“COST EFFECTIVE ALTERNATIVE METHODS FOR STEEL BRIDGE PAINT SYSTEM MAINTENANCE”

CONTRACT NO. DTFH61-97-C-00026

REPORT VIII:
REMOVAL OF LEAD-BASED PAINT USING WATERJETTING

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TECHNOLOGY INTRODUCTION

Waterjetting (WJ) is the process by which high-pressure (HP) (10,000 to 25,000 psi) or ultrahigh-pressure (UHP) (25,000 or greater psi) water is used to prepare a surface for coating. Waterjetting can be used to remove existing coating, rust, surface oil and grease, and water-soluble surface contaminants.[1] The water is propelled through a single nozzle or multiple nozzles on a rotating head. Rotating heads are used to better distribute the amount of energy transferred to the surface. Waterjetting is used in many industries to remove coatings and prepare surfaces for painting. Currently, the technology is gaining popularity or well accepted in the marine industry, petrochemical industry and the transportation sector (highway bridges).

TECHNOLOGY OBSERVATION

During on-site visits, Corrpro Companies, Inc. observed the Ultrahigh-Pressure Waterjetting process on three different bridge structures, and gathered data from a fourth.

Lebanon, New Hampshire: spot cleaning using UHP waterjetting within portable containment followed by application of a zinc, epoxy, urethane overcoating system

The first project was a highway overpass over Rt. 89 in Lebanon, New Hampshire. The project involved removal of delaminated coating and spot preparation of corroded areas to bare metal. The existing coating system was a three-coat system consisting of red lead primer applied over mill scale, an alkyd midcoat, and an alkyd topcoat. The contractor performing the work was Vermont Non-Destructive Inc., Jericho, VT. This project utilized a National Liquid Blasting (NLB) pump capable of a flow rate of 2.5 gpm when operated at its maximum output pressure of 36,000 psi. If multiple waterjetting lances are used on the same pump, the flow rate is distributed equally among each waterjetting lance, while the output pressure remains constant. All of the waterjetting equipment was supplied by Commonwealth Waterjetting Group, Jamestown, RI. Commonwealth also provided training and technical support since this was the first time the contractor performed UHP waterjetting. Lances with rotating heads of four (4) nozzles were used. The contractor used three workers as blasters, who rotated in order to have a consistent crew of two (2) blasters and one (1) helper at all times. An additional helper was available, but did not perform any waterjetting.

Lift truck staging with a deck area of ten feet by twenty-eight feet was used. The containment consisted of tarps hung loosely around three sides of the lift truck and a large tarp on the ground off the fourth side of the truck on the shoulder of the road. Water drained down through the decking area and was funneled into large holding tanks in the back of the truck. Water that had escaped the staging area was collected on the tarp on the ground and vacuumed into the holding tanks.

[1] SSPC SP-12/NACE No. 5 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating, SSPC Publication No. 96-05.

Quebec, Canada: restoration of all bridge steel by LP & UHP waterjetting, as determined by the specification, followed by overcoating using a Calcium Sulfonate Alkyd coating system

The second project observation was on the Quebec Bridge in Quebec City, Quebec. This structure is the longest cantilever truss structure in the world with over 7.5 million square feet of structural steel. The existing coating system was comprised of several layers of aged red-lead primer and green alkyd topcoat. In some cases, the coating measured up to 50 mils thick. The coating was 40-50% deteriorated in most areas, and in some areas up to 100% deteriorated. The contractor for this project was Nor-Lag Coatings LTD., Pointe-Claire, Quebec. This project involved spot preparation of corroded areas and removal of loosely adherent coating using Ultrahigh-Pressure Waterjetting in areas 15 feet above and below the road deck (defined as the “Splash Zone” – the area of concentrated road salt usage). All other areas were prepared using low pressure water washing (5,000-10,000 psi). The contractor utilized a Flow Husky UHP pump capable of a flow rate of 6.5 gpm at its maximum output pressure of 40,000 psi. The flow rate was distributed equally among each lance, similar to the NLB equipment. Each lance had five (5) nozzles on a rotating head. For the low pressure work, the contractor used four (4) small capacity pumps, powered by five (5) hp motors, one for each worker.

