Practice Points NUMBER 08

Using Dry Ice for Spray-Paint Removal on Weathering Steel

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Introduction

The basic concept of weathering steel is that the natural corrosion of the steel is converted into a protective "skin" to retard the deterioration processes. Weathering steel is intended to remain exposed to the elements and develops the aesthetically pleasing warm purple and brown colors of corrosion — no paint or sealer is required or recommended. The skin formed by the corrosion is considered to be a positive characteristic. However, the skin is actually a fragile, porous layer that requires protection if paint or other contaminants have affected the surface.

As with many new materials, unforeseen conditions arose with the passage of time on this naturally corrosive material. The protective skin contains a ferrous particulate in its rainwater runoff that discolors adjacent materials, such as glass, granite, and concrete, and causes cleaning problems. Also, the fragile characteristics of the material, such as the texture and patina, must be taken into account when working on restoration projects, such as removing graffiti, without aesthetically affecting the patina of weathering steel.

Weathering Steel

Cor-Ten is the weathering steel product of U.S. Steel.[1] Mayari R. is a similar product manufactured by Bethlehem Steel. Weathering steel was developed in the 1930s as a high-strength steel that did not require coatings, paint, or maintenance. Its first applications were in railroad cars and bridges. It gained popularity in the 1960s as an architectural and sculptural steel, from sculptures by Pablo Picasso, Richard Serra, and Chuck Ginnever to corrugated roofs in the American West and railroad bridges. It was also used for mid-century Modern architectural facades, such as the Richard J. Daley Center, designed by C. F. Murphy Associates in 1965, and the Time Life Building, designed by Harry Weese in 1968, both located in Chicago, Illinois (Fig. 1).

A challenge with the weathering steel of the Time Life Building was that the visible layer of corrosion does not stop the corrosion process or protect the steel behind or within the skin. The steel continued to deteriorate without visibly apparent distress.[2] This type of corrosion is accelerated in conditions where weather (rainfall, humidity, snow, or marine salts), chemicals (cleansers, acids, or de-icing salts), or natural or animal pollutants come into contact with the steel.

Mayari R., fabricated by Bethlehem Steel, was studied for its weathering capacities in 1988 and was determined to be acceptable for architectural purposes with the qualifications that the use was to be protected from toxic chemicals and extensive weathering; their approval with appropriate detailing and maintenance was

Fig. 1.
The Time Life Building, Chicago, Ill., Harry Weese Architects, 1968. All photographs by the author.

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Fig. 2.
The alley facade of the Time Life Building before treatment. Note the areas of spray paint above and below the guard rail.

also required.[3] Their analysis assessed the susceptibility of the material to corrosion. The options for weathering steel can be ranked in order of decreasing atmospheric corrosion resistance as: A 242 weathering steel > A 588 weathering steel. 0.21 Cu steel, > 0.021 Cu steel.[4]

The challenge to the restoration and conservation community is this: when a material is compromised, how is it restored if its failure is inherent in its material identity? What is the proper treatment when the intended yet deteriorated aesthetic of a material is one which requires restoration? Is it acceptable to "correct" a historic material? Weathering steel was chosen by the original designers of buildings and sculptures specifically for its aesthetic and the expectation of a low-maintenance skin on exposed steel provided by the corrosion patina. The corrosion of weathering steel is an important part of the historic value of the building or sculpture, and it is crucial to the restoration's authenticity. Since neither product is recommended in architectural or roofing applications any longer, buildings and sculptures that incorporate this material could therefore be considered valuable as examples of the limited application of this material.

As the restoration architect on an existing weathering-steel-clad building, we were faced with the uncharted territory of how to remove spray paint from a limited section of a weathering-steel facade.

Cleaning Research

Numerous cleaning methods were researched, discussed, and rejected prior to any testing on the actual wall of the Time Life Building, at 541 North Fairbanks in Chicago. The goal was to remove the paint without leaving a shadow of the marking or having to build up the patina. Chemicals that may have removed the spray paint were rejected due to a concern for the residual effects on the porous and pitted surface. Fabrics enhanced with paint-removal chemicals were also considered and discarded because of the possibility of residual paint smears and an overly clean area on the wall. Each chemical product that was considered may have its appropriate applications, but in this instance none of them was a viable choice.

