National Cooperative Highway Research Program

NCHRP Synthesis 251

Lead-Based Paint Removal for Steel Highway Bridges

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

National Cooperative Highway Research Program

Synthesis of Highway Practice 251

Lead-Based Paint Removal for Steel Highway Bridges

BERNARD R. APPLEMAN
Steel Structures Painting Council
Pittsburgh, Pennsylvania

Topic Panel

THOMAS BERNECKI, *Northwestern University*
JAMES BRYSON, *U.S. Environmental Protection Agency*
L. BRIAN CASTLER, *Connecticut Department of Transportation*
DAVID COPENBARGER, *Illinois Department of Transportation*
DOUGLAS J. EAKIN, *Oregon Department of Transportation*
JOSEPH M. HUERTA, *Federal Highway Administration*
ROBERT KOGLER, *Federal Highway Administration*
FRANK N. LISLE, *Transportation Research Board*
WILLIAM MEDFORD, *North Carolina Department of Transportation*
LLOYD SMITH, *Corrision Control Consultants & Labs, Inc.*
KRISHNA K. VERMA, *Federal Highway Administration*

Transportation Research Board
National Research Council

Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration

NATIONAL ACADEMY PRESS
Washington, D.C. 1997

Subject Areas
Bridges, Other Structures,
Hydraulics and Hydrology

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communication and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

NCHRP SYNTHESIS 251

Project 20-5 FY 1990 (Topic 28-04)
ISSN 0547-5570
ISBN 0-309-06107-5
Library of Congress Catalog Card No. 97-62278

Price $26.00

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

and can be ordered through the Internet at:

http://www.nas.edu/trb/index.html

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to state DOT bridge maintenance and construction engineers; regulators, consultants, and contractors involved with the removal of lead paint from bridges and structures; and structural coatings specialists, chemists, and researchers. This synthesis describes the current state of the practice for the removal of lead-based paint from existing highway steel bridges. It is essentially an update of Synthesis 176 "Bridge Paint: Removal, Containment, and Disposal" (1992). The synthesis reports on the changes in technology, practice, and regulations since the collection of data for Synthesis 176 approximately six to seven years ago. This was accomplished by conducting an extensive survey of U.S. transportation agencies and practitioners and a literature search.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board presents information on paint removal technologies for structures and the containment of debris during removal; regulations for the handling of waste generated during removal, worker health and safety protection, protection of the environment, and training and education; and information on agency specifications and contracts to ensure the work is being done in compliance with appropriate practices and regulations. Additional detailed information on regulations, lead exposures during coatings removal, and containment methods and practices are found in the appendices. Furthermore, the appendices include an annotated bibliography, a listing of relevant standards, abbreviations and acronyms, and a list of key Internet sites.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

ACKNOWLEDGMENTS

Bernard R. Appleman, Executive Director, Steel Structures Painting Council, Pittsburgh, Pennsylvania, was responsible for collecting the data and preparing the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Thomas Bernecki, Senior Research Scientist, Northwestern University, Evanston, Illinois; James Bryson, Abatement Coordinator, U.S. Environmental Protection Agency, Boston, Massachusetts; L. Brian Castler, Manger of Construction Operations, Connecticut Department of Transportation; David Copenbarger, Bridge Maintenance Engineer, Illinois Department of Transportation; Douglas J. Eakin, Structural Coatings Coordinator, Oregon Department of Transportation; Joseph M. Huerta, Federal Highway Administration; Robert Kogler, Coatings Engineer, Federal Highway Administration; Frank N. Lisle, Engineer of Maintenance, Transportation Research Board; William Medford, Chemical Testing Engineer; North Carolina Department of Transportation; Lloyd Smith, Vice President, Corrosion Control Consultants & Labs., Inc., Herndon, Virginia; Krishna K. Verma, Welding Engineer, Federal Highway Adminstration.

This study was managed by Stephen F. Maher, P.E., Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in Topic Panel selection and project scope development was provided by Sally D. Liff, Senior Program Officer. Linda S. Mason was responsible for editing and production.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-05 staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

Lead-Based Paint Removal for Steel Highway Bridges

SUMMARY

Removing lead paint from bridges and other structures is a major challenge facing transportation agencies. The lead paint presents a potential hazard to workers removing paint, to the environment, and to the general public. If lead is left in place indefinitely, loss of corrosion protection and eventually of structural capacity of the bridge will occur, along with the possible erosion of lead into the environment.

Although the hazards of lead paint removal from bridges have been recognized and addressed in some form for at least a decade, the problems are still formidable. The challenge is to devise a strategy that protects the bridges in a cost-effective manner while protecting the environment and the workers and minimizing adverse publicity and owner's liability.

This report assesses the state of the technology and practice for removal of lead-containing paint from highway bridges. It updates *NCHRP Synthesis 176: Bridge Paint: Removal, Containment, and Disposal,* which describes the technology of the late 1980s. In the last 6 or 7 years there have been enormous advances in several aspects of lead paint removal, including

- Removal and reapplication of coatings,
- Containment ventilation systems for preventing emissions from entering the environment,
- Means to verify compliance with environmental regulation, and
- Standards, equipment, and strategies regarding worker protection.

Correspondingly, there have been major efforts by transportation agencies to maintain and protect lead coated bridges. These have resulted in

- New alternative strategies and materials,
- Innovative and variable approaches for contracts and specifications, and
- Increased levels of expenditure for paint removal under maintenance painting and deck rehabilitation.

Since the survey for the previous synthesis, expenditures for lead paint removal have increased more than 100 percent, even accounting for inflation. The amount spent is highly variable among the agencies surveyed. Some have spent as much as $75 million per year (New York state), while others have spent less than $1 million. The amount of

money and the number of bridges recoated is about equal for the two major strategies, full removal and overcoating.

The cost per unit area also varies enormously (i.e., by a factor of 10 or more) for nominally similar work. This reflects uncertainty in areas such as degree of containment, extent of worker protection, quality of work, degree of inspection, and overall compliance with regulations. For full removal, the unit cost ranges from less than $32/m^2 ($3.00/ft^2) to $247/m^2 ($23.00/ft^2). For overcoating the range is $12/m^2 ($1.12/ft^2) to $138/m^2 ($12.80/ft^2). The medians are $115/m^2 ($10.70/ft^2) for full removal and $49/m^2 ($4.56/ft^2) for overcoating.

Bridge painting has traditionally been underfunded and this is expected for the indefinite future. States have sought FHWA financial assistance. Some have started to allocate major resources from 100 percent state funds. Several states are trying to significantly reduce the number of lead-coated bridges. However, if adequate funding is not made available, this policy may result in questionable quality and environmental control. In order to reduce costs, transportation agencies are increasingly looking at the use of overcoating. Often, however, they do not have sufficient data on the performance or long-term costs. The focus is still primarily on short-term costs.

Federal regulations have had an enormous impact on the practice and cost of lead paint removal. The most significant federal rule is the Resource Conservation and Recovery Act, which governs waste disposal and is the driving force for construction enclosures (containments) around bridges. Waste regulations have not changed much since 1990, although variability of the enforcement and compliance are still major issues. Initially, structure owners were considered the primary "generators" of hazardous waste; however, in 1996 the Environmental Protection Agency (EPA) clarified that the contractor is a co-generator of waste with responsibilities and liabilities equivalent to that of the structure owner.

A major new rule was promulgated by the Occupational Safety and Health Administration requiring contractors (as well as transportation agencies) to observe stringent requirements for protecting individuals removing lead or others who may be potentially exposed to it. EPA has announced its intention to issue a rule requiring certification of contractors, supervisors, and workers engaged in lead paint activities. The final issuance of Title X for industrial structures will probably occur in 1998 or 1999, with implementation by the states by 1999 or 2000. A handful of states currently have requirements for certifying and training industrial deleading contractors, including bridge paint workers and supervisors.

Contractors, equipment suppliers, and others have developed substantial improvement in the technology for removing lead paint and for preventing emission through enclosures and other controls. Examples are as follows:

- Vacuum shrouded power tools and vacuum blasting are capable of reducing worker exposure but greatly reduce the production rate. Blast cleaning with expendable or recyclable abrasive continues to be the most productive and widely used method for full removal of lead paint. Hand and power tools are most often used for overcoating projects. There is little data on the effectiveness of containment for overcoating projects.
- Low- to medium-pressure water is widely used for cleaning prior to mechanical cleaning. The channeling, collecting, filtering, and testing of the water are of concern because of its lead content.
- SSPC Guide 6 has become the recognized guidance document for defining the levels of containment and for describing the methods to determine the effectiveness and efficiency of the containment system.
- Containment systems are designed by contractors who may employ design profes-

sionals. A major responsibility of the transportation agency is to determine whether the containment is effective in controlling emissions. Assessing the control of emission is presently done by visual monitoring, costly instrumental monitoring, or soil monitoring. New approaches for more suitable and cost-effective assessment procedures are under development.

Recyclable abrasives and other innovative approaches have been successful in reducing the volume of hazardous waste and the cost of disposal. Waste disposal costs are relatively consistent within regions, but transportation agencies are often paying more than the lowest commercial rate.

This report reviews critical aspects for specifying lead paint removal projects including: defining extent of work, removal and containment, monitoring of emissions, waste handling and disposal, traffic control, worker protection, and quality assurance. Some key findings are:

- Agencies expressed different opinions on the advisability of providing estimates of surface area.
- Performance requirements (which can be very detailed) are preferred by most agencies for specifying containment.
- Traffic control has a major impact on the cost, efficiency, and public impact of paint removal.
- Many specifications and special provisions for lead paint removal appear to have deficiencies that could be corrected by a greater review within the coatings/corrosion community or among peers within the agency or from other bridge agencies.

Specific contracting practices also have a strong impact on the quality and cost of lead paint removal. Key issues are:

- Bid prices are extremely variable. The bidding process appears to be inflexible and does not provide a mechanism for excluding unrealistically low bids.
- Overall, contractors still bear too much risk for bridge painting, which may reflect the variability in cost and in performance.
- Paradoxically, bridge painting has become very competitive. This factor can also affect quality as costs decrease. Requirements for open bidding of public agency projects make it difficult to exclude a contractor from the agency approved list. Survey data show that even for estimates less than 30 or 40 percent of the engineer's estimates, the bid is rarely thrown out.
- Most contractors do not have pollution liability coverage and are vulnerable if there is a claim for property damage or personal injury.
- The Painting Contractor Certification Program, established by the SSPC, is receiving increasing support from transportation agencies as an effective prequalification program.
- Highway agencies have investigated innovative approaches for contracting such as partnering, warranties, and single source responsibility. These approaches have limited use, but bridge agencies are showing a greater willingness to try new alternatives to save money.
- Lead paint removal projects are highly visible public activities, as a result of containment structures, trailers, decontamination facilities, and workers dressed in elaborate personal protective equipment. The news media and public are well aware of potential problems with lead and must be kept well informed by the owner as well as the contractor.

Numerous factors affect agency decision making and strategies. The major options for dealing with lead painted bridges are: full removal of the lead paint and repainting; partial removal and repaint (overcoating or zone painting); replacing the steel; or deferring action. Principal findings are as follows:

- Deciding between full removal and overcoating depends on the condition of the existing coating (both general and localized); the acceptability of emissions and public inconvenience; the severity of the exposure environment; and the agency budget and policy. Overcoating entails more risk of early coating failure but is significantly less costly, less disruptive to traffic, and provides a reduced level of environmental contamination. It is still often a judgment call by the agency, influenced by considerations of life-cycle costs.
- Replacement of steel members is a viable alternative to full removal when replacing the deck. This strategy may necessitate additional training of shops or firms that handle or recycle dismantled steel.
- Several models have been developed to aid in decision making, including one based on risk management.

Based on the current level of expenditure on full coating removal and steel replacement, the transportation industry will be faced with the issue of lead paint removal for 30 or 40 years. Investments in developing and evaluating new strategies, techniques, and decision models are expected to yield very high dividends in both the short and long terms.

CHAPTER ONE

INTRODUCTION

CURRENT STATUS OF BRIDGE PAINT MAINTENANCE

According to the National Bridge Inventory there are more than 200,000 steel highway bridges in service throughout the nation. Protecting bridges against corrosion by painting is an essential aspect of bridge maintenance and an important concern of highway agencies. Approximately 80 to 90 percent are coated with lead-based paint (lead-containing paint) (*1*). The removal and replacement of lead-based coatings has resulted in increased scrutiny by environmental and medical professionals, construction workers, structure owners, and the public. Today, numerous local, state, and federal regulations exist for the purpose of safeguarding both the construction workers' health and safety, and the environment. This has made the removal and disposal process extremely complex and costly.

