CHAPTER 7: BRIDGE MAINTENANCE

Bridge construction and rehabilitation projects are complicated by the environmental sensitivities of working in riparian areas, including restricted work times to accommodate spawning periods of various aquatic species. The majority of the steel bridges in the interstate highway system were constructed between 1950 and 1980; up until the mid 1970s, virtually all steel bridges were protected from corrosion by three to five thin coats of lead and chromate containing alkyd paints, creating dramatic complexity and cost increases for major and routine level bridge paint maintenance. Lead-based paint abatement and the related issues of environmental, worker, and public protection came to the forefront of the maintenance painting industry in the mid-1980s to early 1990s when regulations on hazardous waste disposal and lead exposure to workers were promulgated by EPA and the Occupational Safety and Health Administration. The changes wrought by these rules still shape the direction of maintenance painting in the bridge industry.

NHI has developed a training course, “Hazardous Bridge Coatings: Design & Management of Maintenance & Removal Operations - NHI Course # 13069” for FHWA and State bridge engineers in the area of bridge coatings maintenance and specification. This course includes guidance on coatings selection, surface preparation specification, and environmental and worker safety issues and covers some of the information in a number of the following sections.

In addition to coatings and coating removals, bridge maintenance activities include repairing bent or damaged steel beams, cracked or spalled concrete, damaged expansion joints, and bent or damaged railings. These activities can entail operation of support vehicles and equipment, pavement repair, welding and grinding operations, and associated pollutants. Environmental stewardship practices under paving, structural pavement failure (digouts), pavement grinding, and concrete slab and spall repairs may be pertinent for bridge repairs.

7.1. Preventative Bridge Maintenance Practices

Preventative bridge maintenance avoids larger scale work in stream environments, and thus makes sense from the standpoint of stewardship of both natural and financial resources. Preventive maintenance is defined as a planned strategy of cost-effective treatments applied at the proper time to preserve and extend the useful life of a bridge. Bridge maintenance encompasses:

1. Cleaning activities, including annual water flush of all decks, drains, bearings, joints, pier caps, abutment seats, concrete rails, and parapets each spring.

2. Preventive maintenance activities such as painting, coating and sealant applications and for routine, minor deck patching and railing repairs.

3. Technical and specialized repairs, including jacking up the structures, crack repairs, epoxy injection, repairing or adjusting bearing systems, repair and sealing of expansion joints, repair or reinforcement of main structural members to include stringers, beams, piers, pier and pile cap, abutments and footings, underwater repairs, major deck repairs, and major applications of
coatings and sealants.

4 Stream channel maintenance including debris removal, stabilizing banks and correcting erosion problems.

Life Cycle Decisionmaking and Accounting for Ecological Risks

Transportation Asset Management is driven by policy and performance and considers alternatives and trade-offs, evaluating competing projects and services based on cost-effectiveness and anticipated impact on system performance. As such it employs systematic, consistent business processes and decision criteria and makes good use of information and analytic procedures.

In order to maintain and repair bridges within limited budgets, DOTs are establishing procedures for early detection of problems, timely repair, good preventative maintenance routines, and consideration of long term effectiveness of dollars spent. NCHRP Report 483-Bridge Life Cycle Cost Analysis. Part one establishes guidelines and standardizes procedures for conducting life-cycle costing. Part two is the guidance manual for using the software to evaluate maintenance, repair, and new bridge alternatives. The AASHTO bridge management software, Pontis, can be used to: inventory elements of a bridge (such as coated steel girders); run deterioration and cost models to determine long term preservation policies; determine preservation needs and schedules; and provide network-level performance measures.

European models have gone further in incorporating environmental aspects. The LIFECON Life-Cycle Management System (LMS) is a European model of a predictive and integrated LMS for concrete infrastructures, on both a short term and a long term basis, developed to facilitate decisionmaking. The system is divided into three levels of structural hierarchy: component and module, object, and network, with component- and module-level systems that address structural components such as beams and columns and their combinations in modules. The object-level system deals with complete structures or buildings. The network-level system treats networks of objects such as stocks of bridges or buildings. Besides a structure’s observed condition and evaluated urgency of repair, the life-cycle costs, user costs, minimum requirements of structural performance, structural risks, traffic and other operational requirements, aesthetics, environmental risks, and ecological pressures can be taken into account for multiple-attribute planning on all hierarchical levels of the system. The life-cycle analysis and optimization module involves the data applications for studying the economy of the life cycle and cost-effectiveness of optional maintenance, repair, and rehabilitation strategies. Alternative strategies are compared as life-cycle activity profiles over a defined time frame. The purpose of life-cycle analyses is to find the optimal activity profiles to reach the targets.

In January 2002, FHWA announced that Highway Bridge Replacement and Rehabilitation Program (HBRRP) funds can be used to perform preventive maintenance on highway bridges. Preventive maintenance activities eligible for funding include sealing or replacing leaking joints; applying deck overlays that will significantly increase the service life of the deck; painting the structural steel; and applying electrochemical chloride extraction treatments to decks and substructure elements. FHWA is currently in the process of clarifying language and restructuring the National Bridge Inspection Standards. Proposed changes will reorganize the standards into a more logical sequence and make them easier to understand for inspectors, and state and federal
highway administrators.

**Bridge Inspection and “Smart Bridges” for Preventative Maintenance**

In order to conserve fiscal and natural resources and ensure safety, DOTs are investing in bridge inspection for preventative maintenance and “smart bridges” that may forestall larger construction projects in and adjacent to streams. An increased emphasis on bridge safety and more rigorous inspection protocols followed the December 1967 collapse of a bridge over the Ohio River near Point Pleasant, WV, which claimed more than 50 motorists’ lives. As a result of the incident, Congress began to require the inspection and inventory of all bridges on the National Highway System, with a specific provision that each bridge’s load-carrying capacity be determined. More than 40 state DOTs and 100 engineering consulting firms now use the Bridge Rating and Analysis of Structural Systems (BRASS) software suite developed by the Wyoming DOT. Programs within the BRASS suite now include applications specific to steel, timber and concrete girders, steel girder splices, piers, trusses, culverts, and poles, as well as for illuminated signs and signals. The culvert design portion of the package comes from the North Carolina DOT; pre-stress girder design from Kansas; steel-field splice design from Nebraska; pier analysis and design program work by the Portland Cement Association, Georgia DOT and Montana DOT; truss rating from New York; and, cantilever pole analysis and design from Louisiana. (1)

FHWA’s Construction and Maintenance Fact Sheet on Bridge Preservation identifies best practices in bridge preventative maintenance, highlighting PennDOT’s program. (2) PennDOT maintains the third largest number of State bridges in the Nation, spending $300 million on 250 bridge projects each year. To keep costs down and ensure safety, PennDOT has found that it is vital to have both proper and frequent inspections and a good preventive maintenance program. PennDOT’s team of 50 bridge inspectors and numerous other consultant inspectors inspect all of the agency’s bridges at least once every two years. The bridge data is then stored in a management system, allowing engineers to prioritize the maintenance and rehabilitation needs and make sound decisions as to how to best take care of the bridge infrastructure.

Connecticut DOT has been using electronic monitoring systems to keep tabs on the condition of some of its bridges. Systems of linked sensors provide data on structural integrity and wear, and contribute to bridge life and stress assessment data. Portable and continuous systems have been installed on 11 bridges since 2002, allowing for early repair in sites that need it, and saving an estimated $2.7 million. (2) Likewise, high-tech optical sensors embedded in concrete beams in a bridge in Las Cruces, N.M. relay information to New Mexico State University researchers about the performance of the bridge’s design and materials, letting them track structural soundness as the bridge ages. (3)

Recent research has concluded that truck weight is one of the most significant factors in the repair and replacement life of bridges. (3) TRB Special Reports 225 and 227, Truck Weight Limits: Issues and Options and New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal, respectively, noted that trucks produce significant damage to highway bridges. A truck’s gross weight, axle weights, and axle configuration directly affect the useful life of highway bridge superstructures. Damage typically occurs in the bridge deck and in the superstructure elements including floor beams and girders, diaphragms, joints, and bearings. Bridge costs associated with increased truck weights are the result of the accelerated maintenance, rehabilitation, or
replacement work that is required to keep structures at an acceptable level of service.()() While prestressed concrete I-girder bridges and modern steel-girder bridges could withstand a 20 percent increase in truck weight, such an increase would reduce the remaining life in older steel-girder bridges by up to 42 percent.() The “smartest” bridge to date, in terms of density of sensors, is under construction in Star City, West Virginia; it contains 770 sensors, 28 data-collection boxes, and a central data processing unit.() WVDOT is counting on the investment to “help the state make smaller, less costly repairs while problems are still manageable,” said Deputy Commissioner Norman Roush, as well as conserve resources that may be spent through overdesign.() Engineering data collection will be able to be correlated with continuous environmental data collection on-site. West Virginia’ existing “smart” structures have already yielded valuable information, such as that concrete slabs 20 feet long are prone to cracking, while those 15 feet long are not.

Small Bridge Maintenance Activities that Can Eliminate the Need for Larger In or Over-Stream Work Projects

Some of the bridge maintenance activities that provide the biggest benefit for the smallest level of investment generally include:

1. Eliminating deck joints in old bridges
2. Repairing or installing new expansion dams on bridge decks
3. Repairing bridge decks
4. Maintaining proper deck drainage
5. Restoring or replacing bridge bearings
6. Repairing or replacing bridge approach slabs
7. Repairing bridge beam ends and beam bearing areas
8. Bridge painting

Successful control of pollution from bridge maintenance and repair involves minimizing the potential sources of pollutants from the outset.

Maintaining Drainage from Bridge Decks

Effective bridge deck drainage is important because deck structure and reinforcing steel is susceptible to corrosion from deicing salts; moisture on bridge decks freezes before surface roadways, hydroplaning can occur more easily; and drainage occurs over environmentally sensitive areas. Bridge deck drainage is often less efficient than roadway sections because cross slopes are flatter, parapets collect large amounts of debris, and drainage inlets or typical bridge scuppers are less hydraulically efficient and more easily clogged by debris. Because of the difficulties in providing for and maintaining adequate deck drainage, the following practices should be used: ()

1. Gutter flow from roadways should be intercepted before it reaches a bridge.
2. Zero gradients and sag vertical curves should be avoided on bridges.
3. Runoff from bridge decks should be collected immediately after it flows onto the
subsequent roadway sections where larger grates and inlet structures can be used.

