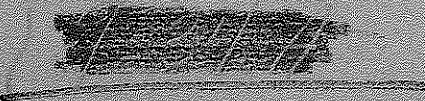


479
.W4
E4
1976



✓
→ COC ✓
→ JCT ✓
→ RGM ✓
→ WDB ✓
→ RCF ✓
→ LDR ✓

EIGHT YEAR CORROSION TEST REPORT EIGHT - MILE ROAD INTERCHANGE

→ TURNER
→ WANG

TRANSPORTATION LIBRARY
MICHIGAN DEPT. STATE HIGHWAYS &
TRANSPORTATION LANSING, MICH.

Sales Engineering Division
BETHLEHEM STEEL

Bethlehem Steel Corporation

BETHLEHEM, PA. 18016



April 12, 1976

Enclosed is the report of corrosion tests conducted at the Eight-Mile Road Interchange near Detroit. The report serves to update with 8-year data the more detailed report which was previously written based on 4-year tests.

This work shows that where boldly exposed and subjected to normal washing and periodic drying, Mayari R (ASTM A242): (1) develops an adherent protective rust layer, (2) exhibits corrosion rates which decrease with time, and (3) as expected has (at least) 4 times the corrosion resistance of carbon steel. Most of the bridge surfaces behave in this manner. However, in the tunnel-like confined areas next to a solid wall beneath the westbound service bridge where road salts and dirt accumulate on the surface of the steel, we observe that Mayari R: (1) develops a flaking, non-protective rust layer, (2) exhibits relatively high corrosion rates which do not decrease with time, and (3) behaves much like carbon steel.

**TRANSPORTATION LIBRARY
MICHIGAN DEPT. STATE HIGHWAYS &
TRANSPORTATION LANSING, MICH.**



BETHLEHEM STEEL

April 5, 1976

FILE REF. 1801-1e
TZ-34-75019

FROM J. C. Zoccola, Engineer, Corrosion Mechanisms

TO H. E. Townsend, Supervisor, Corrosion Mechanisms

SUBJECT CORROSION RESISTANCE OF MAYARI R STEEL ON THE EIGHT-MILE ROAD BRIDGES AT DETROIT, MICHIGAN

Ref. (1) G. F. Melloy to R. E. Simpson, June 2, 1970, 1801-1e.
 (2) J. W. Frame to R. E. Simpson, April 30, 1971, 1801-1e.
 (3) J. B. Horton to S. E. Chehi, June 4, 1974, 1801-1e.

Introduction and Summary

In cooperation with the Michigan State Highway Department (MSHD), we have completed our investigation of the corrosion resistance of Mayari R steel on the weathering steel bridges at the complex interchange of the Eight-Mile Road and James Couzens Expressway at Detroit, Michigan.

The Eight-Mile Road Bridges have been opened to traffic for about 9 1/2 years. Corrosion specimens were exposed for 8 years in the tunnel-like underpass of the Westbound Service Bridge above the southbound lanes of the expressway. For comparison, identical specimens were also located on a nearby building roof free of traffic fumes, road spray, dirt, deicing salts and other deposits. The objective of the test was to determine the effect of road dirt, salts and the like on the corrosion resistance of weathering steels (ASTM A242).

Major portions of the Mayari R steel on the bridges over the expressway, as well as the corrosion specimens on the roof of the building, are showing the pleasing, uniform protective-oxide layer characteristic of weathering steels. However, Mayari R beams on the low-level service bridges above the southbound lanes of the highway, and the 8-year specimens on these beams are not performing well. There is heavy flaky rust and considerable road salts and soil on these surfaces. Corrosion-rate measurements on the 8-year panels confirm previously reported 4-year indications (References 1 and 2) that appreciable corrosion is occurring at these areas. Corrosion is about 1.23 mils per year and increasing with time of exposure in contrast to 0.28 mil per year and corrosion decreasing with time for specimens on the nearby building roof free of traffic fumes, road salts and dirt. There was no significant pitting beneath the scaly rust, nor any significant accumulation of deposits or flaking rust on the steel members in the relatively unconfined sections of the service bridges over the northbound lanes of the expressway.

The poor behavior of the Mayari R steel is due to an accumulation of road dirt and salts on the steel surfaces. There is a high retaining wall along the shoulder of the depressed highway beneath the low-level service bridges and tunnel-like conditions in the underpass next to the wall. These conditions intensify the air blast created by the heavy traffic on the expressway and carry road spray, dirt, and salts to the steel surfaces. The deposits tend to

keep the surface wet and keep chlorides and sulfates in close contact with the steel and cause an accelerated poultice-type corrosion.