Lead-based paint on these structures presents a major challenge and concern for the following specific reasons:

- The paint system on these structures has a limited durability because of the deteriorating effects of aging of the paint, salts and moisture, ultraviolet radiation, and physical and mechanical abuse.
- Any activity to restore or maintain protection and appearance will result in some disturbance to the lead-based paint that could cause adverse effects.
- Coatings on many of the structures are in very poor condition with paint peeling, chipping, and eroding, and active corrosion of the metal occurring. There is wide misconception as to the importance of maintaining the existing coating. If left unchecked, the corrosion can cause structural damage to the bridges within the next 5 to 15 years. In the meantime, the coatings still present a potential for environmental pollution and can be a public eyesore.
- Leaving the coating undisturbed can also cause problems because the lead-based paint will eventually erode or flake off these bridges into the environment. In addition, the mere presence of lead in bridge coatings has impacted the maintenance practices used on steel bridges. Often, agencies have restricted or even avoided other necessary maintenance because of the complications and cost impacts of lead in paint.
- The cost of removing or maintaining coatings on bridges is extremely high compared to historical levels of spending on painting by highway agencies. Because needs exceed available funding, it is vital that funds be used judiciously and effectively.
- Environmental, health, and safety regulations have had an enormous impact on the practice and cost of bridge painting. Some regulations have been generally accepted and complied with by the industry. Others, however, are poorly understood and have been erratically and nonuniformly enforced and explained to the regulated community.
- New regulations may be imminent in areas that could have very significant effects on the cost and practice of bridge painting.
- There is a large diversity among state and local bridge agencies regarding understanding of the risks, causes, and consequences of the lead paint issue.

Figure 1 shows a bridge with a typical containment system so that hazardous material does not affect the environment during paint removal operations.

FIGURE 1 Bridge with containment.

DEVELOPMENTS SINCE THE PREVIOUS SYNTHESIS

NCHRP Synthesis 176: Bridge Paint: Removal, Containment, and Disposal, published in 1992, describes the state of the practice for lead-based paint removal for the period 1986 through 1990 (*1*). In the 6 years since that information was compiled, there has been an enormous amount of activity in the areas of technology, regulations, and transportation agency practices. Some significant developments are listed in the following sections.

Developments in Technology

- Publication of a consensus guide on containment systems
- Design and development of containment enclosures and ventilation systems
- Equipment for abrasives recycling and dust control
- Techniques for removing and recovering existing paint and abrasives

- Processes and materials for reducing volume of total waste and of hazardous waste
- Technology for monitoring environmental releases to the air, soil, and water
- Equipment for protecting workers and monitoring the effectiveness of their protection
- Materials for repainting for interim and long-term protection
- Availability of technical data, information resources, and industry standards

Regulatory Development

- Comprehensive standard for protecting construction workers exposed to lead
- Increased and more visible efforts to enforce the standard by the Occupational Safety and Health Administration (OSHA)
- Recognition of other health and safety hazards to those working on lead-coated bridges (e.g., falls)
- Initiation of regulations requiring state licensing, certification, and training for firms and individuals
- Increased public awareness of lead because of the related issue of childhood lead poisoning
- Recognition of the needs and concerns of the industry by waste management firms and industrial hygiene firms
- Great variability and uncertainty within the industry regarding regulations on air, water, and soil quality
- Recognition of the individual responsibilities and liability of owners, contractors, and others
- Greater involvement among the bridge and highway industry, design and construction industries, and coatings industries, and the regulatory agencies in the development of regulations

Developments in Management and Administrative Practice by DOTs

- Emergence of programs to ensure quality of application and materials
- Greater recognition of the risks and costs of lead-based paint
- Greater recognition of the need to allocate resources, and to identify and assess alternative cost-effective maintenance strategies, both long- and short-term
- Recognition of the need to develop broad-based agency policies and management commitment to address the issues
- Recognition of the importance of the role of the community in the planning and execution phases of bridge paint removal
- Specific programs on training in technical and management areas
- Recognition of the importance of thorough and explicit specifications

OBJECTIVE OF SYNTHESIS

This synthesis reviews the issues outlined above and assesses how highway and bridge agencies and the corrosion and coatings industry have progressed during the past 6 years.

This synthesis updates Synthesis 176 by summarizing technology, practices, and regulations affecting removal of lead-based paint from bridges. Specific areas addressed are:

- Current practices for specifying paint removal, worker health and safety, and environmental and public protection
- Contract development and administration practices, including prebid conferences, prequalification, certification, and partnering
- Environmental monitoring regulations and practices
- Worker protection requirements and practices for contract employees and DOT personnel
- Training and certification requirements and practices for workers, supervisors, inspectors, and DOT personnel
- Engineering controls, removal methods, and containment techniques
- Liability, insurance, and bonding issues
- Comparison of maintenance alternatives: full removal, overcoating, and steel replacement (analysis to address costs, risks, performance)
- Waste disposal practices and requirements
- Role of the community
- Ongoing investigations and evaluations of new materials, techniques, processes, and strategies.

Approach

Acquiring Data

Data and information have been acquired from the following sources:

- Surveys of transportation agencies and industry groups
- Review of the published technical literature
- Review of existing written documents by transportation agencies (e.g., specifications, contracts, cost analyses, internal policies)
- Interviews with representatives of the transportation agencies and industry groups.

Results of Literature Search

There is an enormous amount of published material on this subject. The issue of lead-based paint removal has been addressed in almost every U.S. industry because of the use of structural steel, a large proportion of which is coated with lead-based paint. Consequently, there are numerous industry-specific periodicals (e.g., *Plant Engineering*) as well as those from groups such as the construction specifiers and labor unions. These groups have also developed programs, policies, contracts, etc., regarding lead paint. Health and medical advisory groups (e.g., American Industrial Hygienists Association, The Center to Protect Workers' Rights) have also become involved. Each of these groups has its own slant on these activities.

Seminal Publications

In addition, there have been about 10 key reports or treatises published that provide a concentrated reservoir of detailed information. These are primarily derived from SSPC: The Society for Protective Coatings (formerly the Steel Structures Painting Council) and the Federal Highway Administration (FHWA). Some of these (e.g., *The Industrial Lead Paint Removal Handbook*) (*3*) are encyclopedic in nature. Others are more pedantic (e.g., the SSPC course on Supervisor/Competent Person Training for Deleading of Industrial Structures (*4*)). Still others are oriented more toward research development and evaluation (e.g., FHWA contract research project reports).

Detailed information on areas such as removal methods, components of a containment enclosure, and coating materials are not included but rather are summarized with references to the best and most detailed sources. These major sources were produced between 1993 and 1996, so they are relatively up-to-date.

Electronic Media

Another important aspect is the availability of information on the Internet and in other electronic forms. This report identifies a small but growing set of sources on the Internet and on CD-ROM. An important challenge for the highway industry is to make information more accessible to potential users of the information. Because of the huge amount of information currently available, coupled with its rapid rate of growth, there is a need to compile the information in a form that can be more easily used by bridge agencies.

Use of Information

This report is intended to be used by state and local bridge and highway agencies; by the construction, corrosion, and coatings industries; and by regulators and health and environmental professionals. It is also to be used:

- As a concise summary of practice and technology for lead paint removal in the 1990s
- As a guide to help readers identify and access relevant published information
- As an information resource for transportation agencies and industry that identifies gaps and deficiencies in the knowledge base and addresses these problems
- To promote greater appreciation of the importance of bridge protection and painting and the need for increased attention to this issue, which is expected to persist for many more years.

Organization of Report

Chapter 2 summarizes the major sources of lead exposure from bridge painting and major developments in structure containment and paint removal technologies. Additional details on these subjects are given in Appendixes D and E.

Chapter 3 describes industry and transportation agency practice in handling lead-containing hazardous waste. The regulations on waste handling, along with those pertaining to air, water, and soil protection, are given in Appendix C. Worker protection regulations affecting bridge maintenance painting are summarized, and new and pending regulations on training and certification and changes in the environmental and health and safety regulations are highlighted.

Chapters 4 and 5, respectively, present information on the organization and content of transportation agency specifications and contracts. These demonstrate the great variety in practice and also the major strides and innovations that have been made by these agencies. These also illustrate where significant improvements may be made.

Chapter 6 presents the results of the survey of transportation agencies. The survey requested information on the overall cost of bridge painting over the last 4 years, agency contracting practice, and information on specific projects for full removal and partial removal (overcoating) of the existing lead-based paint. The survey instrument and the identity of the responding agencies are provided in Appendix A.

Chapter 7 discusses the available strategies for rehabilitating bridges and presents processes used to decide which strategies are appropriate for specific project types. Chapter 8 presents conclusions and suggestions for advancing the technology and the practice of cost-effective lead paint removal. Additional information sources are presented in Appendix B, including a listing of relevant standards, abbreviations and acronyms, and a list of key Internet sites.

CHAPTER TWO

OVERVIEW OF REMOVAL AND CONTAINMENT TECHNOLOGY

INTRODUCTION

As noted previously, lead-based paint on bridges presents a potential hazard to the environment. The primary risk occurs when the paint is removed or otherwise disturbed, although there is also a risk of scaling or deteriorating paint contaminating the adjacent soil or water. To prevent such hazardous emissions and to comply with various regulations, the transportation agencies in conjunction with the construction/coating industry have developed technologies to protect the adjacent environment by containing the lead-based paint.

One consequence of containment is an increase in the level of lead (in the form of dust, chips, and debris) in the work area. Over the last several years, it has been recognized that workers removing lead-based paint, as well as adjacent workers, are exposed to levels of lead that can be extremely detrimental to their health and their families' health. So, an important trend has been the emergence of worker health as an issue equal in importance to that of protecting the environment and the public.

The federal agencies responsible for protecting the environment and the workers are, respectively, the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). In addition, each state and many municipalities have agencies that develop and implement similar regulations. EPA has promulgated several major regulations impacting bridge painting. These have been described in detail in previous treatises and are summarized in Appendix C. The principal occupational health and safety regulation is the OSHA Lead in Construction Standard (29 CFR 1926.62) issued in 1993 (*5*). This regulation has had a major (mainly positive) impact on the practice of lead paint removal from bridges, but has also increased costs somewhat. This regulation is also summarized in Appendix C.

DEFINING AND MEASURING LEAD IN PAINT

There is no single, unambiguous definition of lead-based paint in the industry. The definition depends on the application and use of the paint (residential vs. industrial), the particular regulation that is being considered, and on the particular form of the lead (lead in waste vs. lead in air). Different regulatory agencies (e.g., OSHA for workers, EPA for the environment) have different definitions.

Lead is present in various media, including waste, air, soil, water, paint, and blood. For lead in waste, the amount of soluble is of concern. This is the amount of lead that might leach out into groundwater when that waste is land-filled. Thus the total amount of lead in the paint that is removed is not the determining factor for lead-containing wastes. For lead in the ambient air (that is, the air in the general environment), the total amount of lead is of concern. This is also true for lead in the breathing zone of workers. For lead in soil (Figure 2), the total amount of lead (i.e., as a weight percent) is usually of most concern. For lead in water, the amount of soluble lead is of primary concern because of the possibility that it will be ingested by humans or other organisms.

FIGURE 2 Contaminated soil.

Regulatory Definitions of Lead

The following describes the different ways that lead is defined and regulated at the federal level:

- Lead in paint

— In 1968, the Consumer Product Safety Commission banned consumer paints with more than 600 parts per million (ppm) (0.06 percent) of lead (*6*).

— In 1992, EPA, in conjunction with HUD, defined lead-based paints for residential purposes as those containing 0.5 percent lead by weight (5000 ppm) (*7*). This definition is not considered appropriate for industrial settings.

— OSHA's Lead In Construction Standard requires the employer to determine the potential lead exposure of workers when "any lead" is disturbed (*5*). This places a major responsibility on the employer (contractor) and ultimately the bridge owner to accurately define the potential for worker exposure to lead from the lead in the paint.

- Lead in worker breathing zone

— The Permissible Exposure Limit (PEL) is the maximum concentration of lead in air to which a worker can be exposed. The PEL is set at 50 μg/m^3 (micrograms of lead per cubic meter of air) as a time-weighted average for an 8-hour day.

— The Action Level (AL) is the level of lead concentration in air at which medical monitoring and other control measures are triggered. The AL is 30 μg/m^3, also as a time-weighted average over 8 hours.

- Lead in ambient air

— Lead in ambient air is also measured in μg/m^3. The EPA standard allows a maximum of 1.5 μg/m^3/day averaged over 90 days. However, this regulation is not intended for one-time activities such as paint removal (*3,4,* and Appendix C).

