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Case Study: Paint Failure

By

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Examination of paint from a small town Minnesota Water Tower to determine the cause of paint failure. Paint chips that had fallen from the tower were collected for examination, and other samples were removed from the tower structure. The samples were examined by visual examination, microscopic examination, scanning electron microscopic and energy dispersive x-ray analysis, and chemical analysis.

Visual Examination

Visual examination of the Water Tower showed that large sections of paint were missing from the top of the tower, Figures 1 and 2. A Google Earth Satellite photo, which was taken one year earlier than our examination, shows some spots on top of the water tower that were likely bare of paint, but not to the extent shown in Figures 1 and 2.

There were also large sections of paint missing from the personal protection cage at the bottom of the ladder running up a tower leg, Figure 3. The rusted locations indicated that the paint was missing prior to the date of loss. Cracking or chipping of the paint allowed moisture to be trapped beneath the paint layer, causing the paint to flake off. The paint chips found were fairly fine due to the grass around the tower having been mowed, Figure 4, but were still viable as samples.

National Weather Service data for this area in Minnesota showed that the extreme low temperatures in the winter prior to the examination were within the extremes recorded over the last 30 years. The tower had gone through many similar extreme cold weather cycles in its 52 year life.

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Figure 1 – Water Tower Overview

Figure 2 – Missing Paint on Top of Water Tower

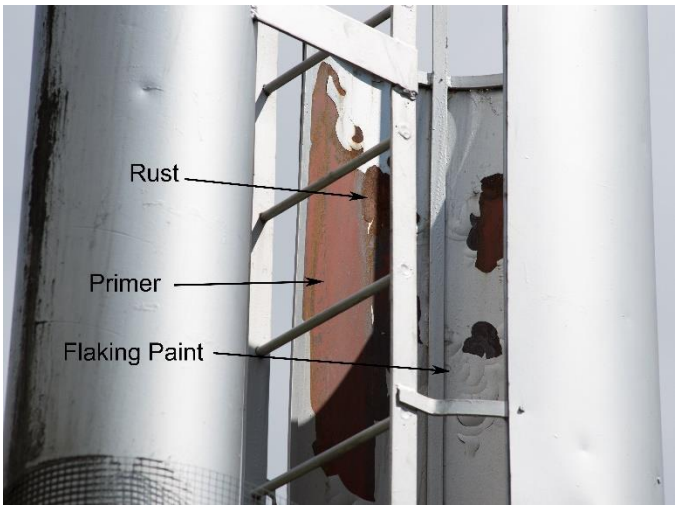

Figure 3 – Missing Paint on Personal Protection Cage

Figure 4 – Paint Chips on the Ground

Figure 5 – Flaking Paint on Leg Tower Bracket

There was flaking and missing paint on a leg crosstie bracket, Figure 5. The bracket showed both rusted steel and bare metal. The rusted steel indicated that the paint had been missing for a period of time, or water had gotten under the paint. Paint blisters similar to the one shown in Figure 6 allow water to get between the paint and steel on any steel structure, causing the paint to flake off, as shown in Figure 5.

Figure 7 shows the water tower's manufacturer's label, which showed it was erected in 1966. The tower was 52 years old at the time of examination.

Figure 6 – Paint Blister

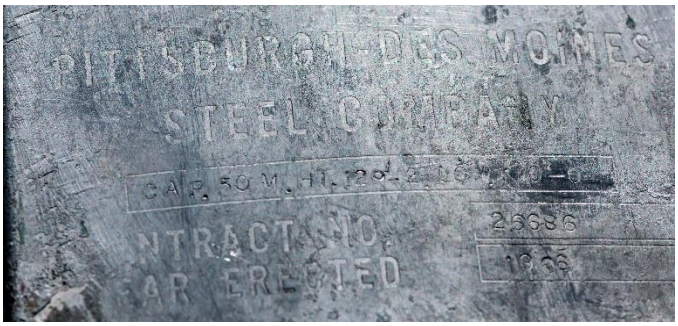

Figure 7 – Tower Manufacturer's Label

A Leg Base Flange is shown in Figure 8. The paint was flaking off the steel as shown. In the areas indicated, there was no paint adhesion to the underlying steel. A paint sample was removed for further testing.