Results of the test clearly show the importance of periodic wetting, rain washing and drying for the development of protective rust on weathering steels and the need to be wary of tunnel-like underpasses and conditions that allow road salts and dirt to accumulate on the steel surfaces. Sales Engineering calculations (Reference 3) indicate that, with an average corrosion rate of 1.25 mils per year, the initial thickness and strength of the beams, and the design data submitted by the MSHD, the structural capacity of the bridge would still exceed the maximum strength requirement by about 20% after 75 years of service. In this calculation, the recently adopted AASHTO* Load Factor Design Criteria and load factors supplied by MSHD were used. However our data (see Figure 2) indicate that the corrosion rate in the confined regions may be increasing with time. We don't know whether this is a long-term trend or due to a short-term change in environmental conditions.

Test Procedure

We had installed 4- x 6-inch Mayari R steel panels on the weathering steel beams of the Westbound Service Bridge, in a vertical position to simulate the beam web and horizontal-top and horizontal-bottom to parallel the beam flanges. As a comparison, specimens were also located on the roof of a nearby building, free from road spray, salts and soil. In a second test, started later, plain carbon steel and Mayari R steel were placed at both sites. Table 1 shows the composition of the steels.

There are 3 bridges at this complex interchange; two low-level service bridges, westbound and eastbound, with a high-level viaduct in between. Mayari R structural beams or plates support the bridges. Reference 2 describes and illustrates by colored photographs the location and condition of the bridges and specimens since our last inspection. Specimens were exposed in a relatively confined, tunnel-like area above the southbound section of the James Couzens Expressway** having a high, concrete retaining wall on one side and concrete

* American Association of State Highway and Transportation Officials.

**The James Couzens Expressway was erroneously referred to in previous correspondence as the John Lodge Expressway. The two expressways are one continuous highway but the section away from Detroit and beneath the bridges is known as the James Couzens Expressway.

abutments on the other. The sections above the northbound lanes, however, are relatively open (no solid wall) and there is an adjacent exit and entrance ramp that slows down traffic and allows greater dissipation of road spray. The service bridges have a clearance of about 14 1/2 feet above the expressway.

Discussion and Results

A comprehensive report (Reference 1) and a paper (Reference 2) on our test of Mayari R steel at Detroit, Michigan were written after the 4-year removal of specimens beneath the bridge beams and an inspection of the bridges after 5 1/2 years of service. These reports included X-ray diffraction and chemical analyses of the soil and rust, as well as comparative studies of corrosion rates on the steel specimens and photographs of the various sections of the bridges and of the specimens. The paper in Reference 2 was sent to each of the state highway departments. This last removal of specimens and inspection was only to determine if conditions continued to progress in similar fashion to that of the 4-year removal and inspection.

The corrosion performance of Mayari R steel has not significantly changed since our last removal of panels and inspection of the bridges (Reference 3). The major proportion of the Mayari R steel on the bridges above the expressway, as well as the 8-year corrosion specimens on the building roof, continued to exhibit excellent performance, having a uniform, pleasing, protective rust layer after 9 1/2 years of service. However, there is still heavy scaling and flaking rust, with continued accumulation of road dirt and salts on the Mayari R beams of the two underpasses of the service bridges above the southbound lanes of the expressway, and on the 8-year corrosion specimens in one of the underpasses. Apparently tunnel-like conditions in these areas intensify the air blasts from the heavy traffic flow on the expressway. The turbulent air carries appreciable road spray, salts and dirt to the weathering steel beams and specimens in the underpasses. The possible source of the salts and soil are listed in Table 2.

An analysis of the soil (Table 3) accumulated during a 4-year period on the painted corrosion rack shows appreciable amounts of chlorides and sulfates which are known to accelerate corrosion of steel.

Eight-year corrosion specimens were removed from corrosion racks on the Westbound Service Bridge and nearby National Guard Armory Roof for inspection, determining corrosion losses and for chloride analyses of the intermingled rust and soil on the panels. Figure 1 illustrates the appearance of specimens on painted corrosion racks. As on the 4-year panels, the 8-year specimens on the bridge continue to show flaking rust, a high corrosion rate (average of 1.23 mils per year) with corrosion increasing with time of exposure, while those on the Armory Roof have a uniform, tight protective rust layer,

a low corrosion rate (average of 0.28 mil per year) with corrosion decreasing with time of exposure, cf. Tables 4 and 5 and Figures 2 and 3. As expected, the horizontal-top panels on the bridge, when there is greatest accumulation of solids, show the most corrosion.