- Lead in waste

— EPA does not regulate the total amount of lead in waste (however, two states, California and Michigan, do).

— EPA regulates the amount of leachable lead in waste, i.e., lead that dissolves when the waste is placed in an acid solution in the TCLP test (Toxicity Characteristic Leaching Procedure). The waste is defined as hazardous if the TCLP result is 5 μg/L (micrograms of lead per liter of solution) or greater.

- Lead in soil

— Lead in soil is measured in parts per million (ppm). There is no federal standard for lead in soil. (See chapter 3 and Appendix C.) Figure 3 illustrates a method of soil sampling.

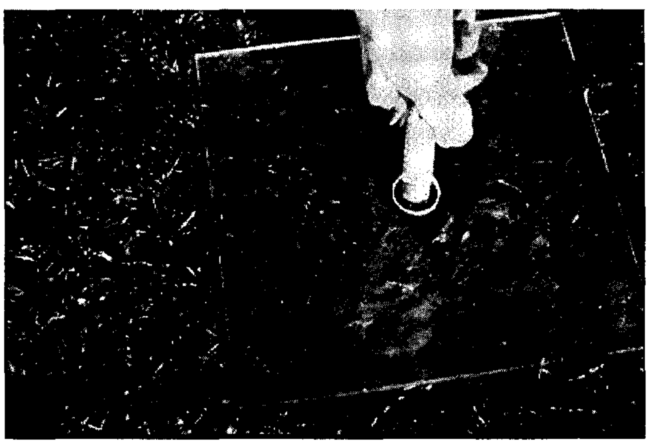


FIGURE 3 Soil sampling.

- Lead in water

— Lead in water (e.g., streams or lakes or sanitary sewers) is measured as milligrams of lead per liter of water (mg/l). There are federal and state standards for lead in water, but they are not directly applicable to lead paint removal (see chapter 3 and Appendix C). The drinking water standard is less than 0.05 mg/l for public water supplies.

- Lead in blood

— Lead in blood is an accurate indicator of exposures and adverse health effects and is tightly regulated. The maximum level for a worker before action is required is 40 micrograms of lead in 1 deciliter of blood (μg/dl).

- Lead in bridge paint

— Typical lead levels in lead-based bridge paint are in the range of 10 to 50 percent by weight, so there is usually little doubt as to the need for control measures to protect workers and the environment. However, even so-called nonlead-containing paints may have trace amounts of lead (or other heavy metals such as cadmium and chromium) which can result in exceeding the AL or PEL for these substances (*8,9*).

Correlations Among Different Forms of Lead

Unfortunately, there is not a strong or consistent correlation among the various forms and manifestations of lead. The total amount of lead in the paint (on the bridge surface) is not a good predictor of the amount of leachable lead that will end up in the waste after the lead is removed (e.g., by blast cleaning). Although several efforts are being made, so far there are also no data showing a strong correlation between the amount of lead in the paint and the amount of lead emitted into the worker breathing zone. In fact, very low levels of lead in paint (0.1 percent or less) have resulted in airborne exposures in excess of the PEL of 50 μg/m^3 (*10*).

OSHA believes that there is a reasonable correlation between lead in the breathing zone and lead in blood, so the OSHA Lead Standard, designed to prevent worker elevated blood lead levels, is based on airborne lead levels.

COATING REMOVAL TECHNIQUES

The challenge for the transportation, coatings, and construction industries is to establish strategies and procedures for removing lead-based paint in compliance with the environmental and worker protection regulations. For each method or system, it is necessary to examine the potential exposure to lead of workers, the environment, and the general public. These considerations are in addition to the normal consideration of the productivity, cost, and effectiveness of the methods. One must not lose sight of the fact that the main reason lead-based paint is replaced is to provide enhanced corrosion protection and to improve the appearance of the bridge. In some instances, the lead is disturbed because of incidental repair or maintenance work or as part of a bridge demolition project.

The most commonly used methods for removing lead paint have been (and continue to be) abrasive blast cleaning and hand and power tool cleaning. Over the last decade or so, several alternate methods and modifications of the conventional methods have been developed that may have potential to improve the overall effectiveness of the process. This is based on considering the reduction of environmental and worker exposure, as well as the ability to effectively remove the coatings. Thus, it is important to identify the known exposure to lead resulting from each of the various paint removal and other lead disturbing activities.

In the preamble to the Lead in Construction Standard, OSHA summarized data it had collected regarding the level of lead exposure experienced by different categories of workers, and workers using different tools (*11*). These levels were the basis for establishing the types of control needed for the different operations or types of exposure. For example, abrasive blasting

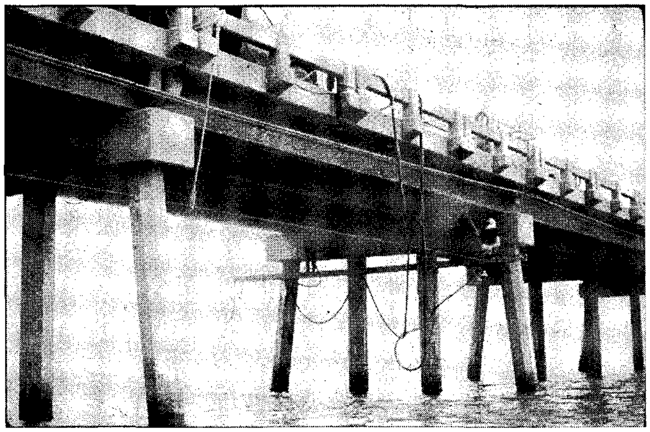


FIGURE 4 Open air abrasive blasting.

workers are expected to be exposed to more than 2500 micrograms of lead per cubic meter of air (μg/m^3), while those performing power tool cleaning with vacuum shrouds are expected to be exposed to a level of between 50 and 500 μg/m^3. It is important to recognize that almost every method (with one or two exceptions) can result in lead exposure exceeding the PEL of 50 μg/m^3. Figure 4 shows workers performing open-air abrasive blasting. Figure 5 shows a worker performing power tool cleaning.

The paint-disturbing activities described in the OSHA standard are shown in Appendix D (Table D-1), along with the median and maximum levels of lead exposure. OSHA did not report the amount of lead in the paint for their exposure data. Many bridges have high concentrations of lead in the paint film, so worker exposures would be expected to be toward the higher concentrations.

Comparing Coating Removal Methods

In the *Industrial Lead Paint Removal Handbook* (*3*), coating removal methods are rated on the following parameters:

- Quality of preparation
- Dust generation
- Volume of debris
- Production rate.

A portion of that table is presented as Table 1.

The more detailed version of this table also rates equipment investment and includes parameters for preparation quality including degree of containment required. Additional descriptions of these methods are given in the test and other recent treatises (*12*). Also, there have been numerous studies evaluating one or more of these methods on bridges as well as other structures.

The removal method is one of the key factors determining the cost and quality of surface preparation. Because of the potential for exposures discussed above, the removal method cannot be selected without also considering the means for containing the debris and controlling the exposure. The need for containment in turn necessitates consideration of a ventilation system to prevent overexposure of workers and to allow proper air flow through the containment.

CONTAINMENT TECHNOLOGY

Need for Containment

Containment is required to prevent debris from contaminating adjacent property and to avoid exposing the public to lead dust and debris (Figures 6 and 7). The most important regulation is the Resource Conservation and Recovery Act (RCRA), which prohibits deposition of "any hazardous material onto the environment." The Clean Air Act has also been mentioned by some in the industry as a rationale for containment, but it is less directly relevant.

The type of containment selected and specified for a lead paint removal project depends on a number of factors (see below). The methods of containment are classified based on the methods of removal and the potential for emission of dust and debris and other factors. The greatest need for containment arises when full removal of the paint has been

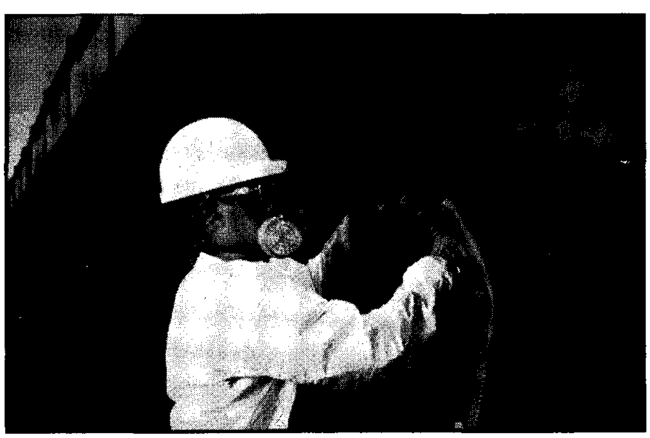


FIGURE 5 Power tool cleaning.

FIGURE 6 Containment on truss bridge.

TABLE 1
Comparison of Paint Removal Methods

Method	Quality of Preparation [a]	Debris Created: Dust Generation[b]	Debris Created: Vol. of Debris[b]	Production Rate [c]
Method 1: Open Abrasive Blast Cleaning with Expendable Abrasives	5	1	1	5
Method 2: Open Abrasive Blast Cleaning with Recyclable Abrasives	5	3	4	5
Method 3: Closed Abrasive Blast Cleaning with Vacuum	5	4-5	4	2
Method 4: Wet Abrasive Blast Cleaning	4-5	4-5	1	4
Methods 5/7: High/Ultrahigh Pressure Water Jetting	3-4	5	2-4	3
Methods 6/8: High/Ultrahigh Pressure Water Jetting with Abrasive Injection	4-5	5	2-3	3-4
Method 9: Hand Tool Cleaning	1-3	4-5	4	2
Method 10: Power Tool Cleaning	1-3	3-4	4	2
Method 11: Power Tool Cleaning with Vacuum Attachment	1-3	4-5	4	2
Methods 12 / 13: Power Tool Cleaning to Bare Metal	4-5	3	4	1-2
Method 14: Chemical Stripping	3	5	2-3	1
Method 15: Sponge Jetting	4-5	4	3-4	2-3
Method 16: Sodium Bicarbonate Blast Cleaning	3-4	4-5	2-4	2-3

Key

(a)	(b)	(c)
5: Excellent	5: No/None	5: Very High
4: Good	4: Little/Low	4: High
3: Marginal	3: Moderate	3: Moderate
2: Poor	2: Sizeable	2: Low
1: Very Poor	1: Substantial	1: Very Low

— Excerpted from: Trimber, Ken, *Industrial Lead Paint Removal,* 2nd Edition, 1993, SSPC Publication 93-02, Chapter 5.

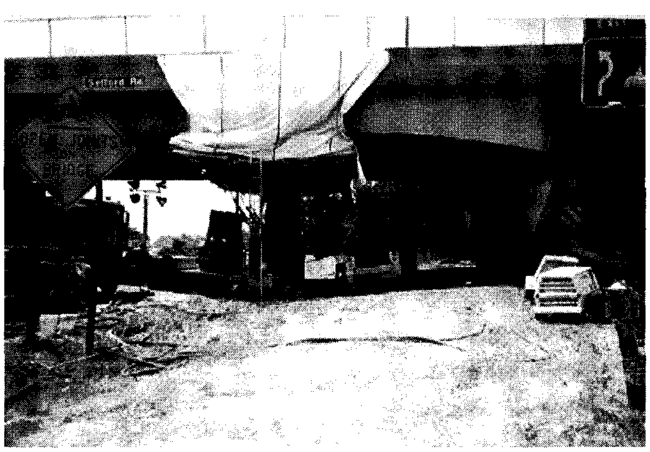


FIGURE 7 Example of containment on girder bridge.

specified and where the bridge is in an urban or environmentally sensitive area. The greatest potential for emission occurs during abrasive blast cleaning. However, whatever the method selected, full removal generates the largest amount of lead debris whether in the form of chips, dust, or spent abrasives.

A guidance document for containment and ventilation of hazardous waste projects is SSPC-Guide 6, "Guide for Containing Debris Generated During Paint Removal Operations" (*13*). The guide is most well known for defining different classes of containment for abrasive blasting, power tool cleaning, wet removal methods, and chemical stripping. This guide also describes methods for coating removal, collecting debris, assessing quantity of emissions, and components of containment enclosures and ventilation systems.

Design and Construction of Containments

The main function of the containment is environmental protection. Enclosures and other types of containments vary significantly in sophistication, effectiveness for different purposes, and cost. The major factors affecting the extent of containment required for bridge paint removal are

- Type of removal methods,
- Sensitivity of adjacent property, and
- Level of control sought by bridge owner.

The most stringent controls on dust and debris release (and hence the tighter containments) are required for abrasive blasting, which produces, by far, the greatest level of dust and particulates. This method may create airborne lead levels as high as 59,000 mg/m^3. Methods such as power and hand tool cleaning and water cleaning methods produce less debris. The typical lead exposure levels and containments for these methods are described in Appendix D.