Figure 8 –Leg Base Flange

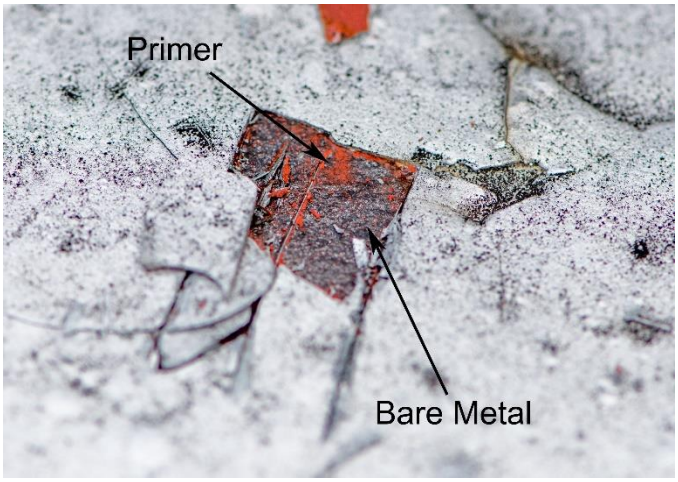

Figure 9 – Cross Hatch Paint Adhesion Test - Leg Base Flange

A cross hatch paint adhesion test was conducted on the paint on a Leg Tower Flange, Figure 9. There was very poor adhesion at this location. Some of the primer was still adhering, but for the most part, there was no adhesion. Paint samples were removed from the flange for further testing.