The thickness of some of the undisturbed, intermingled rust-soil layer on the 8-year bridge panels was measured and analyzed for chloride content. The rust-soil layer was from 55 to 65 mils thick, about double that on the 4-year specimens, which was 25 to 35 mils thick. The surface underlying the flaky rust layer was relatively smooth and free of pits.

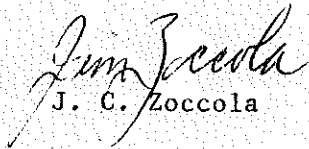
The accumulation of chlorides on the surface of the bridge panels over the 8-year period is shown in Figure 4. The chlorides increase with time as did the corrosion shown in Figure 3. Chlorides, being held in close proximity to the steel by the soil and cement dusts, are probably the major source of corrosion. In this respect, flaking rust and scale on the webs and bottom flanges may be beneficial as the corrosive agents are removed with flaking and scaling of rust. Unfortunately, the new surfaces are quickly contaminated again by road spray, salts and dirt, and deposits are not removed from ledges and horizontal surfaces.

In a second series of tests, we compared the performance of Mayari R steel with plain carbon steel, locating panels beneath the Westbound Bridge as before and on the Armory Roof. There was little difference in the corrosion resistance of the steels on the bridge beams subjected to road salts and spray (Table 6), and both steels exhibited scaly rust. As expected, however, there was a significant difference in the corrosion behavior of the steels on the roof free from deposits (Table 7 and Figure 4). The corrosion of Mayari R steel decreases with time of exposure and exhibits a flattening of the corrosion-time curves, whereas plain carbon steel continues to corrode. Corrosion rates, based on the slopes of the 3- to 7-year portion of the corrosion-time curves, are as follows:

<u>Location</u>	<u>Corrosion Rate, mils per year</u>		<u>Ratio Plain Carbon to Mayari R Steel</u>
	<u>Mayari R</u>	<u>Plain Carbon</u>	
Vertical (web)	0.05	0.27	5.4
Horizontal (flange-bottom)	0.18	0.56	3.1
Horizontal (flange-top)	0.09	0.32	<u>3.6</u>
Average			4.0

Based on a comparison of 3- to 7-year slopes, the Mayari R steel shows an average of 4 times the corrosion resistance of plain carbon steel. Moreover, on the basis of the curvatures evident in Figure 5, we expect the superiority of Mayari R to increase further with time.

Thus, Mayari R is performing well everywhere except at the tunnel-like abutment condition where corrosion is variable but appears to have increased in amount at 8 years over that at 4 years. The reason for this increase may be due to a long-term increase in corrosion rate as a result of increasing accumulation of corrodants or to a short-term variation in rate due to variations in environmental conditions. Further testing is necessary to resolve this.


J. C. Zoccola

JCZ:djj

Attachments

TABLE 1.

COMPOSITION OF MAYARI R AND PLAIN CARBON STEELS
(Percent by Weight)

	<u>C</u>	<u>Mn</u>	<u>P</u>	<u>S</u>	<u>Si</u>	<u>Cu</u>	<u>Ni</u>	<u>Cr</u>
Mayari R (Test No. 1)	.09	.73	.077	.030	.24	.240	.75	.56
Mayari R (Test No. 2)	.09	.78	.080	.029	.36	.340	.72	.64
Plain Carbon (Test No. 2)	.13	.47	.011	.019	.05	.015	-	-

TABLE 2.

POSSIBLE SOURCES OF ROAD DIRT, SALTS AND SOIL

1. Truck loadings (bulk cement, slag, sand, limestone, gravel and evacuated soil).
2. Falloff from passenger cars and trucks.
3. Erosion of concrete highway by normal wear and from studded tires.
4. Windblown soil from turbulent movement of traffic and from natural conditions.
5. Winter deicing salts.
6. Conversion of lime dust by sulfur dioxide and carbon dioxide in the atmosphere and from traffic fumes to sulfates and carbonates.

**TRANSPORTATION LIBRARY
MICHIGAN DEPT. STATE HIGHWAYS &
TRANSPORTATION LANSING, MICH.**

TABLE 3.