The approaches for designing containments are described in Appendix E with additional detail given in several sources (*3,4,14,15*).

The major types of containment design are

- Bridge-to-grade (Figure 8)
- Suspended tarpaulins
- Suspended platform (rigid)
- Outrigger and cable
- Enclosed staging
- Mini enclosure.

For each of these containment types there are various types of materials and methods of construction. Some of these are commercially available for purchase or rent. In other cases, contractors design containments specifically for the unique characteristics of a bridge. One innovation that is unique to bridges is the trailer-mounted containment. Contractors have built these units for use on overpass bridges where full-time lane closures are not allowed. A recent innovation is the use of a "cyclone fence" to provide support for the containment operation (Figure 9). A containment can impose substantial loads on the bridge. In addition, the enclosure itself must be structurally sound to avoid creating a major hazard on an operating bridge (Figure 10). Therefore, in many instances a structural engineer must be involved in the design and assessment of the containment. As described in chapter 4, practices for ensuring that contractors design, construct, and operate safe and efficient containments vary widely among transportation agencies.

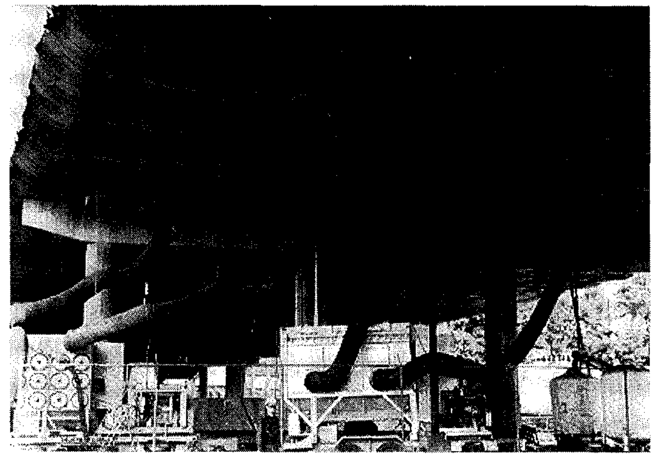


FIGURE 9 Cyclone fence containment.

In any case, the agency must be aware of the effects that the containment will have on the integrity of the bridge, the level and disruption of area traffic that it will cause and its cost, and perception of the impact of these activities by the public. These are discussed in chapters 4 and 5.

Ventilation of Containment

From an environmental and public protection perspective, the containment's main function is to prevent release of dust and debris. However, the interior design of the containment is also critical to the efficiency of the work and the health and safety of the workers.

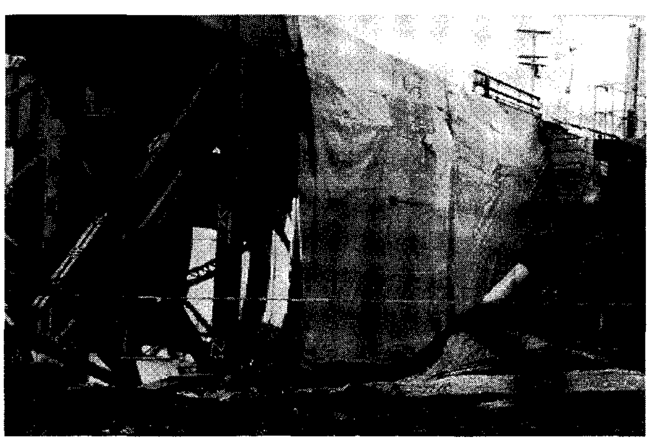


FIGURE 8 Bridge-to-grade containment.

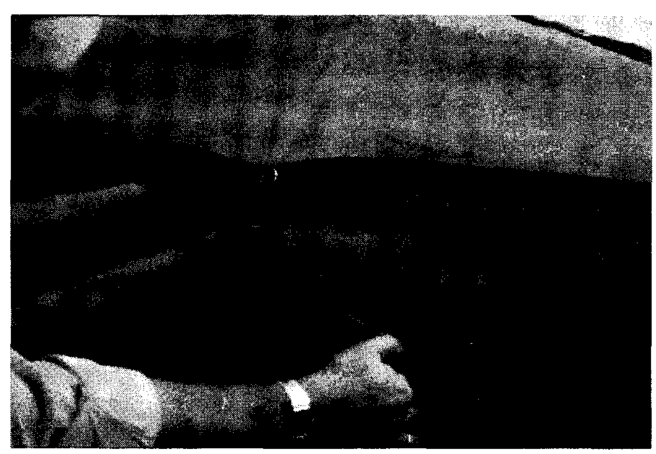


FIGURE 10 Partially sealed joint.

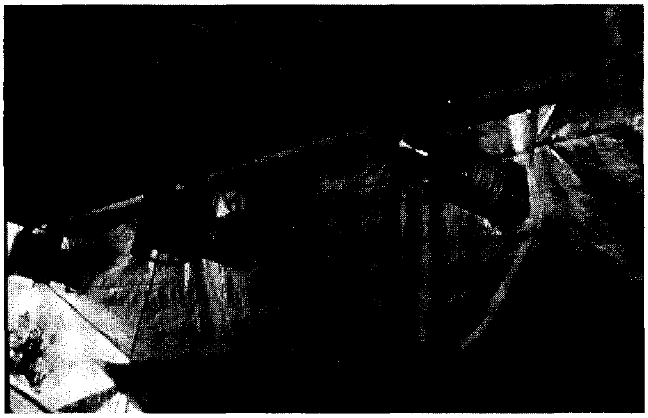


FIGURE 11 High-speed fans for ventilation.

It is essential that the containment be properly ventilated (Figure 11). Air movement is needed for several reasons:

• To prevent buildup of dust that can obscure the vision of the workers,
• To minimize the probablilty of air escaping through breaches of the containment, and
• To minimize the exposure of the workers to lead (as part of an engineering control of the work environment (Figure 12).

A generally accepted level of air velocity inside a containment is 33m/min (100 ft/min) minimum for cross draft (horizontal with ground) and 20m/min (60 ft/min) for down draft (vertical). Proper air flow and exhaust will help prevent dust buildup and escape. However, research has shown that air movement alone is insufficient to reduce worker's exposure to below the PEL for the extremely high level of lead dust generated during blast cleaning of high lead-content paints (*16*).

The design of ventilation systems is the responsibility of the contractor, and one in which some expertise is required. It may also require some expertise (either in-house or contracted out) on the part of the DOT to assure that the standard criteria are met.

Determining the Effectiveness of Containment

Design of containment systems is the responsibility of the contractor, who may employ design professionals. Determining whether the containment is effective in controlling emissions is a major responsibility of the DOT. SSPC Guide 6 describes several methods for assessing the effectiveness of containment by measuring air emissions (by visual and instrumental methods), measuring soil emissions, measuring water and sediment contamination, and measuring efficiency of waste collection. A visual assessment can be quantified by the opacity scale method (i.e., the degree to which vision is obstructed, Figure 13) or by recording the amount or percent of time when visible emissions are observed. Instrumental methods are based on using sampling devices, such as those used for sampling the worker breathing zone. The high-volume samplers are the most precise (and expensive), but the reliability and relevance are questioned by many practitioners.

Over the past 6 or 7 years, there have been major advances in containment design and materials. Many contractors are becoming very proficient in this area. However, better means are still needed for determining the efficiency and effectiveness of containment.

Prejob and postjob soil analysis for lead or other toxic metals is useful for determining if the containment has provided adequate ground protection. Examples of the use of the abrasive recovery method and visible emissions monitoring to determine the efficiency of containment are described in Appendix E (*17*).

The Containment Ventilation System as Part of Systematic Approach

The selection of the containment ventilation system along with the paint removal method can be incorporated into an overall process, based on the sensitivity of the environment, the potential exposure of the public and the risk to adjacent workers. (See the discussion of risk methodology described in chapter 7 and Appendix E.)

FIGURE 12 Worker inside containment.

FIGURE 13 Visible emissions (dust escaping containment).

CHAPTER THREE

WASTE HANDLING PRACTICES

INTRODUCTION

This chapter describes transportation agency and contractor experience with waste handling and disposal, and alternative approaches to minimize the volume of waste, the cost impact, and liability. Appendix C reviews current and proposed federal regulations pertaining to waste handling and disposal, Resource Conservation and Recovery Act (RCRA), and to spills and releases, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Proper treatment and disposal of lead-containing waste is an extremely critical issue as the DOT will be classified as the generator or co-generator. The DOT can be held financially responsible for clean-up costs in perpetuity under CERCLA.

FIGURE 14 Abrasive recycling equipment.

ALTERNATIVES FOR HANDLING LEAD WASTE FROM BRIDGES

The conventional approach for handling waste is to have the contractor collect the waste, place it in drums or bins, and hire a waste firm to transport and dispose of it. Typical costs for these activities are described below. Because of the major costs entailed by the conventional approach, a number of alternative approaches have been developed. These include the use of recyclable metallic abrasives, the use of preblast abrasive additives, on-site treatments, and the reuse of the waste in some other process.

Recyclable Abrasives

Recycling Steel Abrasives

Steel grit and shot are the abrasives of choice for most fabricators and painting shops because they have the advantage of being recyclable. These abrasives have also been widely used in field blasting. For field use, the abrasive must be contained, collected, cleaned, and then reused. The abrasive is much too expensive to allow it to be disposed after one use. This process can reduce the amount of abrasive consumed and the debris generated by 90 to 95 percent. However, this depends on the number of recycles of the abrasive, the abrasive's physical properties (hardness and resiliency), the retention of shapes, the amount of paint and other debris generated, and the overall efficiency of the collection and cleaning process. Methods of recycling abrasives are described by Hitzrot (*18*). These have shown significant improvements over the last several years.

A very important consideration is the cleanliness of the recycled abrasive. If it contains too high a lead content it could increase the level of airborne lead that the blaster is exposed to. Figure 14 shows abrasive recycling equipment.

A standard has been developed for the cleanliness of recycled ferrous metallic abrasives (SSPC-AB 2). (See Appendix B.) It requires the lead content to be a maximum of 1,000 PPM (0.1 percent), the nonabrasive residue to be a maximum of 1 percent of the weight of the abrasives, and the conductivity of the abrasives not to exceed 1,000 micromhos/cm (μΩ/cm). Figure 15 illustrates the difference between new and recycled abrasives.

Disposal of Debris from Recyclable Steel Grit

When steel filings are added to lead-containing waste, the waste is often rendered nonleachable and hence nonhazardous.

FIGURE 15 Comparing new and recycled abrasives.

This is attributed to a plating reaction between the lead and iron during the TCLP test. This phenomenon, called "stabilization," also occurs when using recyclable steel grit. Thus, the waste from such an operation (which consists of abrasive fines, paint debris, and rust) will frequently test as nonhazardous during the TCLP test even though lead content of this waste may be quite high.

EPA has pointed out that this "stabilization" caused by the iron and lead combination may be short-lived (*19*). As the iron rusts, the lead may once again become soluble (leachable), changing the waste from nonhazardous to hazardous. Thus, after several years, lead may leach out of the landfill and cause a major release into the environment, and liability for the owner and contractor.

SSPC and other industry authorities recommend that all residues from steel grit recycling be treated as hazardous waste (*4*). This waste may be sent to a licensed hazardous waste treatment facility for treatment and disposal, or it may be stabilized on site with portland cement, as discussed below. Connecticut DOT contracts require the use of recyclable steel grit. This agency, along with the Ohio Turnpike Authority and Maryland DOT, also requires all waste generated from lead paint removal operations to be treated and disposed of as hazardous waste.

Preblast Calcium Silicate Additive

In this technique, a calcium silicate material is added to the abrasive at 15 to 20 percent by volume before the blasting operations. Adding a material prior to blasting is legal, while adding it after the waste is generated is considered treatment of a hazardous waste and is restricted. This technique has been widely used by various agencies (e.g., US Army Corps of Engineers), chemical plants, and DOTs (*20*). DOTs that have used this proprietary calcium silicate additive (PCSA) include California, Oregon, Washington, and Minnesota.

According to RCRA, this waste is defined as a nonhazardous waste if it tests below 5 mg/l leachable lead (by TCLP). In almost all instances, the waste has tested as nonhazardous. The process of adding PCSA results in about a 15 to 20 percent increase in the total volume of the waste generated for a given surface area. As the additive is not itself an abrasive, it does not contribute to the surface preparation process. According to the manufacturer, California DOT uses the spent debris in cement kilns. Note that California regulates total lead in waste in addition to leachable lead.