Due to the structure’s complex geometry, tubular frame and platform scaffolding was necessary for staging. For areas under the roadway, the scaffolding was erected on corrugated steel sheeting that was attached to the bridge. For the upper chords of the bridge, the scaffolding was constructed from the top down, suspended from the upper chords. This scaffolding was under construction during the visit, so access was restricted. Tarps hung on the outside edges of the scaffolding contained the work area. Cleaning water was contained and diverted to holes in the corrugated steel sheeting where a geotextile material filtered the water.

Franconia Notch Parkway, New Hampshire: UHP Waterjetting followed by Repainting of Bridge Fascia Beams

Though a site visit was not made, a third data point was obtained from a project in New Hampshire where seven bridges on the Franconia Notch Parkway were waterjetted with UHP water to remove coating from the fascia beams. Modern Protective Coatings, Inc. from Windham, NH was the contractor for this project. The specification called for WJ-4 spot preparation on the webs and top flanges and WJ-2 full removal on the bottom flanges. Data was supplied by the contractor in the form of photographs, inspector data sheets, and daily work logs. Modern Protective Coatings, Inc. used the same equipment, supplied by Commonwealth Waterjetting Group, as Vermont Non-Destructive Inc. used on the Rt. 89 overpass in Lebanon, NH.

Throgs Neck Bridge, New York City: UHP waterjetting within containment, followed by a 3-coat paint system

Work was also observed on the toll booth structures for this large metropolitan facility where all existing coatings were being removed for repainting. Surfaces included the steel sides and miscellaneous structures around the tollbooths and the underside of the canopies over the booths (which were coated with a baked on factory finish that had since been field maintenance painted). The tollbooths and canopies were specified to be cleaned to WJ-2 and other miscellaneous surfaces were to be cleaned to WJ-4.

While the configurations of this work are not the same as repainting a highway bridge, many of the same concerns arise. Work was conducted during the night shift only as each tollbooth was needed for operation during the day. Full containment with impenetrable walls was constructed and dismantled each night.

RESULTS & DISCUSSION

Lebanon, New Hampshire

The production rate observed for waterjetting in New Hampshire was approximately 142 ft^2/man-hr. This rate was an average of production runs observed over the west abutment span and six moves of the lift truck. Each move of the lift truck covered approximately 305 ft^2 of structural steel. Two blasters worked simultaneously. For safety reasons, the blasters were not allowed to work on opposite sides of the same beam at the same time. Approximately 25 percent of the coating was deteriorated on this structure, with the most deteriorated areas being the bottom flanges. The blasters used power tools to touch up any areas that were noted for additional surface preparation by the onsite third party coating inspector.

The total amount of water used on this structure during three days of blasting was 3,500 gallons. The total surface area waterjetted during the three days was ~3,600 ft^2. This equates to a water consumption rate of less than 1 gal/ft^2.

Workers wore rain suits, work gloves, hearing protection, and face shields while waterjetting the surface. During power tool touch up operations, the workers also wore half mask respirators.

Quebec, Canada

The production rates observed on UHP waterjetted areas of the Quebec Bridge were ~171 ft^2/man-hr for easily accessible areas and ~106 ft^2/man-hr for complex lattice areas. The average production rate observed on this bridge was ~138 ft^2/man-hr. These production rates were observed on areas located below the road deck. Production rates were lower on the lattice areas due to their complex geometry. Blasters often had to lie inside the lattice box to waterjet the interior. Water consumption for the UHP waterjetting portion of this project was ~3 gal/ft^2.

Much of the topcoat on the Quebec Bridge was removed exposing an underlying layer of red lead paint. In some of the areas, this red lead paint was adherent and was allowed to remain in accordance with the specification. On the lattices though, most of the coating was completely deteriorated. These areas required thorough waterjetting to remove loose coating and rust scale.