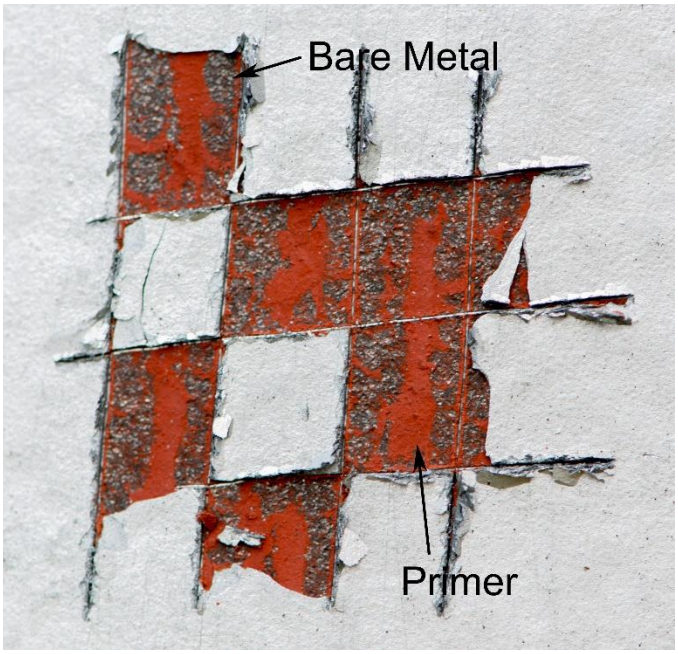

Figure 10 – Cross Hatch Paint Adhesion Test on Tower Leg

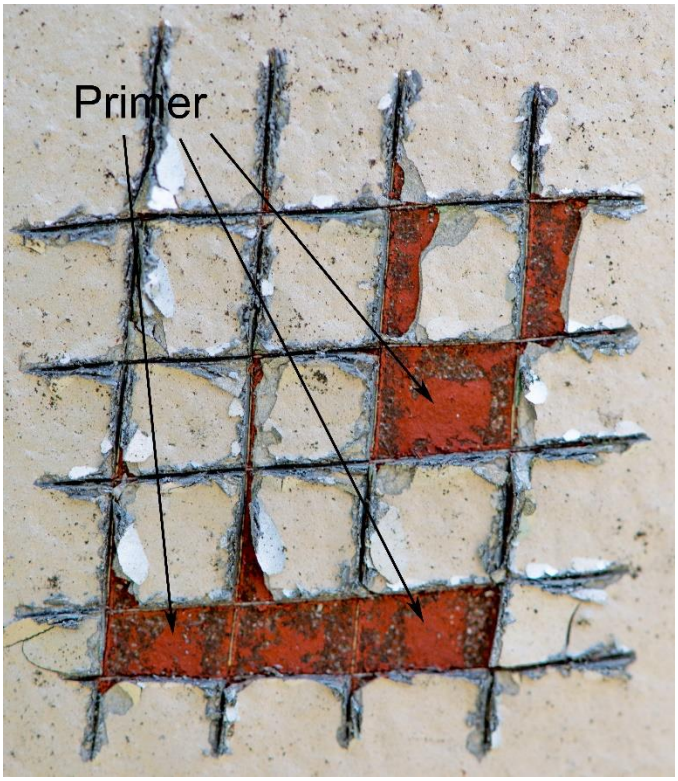

Figure 11 – Cross Hatch Paint Adhesion Test on Tower Leg

The paint adhesion on two different tower legs was poor, as shown in Figures 10 and 11. It appears that only about 50% of the primer was still adhering to the steel.

Scanning Electron Microscopic and EDX Analysis

Paint Sample 1 was the paint material picked up from the ground around the east tower leg. The primer surface of the paint, Figure 12, was examined with a scanning electron microscope. The primer layer was cracked, indicating that the primer was brittle. The energy dispersive x-ray, EDX, spectrum of this surface is shown in Figure 13. The spectrum shows a significant quantity of lead present in the primer. Since the sale of lead based paints and primer has been banned since January 1, 1991, the presence of lead in the primer flakes means that the ground surrounding the water tower was contaminated with lead. The semi-quantitative analysis of the primer is given in the table that follows.

