# Controlling Lead-Based Paint Emissions During Rehabilitation of the Williamsburg Bridge: A Partnering Approach

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The Williamsburg Bridge Main Cable and Suspension System Rehabilitation Project began in 1991 amid public outcry that the communities surrounding the bridge were being contaminated with lead from construction activities. The Occupational Safety and Health Administration was about to lower the construction lead exposure limit to match industry standards. Intense scrutiny existed at the advent of this project: work was about to begin on a structure containing layers of flaking lead-based paint; in addition, the principal protective coating for the main cables would be a 92 percent pure lead paste, all of which would result in a waste stream containing 100 tons of lead. This project was atypical in the sense that containment activities had to address solid wastes (paint chips) and liquid wastes (preservative oil for main cable work) and had to be implemented at the lofty main cable areas over active traffic, transit, and pedestrian ways. The approach taken to make this project an environmental and contracting success was twofold. The first was to incorporate partnering on an informal basis to attain a common environmental standard with which all of the project's parties could concur. The second was to identify each operation that generated a hazardous material and to develop a specific engineering control to address every activity within the operation, from containment to disposal. Each control was tested and evaluated with the appropriate monitoring methods. Each engineering control ultimately was incorporated into the project's Hazardous Waste and Raw Material Management Plan. This "performance-based" approach allowed the development of a readily accepted environmental plan.

By 1890 in New York City, traffic on the Brooklyn Bridge had exceeded everyone's expectations while ferry traffic across the East River continued to flourish. It was clear that a second crossing was necessary, and in fact one had been proposed in 1883, the same year that the Brooklyn Bridge opened. After being delayed for nearly 12 years by ferry interests, legislation was finally passed on May 27, 1895, to build the Williamsburg Bridge.

Leffert Lefferts Buck was commissioned to design this new crossing in 1896. It would have a clear span of 1,600 ft (488 m), making it the longest suspension bridge in the world. It would be 1½ times wider than the Brooklyn Bridge, carry six rail lines, and "yet no feature of the Brooklyn Bridge was to be copied unless it was impossible to substantially improve upon it" (*1*, p. 31). By comparison, the Williamsburg Bridge would dwarf the Brooklyn Bridge in every regard except for its construction cost. The Williamsburg Bridge would be built for $1 million less than the Brooklyn Bridge even though it used twice the tonnage of steel. Table 1 presents a general comparison of the two bridges.

**TABLE 1 Comparison of Brooklyn Bridge and Williamsburg Bridge Construction Data**

| | Brooklyn Bridge | Williamsburg Bridge |
|---|---|---|
| **Construction Data** | | |
| Construction Commenced | January 3, 1870 | November 7, 1896 |
| Opened to Traffic | May 24, 1883 | December 19, 1903 |
| Total Cost *(a)* | $25,094,577 | $24,188,090 |
| **Physical Characteristics** | | |
| Total Length | 6,016 feet (1,835 m) | 7,308 feet (2,229 m) |
| Length of Main Span | 1,595½ feet (487 m) | 1,600 feet (488 m) |
| Diameter of Cable | 15 3/4 inches (40 cm) | 18 5/8 inches (47 cm) |
| Length of Each Main Cable | 3,578 feet (1,091 m) | 2,985 feet (910 m) |
| Total Length of Wire in 4 Cables | 14,357 miles (23,115 km) | 17,404 miles (28,020 km) |
| Total Weight of Steel | 24,000 tons (21,768 Mg) | 47,800 tons (43,355 Mg) |
| Number of Roadways *(b)* | 2/6 lanes | 4/8 lanes |
| Number of Transit Lines *(b)* | none | 2 |
| Number of Pedestrian Walkways *(b)* | 1 | 1 |

*(a) includes cost of land*
*(b) current configuration differs from the original design*

Numerous economic factors at the time may have played a role in the cost savings. However, many believe that the decision to use nongalvanized wire in the main cable construction contributed greatly to the material savings. This decision, coupled with the early inadequate cable wrapping systems and preventive maintenance, resulted in the premature decay of the main cable suspension system. The corrosion and decay were believed to be so extensive that by the late 1980s, the main cables were suspected to be at the end of their service life (2). This condition led to many studies, a blue-ribbon technical advisory committee, and an international design competition for replacement alternatives. After years of study and debate, the decision was made to salvage the bridge (2).

## Rehabilitation of Williamsburg Bridge

The Williamsburg Bridge will be rehabilitated in essentially four major contracts currently estimated to be valued at $750 million. The first contract, which is the topic of this paper, is nearing 75 percent completion; it addresses the rehabilitation of the main cables and suspension system. The remaining three contracts will reconstruct the superstructure areas in longitudinal "slices"—first the south roadways, then the transit tracks in the center of the bridge, and finally the north roadways. This reconstruction work will be a hybrid in which the approaches to the bridge will be demolished completely and rebuilt from the foundations up, while the main bridge areas will be repaired and redecked with a new orthotropic deck system.

The work under the current contract rehabilitates the four main cables from anchorage to anchorage and replaces all of the main bridge suspenders. The suspender replacements are direct in the sense that no temporary suspenders are required. As one suspender is removed, a new suspender is installed and jacked to the same load as the existing suspender was measured to contain. The only exception is that if an unusually high or low suspender load is found, then 156 kips (695 kN) is used as the new suspender load.