**Bridge Cleaning**

Bridge cleaning consists of cleaning all bridge components that are susceptible to dirt, debris, bird dropping and deicing salts. Drainage systems and components subject to dirt or bird droppings accumulation need to be cleaned regularly by hand tools, air blasting or preferably water flushing.

1. Dust or any material that could be inhaled should be avoided by the use of a proper respirator.
2. Other components such as bare concrete decks, pier caps, abutment seats, bearing systems, non-sealed or open expansion joints, joint drainage troughs, head walls, wing walls, select beam flanges, truss joints etc. should receive a thorough water flush every spring (after applications of deicing salts have ceased) as a bare minimum.
3. Personnel should become familiar with various types of bearing devices. Mechanical bearing devices should be lubricated after cleaning to prevent rusting and assist in their movement.
4. Clearing of weeds, float debris, brush and overhanging limbs from the vicinity of the bridge should be performed according to best practices in channel maintenance.

**7.2 Avoiding and Minimizing Impacts to Fish and Wildlife And Enhancing Habitat**

**Scheduling Maintenance and Repair**

There are times of the year when the effects of pollution from bridge maintenance and repair would cause the most damage and times when the damage would be minimal. The exact timing depends upon the site and the species involved.

1. Schedule bridge maintenance to avoid egg incubation, juvenile rearing and downstream migration periods of fish.
2. Call upon state DOT fish and wildlife specialists or local fish and wildlife agencies for assistance in scheduling to avoid aquatic impacts.

Maintenance modifications TxDOT has undertaken to protect bats in bridges include postponing tree trimming and/or bridge maintenance work until outside of bat season.

**Using Pre-Fabricated Bridges to Help Accommodate Stream/Fish Timing Restrictions**

Using prefabricated bridge elements and systems makes construction less disruptive for the environment. As traffic and environmental impacts are reduced, constructability is increased, and safety is improved because work is moved out of the right-of-way to a remote site, minimizing the need for lane closures, detours, and use of narrow lanes.
Prefabrication of bridge elements and systems in a controlled environment without concern for job-site limitations can increase quality and lower costs, especially where use of sophisticated techniques would be needed for cast-in-place, such as in long water crossings or higher structures, like multi-level interchanges. NCHRP Synthesis 324 recently concluded that while prefabricated bridge components are more expensive in some cases, environmental impacts are reduced, quality is generally higher, and costs may fall as standardization increases in the industry.

In February 2003, FHWA and AASHTO sponsored a conference showcasing the successful uses and benefits of prefabricated bridge elements and systems. Along I-40 in Oklahoma where the cost of labor and materials to replace a collapsed bridge across the Arkansas River was $11.8 million, while the cost to control traffic and detours around the construction zone was $12 million, the higher upfront costs of prefabricated materials were offset by the amount of money saved by reduced construction times. In San Juan, Puerto Rico, construction crews were able to minimize traffic delays and reduce construction times by using prefabricated bridge modules, while building four bridges at a congested intersection of a four-lane arterial. Crews completed the first bridge within 36 hours, and construction of each of the other three bridges took only 26 hours, using prefabricated elements. The conference profiled several new technologies and construction techniques, including new specifications for high-performance concrete and steel and self-compacting concrete, and contracting procedures that ensure that bridges are built within one day and charge high penalties for any delays.

Figure 7: Prefabricated Bridge Construction - Hawaii DOT

Using prefabricated substructure elements reduces the amount of heavy equipment required and the amount of time required on-site for heavy equipment, causing less disruption to sensitive environments. For example, the Hawaii DOT’s Keaiwa Stream Bridge minimized environmental disruption because deck topping did not require shoring or falsework in the streambed, and minimized traffic disruption because precast planks were fabricated during pier construction.

In North Carolina, to avoid placement of heavy equipment in a sensitive environment on the Blue Ridge Parkway, the Linn Cove Viaduct on the Blue Ridge Parkway was built in one direction from the south abutment to the north almost entirely from the top down. The only exceptions to the top down method were construction of the initial span on falsework and construction of a temporary timber bridge that enabled the micropile foundation drilling machine to prepare several of the foundation sites ahead of the superstructure erection. Precasting each segment of the bridge allowed construction workers to assemble the bridge with little impact to the most environmentally sensitive section of Grandfather Mountain. This bridge proved that a design could be environmentally sensitive in addition to being utilitarian and economical.

The Wolf River Bridge in Fayette County, Tennessee, crosses sensitive wetlands and carries the only east-west route through its geographic region. TDOT designers selected
precast prestressed beams to facilitate speedy construction and allowed optional stay-in-place precast prestressed concrete deck forms. TDOT and the contractor developed details for precasting bent caps in two pieces to suit staged construction. Construction of the 1,408-foot long, 46-foot wide bridge was completed in eleven months without putting any equipment in the surrounding wetlands. Photo Credits: Tennessee Department of Transportation. ()

FHWA’s segmental concrete bridge technology website offers resources and best practices in SCBT bridge use, a method of joining multiple cast-in-place or precast bridge elements to form a continuous span. The site addresses engineering issues and construction methods, and features a photo gallery and an archive of “Ask the Experts” questions that have been submitted by site users and answered by team members. Geosynthetic Reinforced Soil (GRS) abutments and walls can help reduce the access needed for large equipment.()
Reducing the Space Needed for Large Equipment Access
Geosynthetic Reinforced Soil (GRS) abutments and walls can reduce the space needed for access by large equipment in building bridge abutments. FHWA has completed a substantial amount of research on this technology and feels it has great potential for future application. (See www.tfhrc.gov, geotechnical programs, “Performance Test for Geosynthetic-Reinforced Soil Including Effects of Preloading, FHWA-RD-01-018” and “Effects of Geosynthetic Reinforcement Spacing on the Behavior of Mechanically Stabilized Earth Walls, FHWA-RD-03-048.”)

Bird and Bat Roosts in Bridges
Nests in and on bridges are often regulated under the Migratory Bird Treaty Act. Migratory bird concerns often require DOTs to time projects for “off-season” work so as not to disturb active nests. In some cases, large unoccupied nests may be relocated during the off-season. Maintenance forces have used deterrents for nesting swallows on bridges such as netting or discouraging coatings.

Virginia Department of Transportation Program Key in Comeback of Peregrine Falcons
Peregrine falcons were classified nationwide as an endangered species from 1970-1999. In the 1980s, the falcons began showing a preference for VDOT’s coastal bridges. At that time, VDOT began working with the Virginia Department of Game and Inland Fisheries and the College of William and Mary to aid bridge-nesting efforts. VDOT installed nesting boxes on ten bridges and video cable on one. From 1978 through 1985, the Department of Game and Inland Fisheries led a recovery effort that released 115 young birds on the Eastern Shore. Rather than moving to western Virginia as anticipated, VDOT bridges became one of the most popular nesting sites. Native to Virginia’s Allegheny and Blue Ridge mountains, peregrine falcons were nearly wiped out by unintended side effects of pesticide use by the early 1960s. All known breeding pairs east of the Mississippi had disappeared and their numbers were drastically reduced worldwide by the mid-’90s.

The Department reports falcon activity to wildlife experts, and limits maintenance work to avoid disturbing nesting pairs or their young. In 1998 VDOT’s Environmental Division earned a Federal Highway Administration Award for Excellence in Highway Design for Environmental Protection and Enhancement for the effort. VDOT employees have been recognized by the Board of Directors of Virginia Game and Inland Fisheries. VDOT has continued its habitat enhancement and sensitive maintenance practices even after the species was delisted. In the spring of 2001, VDOT and eight other public and private agencies began FalconTrak, a three-year program to protect eggs and hatchlings, track young falcons via satellite, and monitor nests with video cameras for researchers and the public to view on VDOT’s web site, VirginiaDOT.org. Pairs of peregrine falcons are currently nesting on eight VDOT bridges and offspring are thriving.

Protecting and Increasing Bat Roost Habitat in Bridges
Bats are primary predators of vast numbers of insect pests that are extremely costly to farmers and foresters. One bat can easily eat 20 female corn earworm moths in a night, and each moth can lay as many as 500 eggs, potentially producing 10,000 crop-damaging caterpillars. Yet as few as eight caterpillars per 100 plants can force a farmer to apply

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Protecting and Increasing Bat Roost Habitat in Bridges
Bats are primary predators of vast numbers of insect pests that are extremely costly to farmers and foresters. One bat can easily eat 20 female corn earworm moths in a night, and each moth can lay as many as 500 eggs, potentially producing 10,000 crop-damaging caterpillars. Yet as few as eight caterpillars per 100 plants can force a farmer to apply
A number of bat species nationwide are listed as threatened or endangered under the federal Endangered Species Act. Bats are especially susceptible to extinction because most species form large colonies in vulnerable locations, such as caves that are sometimes inadvertently sealed. In addition, bats usually produce only one pup per year. As a consequence of losing natural roosts in caves and old growth forest snags, bridges and culverts have become havens of last resort. Bridges from Canada to Florida are being used by at least 24 of the 46 North American bat species; it is estimated that within the southern United States alone, 3,600 highway structures are being used by approximately 33 million bats. State DOTs can contribute to bat recovery at little or no cost, through proactive measures. Most bat species that will roost in bridges choose concrete crevices that are sealed at the top, at least six to 12 inches deep, .5 to 1.25 inches wide, and ten feet or more above the ground, typically not located over busy roadways. Day roosts are places that protect bats from predators and buffer weather conditions while resting or rearing their young. Such roosts are usually in expansion joints or other crevices. In contrast, night roosts, where bats gather to digest their food between nightly feeding bouts, are often found in open areas between bridge support beams that are protected from the wind. Retrofitting existing bridges and culverts proved highly successful in attracting bats, especially where bats were already using them at night.

**Figure 8: TxDOT Bats in Bridge Retrofit Partnership**

Citizens have gotten involved as well. When 33,000 Mexican free-tailed bats became a nuisance in the school attic at Canadian Middle School in Canadian, Texas, teachers and students purchased materials, constructed, and installed alternate roosts for up to 50,000 bats in a nearby highway bridge by collaborating with Bat Conservation International (BCI), the TxDOT and local businesses. Bats have the largest surface area to body mass of any mammal, and this requires greater energy to maintain body temperatures. Sun-warmed bridges help adult bats to conserve energy and foster development of their young. During the summer months, sun-exposed bridges act as thermal sinks, often achieving and holding temperatures above the ambient average for most of the 24-hour cycle.