Projectile cleaning methods were considered and tested on weathering-steel samples from the building's storage of attic stock, including fine micropowders similar to talc; natural materials, such as nuts, shells, and citrus peels; and metal particles imbedded in other materials. The micropowders did not satisfactorily remove the spray paint, and the imbedded metal particles over-cleaned the surface, removing the patina. The goal was to find an abrasive or mild projectile technology that could remove the spray paint and was both stronger than the paint and softer than the patina. Many were attractive for containment and environmental reasons, but discussions with product representatives often removed the technology from consideration prior to testing. Their concerns were based on the fragility of the patina and a desire to avoid discoloration or over-cleaning the metal.

The project team also investigated paint removal by projectile dry ice. Dry ice is a useful technique in cleaning materials as varied as timber, brick, and stone. Samples of weathering steel were provided for testing, and arrangements were made for a test to be performed on the building and assessed by the owner and the architect.

Dry-Ice Cleaning

Dry ice is the solid form of carbon dioxide (CO_2), which is a colorless, tasteless, and odorless gas found naturally in the atmosphere.[5] Upon impact after high-velocity projection, dry ice evaporates, leaving no apparent residue. One attractive aspect of the dry-ice system is that it can be used on soft metals, such as chrome and nickel, and even on timbers without damaging the substrate. The first patent regarding dry-ice cleaning was awarded in 1947 (U.S. Patent 2,421,753) for the cleaning of optical lenses. Dry-ice cleaning technology evolved from a two-hose ("venturi") system to a single-hose system in 1987. The single-hose technology was pioneered and patented by Cold Jet, LLC, of Loveland, Ohio.

Dry ice is available in the form of rice-sized pellets, nuggets, or blocks. The hose nozzle passes over the surface being cleaned in a continuous motion. Most dry-ice cleaning systems use a standard 3-mm blasting pellet. Block systems, however, shave the dry ice to create consistently sized particles approximately the size of grains of sugar. The projected force of the dry-ice particles is adjusted according to contaminant and substrate sensitivities.

For the Time Life Building project, the hope was that during cleaning the dry ice would freeze and explode, or at least dislodge, the paint but would not affect the steel. The steel would react to the cold but not in a manner that would damage the patina. There was concern, however, that a concentrated application could cause a temperature transfer that could adversely affect the metal. Experienced technicians can avoid over-cleaning.

The process of dry-ice cleaning requires protective clothing for the technicians. Due to the projectile shrapnel effect, the head, eyes, and all exposed body parts should be covered for the duration of cleaning. It is also a very loud process, due to the generator and the projectile impact, and requires ear protection.

Case Study: The Time Life Building

The project profiled in this case study is the 1968 Time Life Building in Chicago. The original architect was Harry Weese, of Harry Weese Associates. Jack Hartray, the lead architect with Harry Weese for this building, was consulted at the time of the restoration work in 2007.

The exterior-wall system of the Time Life Building consists of weathering steel and gold-reflective insulated glass units. Previous repairs to the exterior wall system in 1988 included the replacement of numerous panels at the second, third, and penthouse floors with new panels of thicker-gauge weathering steel, due to extensive corrosion of the panels.[6] The base panels at the perimeter of the entire building, including those along the alley and plaza, are irregularly discolored due to the erosion of the protective skin from the chemically enhanced de-icing salts used for cold-weather maintenance and safety. The cladding has weathered over the past 40 years to a uniform color of warm brown corrosion with hints of purple and burnt umber. The corrosion particles in the storm-water runoff from the weathering steel has caused problems since the time of construction: the runoff has stained the window glazing, storefront glazing, concrete, and granite paving units at the building's plaza.