ANALYSIS OF SOIL ON 4-YEAR CORROSION RACK

I. X-Ray Diffraction Analysis

<u>Major Constituents</u>		<u>Minor Constituents</u>	
gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	Calcite	CaCO_3
silica	SiO_2	Calcium Chloride	CaCl_2
dolomite	$\text{CaMg}(\text{CO}_3)_2$	iron oxide	($\alpha\text{-FeOOH}$)
salt	NaCl		

2. Chemical Analysis (Percent by Weight)

<u>Aluminum</u>	<u>Sodium</u>	<u>Calcium</u>	<u>Chloride</u>	<u>Sulfate</u>	<u>Silica</u>	<u>Iron</u>
2.2	4.9	12.4	6.7	11.8	28.2	3.0

3. Ion Microprobe Analysis (White Deposit Beneath Scale)-
Major amounts of sodium chloride and calcium carbonate

TABLE 4.

WEATHERING OF MAYARI R STEEL SPECIMENS ON THE
NATIONAL GUARD ARMORY ROOF, DETROIT, MICHIGAN
(Test No. 1)

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

<u>Position</u>	<u>Weathering Loss, mils</u>				
	<u>0.50 Year</u>	<u>1.00 Year</u>	<u>2.00 Years</u>	<u>4.00 Years</u>	<u>8.17 Years</u>
Vertical (Web)	0.46	0.72	1.18	1.36	2.16
	0.49	0.77	1.22	1.64	1.82
	0.53	0.83	1.43	1.72	1.87
	0.61	0.85	1.50	*	*
	Average	<u>0.52</u>	<u>0.76</u>	<u>1.33</u>	<u>1.57</u>
Horizontal (Flange-Bottom)	0.66	1.11	1.84	1.88	2.52
	0.67	1.12	2.02	1.92	2.93
	0.79	1.23	2.12	2.52	2.49
	0.90	1.26	2.22	*	*
	Average	<u>0.76</u>	<u>1.18</u>	<u>2.05</u>	<u>2.11</u>
Horizontal (Flange-Top)	0.56	1.02	1.55	1.64	1.92
	0.71	1.03	1.59	1.76	2.44
	0.69	1.13	1.65	2.16	2.51
	1.01	1.22	1.94	*	*
	Average	<u>0.74</u>	<u>1.10</u>	<u>1.68</u>	<u>1.85</u>
Overall Average	<u>0.67</u>	<u>1.01</u>	<u>1.69</u>	<u>1.84</u>	<u>2.30</u>

* In each case, one specimen was retained to show the surface appearance.

TABLE 5.

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

(Test No. 1)

Position	Weathering Loss, mils				
	0.50 Year	1.00 Year	2.00 Years	3.90 Years	8.04 Years
Vertical (Web)	0.48	0.81	1.54	2.49	10.07
	0.48	0.85	1.68	3.00	6.61
	0.50	0.86	1.78	3.51	10.64
	0.51	0.89	1.81	*	*
	Average	<u>0.49</u>	<u>0.85</u>	<u>1.70</u>	<u>3.00</u>
Horizontal (Flange-Bottom)	0.51	0.81	1.44	3.35	7.28
	0.52	0.84	1.58	3.43	11.12
	0.53	0.86	1.62	4.33	8.73
	0.54	0.89	1.77	*	*
	Average	<u>0.53</u>	<u>0.85</u>	<u>1.60</u>	<u>3.70</u>
Horizontal (Flange-Top)	0.36	0.73	1.70	4.05	11.85
	0.37	0.75	1.85	4.41	10.62
	0.43	0.75	2.20	4.84	11.95
	0.45	0.83	2.73	*	*
	Average	<u>0.40</u>	<u>0.77</u>	<u>2.12</u>	<u>4.43</u>
Overall Average	<u>0.47</u>	<u>0.82</u>	<u>1.81</u>	<u>3.71</u>	<u>9.87</u>

* In each case, one specimen was retained to show the surface appearance.

TABLE 6.

WEATHERING OF MAYARI R AND PLAIN CARBON STEELS BENEATH
 THE WESTBOUND SERVICE BRIDGE, DETROIT, MICHIGAN
 (Test No. 2)

<u>Position</u>	Weathering Loss, mils			
	<u>Mayari R Steel</u>		<u>Plain Carbon Steel</u>	
	<u>2.92 Years</u>	<u>7.00 Years</u>	<u>2.92 Years</u>	<u>7.00 Years</u>
Vertical (Web)	2.04	4.58	3.01	6.89
	<u>2.04</u>	<u>7.08</u>	<u>3.01</u>	<u>8.82</u>
Average	2.04	5.83	3.01	7.86
Horizontal (Flange-Bottom)	2.19	7.73	3.56	8.82
	<u>2.72</u>	<u>8.78</u>	<u>4.03</u>	<u>9.28</u>
Average	<u>2.41</u>	8.26	3.80	9.05
Horizontal (Flange-Top)	2.51	9.62	3.91	9.77
	<u>2.72</u>	<u>9.49</u>	<u>4.06</u>	<u>7.63</u>
Average	<u>2.62</u>	9.56	3.99	8.70
Overall Average	2.35	7.88	3.60	8.53

TABLE 7.