Bat Conservation International cooperated with 20 state DOTs in a national study of bats in bridges and found 217 highway structures used as day roosts and 714 highway structures used as night roosts. Information from this study is summarized in this section and those following, pertaining to construction and retrofit recommendations. The study found that the higher, more consistent bridge temperatures are especially
important in mountainous or desert regions where ambient temperatures fluctuate
dramatically within a 24-hour cycle. An Oregon study found that bats prefer bridges
with greatest sun exposures. Bridges receiving no sun had little or no bat use. This
preference was especially obvious within partially shaded bridges, where roosting
activities occurred only in the sun-exposed halves of bridges.() The northernmost day
roost discovered in this study was occupied by a maternity colony of roughly 300 little
brown myotis in an Idaho bridge at 44 north latitude. However, the number of day roosts
appears to drop rapidly above 42 north latitude.()

Bats use parallel box beam bridges as day roosts more than any other kind. The next most
preferred bridges are cast in place or made of prestressed concrete girder spans. These
designs are the most likely to contain spaces suitable for bats. Although parallel box
beam bridges were rarely encountered during the survey, they can provide numerous
crevices of suitable width. Metal and small concrete culverts are the most frequently
encountered highway structures and are the least preferred as roosts. Even ideal
structures were rarely used by bats in areas dominated by open plains, perhaps due to a
lack of appropriate habitat. Creation of day-roost habitat for bats in new or existing
highway structures is easy, often at little or no extra cost to the taxpayer. For new
structures, the minimum needs for day-roosting bats can be met by specifying the proper
dimensions for crevices such as expansion joints.

Night use of highway structures is even more common; 29 percent of all structures
surveyed had signs of night-roost activity. In some regions of the southwest, all suitable
structures were used by night-roosting bats. Night-roosting bats are believed to be
attracted to bridges that provide protected roosts and have a large thermal mass that
remains warm at night. Bridges constructed of prestressed concrete girder spans, cast-in-
place spans, or steel I-beams are preferred. Vertical concrete surfaces located between
beams provide ideal protection from wind and are especially used when they are heated
by full sun exposure. Bats typically do not use bridges with flat bottomed surfaces that
lack inter-beam spaces. They will avoid small culverts but will roost at night in the long
concrete box culverts that often pass under divided highways, if the culverts are at least 5
feet (1.5 m) tall. Night roosts appear to play important roles in body temperature
regulation and social behavior.

Figure 9: Night Roosts Located in Open Spaces between Bridge Beams. Credit: Bat
Conservation International

TxDOT Study and Bridge Modifications to Support Bat Usage
TxDOT and Bridge Engineer, Mark Bloschock, have received an award of excellence from Bats Conservation International, the first given to a person outside the field of wildlife conservation. Bloschock began a study with BCI in 1994 after a large colony of Mexican Free-Tailed bats settled under the Congress Avenue bridge in Austin and each wanted to determine why the bats settled there, whether bats might damage the bridge, and if there might be potential effects on human health. The study determined that slot-shaped crevices under the bridge were similar in size to spaces found in bat caves and uncovered bat roosting preferences in both bridges and culverts throughout the state. The study indicates that minor modifications to highway structures can maximize or minimize the potential for use by bats, and that less than 0.01 percent of Texas highway structures currently meet the day-roosting requirements for bats. In central, southern, and western Texas, there is a 62 percent chance that structures with suitable characteristics will be used by bats. The Mexican free-tailed bat (*Tadarida brasiliensis*) was found to be the most frequent bat species day roosting in highway structures. Bridge characteristics preferred by day-roosting bats were defined by a paired comparison study where bat-occupied and unoccupied bridge characteristics were statistically compared. Today, 1.5 million Mexican Free-Tailed bats migrate from Mexico every year and stay from March to October under the popular Austin bridge. It’s estimated the bats eat ten to 15 tons of insects on their nightly flights. The sight of the bats taking flight at dusk from beneath the Congress Avenue bridge had another unexpected benefit as thousands of tourists visit the bridge to see the nightly flights. The bridge is listed as a top tourist attraction on the City of Austin web page. Each year, the bridge attracts tens of thousands of tourists from all over the world, and has been estimated to generate more than $8 million for the local economy.() Based on the success of the bat habitat in Austin, Bloschock established the Bats and Bridges program, which has spread to 24 states and 17 countries. Overall, TxDOT has 218 structures currently used as roosts, almost three times as many habitats for bats as any other state taking part in the program.()

**Practices to Incorporate in Design, Construction, and Retrofitting of Bridges for Bats**

TxDOT performed a statewide evaluation used to identify the distribution of highway structures used by bats. Day-roosting bats prefer concrete bridges and culverts with secluded locations such as crevices that are 0.5 to 1.25 inches-wide (1.2 to 3.2 cm), especially those that are 12 inches deep (30 cm), have covered tops, and are located in central, southern, and western Texas. Additional experiments further supported the results of the paired comparison and statewide evaluations. Bat colonies, even large ones, do not damage highway structures and water sources under roosts are not negatively impacted. Human health risks are minimized by educating people not to handle bats.() In sum, the study found that:

1. Highway structures that incorporate crevices between 0.5 and 1.25 inches wide (1.2 and 3.2 cm) can provide ideal roosting habitat for several of the most rapidly declining and valuable bat species in Texas, especially if these crevices are 12 inches (30 cm) or more in depth and covered at the top.
2. Bats typically use only concrete or wooden roosting surfaces, preferring the highest, darkest locations.
3. Structures can be retrofitted with Bat-Abodes or concrete panels to create bat habitat.
4. Large concrete culverts under divided highways can provide excellent roosts for threatened and endangered bats, though most would require provision of roughened ceiling cavities during construction.

5. No structural damage, aquatic pollution, or disease transmission to humans has been associated with even the largest bat colonies living in Texas bridges and culverts, but warnings not to handle downed individuals or inhale dust associated with bird or bats droppings are recommended.

6. Where bats are unwanted, simple elimination of preferred crevice widths can prevent potential nuisance problems.

Incorporating characteristics into new structures specifically for bats can be relatively inexpensive and easy to do. TxDOT has developed a bat-friendly domed culvert, for which customization costs are minimal; modifications can even be implemented during construction.

As part of their national study, Bat Conservation International determined in consultation with state DOTs that bat-friendly habitat can be provided in either new or existing bridges or culverts, at little or no extra cost to taxpayers. During construction planning, there are no costs for an engineer to specify the appropriate crevice widths of 3/4 to 1-inches (1.9 to 2.5 cm) for expansion joints or other crevices. Existing structures can be retrofitted with bat-friendly habitats using the designs described in the following sections. Signs of bat use in nearby bridges and culverts increase the chances of success for habitat enhancement projects.

Ideal day roost characteristics for crevice-dwelling bat species that use highway structures, include (in descending priority): ()

1. Location in relatively warm areas, primarily in southern half of the country
2. Construction material: concrete
3. Vertical crevices: 0.5 to 1.25 inches (0.25 to 3 cm) wide
4. Vertical crevices 12 inches (30 cm) or greater in depth
5. Roost height: ten feet (three meters) or more above the ground
6. Rainwater-sealed at the top
7. Full sun exposure of the structure
8. Not situated over busy roadways

Culverts:

1. Location in relatively warm areas
2. Concrete box culverts
3. Between five and ten feet (1.5 and 3 meters) tall and 300 feet (100 meters) or more long
4. Openings protected from high winds
5. Not susceptible to flooding
6. Inner areas relatively dark with roughened walls or ceilings
7. Crevices, imperfections, or swallow nests
The Texas Bat-Abode, Big-eared Bat-Abode, and the Oregon Bridge Wedge bat roosts are designed for day-roosting bats in bridges and culverts. In the protected environment of a bridge or culvert, a properly constructed and installed bat habitat made of quality materials should last as long as the highway structure. BCI would appreciate photographs of the installation and especially of bats using any bat-friendly modifications. For more information on adapting the designs to specific bridges, or to report occupied units, contact Bat Conservation International (BCI), Inc., at 512/327-9721. BCI maintains a list of bats, documented bridge/culvert use, potential use, roost type (crevices or open beams), preference, nationwide distribution, and status at: http://www.batcon.org/bridge/ambatsbridges/index.html.

**Texas Bat-Abode**
The Texas Bat-Abode is designed to retrofit bridges with bat habitat for crevice-dwelling species. It has an external panel on either side and 1x2-inch (2.5 to 5.1 cm) wooden spacers sandwiched between 0.5 to 0.75 inch (1.2 to 1.9 cm) plywood partitions (Figure 29). Recycled highway signs are ideal construction materials. Note that only the external panels need to be cut to fit the bridges’ inter-beam spaces. The internal partitions should provide crevices 0.75 inch (1.9 cm) wide and at least 12 inches (31 cm) deep. Smooth roost surfaces need to be textured to provide footholds for bats on at least one side of each plywood partition (preferably both), creating irregularities at least every 1/8 inch (0.3 cm). Many methods have been tested to create footholds, such as

1. Using rough-sided paneling
2. Coating the panel with a thick layer of exterior polyurethane or epoxy paint sprinkled with rough grit
3. Attaching plastic mesh with silicone caulk or rust-resistant staples
4. Mechanically scarifying the wood with a sharp object such as a utility knife
5. Lightly grooving the wood with a saw (do not penetrate to the first plywood glue layer)
6. Lightly sandblasting the wood with rough-grit

The use of rough-sided paneling or polyurethane sprinkled with grit have provided the longest lasting results. Rust resistant wood screws should be used to assemble the spacers and partitions.

**Figure 10: Texas Bat-Abode for crevice-dwelling species. Credit: Bat Conservation International**
The Texas Bat-Abode should be installed in bridges that are at least ten feet above ground, free of vegetation, and not susceptible to flooding or easy vandalism. Measurements of the exact location where the Bat-Abode is to be placed will ensure a proper fit. The number of partitions is arbitrary and limited only by availability of materials and support for the weight of the Abodes. Because of the weight, it may be easiest to assemble the cut pieces in the bridge. In wooden bridges, the unit should be anchored to the structure with heavy-duty rust-resistant lag-bolts.