The main cable rehabilitation work has been much more involved, requiring the erection and use of footwalks below each of the main cables to conduct the work. The main cable rehabilitation work generally proceeds in "bays" 20 ft (6 m) long, each bay centered on an existing cable band. The cable bands are steel castings that carry the suspenders on the main span. However, since the end spans are not suspended, these castings merely act as stay bands. Work begins by removing the cable band casting (and suspender) and the outer wire wrapping to expose the main cable wires. The exposed wires within the bay are cleaned of the old lead paste, previously applied preservative oils, and cor-

rosion by-products. The main cable is then opened into "slots" by driving wooden or plastic wedges in a radial pattern into the cable at 18-in. (45-cm) intervals; Figure 1 shows details of this arrangement. Raw linseed oil is poured into these slots and allowed to penetrate into the interior wire areas of the cable. Waste oil is collected using a series of troughs, hoses, and drums.

After the 20-ft (6-m) section of cable has been saturated with oil, the wedges are removed and any broken outer wires are repaired by splicing lengths of new bridge wire in place. Following these repairs, the cable is recompacted using a four-part hydraulic compactor, "squeezing" the main cable at 1-ft (30-cm) intervals, and applying temporary strapping material to maintain the compacted shape. A new cable band casting is installed, and, where applicable, a new suspender is positioned and loaded. These series of operations were repeated along the entire length of each cable, beginning at the low areas of the cable and proceeding to the towers.

After the oiling operation, crews installed the main cable protection systems on the rehabilitated areas. The first level of protection for the main cable is a thick, red lead paste consisting of 92 percent pure lead oxide powder and 8 percent linseed oil. The paste is applied to the outer main cable wires before wire wrapping. Custom-designed wire wrapping machines spirally apply No. 9 (4-mm) wrapping wire onto this red lead paste "bedding" from casting to casting. This operation is illustrated in Figure 2.

The final protective measure for the main cable areas is a neoprene system applied over the wire wrapping. Three coats of liquid neoprene are painted over the wire wrap and sheets of ⅛-in. (3-mm) neoprene 6 in. (15 cm) wide are wrapped spirally in an overlapping fashion from cable band to cable band. The neoprene system is finally coated with three applications of liquid chlorosulfonated polyethylene, or Hypalon.

Clearly, each of the cable operations created a waste stream that included dislodged paint chips, lead-contaminated linseed oil (collected from the oiling work), and red lead-coated rags, and protective suits.

## Lead and the Williamsburg Bridge

The Williamsburg Bridge does not differ substantially from most bridges of its era with regard to lead-based coatings. The coatings on the original (nonrehabilitated) members contained 42 percent total lead and 8,500 ppm as determined by the toxicity characteristic leaching procedure (TCLP) (Eder Associates, unpublished data). Lead paint debris is classified as hazardous because of its toxicity. If five mg/L of lead or more is extracted from the debris when tested by TCLP, the debris is considered hazardous. The cable areas, once unwrapped, have a dried layer of old red lead paste mixed with a variety of preservative materials ranging from graphite compounds to fish oil. Samples of these materials have been found to contain 29.2 percent total lead (CONSAD Research Corporation, unpublished data).

Unfortunately, not all of the lead associated with the painted areas of the bridge stayed on the structure. Since the last large-scale painting effort, approximately 15 years ago, the bridge generally exhibits flaking, peeling, and debonded paint coatings that are shaken free of the structure with literally every passage of a subway train. These paint chips have fallen and accumulated in the soils beneath the bridge and on the rooftops and in playgrounds adjoining the bridge. Lead accumulations in these areas are also suspected to be linked to leaded fuel emissions originating from the hundreds of thousands of vehicles using the bridge each year. Studies by the New York City Department of Transportation (NYCDOT) have found the lead content in some soils directly beneath the bridge to be 2,020 ppm and that in rooftop samples to be 63 ppm (GRB Environmental Services, unpublished data). The Environmental Protection Agency's (EPA's) interim guidance for establishing lead clean-up levels at Superfund sites is 500 to 1,000 ppm total lead and is used when the corrected or predicted land use is residential.

But the most problematic emission source, which attracted the greatest media and public attention, was construction activities—in particular abrasive blasting for repair or bridge painting operations. As a result of a poorly contained maintenance painting and abrasive blasting operation (a separate contract) in spring 1992 that affected the community adjoining the bridge in Brooklyn, extremely negative attention was directed to the Williamsburg Bridge just before the start-up of the cable rehabilitation. The media focused on the elevated lead levels in the soils, on roofs, and in the playgrounds, and not only of the Williamsburg Bridge but of numerous bridge facilities throughout the New York metropolitan area. Abrasive blasting and related bridge painting work on public works projects was virtually stopped for 18 months until dramatic changes in containment and monitoring practices were instituted. This was certainly not the climate in which to begin a project that would generate a high volume of lead waste and require the application of nearly pure lead (red lead paste for the wire wrapping work) as a protective coating.