Data from the recent FHWA Report has shown that lead from PCSA "treated" waste does not leach out after 12 iterations of the multiple extraction procedure, an EPA test (Method 1320) designed to simulate long-term exposure in a municipal landfill. In the FHWA study (*21*), lead debris stabilized with portland cement also gave similar results for long-term stability, while lead waste treated with steel grit showed increased leachability that exceeded the 5 mg/l after five to six extractions according to EPA Method 1320. However, the performance of PCSA for long-term stability under actual field situations has not been demonstrated. This product has only been on the market for about 5 years.

Tests conducted by an engineering firm provided the results shown in Table 2 for treating lead containing waste with the PCSA (*personal communication, M. McGrew, TDJ Group, Inc., May 1997*). For several of the entries, a test portion of the structure was blasted without the PCSA added to the abrasive; this served as a control. In all cases, the waste tested as nonhazardous. (This information was furnished by the manufacturer of the PCSA.)

There is some question as to the specific mechanism by which PCSA reduces the leachability of lead. The manufacturer claims that there is a true chemical binding reaction; however, this reaction would only be possible if the mixture were wet. There have been claims that this material is effective at stabilizing chromate containing waste, but this has also not been conclusively proven. However, Oregon DOT reports the successful use of 20 percent PCSA mix for paint containing chromate (*Personal communication, D. Eakin, Oregon DOT, May 1997*).

The effect of the additive on performance of coatings applied over the blast surface have not been investigated. However, no specific problems with early failure associated with this product were identified in the literature or from the survey. As a water soluble material, however, it is conceivable that the residue from the PCSA could induce osmotic blistering of a coating or interfere with the adhesion of the primer to the steel. The following is a list of the advantages and limitations of using PCSA:

Advantages of Using Proprietary Calcium Silicate Additives (PCSA)

- Renders generated waste nonhazardous, thereby greatly reducing disposal costs
- Eliminates the need for restrictions on waste accumulation time
- Reduces recordkeeping and reporting requirements
- Has been shown to be effective based on practical experiences of DOTs and other users.

TABLE 2
Effects of Proprietary Calcium Silicate Additive (PCSA) in Stabilizing Lead Waste

Total Lead In Waste %	TCLP (Without PCSA)*	TCLP** (W-PCSA) (PPM)
6.2	not tested	BDL,*** BDL, 1.6
7.3	not tested	0.15, 0.02, 0.03
20.2	not tested	BDL, BDL, BDL, BDL
29.2	not tested	BDL, BDL, BDL, BDL
11	10.2 ppm	BDL,0.064, 0.39, 3.15
8.0	6.7 ppm	0.043, 0.031, 0.040, 0.020
4.7	not tested	0.031, 0.021, 0.028, 0.024
32.6	8.2 ppm	BDL, BDL, 0.141

* = In a test a portion of the tank was blasted with abrasive not mixed with PCSA
** = Multiple samples tested
*** = Below detectable limit

Limitations of Using Proprietary Calcium Silicate Additives (PCSA)

- Increases cost for abrasives by about $20 per Megagram ($18/ton)
- Decreases productivity of abrasive because of the presence of a nonabrasive diluent
- Does not reduce the total amount of waste generated (might slightly increase it)
- The waste still contains lead and is still a hazardous material and must be handled as such
- May have limited effectiveness if the waste has substantial amounts of chromate (e.g., from basic lead silica chromate). In this case, a higher percentage of PCSA may be required.
- Could affect the paint life (although no adverse effects have been reported in bridge trials of 4 years)
- Is a proprietary product without established procedure for quality control (i.e., to verify that the materials purchased are the same as those tested or used on a previous job).

Overall, however, the use of PCSA has proven useful to transportation agencies seeking means to control cost and reduce the liability from hazardous waste.

A more recent development has been incorporation of lead stabilizers in paint formulations. The paint is applied prior to blasting. Laboratory tests indicate the lead-containing wastes generated after using these products will be classified as nonhazardous (*21*). These products are very new and field data are limited.

This method would not be affected by the proposed rule on reduction in the treatment standards (see Appendix C). That rule applies to waste initially testing at 5 mg/l or higher. In this process the waste will have initial leachable lead levels of less than 5 mg/l.

On-Site Treatment and Disposal

Under RCRA, EPA has defined conditions under which hazardous waste may be treated on-site, although this is rare among agencies generating lead paint waste (*21*).

Requirements for On-Site Treatment

- *Containers:* Generators can treat the waste on-site in 90-day holding containers or tanks, if approved by the state environmental agency or regional EPA office. Once the waste has been treated and is determined to be nonhazardous (e.g., leachable lead level below 5 mg/l as measured by TCLP), it can be disposed of at a Subtitle C (required for hazardous waste) or Subtitle D (required for nonhazardous waste) landfill.
- *Treatments for Lead:* A number of treatment methods have been used on lead-containing debris that have resulted in the treated waste having leachable lead levels below 5 mg/l when measured by TCLP. These processes are typically based on mixing the waste with portland cement, lime, lime-fly ash, or silicates. Proprietary commercial treatments are available. Lead may also be incinerated. Appendix D, SSPC Guide 7 (*22*) presents information on treatment methods.
- *Waste Analysis Plan:* On-site treatment requires filing a waste analysis plan with the regional EPA office or the state agency within 30 days prior to treatment (40 CFR Part 264.13). The generator is not required to obtain approval of the waste analysis plan before starting the on-site treatment, but the EPA can reject the plan at any time. Additional information is given in SSPC Guide 7 (*22*).

Lead Recovery

If lead is in sufficiently high concentrations in the waste, it can be recovered and reused in a secondary lead smelter. Several factors will affect a decision to accept lead-containing debris (*21*):

- Lead Content: Lead levels of 10 to 20 percent are often needed for smelting to be profitable; alternatively, the smelter may accept lower levels of lead and charge a fee based on the actual processing cost.
- Chemical Make-Up of Debris: The presence of aluminum, magnesium, sulfide, or chloride may preclude the use of the debris or increase the cost for processing.
- Distance from Smelter: Transportation costs are an important factor in viability of treatment options.

The most likely candidate for lead smelting is debris from recycled steel grit. Because the grit has been recycled numerous times, the lead content of the debris (consisting of abrasive fines, paint, and dust residues) is considerably higher than for expendable abrasives. In addition, the presence of the iron in the grit can aid in the smelting process. This process can eliminate long-term liability of the agency and the contractor because the lead is no longer classified as a waste. The generator's responsibility for the lead ends once it is recovered. The lead is actually used for manufacture of industrial or consumer products, such as car batteries.

Because of the presence of a lead mining industry in the state, the Missouri DOT has arranged for its lead debris to be transported to a smelter. The DOT pays the contractor for transportation costs and any fee associated with the smelter accepting the lead debris. Smelters in other states (e.g., Pennsylvania and Texas) have also accepted lead-containing waste.

According to a representative of a waste transport and recycling facility, the quantity of lead in a typical lead removal job is of little value to a smelter. But the use of a smelter is of value to the structure owner and contractor. Taking the material to a smelter keeps it out of the landfill and avoids possible future liability.

Bridge Agency Experience

A few bridge agencies have developed procedures to use lead-containing waste for other construction purposes. Under RCRA, if the debris is reused for some beneficial purpose, as in the examples below, then the debris is not considered waste and is exempt from most of the RCRA requirements.

- North Carolina DOT—This agency incorporated lead waste into manufacturing asphalt pavement material (*17*). This procedure had some success after the agency examined alternative mix designs with selective abrasives. Ultimately, the DOT discontinued the practice because of the potential for liability and exposure.
- Kansas DOT—This agency developed a procedure for constructing cement blocks containing blasting debris for use in highway construction. (See report FHWA-RD-94-100 (*21*) for specifics of mix design and handling procedures.) State environmental agencies eventually denied their use and the blocks were disposed of.
- Georgia DOT—This agency adopted a procedure combining two stabilization methods. Initially, 10 percent steel grit is added to the nonmetallic abrasive (copper or coal slag) to ensure that nonhazardous waste is generated. (Without this step, licensing of the DOT as a waste treatment facility would have been required.) After the waste is collected, it is mixed with 20 percent, by weight, portland cement and used in a portland cement concrete.
- Maine DOT—This agency proposed procedures similar to that of Georgia DOT.

In some states, however, the regulatory agencies (e.g., Oregon Department of Environmental Quality), do not allow the reuse of lead-containing waste for any procedure.

Texas DOT-Sponsored Study

The Center for Transportation Research at the University of Texas conducted a study on the solidification/stabilization of used abrasive media for nonstructural concrete (*23*). In the study, portland cement was mixed and reacted with the spent abrasive to stabilize the heavy metal. Each type of waste examined contained several different levels of lead and chromium. The abrasives used were coal slag and silica sand. In the development phase, the researcher concluded that this process had high potential to produce a stable mix that could be used for construction projects. Along with the sponsor (Texas DOT), the Center was planning a field trial to determine the viability of the process.

These researchers also developed the following guidelines for a project to study stabilization: 1) Determine TCLP and total metal content; 2) Establish required physical properties; 3) Determine mix proportions by trial batches; and 4) Define field mix proportions, do field testing.

PROCEDURE FOR WASTE GENERATORS

General Guidance

Several practical guidance documents are available to assist transportation agencies and contractors (both considered co-generators of waste) in dealing with those critical aspects of lead paint removal.

SSPC Disposal Guide (Guide 7) (22)

This guide defines several procedures including:

- Procedures prior to waste collection
- Site procedures prior to and including classifying waste
- Procedures for disposing of hazardous waste
- Procedures for disposing of nonhazardous waste.

Requirements for Generators

The *Industrial Lead Paint Removal Handbook* (*3*) identifies 10 RCRA requirements for waste generators including:

- Identifying waste
- Acquiring EPA ID number (federal or state)
- Notification of appropriate agency that waste is hazardous
- Preparing and signing the waste manifest
- Packaging and labeling requirements
- Requirements for drums or other containers
- Contingency plans
- Waste accumulation time permitted
- Recordkeeping and reporting.

EPA Guide for Waste Generators (EPA 1996)

This booklet ("Understanding the Hazardous Waste Rules: A Handbook for Small Business" 1996 update (*24*)) is intended to help small businesses (including painting contractors) understand how to best comply with federal hazardous waste management regulations. It includes:

- Defining and identifying waste,
- Obtaining an EPA ID number,
- Managing waste on-site,
- Shipping waste,
- Sources of added information.

Waste Management Plan

The contractor as the co-generator is normally required to prepare a waste handling and disposal plan to be reviewed by the DOT. The plan should include previous sampling and testing, handling, labeling and storing, transportation, and contingency plans.

Sampling and Testing

A plan is needed for waste sampling and testing (e.g., number and location of samples, method for collecting samples, and a specific laboratory where the samples are to be taken). The National Lead Laboratory Accreditation Program accredits laboratories to test waste samples (*25*).

Proper sampling of waste is a very important element of the waste management program. Tinklenberg and Smith (*26*) discuss sampling requirements, documentation, interpretation, and quality control. Normally, a minimum of four samples is required to verify that the waste is nonhazardous. It is also advantageous to maintain a homogenous waste stream and to avoid mixing of different waste streams. Ohio Turnpike Authority requires that contractors collect more than four samples of waste to ensure testing four that are representative. Random sampling methods are prescribed.

This agency (as well as Pennsylvania DOT) requires initial analyses for all eight TCLP metals. Subsequent samples are analyzed for any metals detected initially. Massachusetts Turnpike requires sampling per SSPC Guide 7 and the samples must be submitted to a Massachusetts certified laboratory. Washington DOT requires three waste samples, each from a different waste container.

Waste Handling, Labeling, Storing

This section of the waste management plan defines what types of containers are to be used, where waste is to be stored, the length of time it is to be stored, and labeling requirements.

Transportation

In this section of the waste management plan, the contractor is asked to identify the specific licensed firms that will transport and dispose of the waste. Many transportation agencies (e.g., Ohio Turnpike Authority) require the contractor to have a commitment from a waste disposal firm and/or a waste transporter (both licensed) prior to undertaking the work (or even submitting a bid). In some instances (e.g., New Hampshire), the contractor may choose from a list of approved haulers in the state. In other cases (North Carolina), the DOT has a contract with a waste disposal firm to dispose of all kinds of waste.

Contingency Plan

As required by RCRA, a contractor must define procedures for spills or releases of waste and indicate the training of workers handling the waste. (Note: Although RCRA requires specific training for such workers, there is little known evidence that contractors are providing this training to their workers or that DOTs are asking for it or enforcing it.) A few agencies (e.g., Pennsylvania DOT and the Ohio Turnpike Authority) have started requiring contractor employees to receive training according to 40 CFR 265.16, Interim Status Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal (TSD) Facilities Personnel Training.