**Big-eared Bat-Abode**

Big-eared bats are frequent bridge users in both the eastern and western United States. They prefer open roost areas such as cave entry rooms, large hollow trees, darkened undisturbed rooms in abandoned houses, or between the darkened beams of quiet bridges over streams. The Big-eared Bat-Abode creates these conditions.

The Big-eared Bat-Abode has two external panels with 1x2-inch spacers that are used as braces to hold the panels together with a plastic mesh lining to provide footholds for bats. The netting should be attached using rust-resistant staples (Figure 30). The other methods of creating footholds mentioned above would also be effective.

**Figure 11: Big-eared Bat-Abode. Credit: Bat Conservation International.**
the fly-way entrance should not be blocked. Other bat species are likely to use this structure.

The Oregon Wedge
The Oregon Wedge (Figure 12) is an inexpensive method of retrofitting bridges or culverts with day-roost habitat for bats. The Wedge is made from an 0.5 to 0.75 inch (1.2 to 2 cm) exterior grade plywood panel that is at least 18 inches high and 24 inches wide (46x61 cm) with three 1 x 2 inch (2.5x5 cm) wood strips attached along the top and sides, leaving an opening along the bottom. If larger panel sizes are used, vertical wooden pieces should be placed every 24 inches (61 cm) to support the plywood and prevent warping. The pieces should not run from the top to the bottom so that bats can move about within the panel.

![Oregon Wedge Diagram](image)

Designs courtesy of David Clayton and Dr. Steve Cross and Bat Conservation Int’l

Figure 12: Oregon Wedge

The Wedge can be attached to a vertical concrete portion of a bridge or culvert using concrete anchor-bolts or a fast-drying environmentally safe epoxy cement (such as 3M Scotch coat 3-12). The transportation department should install the panels if anchor bolts are used. If the panel is to be attached to wood, then use appropriate rust resistant wood screws. Before applying the epoxy, check the preferred installation site to make sure the support strips fit flat against the concrete surface.

Wedge placement is possible on any adequately sized, flat concrete or wood surface. However, we recommend that the panels be placed near the sun-warmed road slab (preferably as high as possible between heat-trapping bridge beams). They should be at least ten feet (three meters) above ground, with a clear flyway (at least ten feet), and be out of view or reach of vandals. The Wedge can be installed in the middle sections of culverts higher than five feet (1.5 cm). A Wedge should not be placed in structures that flood. As a precaution against flooding, a 1.5 inch (3.8 cm) gap can be left at each corner where the support strips join to act as an escape route in the event of fast-rising water.
partitions, such as female threaded inserts, can be incorporated into the raised walls and ceiling to create more surface area once the culvert is completed. Bat-domed culverts should not be placed in areas susceptible to flooding. However, in the event of rising water, the dome may serve as a temporary air-trap. Almost any cave-dwelling species may use these, including several that are endangered.

**Success in Retrofitting Bridges to Accommodate Bats**

Retrofitting habitat into existing highway structures has become a popular and successful method of accommodating bats. Pre-surveys to look for bat signs in nearby bridges are useful to predict the success of proposed enhancement projects. Four bridges in Oregon and five bridges and two culverts in Texas with signs of night roosting were retrofitted with ideal crevices, and all were occupied by bats within the first year. All retrofit designs tested in bridges and culverts so far have successfully attracted bats, and at least six states are already using retrofitting projects to accommodate bats. Retrofits are adaptable to almost any structure and can be placed where they will have a high potential for success and that will minimize disturbance from maintenance or vandalism. Retrofits are generally inexpensive and can be sized to accommodate small or large colonies, with potential expansion by adding more units if initial efforts are successful. Retrofits are usually highly beneficial to local agricultural and can be easily moved if necessary.

**Figure 14: TxDOT’s Concrete Version of the Oregon Wedge**

Two basic designs can be used to retrofit almost any bridge or culvert. Texas Bat-Abodes can accommodate thousands of bats each, and have been modified to fit three different bridge designs. Four of the five tested were fully occupied, one within the first month. The Oregon Wedge can house several hundred bats and has been accepted for day roosting by 12 species, including a maternity colony of Yuma Myotis (*Myotis yumanensis*). This design has been successful in both bridges and culverts in Oregon, Arizona, and Texas. The Texas Department of Transportation developed a concrete version that attracted bats within a year.

**Preserving Portions of Old Bridges as Habitat**
When old bridges must be replaced, some of those occupied by bats have been retained as wildlife sanctuaries. The Santa Barbara Public Works Department and Caltrans are collaborating to preserve a colony of 10,000 Mexican free-tailed bats and 200 pallid bats (*Antrozous pallidus*) by retaining a portion of an old bridge that is surrounded by agricultural fields (Storrer, 1994). It is calculated that these bats consume roughly 10,000 pounds (4,540 kg) of insects each summer, many of which are pests. Bridge habitat enhancement techniques are being developed in other countries. In Australia, the roost portion of an old wooden bridge was retained and incorporated into the underbelly of a new replacement bridge.

**Further DOT Efforts to Identify Characteristics and Design Features of Roost Bridges and Conservation Efforts**

FDOT is in the process of undertaking a survey of bridges with bats to help FDOT predict and control where bats will roost. At least five species of bats in Florida use concrete highway bridges as roosting sites. Because many natural roosts such as caves and large hollow trees are rare, bridges serve as the most common or primary roosting sites for bats in some areas. The objectives of this project are to: 1) identify FDOT maintained bridges in Florida that are occupied by roosting bats; 2) summarize characteristics and design features of roost bridges, and correlate bridge features with presence, number, and species of roosting bats; 3) prepare guidelines for FDOT employees to record the presence of bats during routine activities; and 4) identify all bridges that support bat roosts and are planned for replacement by 2020, and to identify ways to conserve the roosts when these bridges are replaced.

Likewise Georgia DOT will 1) identify the highway bridges and select culverts in Georgia that are occupied by roosting bats; 2) evaluate the characteristics and features of bridges being used as roosts, including an assessment of surrounding habitat features; 3) recommend bridge design elements that provide the roost features preferred by bats; and 4) prepare standard procedures for assessing the presence of bats, minimizing disturbance to the bats, and preserving the existing or potential roosting opportunities during management, repair, and demolition of highway bridges by the Georgia Department of Transportation (GDOT). Those research results will be available in mid-2005.

**7.3 Bridge Painting/Coating/Sealing and Containment Stewardship Practices**

Bridge painting/coating/sealing covers all protective and preventative maintenance activities designed to prevent deterioration of structure components. Components made of non-weathering steel are generally painted with a multicoat paint system to protect the steel from rust and corrosion. Bridges painted prior to 1975 typically used lead, chromium, or cadmium pigmented paints, which if removed must be removed according to strict EPA and OSHA guidelines and disposed of as a hazardous waste. The 1990s saw great increases in the costs and complexity associated with steel bridge maintenance painting. While a low-tech, least cost approach to combating corrosion and deteriorating aesthetics prevailed as recently as 15 years ago, the increasing age of the infrastructure, increasing needs for immediate maintenance, over the past few years, environmental regulations have become the single most influential force affecting the bridge painting industry; specifically, the regulations regarding the VOC content of
protective coatings and the environmental and worker health and safety regulations associated with the removal of lead-containing paint have had a significant impact on the bridge painting industry.

Table 16: Regulations Impacting the Bridge Painting Industry

<table>
<thead>
<tr>
<th>Impacting Regulation</th>
<th>Effect on Coating Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSHA; CFR 29 1926.62, Lead in Construction</td>
<td>Establishes guidelines for protection and monitoring of workers removing lead paint from bridges. Requires lead training and monitoring for workers.</td>
</tr>
<tr>
<td>EPA; Resource Conservation and Recovery Act (RCRA)</td>
<td>Regulates the handling, storage, and disposal of lead (and other heavy metals) containing waste. Can increase the cost of disposal of waste from bridge paint removal by 10 times.</td>
</tr>
<tr>
<td>EPA; Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund)</td>
<td>Assigns ownership of and responsibility for hazardous waste to the generator “into perpetuity.”</td>
</tr>
<tr>
<td>EPA; Clean Water Act</td>
<td>Regulates discharge of materials into waterways.</td>
</tr>
<tr>
<td>EPA; Clean Air Act Amendments</td>
<td>Mandates restrictions on allowable volatile-organic-compound (VOC) content of paints and coatings. Regulates discharge of dust into air from bridge painting.</td>
</tr>
</tbody>
</table>

The impact of regulatory compliance has spurred a shift in focus to achieving long-term effectiveness for the dollars spent, both to maximize the return on DOT investment and minimize environmental impacts. A number of FHWA research projects with regard to bridge coatings have addressed the life-cycle cost issue in detail. Research on the removal of lead-containing paint considered the relative cost increases associated with changing regulations that deal with removal and handling of hazardous debris during bridge maintenance painting operations. Research on environmentally compliant materials and testing of low volatile-organic-compound (VOC) coating systems focused on the relative cost/benefit of the durability of various paint systems based on performance data and relative costs of material and application. Materials testing projects — such as those on Performance of Alternative Materials in the Environment, Comparison of Laboratory Testing Methods for Bridge Coatings, and Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges — have had a direct influence on regulatory development and the development of measures for compliance by bridge owners. These projects provided critical, long-term performance data for many new, environmentally compliant bridge paint materials and provided justification for bridge owners to move away from technologically old, lead-containing paints to new, more durable formulations that contain little or no toxic pigments and significantly less solvent. A project on Issues Impacting Bridge Painting, performed an extensive life-cycle versus initial-cost analysis for various bridge painting scenarios and presented results in a spreadsheet program, to facilitate comparison of the various maintenance painting options based on a life-cycle cost analysis. The projects Performance of Alternative Coatings in the Environment (PACE), Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges, Effects of Surface Contaminants on Coating Life, Maintenance Painting of Steel Bridges, Issues Impacting Bridge Painting, Methodology for Evaluation of Corrosion Control Coatings, and Comparison of Laboratory Testing Methods for Bridge Coatings have had aspects that addressed the need for higher quality and shorter term coating-durability data. Common findings of these programs with respect to cost considerations were:

1. The relative cost of paint material is almost always insignificant when viewed in combination with the overall cost of the bridge painting operation.
will be the optimum choices from a life-cycle cost standpoint.