The main question at the time was, How will the contractor perform the work required and ensure that the communities and areas adjoining the bridge were being protected? Ancillary to that question was, How

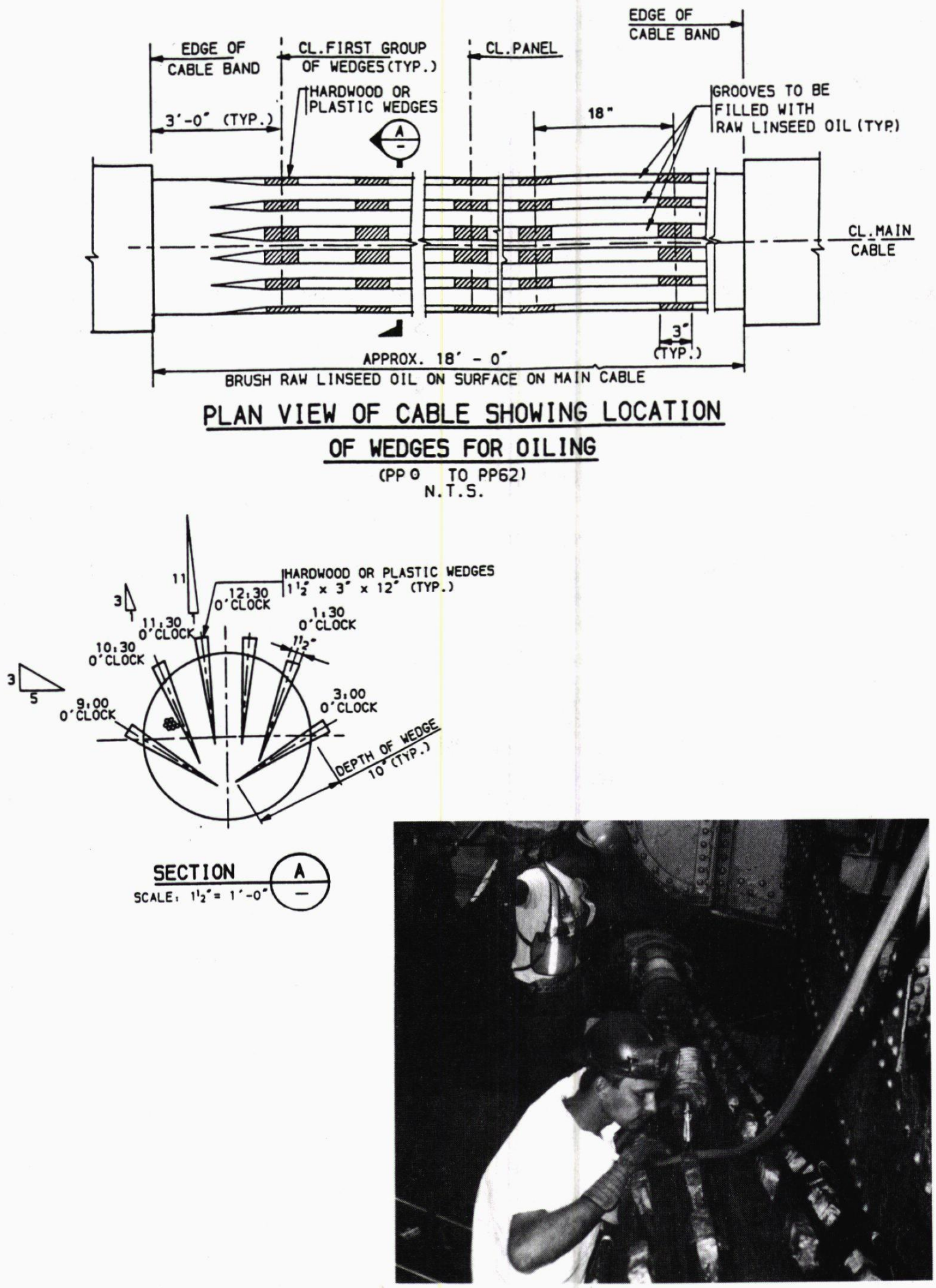



**FIGURE 1** **Typical main cable wedging arrangement.**

will it be done cost-effectively? Contract specifications and language cited guidelines for worker safety and requirements for handling and disposing of lead. However, very little was specified regarding work practices and containment levels other than to assign responsibility to the contractor. Outside the contract specifications, NYCDOT developed its Lead Paint Removal Protocol to address the removal of lead-based paints from its structures in the wake of the 1992 Williamsburg Bridge painting incident. But this document was geared toward removal for bridge painting and localized repair work and did not apply to the type of work involved in the cable rehabilitation. What was needed was a specific work plan that was developed with the contractor to be cost-effective and that addressed the unique nature of the cable rehabilitation work.

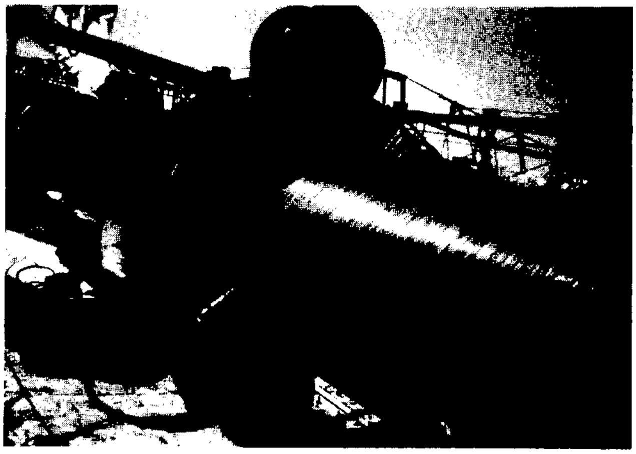


FIGURE 2 Wire wrapping main cable areas.