Disposal of Waste Water

Surface preparation water used to remove lead paint and hygiene water for showers or laundering must be tested to determine if the waste is hazardous. Therefore, it follows that this water must be collected, and not allowed to be discharged into a sewer or onto the ground. Figure 16 shows water buffaloes used to store filtered water. The procedure for testing liquid waste differs from the procedure for testing solid waste (*27*). The specific testing procedure depends on whether the sample has more or less than 0.5 percent solids.

There is considerable variation and, in some cases, confusion about what the requirements are for treating the waste water. The DOT often refers to the local requirement for discharge into a sanitary or storm sewer. Typically, this level is 1 ppm or less for lead. Results of analysis of waste water from a lead paint removal project in Connecticut showed a level of 6 μg/liter which is well above the City of Waterbury limit of 0.1 μg/liter.

- Pennsylvania DOT requires special handling and disposal conditions for waste water. Contractor must:
  - — Provide containers for collection and retention of all waste water.
  - — Filter visible paint chips and particulates prior to placing waste water in container.
  - — Prior to disposal, test water for total toxic metals and provide ample filtration (e.g., through a multistage filtration system ending in five microns or better, if needed) until the water is not classified as hazardous.
  - — Make disposal arrangements with local publicly owned treatment works (POTW).
- Iowa requires that solids be filtered from waste generated from ultra-high pressure water jetting and wet blasting, and that a TSD facility be assigned for disposal of this waste. On-site filtering of waste water is required to remove solids to a level below the pretreatment discharge level required by the appropriate water disposal facility.
- Massachusetts Turnpike has set the following criteria for waste water disposal: greater than 100 ppm, hazardous waste; between 5 and 100 ppm, nonhazardous waste; less than 5 ppm, screen through 45 micrometer mesh to remove solids and discharge.

FIGURE 16 Water buffaloes to store filtered water.

• New York State Transit Authority requires that water used to remove bird droppings be collected.

• Ohio Turnpike Authority requirement is as follows:

—If initial lead in water is less than 3.5 μg/l, an impact has occurred if final lead concentration exceeds initial lead concentration by 1.5 μg/l.

— If initial lead in water is greater than 3.5 μg/l, an impact has occurred if final lead concentration exceeds initial lead concentration by 1.5 μg/l or two standard deviations, whichever is greater.

Other Transportation Agency Requirements for Waste Handling

• Iowa uses a criterion of 3 mg/liter instead of 5 mg/liter for determining whether lead waste is hazardous.

• New Hampshire Environmental Department charges a waste generator's fee of $0.066/kg ($.03/lb) and $50.00 per calendar quarter.

• Massachusetts Turnpike also specifies minimum criteria for a waste transporter including insurance. The agency must be notified at least three days prior to transporting.

• Louisiana DOT requires that the transporter carry pollution insurance in case of accident while the waste is enroute.

• West Virginia DOT requires that a DOT representative be present during waste sampling and that the waste not be disposed of until authorized by the engineer.

• Oklahoma DOT requires written approval from the Department of Environmental Quality for waste handling procedures.

• Oklahoma DOT provides a $3,000 bonus to contractors for submitting waste to a blast furnace (for destruction) or to cement kiln (for beneficial reuse).

• Illinois DOT requires that all waste be handled as hazardous and be disposed of in Illinois. Illinois DOT also requires contractor to dispose of waste paint solvent as a hazardous waste.

• Arkansas designates a state representative who will perform the sampling and handle the testing. The state pays for disposal and transportation of the waste.

• Oregon DOT requires that a DOT representative collect and test waste samples. For bidding purposes, a contractor is to assume that waste is nonhazardous. If it is hazardous it will be an extra pay item.

• Maryland DOT requires that a certified industrial hygienist, hired by the contractor, collect four waste samples from each bridge or a sample from every drum, whichever is greater.

• New York state has a separate contract with a disposal firm for sampling, testing, and disposal of waste.

• Connecticut DOT requires storage site to be enclosed with a 2.5-m (8-ft) fence covered with a waterproof tarpaulin.

• Pennsylvania DOT identifies waste to include rags, tape, coveralls, filters, paint debris, and paint cans.

RESULTS OF SURVEY ON COST OF WASTE DISPOSAL

Surveys of transportation agencies, contractors, and waste treatment disposal firms have shown a very large variation in the cost of waste disposal.

Units

One reason for the variation in disposal costs is that the different units for measuring waste include both volume unit (drums, barrels, cubic yards) and mass units (tons). Rough correlations are as follows:

• Correlation of volume to volume:

—A drum or barrel contains 208 liters (55 gallons) which is equivalent to 0.21 m^3 (0.27 yd^3).

• Correlation of weight to volume.

—A 208-liter (55-gal) drum of spent nonmetallic abrasive and paint debris (fully loaded) weighs about 0.5 Mg (1,100 lbs).

—A 208-liter (55-gal) drum of spent metallic abrasive and paint debris (fully loaded) weighs over 0.75 Mg (1,650 lbs).

However, according to U.S. Department of Transportation regulations for shipping hazardous waste, a 208-liter (55-gal) drum can be filled with a maximum of 400 kg (882 lbs), including weight of drum. Alternative packaging materials are bulk bags, boxes, or gaylords, which are described in 49 CFR 178.504 ("Standards for Steel Drums"). Based on a drum weighing the maximum of 400 Kg (882 lbs), there are about 2.2 drums per Mg (2.0/ton). Ohio Turnpike Authority restricts contractors from filling containers or rollers in excess of the capacity marked on the container.

Surveys on Cost of Disposal

DOT Survey

The costs for stabilization (treatment) and disposal of hazardous waste ranged from $80/Mg ($73/ton) to $1,400/Mg ($1,300/ton). The average and median costs were about $240/Mg ($220/ton). In a previous survey done under an FHWA project (*22*), the costs range from a low of $90 to $125/Mg ($82-$110/ton) to a high of $750-$800/m³ ($570-$610/yard³). Median cost was about $175/Mg ($159/ton). There is also a wide variation in the disposal costs for nonhazardous wastes. These range from $15/Mg ($14/ton) to $230/Mg ($210/ton).

Multistate Survey of Hazardous Waste Disposal Fees

Table 3 presents the results of a survey of disposal cost of hazardous lead-containing waste. The data include disposal cost, state fees, and profiling fees; they do not include transportation. A profiling fee is charged by the testing facility to determine quantity, type of treatments, and analysis necessary.

The cost of transporting hazardous wastes is estimated constant at about $20/Mg ($18/ton) for large quantities for 1700 km (1,060 miles), based on responses from several waste disposal firms.

TABLE 3
Survey of Hazardous Waste Disposal Fees

Location	Disposal Fee ($/Mg) [$/Ton]	State Tax ($/Mg) [$/Ton]	Profiling Fee	Comments
Pompano, Fl	$200-$250	$51		added $21/Mg to ship to Alabama
Columbia, SC	$165- $190	$39		10-30 mg/l is lower cost, 41-60 mg/l is higher cost
Emelle, AL	$175			state tax included
Canton, OH	$110- $120	$2	$350	
York, PA	$110- $125	$3	$350	$1/Mg host tax, $5/Mg out of town tax
Astoria, NY	$225 per drum			only small quantities (< 100 mg)
Flanders, NJ	$200	$8-10		local roll-off transportation $2500/trip (15-20 Mg per trip)
Ft Wayne, IN	$125-$180	$19	$500	
Belleville, MI	$120	$10	$290	profiling charge if need to test for lead
Wyandotte, MI	$100	$10		
Harvey, IL	$120-$140	$6		
Peoria, IL	$130	$6	$385	$1200 one time permitting package fee
Menomonee Falls, WI	$145			$400/load transport from Milwaukee plus $450 first time fee
Kansas City, MO	$290			$508/load from Kansas City vicinity
Kettleman Hills, CA	$250 -$370	$293	$160	lower cost for roll-off, higher for drum $500 transport from Bakersfield
Knowles, UT	$294- $444	$28		lower cost for roll-off, higher for drum; $260 per load from Salt Lake City

Note: Survey conducted by TDJ Group, Inc., Cary, Illinois.

ENFORCEMENT OF WASTE REGULATIONS

Penalties

EPA and the state regulatory agencies have very broad authority to impose penalties, fines, and jail sentences under RCRA and CERCLA. Typically, there is a maximum fine of $25,000 per incident per day. Examples of penalties imposed by New Jersey Department of Environmental Protection for waste handling and disposal infractions are cited below (*28*).

- Failure to obtain EPA ID number: $2,000
- Failure to prepare manifest before transporting: $10,000
- Failure to sign manifest: $1,000
- Failure to use registered hauler: $5,000
- Shipping to unauthorized facility: $25,000
- Failure to determine if waste is hazardous: $10,000
- Failure to ship waste off-site within 90 days: $2,000
- Use of nonstandard containers: $2,000.

Examples of Enforcement

Missouri

The EPA cited the Missouri Highway and Transportation Department (MHTD) for violations of RCRA (*29*). In 1991, a representative of the Missouri Department of Natural Resources visited a bridge rehabilitation site and observed that some abrasive blasting residue was not collected but allowed to fall into the river under the bridge and onto the ground nearby. For failing to determine whether the waste was hazardous, a civil penalty of $22,500 was assessed against the MHTD.

The MHTD also failed to file notification of its activity as a generator of hazardous waste and an owner/operator of a hazardous waste treatment, storage, and disposal facility. The civil penalty proposed for these counts was $406,500 ($22,500 for the gravity of the violation and $384,000 for multiday violations). The actual amount paid by the agency was substantially reduced following corrective actions.

Massachusetts

In 1994, the Massachusetts Environmental Strike Force announced that an Ohio painting contractor and its president had been indicted for allegedly illegally transporting hazardous waste, for forgery, and for filing a false report in connection with a shipment of hazardous waste (*30*). The contractor was hired by the Massachusetts Highway Department to repaint highway bridges during the summer and fall of 1991. The contractor specified that the waste from abrasive blasting was hazardous and had to be transported by a licensed hazardous material hauler. The president of the contracting firm was indicted for causing 15 drums to be removed illegally to an unknown destination. The contractor allegedly failed to produce a manifest showing that the drums had been removed by a licensed hauler. An employee of the contracting firm gave the Highway Department a document reported to be a manifest, but some of the information was allegedly falsified by the contractor. If convicted on all counts, the contractor faces fines of $450,000 and imprisonment for a total of 52 years.

Washington State

The Washington State EPA found 292 208-liter (55-gallon) drums in a cow pasture in south-central Washington and 28 more drums in a trucking yard near Portland, Oregon (*31*). Although many of these drums were labelled "liquid slop," they contained paint sludges, thinners, solvents, and old paints, some of which were highly flammable and contained heavy metals such as chromium. The wastes were generated in the application of primers to steel pieces. The drums were eventually traced to a Washington steel company. While the owners claimed no knowledge of how the drums got to their final sites, they agreed to plead guilty to the charges because they had failed to obtain a federal permit to store the wastes and allowed the drums to be transported without a required manifest. The owners did not act on proposals by consultants advising them that proper disposal would cost about $70,000. Rather, they informed the consultants that they would seek out less costly ways of addressing their problem. Now the owners each face a year in prison and fines of $250,000 each. The firm previously paid about $115,500 in fines and clean-up costs.

CHAPTER FOUR

SPECIFICATIONS FOR LEAD PAINT REMOVAL

This chapter describes current practices and available resources for specifying containment and paint removal, worker health and safety, waste handling, and environmental and public protection.

GENERAL DESCRIPTION OF SPECIFICATIONS

Organization and Structure of a Specification

Highway agencies use varying formats and methods of describing the requirements for a paint removal project (*32,33*).

Whatever model or approach is used, the following critical items must be addressed:

- Extent of work and nature of existing surface (i.e., portions of structures to be cleaned and painted) and what hazardous material, if any, is present
- Procedure for the removal of paint
- Containment of debris and ventilation system
- Monitoring emissions (air, soil, water)
- Waste handling and disposal
- Traffic control
- Worker protection
- Quality assurance (e.g., inspection, monitoring, contractor submittals).

For each of these, the critical aspects will be described along with various options adopted by states or recommendations based on other industry practices or technology. Waste handling and disposal was discussed in chapter 3.

EXTENT OF WORK

The DOT must identify and quantify the specific work to be undertaken. For full removal, this consists primarily of defining the bridge, its location, and the approximate size of the bridge. The presence of lead paint and the configuration of the bridge are also important. Most DOTs identify the presence of lead and/or chromate containing paint on the structure. Some DOTs provide analysis of the total lead content or the leachable lead content.