**Guidance and Specifications for Bridge Painting, Coatings, and Removal**

Some states routinely involve state and federal environmental regulators in bridge painting design to help them satisfy the regulations. This has reduced compliance problems, cost increases associated with contractor force account work, and time delays; however, environmental regulators look for transportation agencies to come to them with good bridge painting plans and specifications. They are often reluctant to suggest specific methods and techniques, because it could compromise their regulatory role in the event of pollution problems. The FHWA website, allows searches of specific state highway agency specifications using key words such as paint, coatings, and recycling. The site has a discussion feature to facilitate questions. Also, the FHWA users guide and spreadsheet *Cost Effective Alternate Methods for Steel Bridge Paint System Maintenance-Cost Model Users Guide* (FHWA Contract No. DTFH61-97-C-00026) can be used to evaluate cost effective bridge painting approaches. DOTs often use multiple factors such as adhesion test results, structure life, maintenance needs, layers of coatings, costs, and available funding to make bridge painting program decisions.

The FHWA Publication No. FHWA-RD-94-100, *Lead-Containing Paint Removal, Containment, and Disposal*, provides information on the environmental and health regulations affecting the removal of lead-containing paints from steel bridges and includes a guide for waste reduction, control and disposal of the hazardous material generated by bridge paint removal operations. NCHRP Synthesis 251: Lead-based Paint Removal for Steel Highway Bridges and NCHRP 257: Maintenance Issues and Alternate Corrosion Protection Methods for Exposed Bridge Steel are earlier publications that remain valuable resources. Society for Protective Coatings (SSPC) Guide 6 (Containment design) and SSPC Guide 7 (Environmental monitoring) contain state-of-the-art guidance.

**Missouri DOT Lead Paint Recycling**

The Missouri Department of Transportation (MoDOT) maintains 7,138 bridges throughout the state of Missouri. Many of those bridges require lead paint removal and disposal prior to repainting. To safely accomplish this, the department contains and recycles the lead-paint waste through a lead-acid battery recycler. The lead is recovered in the smelting process and the steel grit or silica sand used as blast material and steel drums provide a substitute for fluxing agents used in the process. This has resulted in the complete recycling of hundreds of tons of former waste and saved valuable landfill space. In 1996, MoDOT purchased two abrasive recycler systems. The abrasive recycler removed the lead paint from the steel grit by vacuum washes and magnetic separators. This reduced the amount of blast residue about 80 percent. In recent years, water blasting of bridge paint has greatly expanded and further reduced the amount of blast material sent to the smelters by 99 percent. In water-blasting, the water is recycled through a filter that removes the paint chips and the water is reused and at the end of the project, safely discharged to a permitted wastewater treatment facility. The paint sludge is recycled at a smelter.

MoDOT recommends the following practices when selecting a recycling company: ()

1. Always check operating permits and qualifications of a prospective recycler.
2 Check their history and ask a lot of questions about past problems.
3 Review the environmental agency’s files for any problems.
4 If the files are sealed, find out why, and if you do not get a satisfactory response, reconsider that company as a prospect to be your recycler.
5 Get a list of present and previous customers and talk to them about the company.
6 Most importantly, visit their facility and get a tour of their operation.

**Metallizing**

As a result of life cycle cost analyses, a few states have begun to explore metallizing as a coating option. Metallizing is a term used to describe thermal sprayed metal coatings. For corrosion control coatings on steel structures, metallizing refers to the thermal spraying of zinc or aluminum alloys as a coating directly onto steel surfaces. The coatings are created by using a heat source (either flame or electric-arc) to melt the metal which is supplied as a wire or in powder form. An airstream sprays the molten metal onto the steel surface in a thin film. Once the metal strikes the steel it resolidifies to become a solid coating. Metallized coatings provide corrosion protection to steel by sacrificial and barrier protection. The coating itself provides a barrier between the environment and the steel surface, especially when applied in combination with conventional sealers as topcoats. Due to the electrochemical reaction between steel and zinc or aluminum in an aqueous and salt-contaminated environment, these coatings tend to “sacrifice” themselves to protect the steel at the site of any damage in the coating. This sacrificial protection is similar to the protection provided by zinc-rich primers or galvanizing. According to the Turner Fairbank Research Center, metallizing has been reported to be highly effective in numerous research projects and in observation of historical applications. Many reports have proclaimed that a metallized structure will last 25 to 40 years with no need for maintenance touch-up. This greater life expectancy and higher effectiveness brings a higher initial cost, but a potentially lower long term cost. A project recently completed by the Illinois Department of Transportation (IDOT) incorporated metallizing technology as an experimental feature. For this project, the structural steel was metallized in the shop then transported and erected in the field. There have been several bridge rehabilitation projects around the country which have had metallizing done in the field on existing steel, but only a few have been completely metallized in the shop. The production rates, cost concerns, logistics, handling and construction issues were examined in this study in order to assist in determining the feasibility of and issues involved in using metallizing in shop applications. The project was considered successful and equipment advances enabled metallizing to be done much faster than in the past. The project illustrated that under life-cycle costing, metallizing can be advantageous despite its cost, on this project, of $9.18 per square foot versus $2.00-$2.50 per square foot for painting.

**Overcoating**

As an alternative to removal, some toxic based paint is in a condition that permits an overcoating of paint to effectively contain the toxic material and protect the steel. Critical variables which determine the success or failure of an overcoating job include:
the condition of the existing paint, the extent of corrosion on the substrate, the level of surface cleanliness achieved, and the environment of exposure. A recently completed FHWA-sponsored study of various overcoating materials applied to bridge structures in various parts of the country resulted in the following general results: ()

1. Multicoat systems, overall, performed better than single coat systems, with three coat systems showing generally better performance than two coat systems. This result is thought to be directly related to the occurrence of pinholes during brush application of maintenance coating materials; however, it shows a measurable benefit of the application of multiple coats in a realistic scenario. Other studies have shown similar results.

2. Coating materials performing well in the study were three-coat moisture-cured urethane systems, and three-coat epoxy based systems using a penetrating low-viscosity sealer as a primer. In addition, two separate three-coat low-VOC alkyd systems performed well. Of the single coat systems, the coatings based on calcium-sulfonate alkyd resins did best. Similar generic results have been found by other investigators.

3. In general, coatings that did well at any one test site did well at all four, diverse test sites (indicating some measure of surface tolerance, or “overcoating acceptability” for specific paint materials). Those materials that failed badly and early at any one site generally failed at more than one site. This would lend support to the use of patch tests as screening for acceptability of a particular overcoating material on a particular structure.

4. In the subject testing, failures were of two varieties, 1) early coating disbondment due to incompatibility of the overcoating material with the existing paint, and 2) rust through of the newly applied overcoating material at areas where the coating is over bare steel or existing rust.

The performance of a newly applied overcoating is highly dependent upon the condition of the existing coating over which it is applied. Overcoating over existing aged paints that are often brittle and loosely adherent can pose risks of early failure and large scale disbondment. The applied overcoat applies added stress by adding physical weight to the existing coating, shrinkage during drying, different expansion and contraction rates between two different paint systems with ambient temperature cycles, and softening of the existing coating due to solvents in the overcoat. The following steps can minimize this risk: ()

1. Prior to deciding to overcoat a particular structure, assess the condition of the existing steel and paint system. Condition can include extent and distribution of rusting, and adhesion. The extent of metal loss due to corrosion and the extent and distribution of paint breakdown are important in determining the scope of the work required to clean and overcoat the structure. Paint failure confined to specific definable areas is easier to clean and overcoat than general paint failure over the entire structure. Adhesion should be assessed using either standard test methods (ASTM D4541 or D3359) or by attempting to cut and lift the coating with a knife blade. If the coating lifts easily or crumbles at the tip of the knife blade, then application of overcoating paints should be considered high risk.

2. Conduct a representative patch test of the new material over the existing material
using representative maintenance painting practices. Allow this patch to weather several seasons and assess the compatibility of the systems. Research has shown that reasonably good performance is achievable with various different overcoating materials. A patch test will help eliminate coatings grossly incompatible with the existing paint on the structure.

3. Where possible, consider using coatings similar to those currently on the bridge. Some investigators have seen good results from the application of newer, but generically similar alkyd coatings over older existing alkyd coatings. Some of the older technology coatings may present a compromise in overall durability when compared to newer coating materials, but in a maintenance mode, the compatibility of these materials is a definite advantage.

After the existing paint has been sampled and a plan of action developed for an appropriate paint system, spot painting can be performed by maintenance staff using the following guidelines:

1. If the paint has not been proven to be lead/chromium/cadmium free, treat it as if it were hazardous and brief personnel accordingly (refer to OSHA pamphlet 3126).
2. Personnel removing the paint should wear coveralls, gloves, goggles, and a certified, properly fitting respirator for protection.
3. Ensure a containment system is arranged to catch and retain all the paint removed.
4. Apply an approved chemical paint remover on the desired area and allow it to stand.
5. Remove the paint with hand tools or scrapers that do not cause the paint particles to become airborne.
6. Dispose of hazardous paint at the nearest district headquarters yard at the hazardous waste site in the area marked for toxic paint. Inform district personnel.
7. Prepare and clean the now paint-free surface and repaint the area with an approved paint.
8. Ensure that personnel do not eat, drink or smoke until they are finished and have washed and properly disposed of all contaminated tools and clothing.
9. Cracks in any bridge component should be evaluated and corrective action taken. A crack in any steel component must be promptly reported to the Bridge Engineer and corrected per recommendation. Cracks in wood or concrete should be evaluated first and then cleaned and sealed with an appropriate crack sealant. Larger cracks in concrete should be sealed with polymer or epoxy based sealants. Small shrinkage cracks and all concrete surfaces where the concrete is not a specialized or high density concrete such as latex modified or silica fume concrete should be treated with a silane based sealant.

Painting operations generate dust, solvent fumes, and noise. Every effort should be made to minimize the impact of these operations on the surrounding community.

**Inspecting the Structure and Preparing Equipment**

1. Inspect the structure paying particular attention to areas of localized rust because these are the areas that have shown to be prone to premature coating failure. Extra
effort should be made to ensure that both the proper degree of surface preparation and the proper coating thickness are achieved in these areas. The presence of mill scale under the existing paint indicates a potential need for additional surface preparation. If mill scale is observed and abrasive blasting is not specified, the project Engineer should be notified since abrasive blasting may be required.