## Hazardous Waste and Raw Material Management Plan

The objectives of the Hazardous Waste and Raw Material Management Plan (HWRMMP) were to identify the individual hazardous waste emission sources on an operation-by-operation basis and to develop engineering controls to contain the waste within acceptable levels. In addition, procedures were developed to control the handling of waste products from the point of generation to the storage areas. Each procedure was tested on the bridge using the workers who ultimately would perform the day-to-day rehabilitation work. This test served as an initial training session and afforded an opportunity to perform the appropriate monitoring activity to assess the effectiveness of the control and handling procedures. Once acceptable, the procedure was incorporated into the HWRMMP manual. The various New York City agencies and community groups would have the assurances of a tested work plan for handling and controlling the project's lead-based materials.

A key element of this process was that each engineering control was developed jointly with the contractor, the project's environmental engineering firm, and the construction inspection firm. It was agreed to perform this development work under an informal partnering agreement to expedite the development process and to become as cost-effective as possible to both the owner (NYCDOT) and the contractor. As each engineering control was developed, it was judged whether the additional cost would be borne by the owner or whether the control was inherent to the contract work and therefore accommodated in the contractor's original bid price. Having these discussions during the development of the HWRMMP has mitigated any post-project claims; to date the project is claim-free.

As previously outlined, the main cable areas were unwrapped, the cable was wedged open for the application of oil, and the cable was rewrapped using both a wire wrap and neoprene jacketing system. In addition, all of the cable bands and suspenders were removed and replaced. Plan development began by identifying each work activity along with the hazardous waste that it would generate. The next task was to develop an engineering control or containment structure for each activity. Tables 2 and 3 present summaries of the main cable rehabilitation activities, the generated wastes, and a brief description of the containment method. The final task was to develop a procedure for transporting waste containing flaking paint or dripping oils in areas over active traffic to the storage areas at roadway level.

It was important to identify the tasks requiring containment because of the linear constraints posed by the footwalks. Since almost all of the cable work was performed from these footwalks, which also served as an access way for workers and equipment, containment areas had to be at the "top end" of the rehabilitation cycle. It would be impractical to have workers continually moving through the containment areas to access other operations. After the data presented in Tables 2 and 3 were compiled, it was apparent that in the typical work progression for a span of main cable, the wrapping and cleaning would have to proceed uninterrupted ahead of the oiling operations, followed by the wire wrapping. However, the cleaning for the neoprene system would require stricter containment and consequently, cleaning for neoprene could not begin until the unwrap-oil-wrap cycle was complete. The main cable rehabilitation schedule would be driven essentially by the unwrapping and cleaning operations and the ability to move a containment structure efficiently along the footwalks.

### Wire Wrapping Removal and Cleaning Operations

The first construction activity in the cable rehabilitation cycle is to remove the spirally applied wire wrapping and clean the outer main cable wires of corrosion and remnant protective coating products. The wrapping wire was coated with many layers of flaking lead-based paint, and the cable wires contained a variety of dried materials such as lead paste, fish and linseed oils, and, in some areas, more lead-based paint.

To remove the wire wrapping, the wire was initially chisel-cut to loosen an area of it. The wire was loosened in an area approximately 6 in. (15 cm) long and cut with snips along this length. The bundle was opened from the cut line (in the shape of a large C) and removed from the cable. This process was repeated until

**TABLE 2 Summary of Cable Rehabilitation Operations, Generated Wastes, and Containment Methods: Main Cable Operations**

| Rehabilitation Operation | Generated Waste | Containment Methods |
|---|---|---|
| Existing Wire Wrapping Removal | Moderately-sized flakes of lead-based paint with some lead contaminated dust released from underlying dried coating. | *1st level* - pouch tarp to catch paint chips.<br>*2nd level* - floor tarp placed on footwalk to catch any errant chips.<br>*3rd level* - tarped sides and roof around cable to act as a secondary containment and wind block. |
| Cleaning Main Cable Wires | Fine dust containing lead and various preservative materials such as graphite and fish oil. | Same as wire wrapping removal only with pouch lowered for access to underside of cable and door flaps closed for dust containment. |
| Main Cable Wedging | Some small sized pieces of corrosion product commingled with dried lead paste. | Footwalk floor tarp to catch waste with wind blocks when necessary. |
| Main Cable Oiling | Lead contaminated oil. | Metal and plastic catch pans with a hose bib connected on downhill side. Hoses were connected to troughs and emptied into containment drums located at roadway level. |
| Compacting Oiled Cable Section | Lead contaminated oil as cable is squeezed. | Same as main cable oiling. Once compacted, cable is wrapped with plastic shrink wrap and the trough is removed. |
| Wire Wrapping | Red lead paste contaminated rags, tyvek suits, tarps, empty containers, etc. | Burlap faced tarps (burlene) used as floor tarps to catch any drips. Also, burlap used to prevent "tracking" of any red-lead by continually wiping the worker's boots. |
| Cleaning Wire Wrap for Neoprene Jacketing System | Lead dust generated by grinding excess (dried) red lead paste from wire wrap. | Floor tarps and tent arrangement similar to that used for wire wrapping removal. |

