 1 mil per year and about twice as great as the rooftop specimens.

ANALYSIS OF SCALY ROAD SOIL AND RUST

Some of the scaly road soil and rust was removed from the surface of the four-year corrosion specimens from the bridge for visual examination and thickness measurement. The soil was a gray, cement-like material intermingled with brown rust. Intermittent spots of a white powder were often found beneath the scale. The scale, as removed from the surface, was 25 to 35 mils thick. Underlying these scales was a smooth, light rust layer with an ccasional white deposit. No significant pitting was evident. The scale was apparently a mixture of caked roadway soil and rust that had gradually built up on the surface until flaking occurred.

The corrosion rack had been initially painted before installation of the four-year corrosion specimens. An x-ray diffraction analysis of the soil removed from the painted surfaces of the corrosion rack revealed the following major constituents:

gypsum	$CaSO_4 \cdot 2H_2O$
silica	SiO_2
dolomite	$CaMg(CO_3)_2$
salt	$NaCl$

There was also a small amount of calcite ($CaCO_3$), calcium chloride ($CaCl_2$), and iron oxide (α-FeOOH). Chemical analysis of the same road dirt showed the following:

TABLE 4. WEATHERING RATES FOR MAYARI R STEEL SPECIMENS EXPOSED FOUR YEARS BENEATH THE BRIDGE AND ON A NEARBY BUILDING ROOF

Position	Corrosion Rate, mils/year Bridge	Roof
Vertical	0.77	0.39
Horizontal Bottom	0.95	0.53
Horizontal Top	1.14	0.46
Overall Average	0.95	0.46

Aluminum	Sodium	Calcium	Chloride	Sulfate	Silica	Ferrous Iron	Ferric Iron
2.2%	4.9%	12.4%	6.7%	11.8%	28.2%	1.2%	1.8%

An ion microprobe analysis of the white deposit from beneath the scale showed constituents similar to those in the soil, except that the major amounts were sodium chloride and calcium carbonate.

Possible sources of these soil constituents are materials from typical truck ladings, including bulk cement, slag, sand, limestone, gravel, and fill dirt. Other possible sources are dusts produced by the natural erosion of the concrete highway or by the action of studded tires. The calcium sulfate and carbonate could also be due to the conversion of lime dust from the sulfur dioxide and carbon dioxide in the atmosphere and from traffic fumes. Dirt and sand from truck ladings and falloff from vehicles as well as from windblown soil could account for the silica. Dolomite could come from truck ladings, and the sodium and calcium chlorides from deicing salts employed in the winter months to remove ice and snow on the highways.

Whatever the sources, the deposits and rust tended to cake and also apparently retain moisture, due to the confined conditions beneath the bridge and the hygroscopic nature of calcium chloride and other such salts. Poultice action by this caked mixture containing chlorides and sulfates is probably responsible for the high rates of corrosion of steel on the low bridges over the southbound lanes of the highway.

An x-ray diffraction analysis of the four-year rust from specimens beneath the westbound service bridge and on the roof shows that the rust on the bridge was mainly β-FeOOH (akaganeite) with smaller amounts of α-FeOOH (goethite) and γ-FeOOH (lepidocrocite). The rust from the roof specimens was mainly γ-FeOOH, with some α-FeOOH present. The β-FeOOH is usually associated with rust formed under moist conditions, while the α and γ forms are the normal hydrated oxides expected on weathering steels in open atmospheric exposure.

DISCUSSION

As we have seen, the 5-1/2 year inspection showed that excepting for the relatively restricted tonnage represented by enclosed areas (cf. Figure 4), the weathering steel in the three bridges has the desired tight protective-oxide coating. Flaking soil and rust occurred in the low service bridges above the southbound lanes of the expressway. However in this same area but on the higher viaduct bridge, the usual type of firm corrosion-resistant oxide layer developed. Furthermore, across from the flaking area and above the northbound lanes, medial strip and exit lane, a good protective rust layer has formed and little soil has thus far accumulated.

The fact that the accumulations of caked soil and the like are restricted to confined areas suggests several corrective maintenance or design measures. For example, flushing the bridge members in such areas, especially after a winter of heavy use of deicers, may effectively prevent the build up of dirt and salts. Furthermore, when inspection reveals appreciable flaking on some sections, these areas could be grit-blasted and painted with the realization of greater paint life on the weathering steel than on plain carbon steel.