After the surface had dried, some of the "intact" coating that remained began to lift at the edges. This lifting was not noticeable while the surface was still wet. These lifting areas had to be hand scraped prior to coating application. In some areas, moisture was observed coming from joints up to a week after the surface was waterjetted. If coating was applied over these areas before they dried completely, coating failures occurred. Examples of this were seen on areas previously waterjetted and painted. Several areas of rust through were evident on horizontal surfaces.

Workers wore rain suits, gloves, hearing protection, and face shields. The personnel waterjetting wore respiratory protection ranging from nothing, to dust masks, to half mask respirators.

Franconia Notch Parkway, New Hampshire

Though data was not collected by an on-site visit, supplied inspector data sheets, work logs, and conversations with the contractor provided adequate information for reporting purposes.

The contractor had a difficult time removing the zinc primer and, after consultation with the New Hampshire Department of Transportation, areas of adherent zinc primer were left on the surface. The production rate achieved by the contractor for this project was ~96 ft^2/man-hour.

Throgs Neck Bridge, New York City

The production rate observed for waterjetting of the Throgs Neck Bridge tollbooths was approximately 170 ft^2/man-hr. This rate was an average of production observed for one tollbooth and two adjacent canopies. The contained area was approximately 1,780 ft^2 of structural steel. Three blasters worked simultaneously and were able to clean the area within the five hours allotted during the work shift. Approximately 10 percent of the coatings were deteriorated on this structure, with the canopies showing mostly peeling coating and the booths showing "spotty" corrosion. Prior to primer application, the workers used power tools to touch up any areas that were noted for additional surface preparation.

Workers wore hard hats, rain suits, half mask respirators, hearing protection, and face shields while waterjetting the surface. During power tool touch up operations, the workers removed the rain suites and face shields.

Containment was constructed by draping tarps over the edges of the tollbooth canopy to the ground. The pavement was the base of the containment and the tarps were anchored with sandbags. Wastewater was channeled within the containment using sandbags and/or small ridges of clean fill dirt and collected using vacuum equipment.

The production rates observed at the various project sites are listed in table 1. Readers should be aware that the local conditions and configuration of the surfaces being cleaned plays a tremendous amount into the actual production rate. The first three rates listed in table 1 are for spot preparation of existing surfaces. The Franconia location involved a combination of spot preparation and full coating removal. The Throgs Neck location was full coating removal, but was for very large flat plate type areas that were easy to access.

Table 1. Productivity Rates From Various Site Visits

Location	**Productivity (ft^2/hr)**
New Hampshire (Rt. 89)	142
Quebec Bridge (Easily Accessible)	171
Quebec Bridge (Lattice Areas)	106
New Hampshire (Franconia)	96
Throgs Neck Bridge (Tollbooths)	170

General Discussion

An advantageous characteristic of waterjetting is its use of potable fresh water, which thoroughly washes the surface, typically leaving the surface contamination well below acceptable limits.[2] Although it leaves a clean surface, waterjetting does not leave a surface profile. This can be an advantage or a disadvantage depending on the circumstances and criteria required for the project. Waterjetting does not “peen over” pre-existing profiles to possibly trap contaminants like abrasive blasting.

When spot preparation and overcoating is specified, waterjetting is used to “sweep” the surface to find areas of loosely adherent paint. When such areas are found, the blaster can remove the deteriorated coating up to the point of the adherent coating. Waterjetting does not “feather” the cleaned areas into the existing adherent coating the way that abrasive blasting does, so improper waterjetting technique can result in the edges of remaining coating lifting or peeling. This condition requires additional hand/power tooling. It is therefore important that waterjetting workers be properly trained and experienced.

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[2] Kuljian, G. and Melhuish, D. “Water-Jetting Productivity Study for the Marine Industry,” Presented at SSPC-98, Orlando, FL, November 1998.