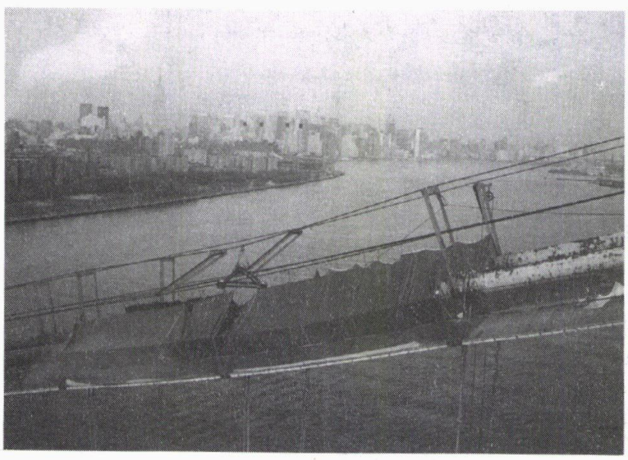
**TABLE 3 Summary of Cable Rehabilitation Operations, Generated Wastes, and Containment Methods: Suspender Replacements**

| Rehabilitation Operation | Generated Waste | Containment Methods |
|---|---|---|
| Cable Band Removal | Small amounts of lead-based paint chips. | Floor tarps to catch chips and when applicable, side wind block tarp. |
| Suspender Removal | Large amounts of paint chips as the suspender flexes and is lowered to the roadway. | Plastic shrink wrap applied to the entire length of each suspender. |
| New Cable Band Installation (upper attachment for new suspender) | Lead contaminated rags, clothing, etc. as in the wire wrapping operation. The casting is set in a thick bedding of red lead paste. | Same as wire wrapping containment. |
| Suspender Installation | None | None |
| Removal and Replacement of the suspender/truss connection (lower attachment for suspender) | Paint chips resulting from cleaning to bare metal for new steel connection. Some minor lead fume from torch cutting. Paint is generally removed prior to cutting, however, there are some inaccessible areas inside the truss framing where the paint cannot be fully removed. | Tarp containment structure to catch paint chips. This containment is built on the underdeck traveling maintenance and inspection platform. HEPA vacuum system to remove lead paint fume. |

the area from one cable band to the next was free of wrapping wire. When the outer wires were exposed, they were cleaned by scraping the heavy deposits and then using a power tool (wire wheel).

Hazardous waste was generated in copious amounts and ranged from large flakes of lead-based paint as the wire wrap was bent and removed to a fine dust containing lead particles from the power tool cleaning. The containment structure devised for this work was constructed primarily from tarps and secured to the footwalk and footwalk "high lines." These high lines doubled as hand-ropes and a system to move (slide) the heavy compacting and wire wrapping equipment. Figure 3 illustrates the general arrangement on the footwalk areas.

The tarp containment structure has three basic components and levels of protection. The first containment level consists of a tarp "pouch," which is suspended approximately 1 ft from the main cable. This pouch is used to catch the large chips coming from the wire wrap



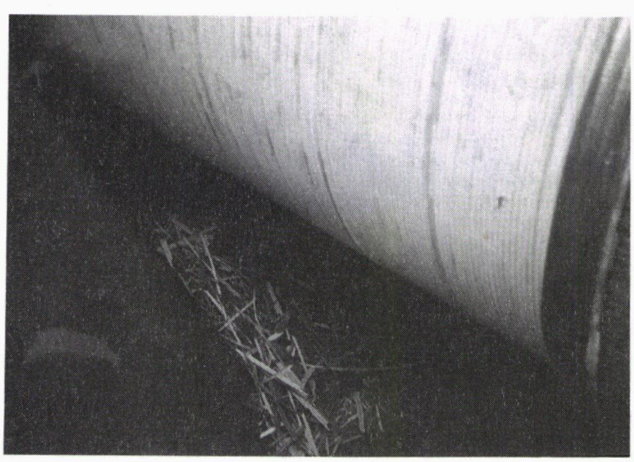


**FIGURE 3 Containment system for wire wrapping removal and cleaning operations (*top*); paint chips contained in tarp pouch below main cable (*bottom*).**

and to temporarily hold the wire wrapping bundles as they are removed. This collection method is also illustrated in Figure 3. The second level of containment is a floor tarp placed directly on the wooden footwalk planking. This tarp also wraps up the sides of the footwalk side rails. This tarp is used to catch any chips that miss the pouch. The third level of containment addresses the high winds experienced at the cable areas. These windblocks are again tarps, affixed to the footwalk rails and high lines; they serve as a tent over the other containment measures to keep dust and chips from blowing from the work areas. These windblocks also extend across the footwalks to form "flap" doors to provide full containment. This containment system afforded a simple, inexpensive, yet effective method to contain the generated wastes and was readily moved along the footwalks as work progressed. The only precursor to moving this system was that it was vacuumed with a high-efficiency particulate air (HEPA) filtered vacuum to prevent the release of any loosely adhering dust particles.