The 2007 restoration work was very limited in nature. The building management was concerned about the material condition and aesthetics of the weathering steel after it suffered from an unwanted application of spray paint by an adjacent construction-site crew (the spray paint was located on an alley wall adjacent to a neighboring construction site). The spray paint was primarily either a construction-grade bright orange or green color. Markers were then used to write dimensions and numerical notations on top of the spray paint. The wall was further compromised by the effects of de-icing salts and water spray from vehicles. The goal was to remove the writing and spray paint without affecting the weathering-steel patina (Figs. 2 through 4).

The exposed metals of the wall-cladding system are entirely weathering steel and in the work area consist of vertical steel I-sections 4 feet on center with intermediate steel panels. The modular spacing is a 4 feet horizontal by 10 feet 8 inches vertical. The alley wall had intermittent spray paint along its entire 218-foot length, ranging from 2 feet (just above the guardrail) to approximately 4 feet 6 inches above grade. The scope of work was restricted to the removal of the paint contaminants and mortar and concrete accumulations on the lower panel of the wall, i.e., the lower 10 feet 8 inches of the wall cladding.

The cleaning methods that were tested on the spray-painted wall included projected particles of dry ice and of metals impregnated in other softer materials. The metal-particle test was not acceptable due to an over-cleaning of the patina. The dry-ice test area was successful, with quick removal of the paint, and the only aesthetic alteration was a wet surface to the steel. Upon natural drying, it was determined to have not caused an alteration to the patina on the immediately adjacent weathering-steel areas.

The test area for dry-ice cleaning was determined by the architect to be a typical paint area of orange paint with additional writing on the painted surface. Dry-ice pellets were selected by the technician as the form appropriate for the weathering steel. The equipment used for this project was a 375 cfm diesel compressor and Cold Jet Aero 75 DX dry-ice cleaning equipment. The testing began with a low pressure (90 psi) and gradually increased until it was visibly apparent that the paint was being removed, at 110 psi. The nozzle size and angle of application were also modified until the appropriate technique was selected. The paint was removed by waving the hose and steady stream of projectile dry-ice pellets past the discolored area. No residue was visibly apparent. Particles or debris from the cleaning did not accumulate on the ground (Figs. 5 and 6).

Fig. 3.
The contaminants on the weathering steel of the Time Life Building shown here include spray paint, de-icing salts, and corrosion runoff from the building. The concrete base of the facade below the steel is also discolored.

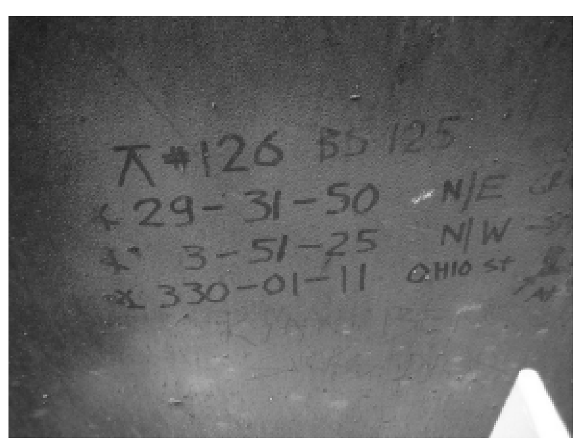

Fig. 4.
An example of the spray-paint contaminant on the weathering steel.

The weathering-steel surface was wet due to condensation and natural humidity in the air. The localized temperature change created by the dry ice caused moisture to accumulate on the steel. Upon drying, the treated surface was determined to be slightly cleaner than the adjacent areas. Therefore, the presumed scope of work, including the entire height of the lowest course of metal panels, was approved as the work area.

The test locations also included areas affected by de-icing salts; these areas showed a minor improvement, and the mortar and concrete splashes were completely removed. The deterioration and discoloration resulting from the de-icing salts were considered less important, because it was seen as a recurring condition beyond the control of the building management. The spray paint and the mortar and concrete accumulations were a by-product of the adjacent construction site. When the testing was complete, the removal of the mortar and concrete accumulations was added to the scope of work.