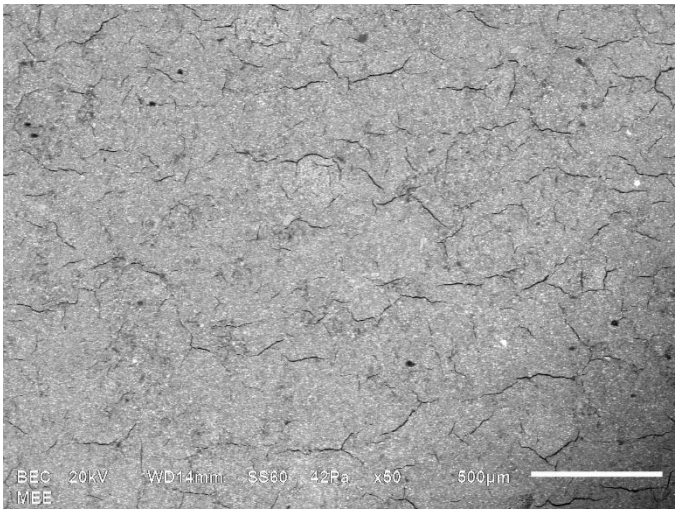

Figure 12 – 50X Primer Surface of Paint Sample 1

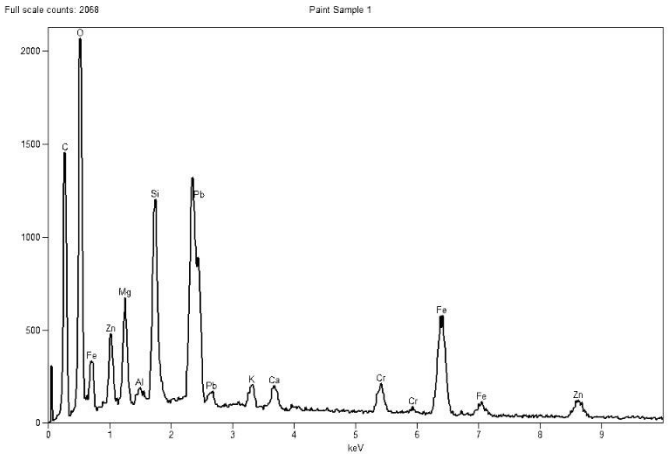

Figure 13 – EDX Spectrum of Primer, Paint Sample 1

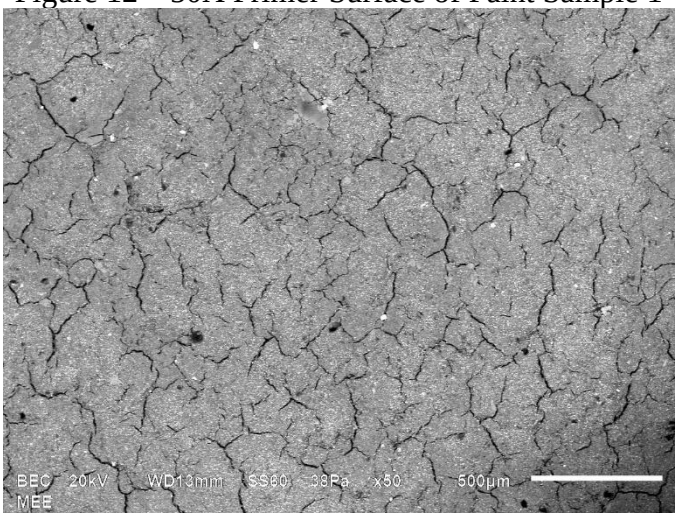

Figure 14 – 50X Primer Surface of Paint Sample 2

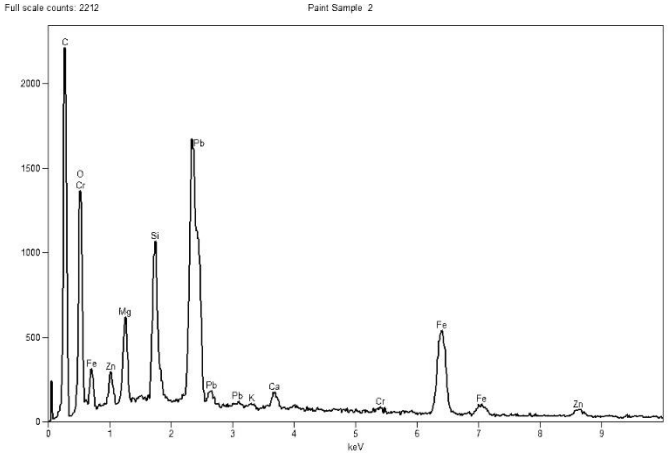

Figure 15 – EDX Spectrum of Primer, Paint Sample 2

Paint Sample 2 was removed from another Leg Base Flange. Examination by the scanning electron microscope showed that the primer layer was cracked, Figure 12. The EDX spectrum shows the presence of lead, Figure 13. The semi-quantitative analysis of Sample 2 is given in the table that follows.

The cracking in the primer layer, shown in Figures 12 and 14, indicated that the primer had become brittle. All paints and primer continue to age and become brittle after many years.