Worker safety inside these tarped structures was provided with half-face respirators and disposable tyvek suits. Air monitoring was conducted inside the containment areas using MSA Flowlite low flow pumps with 37-mm filter cassettes and calibrated at 2 L/min. Lead concentrations in these areas ranged from 0.71 to 4.63 $\mu g/m^3$ during the power tool cleaning activities (Eder Associates, unpublished data). It should be noted that at the time of this sampling, the Occupational Safety and Health Administration's (OSHA's) regulatory limit was 200 $\mu g/m^3$ (*3*). These results were well below this standard and below OSHA's interim final rule established at 50 $\mu g/m^3$ in June 1993 (*4*). Outside of the containment areas, no particulates were detected above ambient conditions using real-time monitoring equipment.

Waste material handling procedures were developed to convey the paint chips safely from the containment area to disposal drums several hundred feet below, at roadway level. Most of the waste wire wrap and chips were contained in the tarp pouch below the cable. Dislodged paint chips were put into nylon bags at the point of generation, and the bags and wire wrap were placed in a lightweight plastic tub. The tub was lowered by a crane line to a tarped receiving area at roadway level. The contents were emptied into the disposal drum and the drum manifested for disposal. After the pouches were emptied, the interior of the containment structure was vacuumed clean with a HEPA vacuum.

## Main Cable Wedging, Oiling, and Compacting Operations

Following the cleaning crews were the wedging, oiling, and recompaction operations. Hardwood or plastic

wedges were driven into 20-ft (6-m) sections of main cable after the cable band casting within the 20-ft (6-m) bay was removed. The wedges were driven manually with hammers in a radial pattern, as shown in Figure 1, so that oil could be introduced into the central areas of the cable. Raw linseed oil was poured into the slots created by the wedges at a rate of 1 gal/linear ft and allowed to penetrate the interior areas. After the cable was oiled, a hydraulically activated compactor was used at 1-ft intervals to compact the main cable wires back to a reduced diameter. The cable was held in this compacted shape with temporary metal strapping. The final operation, performed in a 20-ft bay, was to install a new cable band on a bedding of red lead paste.

These operations created a wide variety of wastes; fortunately, none of them were readily airborne, and the need for full containment was mitigated. The containment system did have to address both solid (corrosion products and red lead-contaminated materials) and liquid (used linseed oil) waste. As the wedges were driven into the cable, the wires moved from their compacted positions and released moderate quantities of corrosion products, old lead paste, and many dried preservative compounds. Containment for this work was accomplished with floor tarps similar to those used in the cleaning containment system. Windblocks were used as necessary to keep the materials within the floor tarp areas.

Linseed oil was poured into the cable from self-capping 5-gal containers. Oil generally dripped from the bottom of the cable section being oiled, but it did travel to lower areas and drip from the new cable bands. To minimize this, bungee cords coated with petrolatum (petroleum-based jelly) were placed radially on the cable at the lower end of the bay being oiled to create a drip point. Metal troughs were used below the cable to catch the oil, which was then piped through hoses to disposal drums at roadway level. In the cases in which oil was observed leaking from the lower castings, half barrels were fitted up to the casting to collect oil. These barrels were drained periodically to the trough system.

The contractor originally had intended to collect and recycle the linseed oil for a paint manufacturer. However, the paint manufacturer elected to perform a series of tests to determine the quality of the oil for recycling purposes and, in doing so, detected small amounts of lead. This lead evidently went into suspension as the oil penetrated and traveled through the cable areas. The lead concentrations were low, 8 to 22 ppm (Eder Associates, unpublished data), but they were above the allowable 5 ppm and the waste oil was characterized as a hazardous waste. All of the applicable regulations pertaining to the storage, transportation, and disposal were incorporated into the waste handling procedures. This included secondary containment barrels, as illustrated in Figure 4, for the waste oil drums stored at roadway level and a fully documented spill response plan.

## Suspender Removal and Replacement Operations

The suspenders were replaced one at a time, and five suspenders had to be in place between adjacent removals. The suspenders were unloaded using large impact wrenches to loosen the tension rod nuts, and the suspender was lowered to the roadway using a crane line. With the existing connection clear, structural modifications were performed at the lower attachment point at the truss chord level. Once the cable work at the upper attachment point was completed, a new suspender was hoisted into position and loaded with a hydraulic jacking system.

Full containment for the suspender removal and truss chord connections was required in two very different configurations. The lead-based paint was flaking pro-