2 Inventory, inspect, and calibrate the equipment.

Surface Preparation
Proper surface preparation and proper paint application are the two most important factors needed in a high quality job that will avoid peeling paint and future environmental contamination. It has been estimated that 75 percent to 80 percent of all premature coating failures are caused, partially or completely, by deficient surface preparation and/or coating application. Cleanliness is essential since the presence of oil, grease, dust, or soil prevent the paint from bonding. Mill scale, rust, and the existing paint may increase the chance of failure of the new coating. Clean surfaces must have an appropriate anchor pattern (surface roughness). This roughness helps the new paint to mechanically bond to the surface, promoting adhesion.

The Society for Protective Coatings (SSPC) has developed a nomenclature for the different types of surface preparation methods. Best practices for each are noted in a bulleted list following description of the SP level practice. FHWA has two studies that speak to this issue.

Hand Cleaning

SP-1 - SP-1 denotes “solvent” cleaning and can refer to solvent wiping, water washing, or steam cleaning. The surface is cleaned to remove oil, grease, etc. This must be done prior to ALL other cleaning operations as some final surface preparation methods will actually force the contaminants into the steel, which can lead to poor bonding and premature failure.

1 Clean, lint-free rags and clean solvent should be used to avoid the spreading of contaminants.

2 Once the contaminants have been visibly removed, a final wiping should be done with clean rags and solvent.

3 Workers should wear goggles, protective clothing, rubber gloves, and petroleum jelly on exposed body parts and should be equipped with appropriate respirators to avoid hazardous fumes.

4 Benzene and carbon tetrachloride are poisonous and should not be used as solvents and neither should materials with low flash points such as gasoline, methyl-ethyl ketone (MEK), and acetone. Consult the Materials Safety Data Sheet to determine the specific hazards and protection procedures to be followed for the solvent being used.

SP-2 - SP-2 denotes hand tool cleaning. Hand tools are used to remove loose mill scale, loose rust, loose or otherwise defective paint, weld flux, slag, and spatter. This is done by brushing, sanding, chipping, or scraping the surface. Tools used include wire, fiber, or bristle brushes, sandpaper, steel wool, hand scrapers, chisels, or chipping hammers. Tightly adhering rust, mill scale, and paint are allowed to remain. This method is
generally confined to small areas.

- Verify that the level of cleanliness noted in SP-1 has been achieved. Pay particular attention to the problem areas such as the top side of bottom flanges, the backside of nuts and bolts, the interior of box beams, and those areas where climbing is difficult and access is limited.

**SP-3** - SP-3 denotes power tool cleaning. This is very similar to SP-2 except that power tools are used instead, thus making this a more viable and efficient cleaning method for larger areas.

1. Check that the power tools have not placed any oil or grease back onto the surface. If they did, the surface should be re-cleaned per SP-1.

2. Paint, rust, or millscale that can be removed with a hand scraper should not remain after a proper SP-3 surface preparation. A “dull putty knife” can be used to assess the acceptability of the surface.

**SP-11** - SP-11 denotes power tool cleaning to bare metal. This method uses power tools to remove ALL paint, rust, and millscale and to roughen the surface to promote paint adhesion. SP-11 offers performance advantages over SP-2 and SP-3, which result in an irregular surface of bare steel, rusted steel, mill scale, and paint but it tends to be quite expensive because of the labor involved.

**Blast Cleaning**

Blast cleaning is the most effective method for surface preparation is blast cleaning. Blast cleaning is broken down into four levels according to the desired condition of the base metal. Blast cleaning does not get rid of oil and grease, which is done by solvent cleaning.

There are many types of abrasive on the market. Recyclable abrasives have gained popularity in recent years because their use can reduce waste handling and disposal by 90 percent.

**Blasting Using Recyclable Abrasive**

In this system the abrasive is accumulated after usage, cleaned, and reused more than one time. Recyclable abrasives must be hard and durable. Thus metallic material is typically used, and typically requires special equipment to collect, classify, separate, and convey collected waste residue. Also, since the abrasive is harder, contractors must pay close attention to abrasive gradation to keep a cleaned surface profile within acceptable ranges. A contractor must closely monitor the separation process. It is important to completely remove all fine material from abrasives. If the abrasive is improperly or incompletely cleaned, dust concentrations within the containment can be adversely affected.

Several methods are available in the industry to filter discharged air from the system. Often systems using water for blasting or water filters to remove particulates are not acceptable as the water then becomes another different waste for disposal; however, MDSHA uses a pressurized filter system to remove particles from bridge cleaning waste water. The Golden Gate Bridge Authority in the San Francisco Bay area uses filters to remove particles from bridge painting waste water.

As with all open blasting operations, the recycled abrasive method must be fully contained. Costs associated with recyclable abrasive include additional equipment and increased initial abrasive costs. This is offset by increased cleaned surface area per unit
of abrasive (some times up to 100 cycles) and reduced volume of waste produced. The Missouri DOT has developed a model recycling program for abrasive lead blast. MoDOT no longer does abrasive blasting with Department forces; the agency has tried to create incentives for contractors to develop cost saving techniques and technologies for recycling its abrasives. All MoDOT bridge painting waste containing lead collected by Department crews is taken to lead smelter for recycling.

Closed Abrasive (Vacuum) Blasting
Closed abrasive blasting or vacuum blasting allows dust, abrasive, and paint debris to be vacuumed simultaneously with the blasting operation. Debris is separated for disposal and the abrasive is returned for reuse. Typically, hard metallic abrasives are used for this system.

Vacuum blasting equipment is expensive; however, both worker exposure to dust and environmental emissions can be minimized if operations are conducted properly. Special Provisions may allow vacuum blasting to be conducted without requiring full containment. Once again, systems that uses water or water filters cannot be used. Vacuum blasting is limited by its reduced production rate and operational problems cleaning edges and irregular surfaces. To be completely effective, the whole nozzle assembly must be sealed against a surface to maintain proper suction for the vacuum operation.

Figure 15: Shrouded Power Tools
Shrouded power tool technology has proven an effective engineering control that effectively prepares structural steel for new coatings, while simultaneously controlling all emissions in excess of 99.5 percent. On the Woodrow Wilson Bridge outside of the District of Columbia, this eliminated the need for containment and respirators and reduced the potential for lead poisoning to the environment or workers in the first place. These DOE, EPA, OSHA, and HUD-tested and approved tools utilize a mechanical, air-driven process that cleans surfaces to a bare substrate, while a High Efficiency Particulate Air (HEPA) filtered vacuum collection unit, the VAC-PAC, simultaneously captures dust and debris and transports it into an on-board 55-gallon drum. The Pentek system offers a fully integrated deleading system that removes, collects, drums, and seals the waste in a single step process for safe disposal. The shrouded power tools allow the workers to prepare the structural steel to a bare metal finish comparable to a Steel Structures
Painting Council SP 6 specification, Commercial Blast Cleaning. Pneumatic-powered rotary scalers and needle guns are being operated simultaneously—the former for the rapid deleading of large, flat surfaces and the latter with adjustable shrouds and pivoting head for access to hard-to-reach areas, such as around bolts and angles, or in corners. Fifty-foot vacuum hoses attached to the tools convey all removed dust and debris down to the HEPA-filtered vacuum and waste collection unit, which is stationed on the deck of a barge below. The 100 percent mechanical coatings removal system minimizes the amount of waste for disposal, as well as the degree of the owner’s liability and disposal costs, by adding nothing to the waste stream and collecting only the dust and debris of the coating itself. A typical lead abatement project employing Pentek’s system deposits 2,500 square feet of surface in a single waste drum. An independent company conducted air quality monitoring for the project with personal sampling and high volume environmental monitors, which were placed strategically at the site. Two separate air readings with the high volume environmental monitors were conducted six weeks apart, one on land and one on the barge. The efficiency of the dustless power tool system was verified by air sampling results of two to three micrograms per cubic meter, far below both OSHA’s Permissible Exposure Limit of 50 micrograms per cubic meter and the action level of 30 micrograms per cubic meter per eight-hour exposure limits.()

**SP Levels of Blast Cleaning and Associated Practices to Avoid Current and Future Environmental Impacts**

The following methods are presented in order of ascending cleanliness (i.e., SP-5 is most clean):

**SP-5** - SP-5 denotes white metal blast cleaning. This level of cleaning is costly and is rarely specified for use on bridges.

- The resulting surface should be free of oil, grease, dirt, rust, mill scale, all paint, and foreign matter leaving only a uniform grey-white color.

**SP-6** - SP-6 denotes commercial blast cleaning.

1. The resulting surface should be free of oil, grease, dirt, all rust, mill scale, paint, and foreign matter (except for slight shadows, streaks, or discolorations caused by rust stains, mill scale stains, and tight residue of previous coatings).

2. At least two-thirds of each 150-cm² (9 in² ) area must be free of all visible residue and the remainder limited to those discolorations just mentioned.

**SP-7** - SP-7 denotes brush off blast cleaning.

1. The resulting surface should be free of oil, grease, dirt, loose mill scale, loose rust, and loose coatings, retaining only tightly bonded mill scale, sound rust, and previous coatings.

**SP-10** - SP-10 denotes near-white blast cleaning.

1. The resulting surface should be free of oil, grease, dirt, rust, mill scale, paint, and any foreign matter (leaving only slight stains from rust and mill scale).

2. At least 95 percent of each 150-cm² (9 in² ) area should be free of all visible residue with the remainder limited to slight discoloration.

**SP-12** – SP-12 is the standard for pressurized water blasting.

The most common surface preparation specified for bridge use is SP-6, which requires SP-1. When repainting an existing structure, the Specifications may call for SP-2 or SP-3
in areas of limited accessibility. Recent research indicates SP-10 may be more cost effective than SP-6, particularly in more corrosive environments. Inspection should verify that both the proper level of cleanliness and the proper anchor pattern have been achieved.

Blasting operations require that several additional checks occur. The contractor’s equipment and material must be checked along with the resulting anchor pattern.

- **Inspection of the Abrasive** - The contractor will select the abrasive to be used based on the specified anchor pattern. The chosen abrasive should be free of toxic heavy metals such as lead, chromium, and cadmium and should not contain any free silica (sand) either. A sieve analysis from the abrasive supplier should be requested prior to delivery of the first load of abrasive. Once the abrasive is on site, obtain a sample of the stored abrasive material. It should be stored in a dry environment and should be clean, uniform, and free of any sign of moisture. To check, drop some of it into deionized water and shake. Watch for a film of grease or oil indicating the presence of contaminants. Keep a small sample of abrasive from each subsequent delivery. This will allow for a future analysis in the event that changes occur in the anchor pattern.