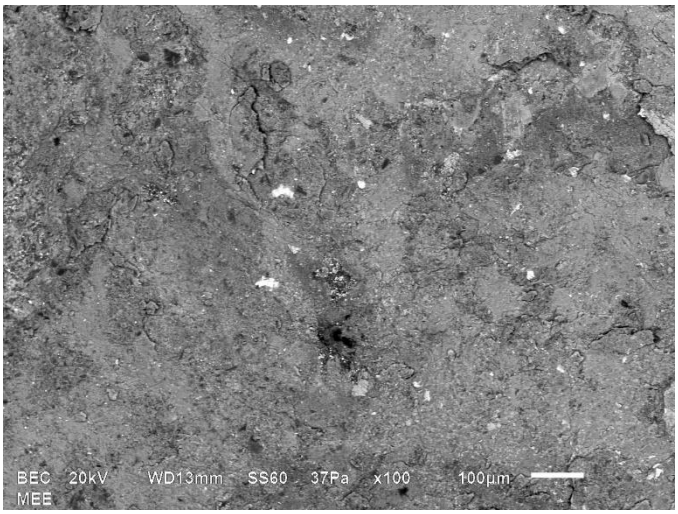

Figure 16 – 100X Primer Surface of Paint Sample 3

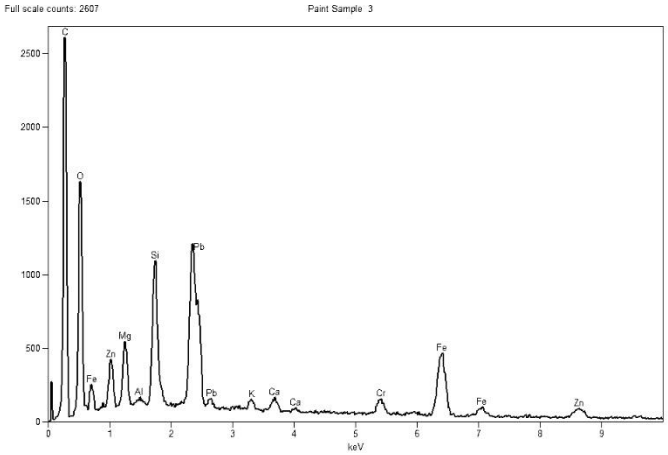

Figure 17 – EDX Spectrum of Primer, Paint Sample 3

Paint Sample 3 was removed by the cross hatch test on a tower leg. The primer surface is shown in Figure 18. The EDX spectrum is shown in Figure 19. Lead was present at this location. The semi-quantitative analysis is given in the table that follows.

EDX Analysis of Paint Samples
(Percent by Weight)

Element/Sample	Paint Sample 1	Paint Sample 2	Paint Sample 3
Carbon	16.3	22.7	26.7
Oxygen	32.7	26.1	29.9
Magnesium	3.8	3.4	3.1
Aluminum	0.4		0.2
Silicon	5.9	4.9	5.1
Potassium	1.0	0.2	0.5
Calcium	1.1	0.9	1.0
Chromium	2.5	0.4	1.8
Iron	13.4	13.2	11.1
Zinc	5.6	2.4	3.9
Lead	17.1	25.8	16.8
Total	100.0	100.0	100.0

The EDX analysis showed high quantities of lead on the primer side of the paint flakes. The presence of chromium indicated that the tower was treated with a chromate wash prior to the original painting. This was done to improve the adherence of the primer, and was a common practice in the 1960's. It could also indicate that zinc chromate could have been added to the primer as a corrosion inhibitor.

Chemical Analysis

Chemical analysis was done on the primer in Paint Sample 1, the paint flakes picked up off the ground at the water tower site during inspection. The analysis was conducted to EPA Standard. The analysis showed that the primer contained 190,000 ppm, or 19% lead.

Future work on this tower would need to follow guidelines for handling and cleanup of lead based paints and chromates.