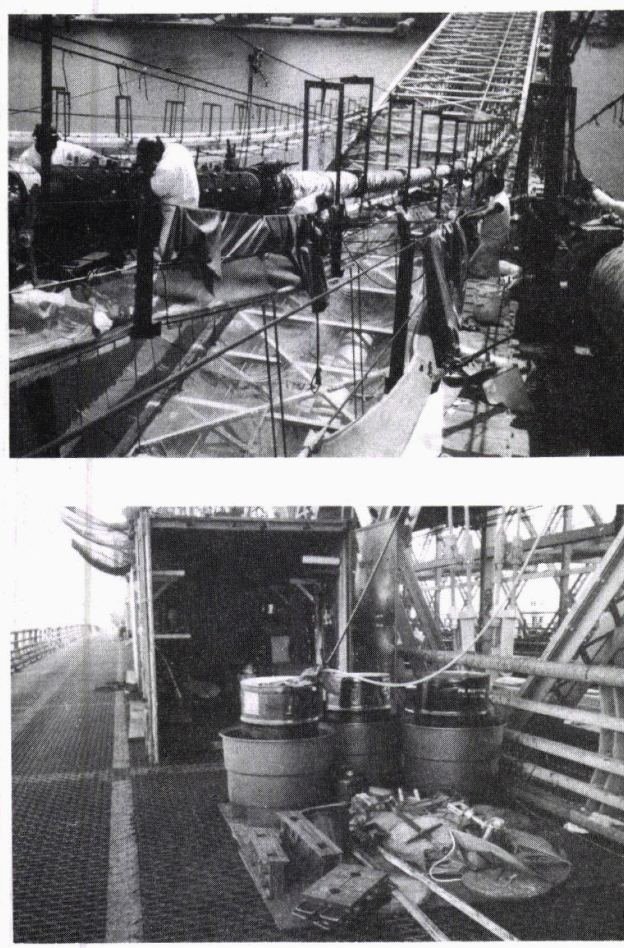


**FIGURE 4 Containment system for main cable oiling: *top*, troughs for dripping oil; *bottom*, oil conveyed by hoses to disposal drums.**

fusely from the suspender areas as a result of badly deteriorated paint coatings. Several efforts were made to contain the paint chips, beginning with a large footprint of tarps at roadway level to catch chips as the suspender was lowered. As it flexed and curled onto the roadway, the suspender literally rained flakes of paint. This method was abandoned on the first attempt. The next idea considered was a tarp "jacket" loosely fitted to the suspender and hoisted along its length to contain the flaking material and to direct it onto a tarp at roadway level. This approach was abandoned because of its unwieldy nature when applied to the very long suspenders.

The solution was to completely encapsulate the entire length of the suspender ropes with a plastic shrink wrap material. The application of this material is illustrated in Figure 5, along with the lowering operation. As the suspender was lowered, the paint chips were contained in the plastic wrap, and the handling operations were conducted chip-free as long as care was exercised so as not to tear the wrapping. Lowered suspenders were cut into manageable pieces at the point of removal. The cut sections were unwrapped at the designated disposal area, and the dislodged paint chips were collected in disposal drums.

The lower suspender attachment consisted of a pinned structural connection to the existing lower truss chord. The existing connection was removed by removing rivets and torch-cutting several plates from the chord area. The truss chord web areas were cleaned of paint in the faying surface areas, and the new connection was bolted in place. This work was performed in the underdeck areas, and access was afforded from a motorized maintenance platform that ran the length of the main span on traveler rails.

The primary waste from this operation was lead-based paint chips, generated during the removal of the existing suspender connection and from power tool cleaning in the faying areas for the new components. In addition, vaporized lead was released occasionally during the torch-cutting work where lead-based paints

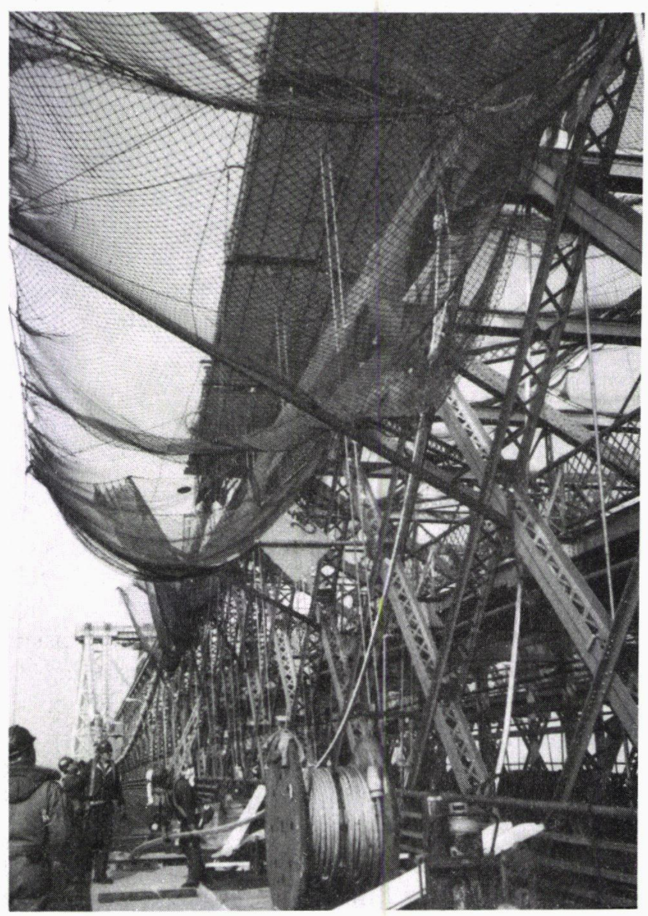


**FIGURE 5 Paint chip containment for suspender removal operations: *left*, shrink wrap being applied to suspender from movable scaffolding; *right*, plastic-wrapped suspender being lowered to roadway level.**

could not be fully removed before cutting. Not all of the paint was accessible within the tight confines of the truss chord.