One of the major hazards to dry abrasive blasters is breathable dust. Waterjetting produces no dust, which means that less personal protective equipment is necessary to maintain adequate worker health and safety. Waterjetting may also allow for less stringent controls for environmental containment. While dust is controlled by waterjetting, the nature of the technology produces a great deal of mist. This mist can obstruct a blasters view, especially in a confined area such as an enclosed lift truck. The mist can be controlled with proper forced ventilation. It is important to note that although lead dust emissions are reduced, they are not eliminated when using waterjetting. Data suggests that waterjetting contributes to the pulverization of lead paint into fine particles that can become suspended in the visible mist. The lead levels sampled during waterjetting never reached the permissible exposure limit of 50 $\mu g/m^3$, however, the measurement techniques may not be optimized to sample water mist.[3]

Weather affects waterjetting different from dry abrasive blasting. Since water is used in the process, there is no need to stop work for rain, fog, etc, unless traffic controls dictate otherwise. Conversely, the primer coating typically requires a dry surface for application. Fastidious attention to blowdown procedures is required. During this time, the bare steel surface may be exposed to contaminants and flash rusting may occur. In some instances, a rust inhibitor is used to hinder the formation of flash rust. The Joint SSPC/NACE Task Group on Surface Preparation is currently reviewing the criteria and requirements for flash rusting, as "light" flash rusting is not considered to have a detrimental impact on the performance of the coating system.

Water can become trapped in joints and under coating that remains on the surface, causing problems when the new coating system is applied. On the Quebec Bridge, rust through was evident in some horizontal areas as little as one month after application of the coating. This was believed to be the result of poor blowdown procedures that left moisture trapped under the edges of remaining coating.

To effectively remove coatings, a specific standoff distance between the nozzle and the surface must be observed. This standoff distance is mainly determined by the level of surface preparation required. SSPC SP-12 recommends a UHP waterjetting standoff distance of ¼"-½" to remove heavy rust scale. The angle of the nozzle with respect to the surface is also a factor in the removal of coatings. Brittle substances can be removed by holding the nozzle perpendicular to the surface while other, more tightly adhered coatings may require the nozzle be held at a sharp angle to peel the coating away.[4]

Automated waterjetting equipment like robotic crawlers work well on flat surfaces like ship hulls and storage tanks. The geometry of many bridges makes the use of such equipment limited at best. With more research and contractor feedback, specialized equipment for the bridge painting industry may make waterjetting even more economical.

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[3] Melhuish, Darren C., Corrpro Companies, Inc. *"On Monitoring Airborne Lead Dust during Water Jetting," Problem Solving Forum,* JPCL (September 1998), 122.

[4] SSPC SP-12/NACE No. 5 Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating, SSPC Publication No. 96-05.

To date there has been little technological improvement in the automated equipment used to waterjet complex structures, such as bridges.

Contractors have expressed significant concerns when using waterjetting equipment. Some are related to productivity, worker safety, operating costs, and equipment maintenance. The following list concisely describes these concerns:

- The typical waterjetting lances are quite "long" compared to abrasive blasting nozzles. This makes working in tight areas difficult and makes it difficult to keep the nozzle perpendicular to the surface in these areas.
- Shorter lances are available, but are more difficult to control. This presents an increased worker safety hazard (high-pressure injection of water into exposed skin is a serious injury). Safety equipment for body protection is available, but is sometimes not preferred by the workers.
- Water filtration must be performed in painstaking detail. This is directly related to wear and tear on the water pump and the orifices in the waterjetting lances. Every contractor consulted was filtering the supply water more frequently and to a smaller particulate than the setup originally supplied with the equipment. This was necessary to extend the useful life of the orifices and to prevent equipment breakdowns.

DISCUSSION (ECONOMIC VALIDITY)

Many factors must be considered when determining the economic impact of a technology on a bridge maintenance painting project. The cost for a maintenance painting project can be broken down into four main areas:

I. Mobilization/Demobilization

II. Coating removal

Productivity
Equipment Cost
Worker and Environment Protection
Waste Disposal

III. Painting

IV. Staging/Containment

In order to validate a technology one must first compare it to the current state-of-practice for a spot repair scenario. A spot repair scenario is defined as preparing areas of corrosion and deteriorated paint to bare substrate while feathering the edges of the transition point from bare area to intact paint. The current state-of-practice for a spot repair scenario is hand-tool/power-tool cleaning. However, in order to make a comparison of waterjetting to the current state-of-practice for a spot repair scenario, consideration must be given to the extent of coating deterioration. The percent of coating deterioration for a structure will determine a technology's particular production rate for that structure.