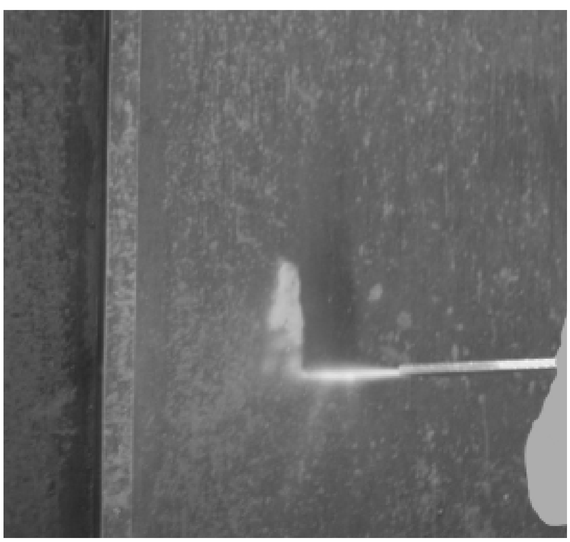

Fig. 5.
The dry-ice cleaning process underway, using a continuous motion of the nozzle across the area of contaminants.

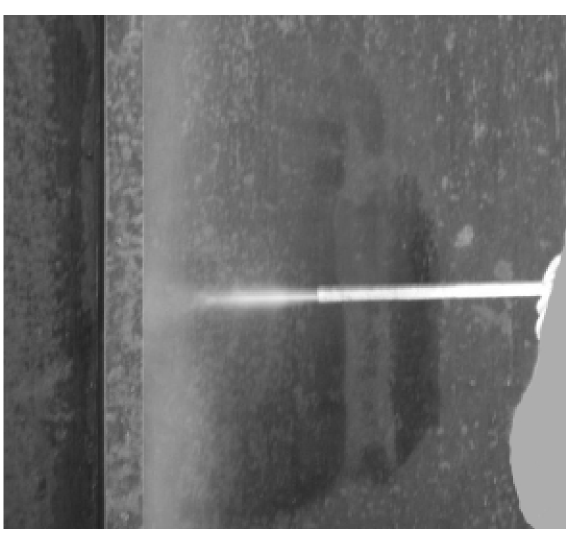

Fig. 6.
The same areas after additional cleaning, showing how quickly the cleaning process removed the contaminant from the metal surface without affecting the patina.

The process used on the weathering steel of the Time Life Building was as follows: A 23-inch-long nozzle with a 3-inch-wide opening (swath) was selected, and the operating pressure was set at 110 psi. The nozzle was held at a distance of 9 to 20 inches from the building's weathered steel surface. Dry-ice pellets were chosen as the appropriate media. During the cleaning process, the nozzle was swept over the steel panels in a continuous motion while feathering off at the tail end of the sweep. This technique allowed a uniform treatment of the patina without streaking.

The process of dry-ice cleaning was successful due to the differences in behavior of the substrate versus the offending material. The contaminants (the paints) were softer than the substrate (the weathering steel) and froze or cracked off faster than the metal could be affected by the cold.

Conclusion

The issue for the client was the aesthetic need to remove spray paint from the weathering steel. The architect's challenge was to find a solution that would please the client without harm to a compromised material. The dry-ice technique was determined to be successful on the delicate weathering-steel surface. As with any project, the appropriate measures must be researched, tested, and varied per the constraints of the materials and their contaminants. The alley wall of the Time Life Building was studied again one year after application. The work area blends in with the adjacent weathering steel. The contaminants on the steel are solely atmospheric and related to de-icing salts. The owner and property manager remain satisfied with the results of the procedure.

MARY BRUSH, AIA, was the restoration architect for the Time Life Building facade cleaning. At the time of the facade restoration, she worked with Klein and Hoffman, Inc., and is currently the preservation group leader at Holabird & Root in Chicago. She can be reached at mbrush@holabird.com.