Full containment was required for these operations and was extremely difficult to attain because of the need to continually move the containment and the numerous penetrations that were required for the bridge's structural framing. Tarps again were used to facilitate the continual remobilizations and to accommodate the variety of configurations presented by the framing. The traveling platform floor grating and sidewalls were first covered with plywood, and floor tarps were affixed to the plywood. When the traveler was in position under the connection being replaced, side tarps were raised and secured to the framing to create a containment structure. This configuration was used for power cleaning and the required level of worker protection was half-face respirators with protective tyvek suits. When torch cutting was planned, a roof tarp was positioned over the top of the bottom chord and a HEPA vacuum nozzle was fitted into the containment area. As cutting progressed, any lead fume was captured and filtered with the HEPA vacuum system. During the cutting operations, workers were required to use full-face masks with supplied breathing air.

Since the containment structure was below the bridge and directly adjacent to roadways in which traffic was generally slow or stopped, public exposure was an added concern. Air monitoring was conducted both inside the containment and at roadway level to ensure public safety. Real-time monitoring was performed using a miniram particulate dust indicator so that any releases could be detected and corrected immediately. Typical readings adjacent to traffic for the cleaning operations were 0.0 to 0.07 $\mu g/m^3$.

### Wire Wrapping and Cleaning for Neoprene Operations

Once the cable rehabilitation work was complete, new protective coatings were applied to the exposed cable areas. The first level of protection was a spirally applied wire wrapping seated in a thick bed of red lead paste. This paste was used as a dense, malleable coating on the outer wires and served to protect against water intrusion in the event of a break or a gap in adjacent wrapping wires. Lead paste was considered to be the optimum material to seal the ungalvanized main cable wires since it is relatively inert and would not promote galvanic action or otherwise present a dissimilar metals condition within the cable. A neoprene jacket was applied to the wire wrapping by coating it with liquid neoprene, spirally wrapping neoprene sheetstock onto this coating, and top coating with Hypalon paint.

The principal waste generated by these operations is red lead. The wire wrapping wastes were in the form of contaminated rags, protective suits, tarps, empty red lead containers, and virtually anything that the lead touched. The secondary waste was generated during the power tool cleaning work and consisted of a fine red lead dust. As the wrapping wire was applied, the red lead squeezed out between the wires and contaminated the outer surface. Most of this paste was wiped clean; however, a fine residue eventually dried on the wire wrap. Before the application of the liquid neoprene, the wrapping was wire-wheel abraded and a fine dust was released. The containment for the cleaning operations after wire wrapping was straightforward in that it was identical to the cable cleaning operations (after removing existing wire wrap). The same waste characteristic was exhibited—a fine dust-containing lead.

The containment for the wire wrapping was similar to that of the wedging and oiling work with the use of burlap-faced tarps rather than plain plastic tarps. These tarps serve a dual function in that they contain any dropped or spattered material in the work area, and with the burlap surface, settled dust is trapped in the fabric and the workers' boots are wiped continually. This dramatically reduces the tracking of lead to other areas on the bridge. Every attempt was made to keep the red lead paste migration to a minimum. Of all of the generated wastes, red lead paste is the most difficult to control. It cannot be swept or vacuumed, and it does not readily wipe off of surfaces. Because of its superior adherence properties and extremely high lead content, the greatest risk to workers is ingestion. Worker training was essential to inform the crews of the need to completely remove any paste from their hands before eating, to dispose of all contaminated clothing, and even to keep their work clothes on site and not at home. Work clothes containing minor amounts of lead paste could contaminate other clothing in the household wash.

## Conclusion

The HWRMMP has played a major role in the success of the main cable rehabilitation project. With the main cable work nearing completion, there has been no negative media coverage, work stoppages, or community opposition. To date, 105 tons (95 Mg) of solid hazardous waste and 12,500 gal (47 300 L) of contaminated oil has been collected safely, manifested, and shipped off site.

It has been traditional to specify a certain level of containment for a project and add the contractual language to place the environmental responsibility on the contractor under a lump-sum bid price. This results in

either a high cost for the environmental portion of the contract or, when underbid, an inordinate number of claims for changes in scope.

A key element of the approach taken on the Williamsburg Bridge Main Cable Project was its focus on identifying the emission sources and preparing a performance-based approach to the environmental issues. The project's environmental consultant, the construction manager, the owner, and the contractor must work together in preparing this plan. Sufficient time must be included in the mobilization phase of the project to perform the testing and demonstrations necessary to the plan development. The owner must be willing to allocate the additional funds for the development phase and consider it an investment given the potential for large losses should a public health problem occur. The owner should also consider new payment methods. Instead of a unit bid price or lump-sum bid price arrangement, an estimated amount should be set aside and stated in the bid documents as a fixed-price lump sum. During the plan development stage and the actual work phases, the contractor is paid from this fixed-price account or on a time, material, and equipment basis. Any unanticipated scope changes are readily accommodated.

The next phase of the Williamsburg Bridge will begin in 1995 and will have the challenge of demolishing nearly 1 mi of elevated approach structure. These approaches are coated with lead-based paints and lie directly adjacent to the communities' residences, schools, and playgrounds. Work has already begun on developing a performance-based approach for the demolition effort and for containing and handling all the project's hazardous materials.

## ACKNOWLEDGMENT

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