There are several schools of thought on the best way to specify the extent of work. Many agencies furnish the number of tons of steel, as that is the basis on which they are constructed; the surface area is not usually recorded by the agency. When accurate data on the surface area are available, the contractor can provide a more precise estimate of the labor and material cost. However, many DOTs prefer not to give an estimate of the surface area; requiring the contractor to determine surface area will help ensure the contractor has evaluated the project thoroughly.

Defining what is to be cleaned for painting is more difficult for an overcoating or a zone painting project. It is normally based on the condition of the coating (i.e., sound intact paint is not intended to be removed). Figure 17 shows a bridge with severely deteriorated lead paint; the bridge in Figure 18 has only moderately deteriorated paint. It is suggested, however, that the owner provide a good definition of sound intact paint, which is not universally agreed on in the industry. Even if such a definition is available, the amount of surface area meeting this condition is somewhat subjective. Sources of the variability include

- The actual condition at the time the contractor does the work versus when the bridge was originally selected or first observed by the owner or contractor,
- Adequacy of the definition of sound paint or other criteria adopted by the DOT, and
- Differences in application of criteria for sound paint (e.g., contractor opinion versus engineer opinion).

Examples of surface areas provided:

- Washington DOT provides a detailed bridge paint history that includes the following: years bridge was painted, information on most recent contract, mass of steel in megagrams (tons), and surface area in meters^2 (ft^2). The presence of lead is also noted.

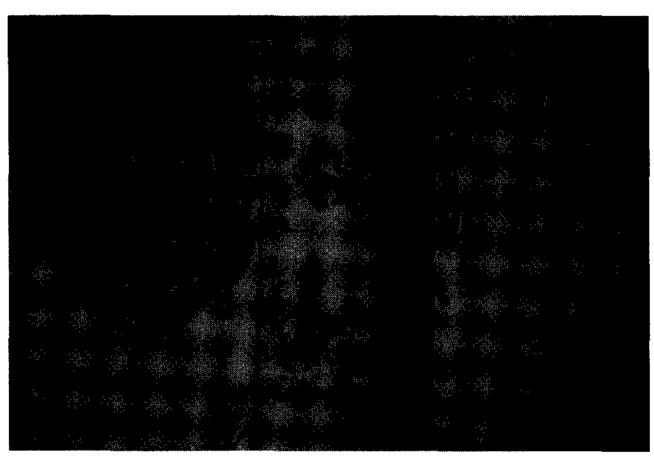


FIGURE 17 Severely deteriorated lead paint.

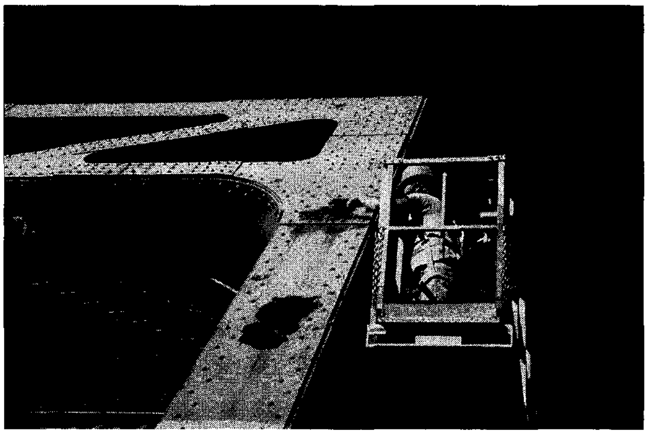


FIGURE 18 Bridge with moderately deteriorated lead paint.

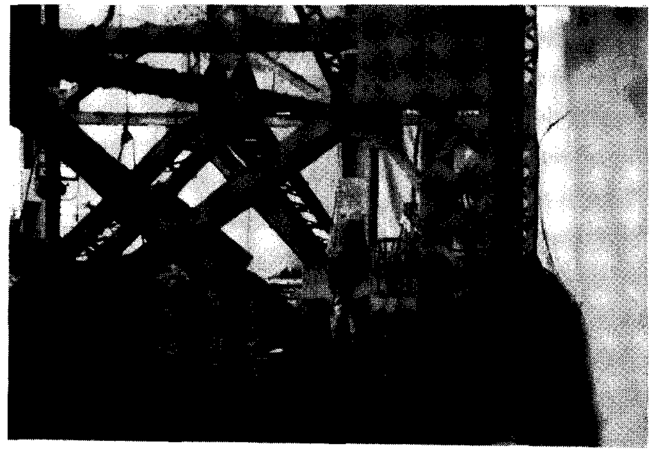


FIGURE 19 Hard to access steel.

• Other agencies that provide specific estimates for surface areas to be cleaned and painted include New York City DOT and Minnesota DOT.

Bridge Surface Area Versus Mass

Many DOTs provide the size in tons of steel rather than square feet of surface area. The surface area per unit mass (e.g., m^2/megagram (ft^2/ton)) varies depending on the steel configuration and gauge. Some nominal conversions have been developed:

Illinois DOT

- plate girders: 13.6 m^2/Mg (125 ft^2/ton)
- wide flange beams: 11.4 m^2/Mg (105 ft^2/ton)
- trusses: 18.1 m^2/Mg (167 ft^2/ton).

Connecticut DOT

- beams and plate girders: 10.9 m^2/Mg (100 ft^2/ton)
- trusses: 21.7 m^2/Mg (200 ft^2/ton).

Accessibility

Some transportation agencies explicitly recognize that restricted access to certain areas of the structure will reduce the effectiveness or practicality of certain surface preparation techniques.

New York State Thruway provides a definition of inaccessible areas as follows:

• Inaccessibility shall mean the inability to use a standard application method because of restrictions such as reduced clearance, insufficient hand space or too narrow an opening. It shall not mean that the element is too high or that the rigging or scaffolding will be difficult. The Engineer will make a final determination as to what will be deemed inaccessible.

• New Hampshire DOT specifies brush blast instead of power tool cleaning (SSPC-SP 3) for "Hard to Reach" areas including bearings and inside truss members, such as those found in Figure 19.

REMOVAL OF PAINT

Performance versus Prescriptive Specification

In the area of removal and containment, the specifier must decide whether to use performance specifications or prescriptive specifications. Performance specifications state the end requirements (e.g., surface shall be cleaned to near white metal with a surface profile of 25 to 75 micrometers (1 to 3 mils)). A prescriptive specification directs contractors to use a specific method or product (e.g., surface shall be blast cleaned with 24/40 blend of coal slag abrasive using a #6 nozzle with a minimum pressure of 630 KPa (90 psi) at the nozzle, etc.). For material requirements, prescriptive specifications are often referred to as "composition specifications." In practice, the two approaches are often combined in a hybrid specification.

The prescriptive specification allows the DOT greater control (and the contractor less control). It may, however, discourage contractor ingenuity. The DOT also has a greater share of the responsibility if the system fails. The pros and cons of these specifications are discussed in the section under containment structures.

Blast Cleaning Methods Specified for Full Removal

For full removal, abrasive blast cleaning is by far the most commonly used method, for obvious reasons. Occasionally, however, blasting is restricted because of potential environmental or health risks, which happened in New York City in 1996 (*34*).

Specifying Abrasives

There are several industry standards for selecting or qualifying abrasives, including:

• California Air Resources Board (CARB)—listing of abrasives meeting the requirements for dust

- General Services Administration (GSA)—standard on steel grit and steel shot
- International Organization for Standardization (ISO)—specifications for various types of metallic or mineral abrasives
- Society of Automotive Engineers (SAE)—specifications for sizing of steel abrasives
- SSPC-AB 1—mineral and slag abrasives
- SSPC-AB 2—specification for cleanliness of recycled ferrous metallic abrasives
- SSPC-AB 3—specification for newly manufactured or remanufactured steel abrasives.

These standards are summarized in an upcoming report by the National Shipbuilding Research Program (NSRP) (*35*). Several are described in Appendix B.

Most DOTs leave the selection of the abrasive to the contractor, requiring only a particular surface profile and the minimization of dust. Some examples of DOTs specifying abrasives include:

- California must meet CARB approved list. For a specific project, California DOT required a mixture of copper slag and calcium silicate (an additive to render the abrasive nonhazardous).
- New Hampshire requires steel grit mixture, either G40 or G40/G50; corresponding to Society of Automotive Engineers (SAE) specifications.
- Iowa requires recyclable abrasives (steel, garnet, or aluminum oxide).
- Washington requires abrasive conformance to the Navy specification for nonmetallic abrasive (Mil-22262-A [SH]). An alternate is a nickel slag mixed with a proprietary cementitious additive.
- North Carolina DOT specifies that recyclable abrasives have a maximum of 100 ppm chloride or sulfate and 1,000 ppm lead.
- New York State Thruway Authority sets a level of 1,000 ppm (derived from SSPC-AB 1) as the maximum conductivity of the abrasive in a standard test.
- Virginia DOT requires recyclable abrasive to meet the RCRA goal of waste minimization.

Soluble Salt Level

Several transportation agencies require that the surface after blast cleaning be checked for the presence of soluble salts (see Figure 20), sometimes requiring a surface contamination analysis kit. At least one state has set limits on the allowable level of salts on the surface of 7μg/m^2 for chloride and 17 μg/m^2 for sulfate (this is based on the levels designated in SSPC-SP 12/NACE 5 (*36*)). Most coating manufacturers are reluctant to recommend specific levels.

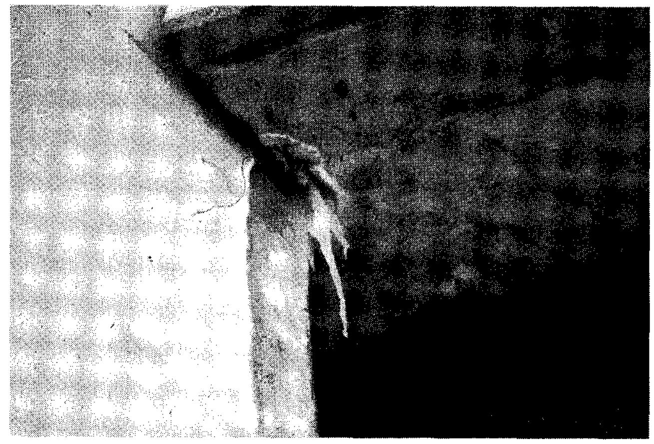


FIGURE 20 Bridge with salt deposits.

- New York State Thruway Authority sets a limit of 15 μg/cm^2 for chloride. The surface is measured in three areas by a procedure that entails field swabbing and analysis. If this level is not achieved, methods are prescribed for removing chloride including: steam cleaning, pressure washing, scrubbing, and a two-step blast procedure with blends of fine and coarse abrasives; the latter is based on a technique developed by W. Johnson (*37*).
- Ohio Turnpike Authority requires that chloride in previously rusted areas be remediated to a level of no greater than 10 μg/cm^2 using a commercial chloride detection kit. If unacceptable levels of soluble salt remain, the contractor is to spot wash until acceptable and reclean to SSPC-SP 10 or SP 11.

Alternate Methods

There are alternative preparation methods that reduce production rates but offer other benefits for environmental and worker health protection.

If the concern is primarily dust emissions outside the work area, a suitable alternative may be wet abrasive blasting. This consists of air abrasive blasting with injected water. (Another type of wet blasting is a variation on pressurized water jetting in which the abrasive is injected into the high-pressure water). The productivity of the wet abrasive blasting method varies from about 50 to 90 percent of the production of conventional dry blasting (*35*). Other methods that had been proposed or used for full removal include vacuum blasting, or power tool cleaning with or without vacuum shrouds. These methods have been evaluated on bridges by the National Institute for Occupational Safety & Health (NIOSH) and other government agencies, but they have not been widely specified by DOTs because of their reduced productivity and resulting increased cost (*38*). Increasingly, these methods are now being addressed by industry consensus standards. High- and ultra-high pressure water jetting at pressures of 70 megapascals (MPa) (10,000 psi) (high pressure) or 175 MPa (25,000 psi) (ultra-high pressure) is capable of removing most paint and rust.

SSPC and NACE (formerly the National Association of Corrosion Engineers) recently issued a joint standard on high-pressure water jetting (SSPC-SP 12/NACE 5) and are working on an accompanying visual standard (expected to be released in early 1998) (*36*). This document presents different levels of

FIGURE 21 Water jetting.

cleanliness. Figure 21 shows a worker performing water jetting. A similar joint standard is expected in 1997 on wet abrasive blasting (with a visual standard expected in 1999). Also underway is development of standards for chemical cleaning or stripping, sodium bicarbonate blasting and blasting with urethane foam sponges (sponge jetting).