Greater clearances would also be helpful not only to minimize corrosion but to provide for adequate passage and transportation of massive equipment and high loads and thereby permit road-spray dissipation and faster drying.

In terms of design possibilities, even modest increases in present overhead and lateral clearances should provide additional space for the effective dissipation of road spray and faster drying. In any event, greater clearances would be more realistic when one considers the height and bulk of modern earthmoving equipment, to name only one example of items that are now transported over our public highways.

CONCLUSIONS

- Inspections, including one at 5-1/2 years, show excellent performance for the major proportion of the Mayari R weathering steel used in the bridges at the intersection of Eight Mile Road and the John Lodge Expressway in Detroit, Michigan. Thus, the weathering steel beams have a uniform, pleasing surface appearance and have developed the tight protective-oxide layer characteristic of Mayari R steel.

- Caking and scaling are evident on the beams in the two underpass areas above the southbound lanes of the expressway, where presumably confining conditions contribute to road spray with substantial amounts of soil, dirt and deicers being carried up to the low overhead beams.

a. The scaling material is 25-35 mils thick and consists of calcium sulfate (gypsum), calcium carbonate, dolomite, silica, β-FeOOH, sodium and calcium chloride, and probably alumina. The sources of these materials are mainly truck ladings, soil, dusts (including cement dust), deicers and rust. Some calcium sulfate and carbonate may result from the reaction of calcium compounds with pollutants present in industrial emissions and traffic fumes.

b. The road dirt and soil, forming most of the scaling material, are carried up to the low overhead beams by road spray and, combined with rust, harden to produce a scaling condition.

c. Low bridge clearance over the southbound lanes and a high retaining wall along the shoulder of the depressed highway intensify the air blast created by the heavy speeding traffic on the expressway. Since there are greater overhead and lateral clearances in the underpass of the northbound lanes, there is little deposition of dirt and no scaly soil and rust in that area. Nor is there scaly soil and rust on the high beams of the Eight Mile Road Bridge over the southbound lanes of the expressway. In general, where clearances are greater and areas are more open, road spray is more easily dissipated and drying action more effective, thus minimizing the development of corrosion.

- The overall weathering rate of test samples of Mayari R steel installed in the confined areas most prone to corrosion was about 1 mil per year and linear for the 4 years' exposure. The average weathering rate of the same steel on a nearby building roof was 0.5 mil per year, but weathering-line curves had flattened after 2 years, with a much lower indicated rate from the second to fourth year of exposure. The surface of rooftop and bridge specimens representing beam flanges was weathering up to 35 and 50% faster than specimen surfaces representing webs.

  a. The high weathering rates at the scaling areas beneath the service bridges presumably result from the combined effects of (1) deposits containing deicing salts, gypsum and other substances, (2) water from road spray and condensation, (3) prolonged wetness due to the restricted area and the hygroscopic nature of deposited salts, (4) the lack of washing action from direct rainfall, and (5) the poultice action created by caked deposits, rust and moisture. Evidence for this conclusion included analyses of the soil and rust, the finding of considerable amounts of β-FeOOH in the rust on specimens from beneath the bridge, and visual inspections of the bridges.

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Future inspections of the bridges will be made, with particular emphasis on determining whether scaling in the confined zones persists at present rates or is a temporary occurrence. Other areas of the bridges will also be inspected to determine whether current unaffected locations will accumulate heavy caked deposits of soil with flaking. In 1974 the eight-year specimens will be removed and weathering-time curves extended to determine if weathering continues at a linear rate or decreases with time of exposure. These inspections and tests will provide additional information about the conditions under which weathering steel may be expected to perform well and those conditions which should receive special attention in the design and maintenance of weathering steel bridges.

We gratefully acknowledge the assistance of B. S. Mikofsky, Bethlehem Steel Technical Editor, in the preparation of this report and that of G. F. Melloy in guiding and supporting this work and A. R. Borzillo, Supervisor in the Bethlehem Steel Sheet and Tin Mill Product Section, for help during the initial stages of this test.