Notes

1. The U.S. Steel Web site states that "Weathering Steel (USS COR-TEN®) uses alloying elements such as copper, chromium, silicon, and nickel to enhance the atmospheric corrosion resistance of the steel. The addition of these elements also results in high-strength steel that typically exhibits 50 ksi minimum yield strength. ASTM A606 Type 4 is usually specified for this product." See www.ussconstruction.com/metal/metal/corten.html, accessed Sept. 29, 2008.

2. The U.S. Department of Transportation Federal Highway Administration (FHWA) issued Technical Advisory T 5140.22 on October 3, 1989, entitled *Uncoated Weathering Steel in Structures.* Their concern for the material was the excessive corrosion that was occurring on highway bridges, including loss of section and/or localized structural failure due to improper application of the material. U.S. Department of Transportation Federal Highway Administration, *Technical Advisory Uncoated Weathering Steel in Structures* (October 3, 1989), T 5140.22, Paragraph 4, subsection a, www.fhwa.dot.gov/legsregs/directives/techadvs/t514022.htm, accessed Sept. 29, 2008. The American Iron and Steel Institute published a report on May 10, 2005, analyzing weathering steel used in highway bridges. Their findings concluded that with the proper detailing, it is a cost-effective low-maintenance material "that performs well in virtually all environments." American Iron and Steel Institute, *Weathering Steel: Performance of Weathering Steel in Highway Bridges: A Third Phase Report*, www.steel.org/Content/ContentGroups/Construction2/Bridges/AISI_Construction_Pe15.htm, accessed Sept. 29, 2008. Both studies addressed concerns for the durability of the material and found that with appropriate application, detailing, and maintenance, weathering steel is an acceptable material for highway bridges. While the studies were not charged with architectural or sculptural applications, the results were useful regarding remediation concerns toward weathering steel.

3. Jeffrey S. Russell, ed., *Perspectives in Civil Engineering: Commemorating the 150th Anniversary of the American Society of Civil Engineers* (Reston, Va.: ASCE, 2003), 340. U.S. Steel no longer recommends weathering steel for architectural applications and has developed alternative materials. In fact, U.S. Steel states that it should "not be sold when the intended use is for an architectural application such as roofing and siding. U.S. Steel maintains this position because of the risk of corrosion from factors beyond the control of the COR-TEN® steel licensee (e.g. improper design, fabrication, and/or maintenance)." U.S. Steel Web site, COR-TEN AZP Prepainted Galvalume® Steel Sheet, www.ussconstruction.com/metal/metal/corten.shtml.

4. C. R. Shastry, J. J. Friel, and H. E. Townsend, "Sixteen-Year Atmospheric Corrosion Performance of Weathering Steels in Marine, Rural and Industrial Environments," ASTM STP965-EB, www.astm.org/DIGITAL_LIBRARY/STP/PAGES/STP25827S.htm, p. 15.

5. Cold Jet Web site, FAQ, www.coldjet.com /en/information/, and www.coldjet.com/en/industries/historical-restoration.php, accessed Sept. 29, 2008.

6. Stanley Ziemba, "Time Building to Get Facelift," *Chicago Tribune*, Dec. 8, 1988.

Additional Sources

Decker, P., et al. "To Coat or Not to Coat? The Maintenance of Cor-Ten Sculptures." *Materials and Corrosion* 59, no. 3 (2008): 239–247.

Glueck, Grace. "Sculptor's Ordeal With Steel: It's Pretty, but Temperamental." *New York Times*, Aug. 22, 1991.

Willett, Thomas O. U.S. Dept. of Transportation Federal Highway Administration (FHWA) Technical Advisory T 5140.22. *Uncoated Weathering Steel in Structures.* www.fhwa.dot.gov/legsregs/directives/techadvs/t514022.htm.

Online Resources

American Iron and Steel Institute, www.steel.org

United States Steel, www.ussconstruction.com

U.S. Department of Transportation Federal Highway Administration, www.fhwa.dot.gov

Cold Jet, www.coldjet.com

Restore1, www.belowzeroblasting.com

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