WEATHERING OF MAYARI R AND PLAIN CARBON STEELS ON
THE NATIONAL GUARD ARMORY ROOF, DETROIT, MICHIGAN
 (Test No. 2)

Position	Weathering Loss, mils			
	Mayari R Steel		Plain Carbon Steel	
	2.97 Years	7.11 Years	2.97 Years	7.11 Years
Vertical (Web)	1.42	1.67	1.90	2.61
	<u>1.42</u>	<u>1.54</u>	<u>1.96</u>	<u>3.49</u>
Average	1.42	1.61	1.93	3.05
Horizontal (Flange-Bottom)	1.99	2.82	2.52	6.45
	<u>2.02</u>	<u>2.69</u>	<u>3.36</u>	<u>4.03</u>
Average	2.01	2.76	2.94	5.24
Horizontal (Flange-Top)	1.49	2.15	2.35	4.10
	<u>1.90</u>	<u>2.01</u>	<u>2.73</u>	<u>3.65</u>
Average	1.70	2.08	2.54	3.88
Overall Average	1.71	2.15	2.47	4.06

TRANSPORTATION LIBRARY
 MICHIGAN DEPT. STATE HIGHWAYS &
 TRANSPORTATION LANSING, MICH.

FIGURE 1. (Test No. 1)