Microscopic Analysis of Paint Samples

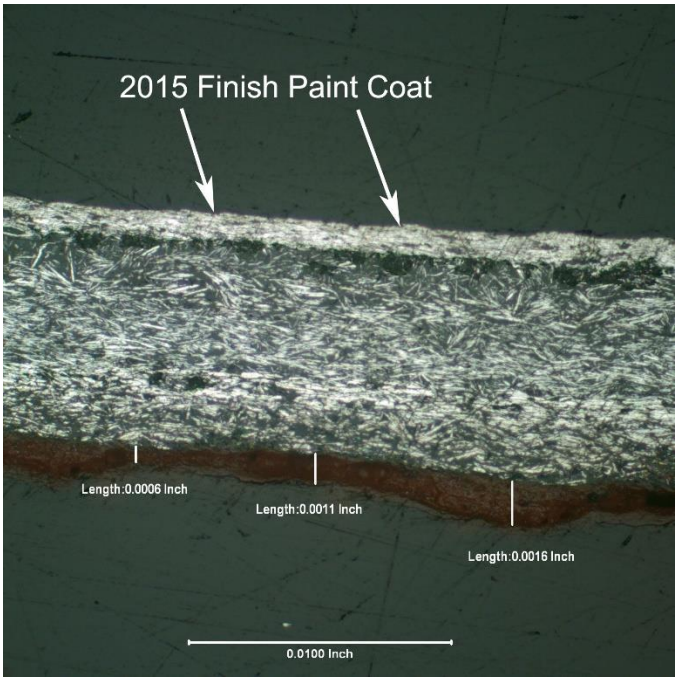

Figure 18 – 200X Cross Section - Paint Sample 1

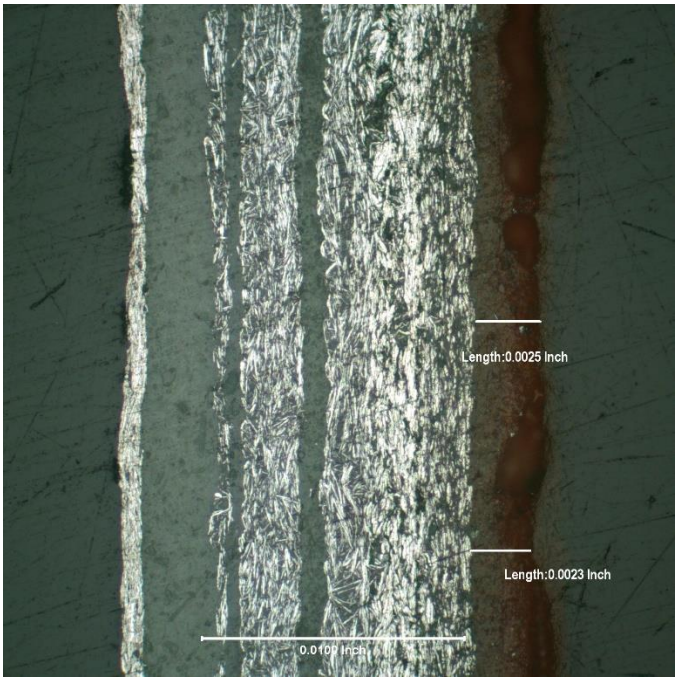

Figure 19 – 200X Cross Section - Paint Sample 2

The cross section of Paint Sample 1 is shown in Figure 18. The average thickness of the primer layer was 0.0011 inches. Typically, primer layers are at least 0.002 inches in thickness. There could have been three coats of aluminum paint present. There were definitely two coats present. City officials indicated that the tower was repainted in 2000, and again in 2015, for touch up and repair. At the writing of this report, there were no official records of the work being done in 2000.

Paint Sample 2 was much thicker than Paint Sample 1, Figures 18 and 19. The primer layer on Paint Sample 2 was over 0.002 inch thick, and there were two primer coats present. Each of the primer coats was approximately 0.001 inch thick. There could have been six or seven total coats of paint on this sample.

Conclusions

Based on the findings of the investigation, the paint failure on this water tower was caused by the lead based primer reaching the end of its 50 year useful life. This was indicated by the microscopic cracks seen in the primer samples, which showed that the primer had become brittle. Because of the presence of lead based primer, lead mediation of the tower and grounds will need to be done prior to repainting the tower.

Many older structures are beginning to show similar conditions as were found in this case, where the cause may need to be identified before repairs can be made. Materials and metallurgical engineering have a wide variety of testing methods that are able to identify the cause of failure of most materials, including non-metals.