A cost model that accounts for percent deterioration in spot repair was developed for this FHWA study. This model estimates the entire itemized project cost taking into consideration, mobilization, profit, insurance, and other factors. Since production rates are dependent upon the amount of deterioration, costs are also dependent upon extent of deterioration. This was accounted for in the model by directly relating production rates as a function of coating deterioration. Data from the four technology observations was input in the model. Results of the Cost Model's detailed comparisons are shown in Table 2. The table shows costs for using waterjetting and hand tools/power tools at varying deterioration. This data is also shown graphically in Appendix A.

Table2. Cost comparison of Waterjetting versus Hand/Power Tool Cleaning for a Spot Prepare and Paint Scenario

Structure Size	Percent Area Deteriorated	Hand Tool Cost per ft^2	Waterjetting Cost per ft^2	Structure Size	Percent Area Deteriorated	Hand Tool Cost per ft^2	Waterjetting Cost per ft^2
5,000 ft^2	5%	$11.82	$13.76	**50,000 ft^2**	5%	$2.40	$2.66
	10%	$12.47	$13.78		10%	$3.33	$2.74
	20%	$15.82	$13.81		20%	$5.09	$2.90
	30%	$17.12	$13.85		30%	$7.01	$3.28
7,500 ft^2	5%	$7.96	$9.25	**100,000 ft^2**	5%	$2.02	$2.31
	10%	$8.81	$9.27		10%	$2.97	$2.39
	20%	$11.48	$9.73		20%	$4.68	$2.66
	30%	$13.20	$9.77		30%	$6.49	$2.93
10,000 ft^2	5%	$6.34	$7.32	**200,000 f t^2**	5%	$1.71	$2.00
	10%	$8.02	$7.33		10%	$2.60	$2.11
	20%	$9.63	$7.37		20%	$4.42	$2.28
	30%	$10.93	$7.73		30%	$6.16	$2.55

It can be seen that the cost for spot preparing and overcoating a bridge using waterjetting is significantly lower than using hand and power tools when deterioration is generally above 10%. This data demonstrates that, based on our field observations, waterjetting is a cost-effective means of spot preparation for bridge maintenance painting.

CONCLUSIONS

1. Waterjetting will remove deteriorated coatings and corrosion. Waterjetting will remove soluble contamination to levels below most practical criteria.

2. Waterjetting will not impart an anchor profile on the substrate. It will expose an existing profile. This fact should be considered when specifying waterjetting as the sole source of surface preparation.

3. Waterjetting does not produce dust, but creates a significant amount of water mist. This mist can be controlled using forced ventilation.

4. For spot preparation and overcoating scenarios, the surface must typically be thoroughly dry before the primer coating is applied. Water trapped within the cleaned surfaces can lead to rust through and other defect in the new coating system.

5. Properly trained and experienced waterjetting personnel will contribute greatly to the success and productivity of a UHP waterjetting project.

6. To effectively remove coating and rust scale, a minimum standoff distance between the nozzle and the surface must be observed at all times. The minimum SSPC-SP12 standard acceptable to the Owner must be determined by the Owner in consultation with the Paint Manufacturer and Specifier. These minimum distances and pressures required are determined by the degree of coating deterioration, type of wands and output pressure of the pump.

7. Safety and Training of the waterjetting crew is important. Protective clothing differs from that required by a sandblasting job. Waterjetting personnel require more solid work surfaces to provide adequate footing for the workers, and protective clothing for different work hazards.

8. The addition of water during final surface preparation of a complex geometric structure using bolted or riveted construction, is fact that must be carefully considered when the coating system is selected. Proper procedures must be in place to prevent coating failures related to the surface preparation water.

9. Coating inspection techniques for surfaces cleaned by waterjetting differ from those required for sandblasting work. The proper identification of work surfaces (what surfaces require spot repair) is more difficult, once all surfaces have become wet.

APPENDIX A
GRAPHS

Figure 1. Graphical Representation of % Deterioration versus Cost per Square Foot