- **Inspection of the Air Supply** - This is necessary to ensure that the air supply is not introducing neither contaminants that will be embedded in the steel nor oil or water into the system. Inspect the air compressor for contaminants. The compressor should have moisture and oil traps on all lines. Shut off the flow of abrasive. Place a white blotter cloth in the air flow. It should be placed approximately 0.6m (24 inches) from an outlet downstream from the oil separator and moisture traps. Let free air flow for two minutes. Check for visible contaminants in the air flow; if there are any, corrective action is needed. This test should be repeated every four hours or more frequently when the humidity is high.

- **Blasting Pressure** - The blasting pressure should be at least 620 kPa (90 psi); any less than this can result in a lower anchor pattern and in slower production. However, jobs that use recyclable steel grit often use higher pressures. All high pressure air supplies and devices should be gauged for easy reading. For blasting, the critical pressure is located at the end of the blast nozzle. This pressure will be lower than that measured at the air supply due to loss in the hose. Hence, limiting the length of air hose is often a critical factor in the efficiency of a blasting operation. A pressure needle gage may be used at the nozzle to measure the true blast pressure.

- **Inspection of SP-6 and SP-10** - Once again, verify that the level of cleanliness noted above has been achieved including the referenced problem areas. The individual DOT Specification may provide a set of visual standards from either the National Association of Corrosion Engineers (NACE) or the Society for Protective Coatings (SSPC) to aid in this effort. Interpretation of the visual standards can take some discretion as well as some practice. Both SP-6 and SP-10 standards require the removal of ALL paint, rust, and mill scale. The only difference is in the amount of staining allowable on the bare steel surface.

- **Inspection of the Anchor Pattern** - The anchor pattern needs to be checked to ensure that proper paint adhesion will occur. Profile inspection requires the use of a micrometer and replica impression tape. Comparison coupons can be used for a
Monitoring
Air and soil monitoring are becoming more common on lead removal jobs. Monitoring protocols differ, and there is no current consensus on what should be done in this area. FHWA’s study tour on Bridge Maintenance Coatings Environmental and Worker Protection Practices reportedly uncovered no requirement or specification for environmental air monitoring for sources other than stationary sources, and bridges are not considered stationary sources; environmental air monitoring requirements for abrasive blasting of lead-containing paint from bridges and other structures were not encountered in the United States or Europe, despite increasing ambient monitoring for total lead in dust and particulate size (PM10) in this country. Nevertheless, many state DOTs, as well as numerous city and local authorities require environmental air quality monitoring for abrasive blasting operations as part of their specifications and policies. FHWA’s study notes that current FHWA research could lead to “more reasonable and applicable protocols for environmental monitoring during bridge-painting operations.”

FHWA’s study found that soil lead level monitoring before, during, and after the project is usually required. The Swiss have noted that as much as 70 micrograms of lead per m² per day may be deposited during movement and teardown of containment systems. Allowable levels of total lead in soils were found to be as low as 50 ppm. Some states are requiring pre- and post-job soil monitoring for lead contamination, but the requirement is not universal. Characterizing the contamination level of soils surrounding bridge job sites and especially the specific source of lead in any one location is difficult at best. Field monitoring and research is currently underway to attempt to better define appropriate soil-sampling protocols.

1 Soil sampling near and under containments is generally a good idea from a liability standpoint. Check for signs of surrounding ground or water contamination.

2 Air monitoring becomes more important if sensitive public access is nearby.

Paint Selection, Storage, Handling, and Mixing

- Use paints with maximum useful lifetimes, where toxicity is acceptable, not lowest cost, to maximize the time between repainting.
- Verify that the paint has not exceeded its shelf life. Shelf life is the length of time, from date of manufacture, that a paint will remain usable when stored in its can. Consequences of exceeding the shelf life include: gelling, odor, changes in viscosity, formation of lumps, pigment settling, and color and liquid separation.
  - Check the date printed on the can with the shelf life to make sure the paint has not “expired.” Some suppliers use a special code on the can which contains the date of manufacture. It may be necessary to call the supplier to read the code and assure that paint is fresh. Two-component paint systems often have a different shelf life for each component.
  - If the contractor desires to use this material that has exceeded its shelf life, he/she may submit a sample to the manufacturer’s laboratory for analysis and possible re-certification. The contractor should not be allowed to use
the material in question until written certification is received from the manufacturer.

- **Follow good storage practices and verify that the paint is not stored in areas subject to temperatures beyond the recommended limits.** Going beyond the acceptable temperature range can cause changes in viscosity and shelf life. Water-based paint will spoil when stored below freezing. Solvent-based paint, on the other hand, may gel or become flammable or explosive when stored at high temperatures.
  - The contractor’s storage site should be monitored with a high/low thermometer. Contractors often like to store the paint on site in a trailer. This is generally not a good idea because these trailers tend to get very hot during the summer and have limited ventilation. Paint should be stored in a climate-controlled environment.
  - Each lot of paint should be stored together.
  - Two-component systems should be stored close to each other, but be distinguishable from one another.
  - If the paint will be stored over several months, the cans should be inverted at monthly intervals to avoid excessive settlement and ease future mixing.
  - When opening the paint, the oldest paint should be used first. Look for signs of aging listed under shelf life.
  - Note the required temperature range for proper storage. Adherence to the temperature requirements noted on the Product Data Sheet is essential.

- **Verify that pot life has not been exceeded.** Pot life refers to the length of time a paint is useful after its original package has been opened or, for two-component systems, the length of time after it has been mixed. Pot life is temperature dependent. The pot life on the Product Data Sheet is generally for 21 °C (70°F). Contact the manufacturer for additional pot life information if the paint has been stored in temperatures outside of this general range. Exceeding the pot life can result in sagging of the fresh paint along with poor performance attributable to film porosity and/or poor paint adhesion. Two-component paints tend to become unworkable at or beyond their pot life.

- **Ensure proper mixing and use of thinner.** Different paints have different mixing requirements. The instructions on the Product Data Sheet should be strictly followed. Thinner is a liquid added to the paint at the time of application to modify its viscosity. The Product Data Sheet will indicate the specific type and maximum amount of thinner to be used.
  - Upon opening the can, check the surface of the paint for “skinning over” of the paint. Any skin should be removed prior to mixing.
  - All paint must be thoroughly mixed in a clean container.
  - Check the bottom of the original can for evidence of unmixed pigment.
  - For two-component paints, verify that they are mixed in the proper
proportion. The mixing operation should be witnessed and documented.

- Unused paint that will be used the next day should not be left in buckets or spray pots. It should be placed in a container and re-mixed prior to use.

- Thinner should be used only to achieve optimum viscosity for proper application and is not always necessary. Do not exceed recommended maximum use.

- Witness and document each and any addition of thinner. Adding too much thinner can prevent proper application thickness and cure of the paint and may result in the mixture exceeding acceptable limits for volatile organic compounds (VOCs).

- **Verify drying and curing times.** Drying time refers to the length of time a coating is sensitive to local damage. Curing time refers to the length of time it takes for a paint to reach structural integrity and be ready for service. The drying schedule on the Product Data Sheet will show how long it takes until the paint is dry to the touch, dry to tack free, and dry to recoat. Dry to the touch implies the paint won’t collect dust; tack-free implies the paint does not feel sticky and can be handled without damage; dry to recoat implies the time needed to dry until the next coat of paint can be applied. Drying times vary significantly with temperature. This is particularly important in determining when the next coat of paint can be applied. Recoating before enough time has passed can seriously affect the curing and integrity of the layer being overcoated. Some paints, particularly two-component paints, have a maximum time to re-coat as well. Exceeding this could jeopardize the adherence of the top coat.

  - After painting, inform the contractor of the estimated time that should be allowed for the paint to cure. Do not allow another coat to be put on until the appropriate amount of time has elapsed per the existing weather conditions.

- **Carry out storing, mixing and cleaning operations on land.**

- **Transport paint and materials to and from job sites in containers with secure lids** and tied down to the transport vehicle.

- **Do not transfer or load paint near storm drain inlets or watercourses.**

- **Test and inspect spray equipment prior to starting to paint.** Tighten all hoses and connections and do not overfill paint container.

- **Plug nearby storm drain inlets prior to starting painting** where there is significant risk of a spill reaching storm drains. Remove plugs when job is completed.

- **Cover nearby storm drain inlets prior to starting work** if sand blasting is used to remove paint.

- **Perform work on a maintenance traveler or platform, or use suspended netting or tarps to capture paint, rust, paint removing agents, or other materials,** to prevent discharge of materials to surface waters if the bridge crosses a watercourse. If sanding, use a sander with a vacuum filter bag.

- **Capture all clean-up water, and dispose of properly.**

- **Recycle paint when possible (e.g. paint may be used for graffiti removal activities).** Dispose of unused paint at an appropriate household hazardous waste...
facility.

- **Keep all materials securely locked up, to avoid vandalism and accidental spills into the watercourse.**

- **Hold a pre-painting meeting with the contractor**, addressing the following issues. Minutes should be kept and a copy should be given to all meeting participants, documenting understandings and any agreements reached.
  
  - The nature of the work and its effects on the surroundings, including possible mitigation measures.
  - Contractor’s method of operation, including equipment and personnel.
  - Contractor’s schedule. Discuss weather-related concerns.
  - Contractor’s job-specific worker health and safety plan (if lead paint is present).
  - Proper storage of material and equipment.
  - Location of recycling and dust collection and storage equipment.
  - Inspector safety, including provision of safe access and safety from lead contamination.
  - Inspection and measurement procedures, including control points.
  - Identification and treatment of inaccessible areas.
  - Product Data Sheets and Materials Safety Data Sheets for all relevant materials.
  - Visual standards to be met. Discuss contractor’s preparation of field reference sections.