BENEATH BRIDGE

ON ROOF

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



Weathering
Loss,
inils

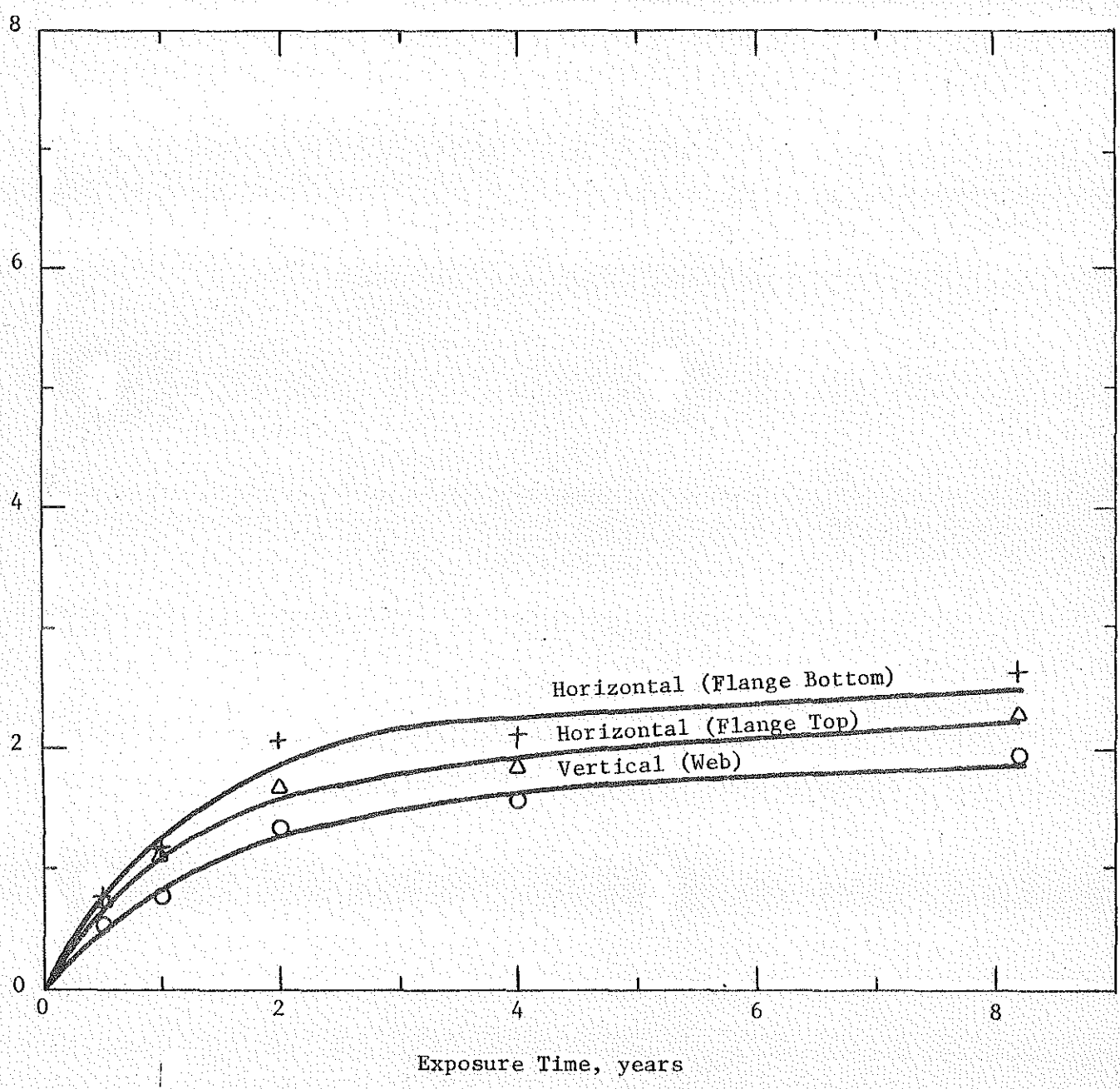


FIGURE 2. WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS ON THE BUILDING ROOF IN DETROIT, MI (Test No. 1)