**Containment and Use of Enclosures**

Lead was a common component of industrial paints until the 1980s, and many of the steel bridges in the highway system are still coated with paint that contains up to 50 percent lead by weight. High lead-containing primers can often be identified by their red or bright orange color. However, not all red and orange paints contain lead, and some paints of different colors can contain a significant amount of lead. Lead is hazardous to humans if it is inhaled or ingested and a relatively small amount of ingested or inhaled lead dust can elevate a person’s blood lead level. Proper respiratory protection should be worn to protect against lead hazards. “Proper” protection consists of either air-fed, positive pressure respirator hoods (as worn by abrasive blasters), or negative pressure, filter-cartridge respirators. Filters should be color-coded bright pink for fine dust particulate (i.e., HEPA filters). The required level of respiratory protection depends on the concentration of lead in the breathing air, and on the amount of time the worker is exposed. For most short-term inspections of jobsites without ongoing blasting, or outside of containments, a half-mask with appropriate HEPA cartridge is enough. However, while inside of containments during or immediately after abrasive blasting, an air supplied hood is likely to be required.
A containment system, or enclosure, is needed to prevent both lead and other debris generated during surface preparation activities from entering the environment and to facilitate its gathering and disposal. Enclosures are generally made up of combinations of cover panels, scaffolds, supports, screens, and tarps. The complexity of any given enclosure will vary depending on the method of paint removal being employed and the degree of surface preparation that is specified. For a simple scraping operation ground-covering tarps may be sufficient while for a blasting operation, the enclosure could be a designed structure with a negative pressure ventilation system.

Containments for abrasive blast (and other paint removal) operations are designed to protect the surrounding environment and the public from debris (flying abrasive) and potentially hazardous material (lead-containing dust) during a paint removal operation. In addition, these containment structures are intended to help contain and collect the lead-containing debris for proper treatment and disposal.

As the use of containments for paint removal jobs has become more common over the past several years, the design of containment structures has evolved. Currently, there are standard features of each containment method, but in large part, containments are custom-designed for each bridge job. The standard features are described in detail in the “SSPC Guide 6 - Containment.” This guide is not all inclusive, but it is the industry standard for description and classification of paint removal containments. In addition, several States have their own classification systems, but most of them are somewhat similar to those in the SSPC Guide 6.

It is important to remember that the purpose of a containment is to do a conscientious, “state-of-the-practice” job in containing and collecting debris. With appropriate specifications, and designs, and a cooperative effort between the owner and contractor, very near 100 percent containment and collection of debris can be approached.

Containment of abrasive blast jobs involving lead are mandatory because the law requires collection of the hazardous waste. While there is no specific rule governing the “fugitive emissions” of lead-containing dust, this dust can be controlled by designing and maintaining the containment and ventilation system properly.

Bridge maintenance involves the installation of safety nets, tarps, enclosures, barges or other means to catch paint chips and removed debris, water and abrasive blasting to remove old paint, rust, grease etc., application of rust inhibitors, primer paint (zinc, aluminum or lead), mid-coat paint (epoxy, vinyl or lead) and final coat (epoxy, polyurethane, vinyl or lead). All of these activities and products are detrimental to aquatic life in the stream below and need to be prevented from reaching the stream.

Components of a Containment System

**Containment System Structure** - Containments can be scaffolded from the ground or rigged to hang from the bridge structure. The key issues to consider are structural integrity under wind load, abrasive waster load, and dynamic loads on the bridge. Access, air movement, and visibility should also be considered.

1. Use custom built enclosures to confine and capture the abrasives, old paint chips and paint where possible.

2. Erect shrouds around working areas and suspending nets and tarps below bridges to catch debris from abrasive removal of old paint and over-spray from painting, where wind conditions permit. The work area should be clearly distinguishable from the surroundings.
3 Anchor tarps to barges below and enclosing the bridge above to confine debris, where the bridge deck is not too far above water level. Using barges and booms to capture fugitive floating paint chips and debris netting is not adequate.

4 Tarps should be overlapped with seams fastened and should be in good condition and free of holes.

5 During blasting operations with negative pressure, the tarps should have a concave inward appearance. They should never appear to bulge during blasting.

6 The containment should be tightly sealed to prevent any dust from escaping. Continually evaluate and/or perform field checks on the effectiveness of any containment. Watch for signs of dust escaping the containment and/or dust being discharged from exhaust system. Check the ground around the containment.

7 The containment must also be able to support workers, construction loads, spent abrasive loads and wind load without placing undue stress on the bridge.

8 The containment should be constructed in accordance with the approved plan.

9 Use vacuum or suction shrouds on blast heads to capture grit and old paint where possible.

**Ventilation** - For work inside an enclosure air movement is necessary to avoid a build-up of dust. High dust concentrations impair visibility and increase hazardous exposure levels to workers. Without ventilation, workers and inspectors will not be able to see within minutes of blasting commencing. Ventilation also reduces the concentration of lead-dust in the work environment and makes clean up operations prior to painting easier. Check for air movement with an anemometer, or get a rough idea of the amount of airflow by using a smoke bomb. Air movement is dependent upon the capacity of dust collectors, the volume of air input by makeup fans and blast nozzles, and interferences to airflow caused by the bridge structure itself. Ventilation ducting efficiency depends on the duct diameter and length, and on minimizing the number of sharp bends in the duct.

**Location of dust collectors** - Airborne emissions are often highest adjacent to dust collectors. While emissions should be minimized, they are unavoidable.

1 Dust collectors should be located in areas where emissions will have minimal effect on sensitive surrounding environmental or public areas.

2 Dust collectors should be operated at the rated capacity or at a capacity consistent with the ventilation design of the containment system.

**Lighting** - Proper lighting is often neglected. Inadequate lighting poses obvious safety concerns as it makes proper surface preparation and painting almost impossible. The potential for escaped lead-contaminated air emissions during blasting operations also warrants the usage by abatement workers of full facepiece respirators operating in positive-pressure mode. Shrouded power tool technology has proven an effective engineering control that effectively prepares structural steel for new coatings, while simultaneously controlling all emissions in excess of 99.5 percent. In other words, the need for containment and respirators is eliminated or drastically reduced by preventing the potential for lead poisoning to the environment or workers in the first place.
**Paint Application and Spraying Practices**

Once the proper level of surface preparation has been achieved and the quality of the coating system has been verified, the contractor is ready to paint. To prevent “rust-back” of the cleaned surface, the first coat of paint (primer) should be applied as soon as possible (within a few hours) after blast cleaning. Painting should begin at a practical time to avoid weather changes that could cause significant changes in the surface condition of the steel, i.e. nightfall.

Painting just before the onset of poor weather is not advisable. The current and expected weather, along with the curing time of the paint being used, should be considered prior to beginning the application process. To ensure that the paint is applied and allowed to dry and cure under reasonable environmental conditions, the following environmental conditions should be followed every four hours:

1. **Temperature** - The Specification will place limits on the ambient temperature to ensure proper curing. Most Specifications will require the temperature to be between 4°C or 10°C and 38°C (40°F or 100°F).

2. **Relative Humidity** - Again, due to of curing requirements, the Specification will limit the maximum permissible relative humidity, which is commonly limited to 85 percent.

3. **Dew Point** - Using the relative humidity, determine the dew point. The temperature of the steel should be at least 3°C (5°F) higher than the dew point. This “dew point spread” is used to ensure that no moisture is present on the steel prior to paint application.

4. **Surface Temperature** - The surface temperature of the steel should not exceed 52°C (125°F) during the painting process, and, again, it should be at least 3°C (5°F) higher than the dew point.

5. **Wind** - Heavy winds can cause problems. Airborne overspray, for example, may be carried onto adjacent houses, cars, etc. and can result in premature drying of the paint. If heavy winds are present, it may be best to delay the painting operation or to restrict spray application.

**Debris Storage**

The disposal of equipment and materials used to remove existing paint is also expensive. The waste must be placed in storage containers approved by the EPA. The contractor had two options for removing and handling the existing paint. Each option is designed to either make the removed material nonhazardous or reduce the amount of hazardous material generated; depending on the removal technology used, the waste is used as a recycled material or placed in a hazardous-waste landfill after being treated. DOTs should and generally do require all waste generated during removal operations to be sampled and analyzed by the contractor and submitted to a laboratory for Toxic Characteristic Leaching Procedure Testing (TCLP) for eight environmentally regulated heavy metals typically found in paint and abrasive wastes. Paint debris is classified as hazardous due to the characteristic of toxicity, if after testing by TCLP, the leachate contains any of the elements in the concentrations equal to or greater listed levels. Other
elements, chemicals, and characteristics can also cause a material to be hazardous as defined in 40 CFR 261, so best practice requires that:

1. No other waste be mixed with paint waste generated during the cleaning process.
2. Accumulated wastes shall not be removed from the temporary storage area without proper documentation.
3. For all projects involving the removal of paint wastes, some form of manifesting is required.
4. Recycling (off-site) or proper disposal of hazardous abrasive-blast media and use of approved haulers to transfer the contained waste to authorized treatment and/or disposal facilities.
5. The production of hazardous paint-removal waste should be minimized by the use of recyclable abrasive and the waste generated should be treated by effective methods to ensure its stability in waste containment sites.

Lead-contaminated paint waste can be classified as hazardous material. As such, it is subject to strict disposal requirements. The contractor may wish to temporarily store barrels containing this waste on site prior to hauling them to an approved disposal site.

1. If the barrels are stored on site, regulations restrict such storage to 90 days. Some entities, such as New York City Transit, voluntarily limit temporary storage of hazardous wastes to 45 days, instead of the allowable 90 days.
2. Barrels should be clearly marked as containing hazardous waste.
3. The barrels should be stored in a location inaccessible to the public, and they should also be in a location where they are not at risk of being hit by traffic.

The SSPC publication, SSPC 96-06, ISBN 1-889060-02-X, Guidelines for Cost-Effective Lead Paint Removal-Final Report includes information about waste testing and disposal. Also, it describes how Kansas DOT has placed bridge painting waste in concrete blocks.

**Quality Assurance and Public Outreach Programs**

In 2001, Illinois’ Department of Transportation (IDOT) revised its overall painting policy along with its environmental and containment specifications for all repainting maintenance. The most significant change in the specifications was related to quality control and quality assurance responsibilities. The Kentucky Transportation Cabinet has also been a national leader in the development of a quality assurance for bridge painting and maintenance.

As a proactive quality assurance measure, the Indiana Department of Transportation outline for bridge painting pre-bid meetings, Specification & Pre-Bid Conference Content Review, is used by the Indiana DOT environmental and safety professionals to make pre-bid conference presentations. The outline helps InDOT staff ensure that important environmental and safety topics are always presented at these conferences. Public outreach programs have become a part of bridge painting and lead removal projects. The Port Authority of New York City provides a good example program.