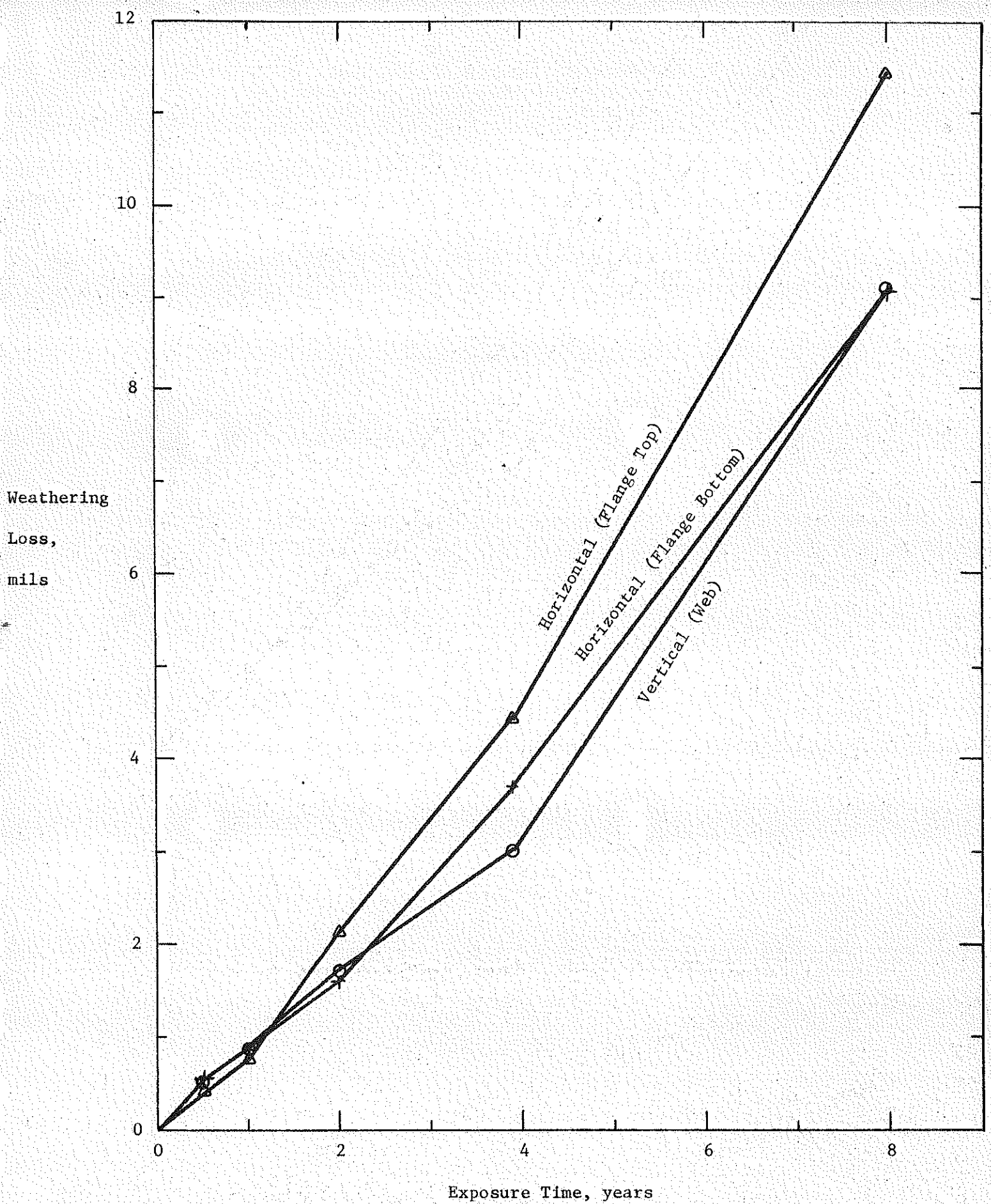


FIGURE 3. WEATHERING-TIME CURVES OF MAYARI R STEEL SPECIMENS BENEATH THE WESTBOUND SERVICE BRIDGE, DETROIT, MI (Test No. 1)

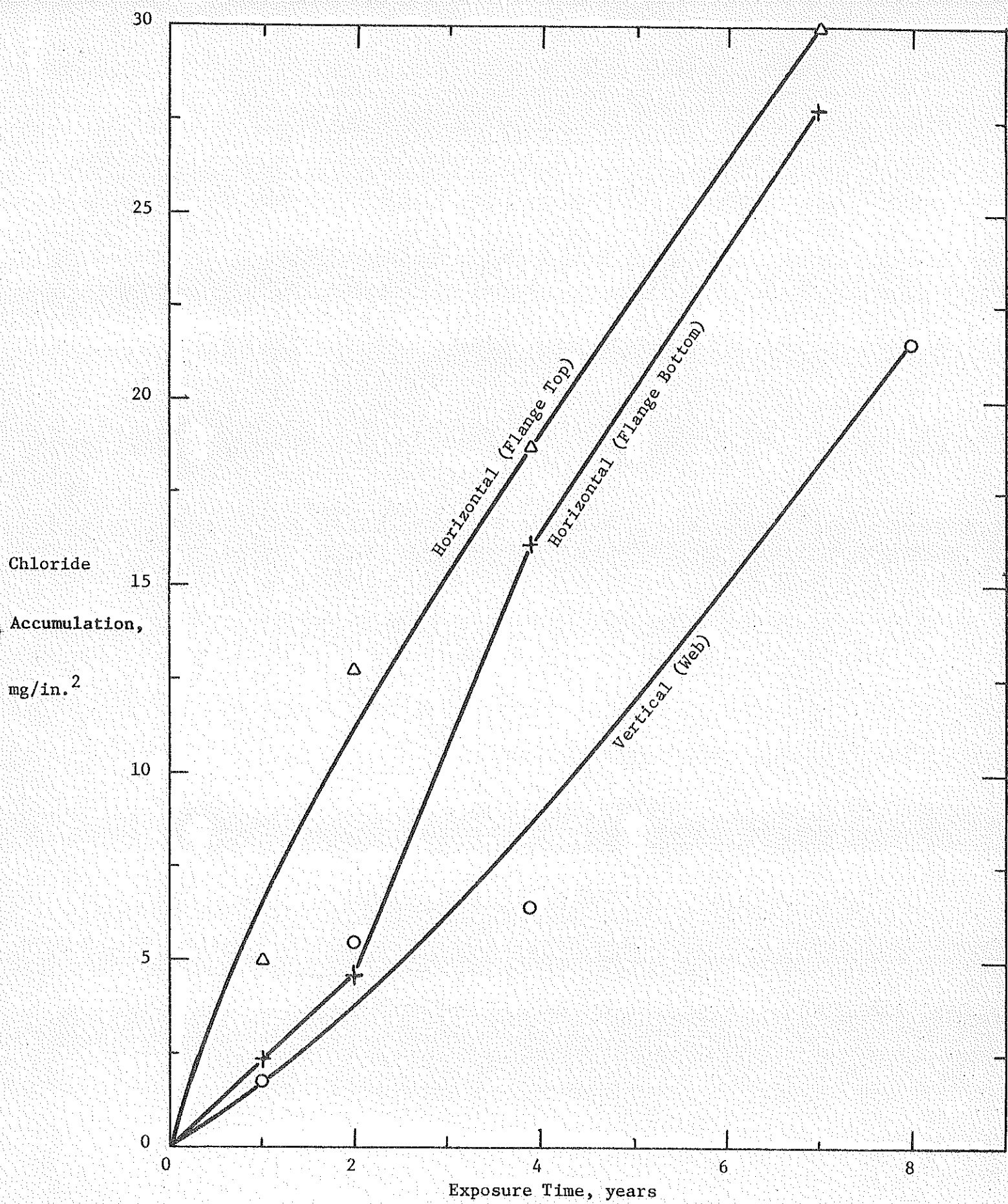


FIGURE 4. CHLORIDE ACCUMULATION ON STEEL PANELS BENEATH THE WESTBOUND SERVICE BRIDGE, DETROIT, MI (Test No. 1)

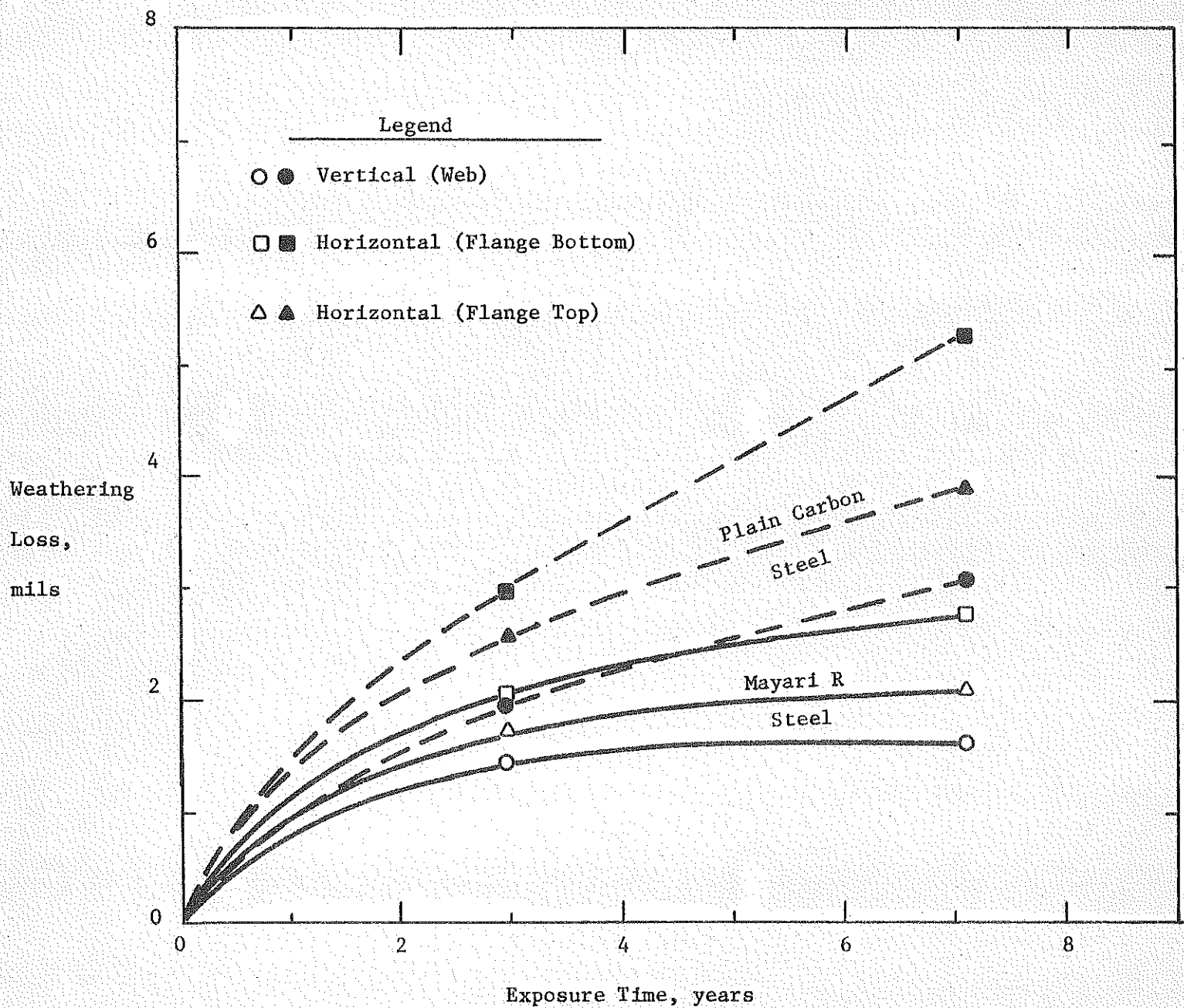


FIGURE 5. WEATHERING-TIME CURVES OF MAYARI R AND PLAIN CARBON STEEL SPECIMENS ON THE BUILDING ROOF IN DETROIT, MI (Test No. 2)