Common Methods of Surface Preparation for Overcoating

For overcoating projects, the surface preparation usually consists of surface cleaning by pressurized water, and spot removal of rust or deteriorated paint by mechanical measures.

Pressurized Water Cleaning

This step is required by most DOTs before any other cleaning or coating application. All agencies responding to the survey require 100 percent of the surface to be washed. Typical pressures are 10.5 MPa to 21 MPa (1,500 to 3,000 psi), but sometimes the pressure ranges as low as 2.1 MPa (300 psi) and as high as 35 MPa (5,000 psi). Low pressures are suitable for removing loose rust, loose paint, and some surface dirt. At high pressures more thorough cleaning is attained and some removal of soluble salts on the surface is also achieved.

- Oklahoma DOT allows pressures between 5.6 and 35 MPa (800 and 5,000 psi), noting that lower pressure will less likely result in the washwater being hazardous.
- New York State DOT restricts washing of steel bridges with flaking paint (i.e., having a rating of 3 or lower in a range of 1 to 7, with 7 best) to avoid generating hazardous waste water.
- Washington DOT has provisions for pressure washing that designate that water be collected and filtered through a nonwoven polypropylene geotextile with specified tensile strength, sieve openings, and permeability ratings. (Figure 22 shows a worker performing pressure washing.)

Results of an earlier survey of these practices are described in a recent FHWA report (*39*). See chapter 6 for results of survey.

Steam Cleaning

This method uses pressurized steam (sometimes with detergent) to loosen and dissolve grease, oil, and dirt. It is described more fully in SSPC-SP 1, "Solvent Cleaning" (*40, see Appendix A-2*) and is often specified as an alternative to pressure washing prior to mechanical cleaning or overcoating.

- Massachusetts Turnpike designates a minimum temperature of 150° C (300° F), a pressure between 1,050 and 1,400 KPa (150 and 200 psi) and a standoff distance of 6 inches maximum; two passes are recommended.
- Massachusetts DOT requires a temperature of 38° C (100° F), minimum pressure between 1,050 and 1,400 KPa (150 and 200 psi), a 760-liter per hour (200-gal per hr) consumption rate and nonphosphate detergent. The procedure is to first wet the surface then go over each area twice. A surface is considered clean if it is "firm and somewhat tacky, but not slick or grimy."

Spot Cleaning by Power and Hand Tools

Based on the survey, there is substantial use of two approaches: conventional power and hand tool cleaning (SSPC-SP 3 or SP 2) and abrasive blasting. Approximately 15 to 20

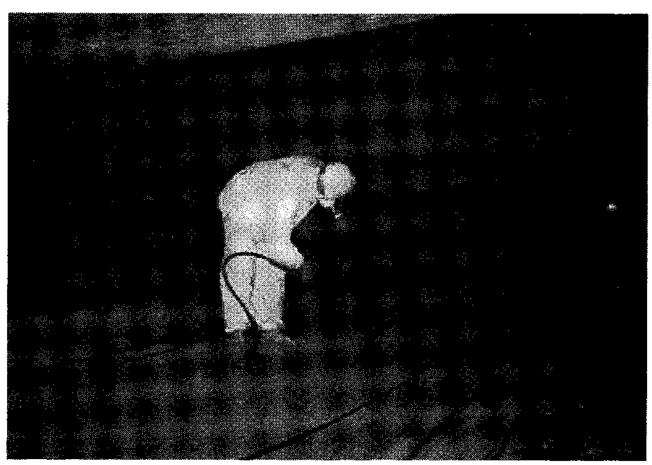


FIGURE 22 Pressure washing.

percent of the agencies specified power tool cleaning to bare metal (SSPC-SP 11). Some agencies also specify the types of power tools (e.g., 2-mm needle gun or nonwoven abrasive disc). Also, in some instances power tools with vacuum attachments are required. This is an alternative to or a supplement to other types of containment. In New Hampshire, vacuum blast cleaning is an alternative to power tool cleaning with vacuum shrouds. Power tools and vacuum blasting have limitations with regard to access to edges and corners. Figure 23 shows a worker performing spot cleaning with a power tool. Figure 24 shows a worker performing spot vacuum blasting. Agencies may permit use of hand tools in these areas or explicitly reduce the cleaning requirements (e.g., New Hampshire).

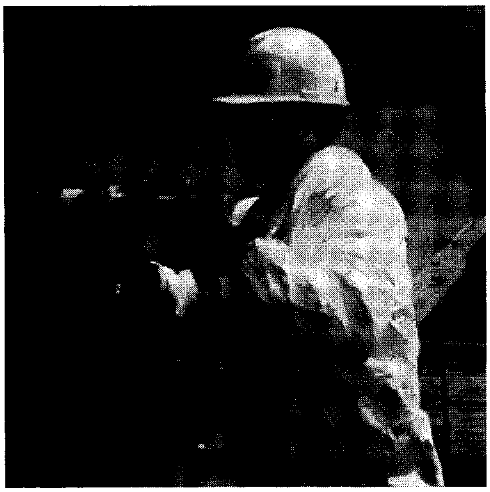


FIGURE 23 Spot cleaning with power tools.

- New York State Thruway Authority requires manual removal of loose dirt and debris first, followed by steam cleaning and power tool cleaning. An interval of two weeks is sometimes required between the steam cleaning and the power tool cleaning to allow the surface to dry.
- New York State Thruway Authority also requires that the surface be wetted down before hand tool cleaning to reduce dusting.
- Massachusetts DOT requires that the surface be vacuumed with a high-efficiency particulate air (HEPA) filter and vacuumed before painting.

Spot Cleaning by Abrasive Blasting

Several agencies (e.g., New York State DOT, Chicago DOT, Washington DOT) require abrasive blasting to SSPC-SP 6 for spot cleaning (*40*). Typically, this would be for structures with substantial portions of the surface covered with rust or degraded paint. In some instances, brush-off blast (SSPC-SP 7) is also allowed. Other agencies allow blast cleaning as an alternative to power tool cleaning (SSPC-SP 3) (*40*). Again, for large, contiguous rusted areas, a contractor may find it more economical to choose this method.

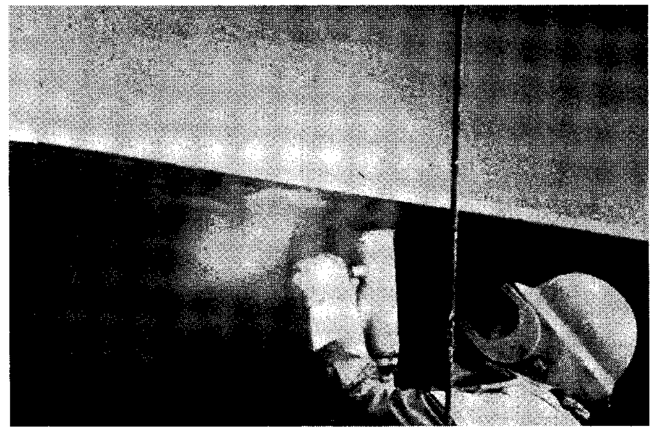


FIGURE 24 Spot vacuum blasting.

Spot Cleaning by SSPC-SP 11

Several agencies (including Alaska DOT, Oklahoma DOT and New York State DOT) specify power tool cleaning to bare metal for coating projects.

Zone Painting

This is a strategy in which the most corrosion prone areas on a bridge are given a higher degree of protection. Typically, these areas are the bearings, sections adjacent to the joints below the deck and the lower 6 to 10 feet above the deck on a truss (e.g., the splash area). In zone painting, the remainder of the structure (noncritical areas) is either not painted at all or given a light cleaning (e.g., water wash or hand tool) and then overcoated. The bridge shown in Figure 25 is a suitable candidate for zone painting.

- Illinois DOT system is as follows: Completely blast the expansion joints 2 m (5 ft) in each direction, and spot power tool clean the remainder of the bridge and apply two or three coats lead-free alkyd /silicone alkyd coating system.

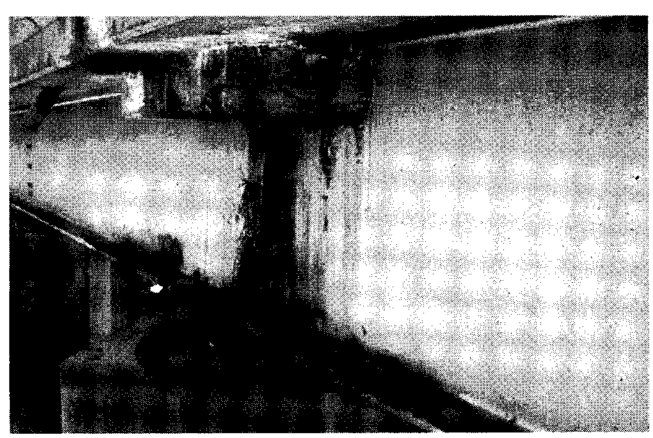


FIGURE 25 Bridge suitable for zone painting.

• Oklahoma DOT identifies zones for full removal (by blast cleaning) based on condition of coating and steel. The remainder of the structure is overcoated following pressure washing.

• Massachusetts DOT defines the bearing area as the end of the stringer, and 2 meters (5 ft) beyond the center of the bearing. The required surface preparations are power tool clean to bare metal (SSPC-SP 11), wet blast to SSPC-SP 10 or vacuum blast to SP 10 (*40*).

CONTAINMENT OF DEBRIS

DOTs differ significantly in the manner in which they specify containment. The considerations for choosing prescriptive or performance specifications for containment are summarized below.

Performance Versus Prescriptive Specifications

Arguments in favor of prescriptive specifications:

• Containments are engineered structures that must withstand high wind and static loads. Many DOTs require engineers to verify the adequacy of the load rating and describe equipment and criteria for ventilation.

• Contractors may not realize the impact of containment on bridge integrity or have enough expertise to realize which containments are most effective.

• It is easier to evaluate bids if the containments are of similar design (e.g., as specified by the DOT).

• It is easier to enforce the specifications. However, many inspectors on paint removal projects are not trained on inspecting containment or environmental monitoring.

• The methods to determine if containments are performing properly are not sufficiently defined or universally accepted.

Arguments in favor of allowing contractors to design their own containment (performance specification):

• Contractor may have the expertise to construct the containment with a more efficient and cost-effective design.

• DOT's primary concern is in determining effectiveness of the containment in preventing emissions into the environment.

• Contractor has liability if containment structure fails. If containment fails when constructed in accordance with DOT direction, there may be a dispute as to which party (DOT or contractor) is responsible.

• DOTs do not always have expertise in design of containment for paint removal.

• Technology is advancing rapidly so prescriptive specifications will be continually out of date.

Containment for Full Removal

An example of a performance specification for containment is that from Iowa DOT. The DOT requires using SSPC Guide 6 Class 2 (61) for conventional open blasting and Class 4 for wet blast or ultra-high-pressure water jetting. This specification further identifies the need for full enclosures with the definition of enclosure given. The contractors must submit the description of the containment to the DOT and engineer to review for wind and static loading. It requires that negative pressure be maintained but there is no minimum pressure specified. The engineer may approve a technique that does not require negative air pressure, such as wet blast or ultra-high-pressure water jetting. The process is required to contain any wash water, blast water, or hygiene water. An example of a containment for full removal is seen in Figure 26.

An example of a prescriptive specification for a containment enclosure is given by New Jersey DOT:

> The containment enclosure shall extend from the bottom of the deck down to ground level or to a solid work platform. Materials for the enclosure shall be framed and fastened securely to prevent billowing or opening from the weather. All edges and seams of tarpaulins, if used, shall have a flap that clamps over the connected edges for the entire enclosure. These flaps shall be completely fastened along the tarpaulin edges to prevent dust from escaping.

Detailed requirements are also included in Connecticut DOT's specification. The agency designates two types of containment designs: "containments with suspended platform" and "containments without suspended platforms." For the former, a detailed plan and drawings are required; requirements include rigid, solid floor platform; flexible walls; rigid supports and bracing; calculation of stresses and maximum load; minimum negative pressure of 0.75 mm (0.03 in) of water; maximum cross-section area of 40 m^2 (400 ft^2); requirements for connecting to the bridges; dust collection and filtration; air intake points including filters, louvers, baffles; completely sealed entrance and exit compartments; location of equipment; impact on traffic; and elevation view of the containment enclosure. A less stringent set of requirements is designated for containments without suspended platforms.

Overall, there is a strong tendency to give contractors the latitude to design containments. North Carolina DOT requires that the contractor submit a similar containment plan for review as well. Several transportation agencies carefully review the design, but others simply rely on the contractor's expertise.

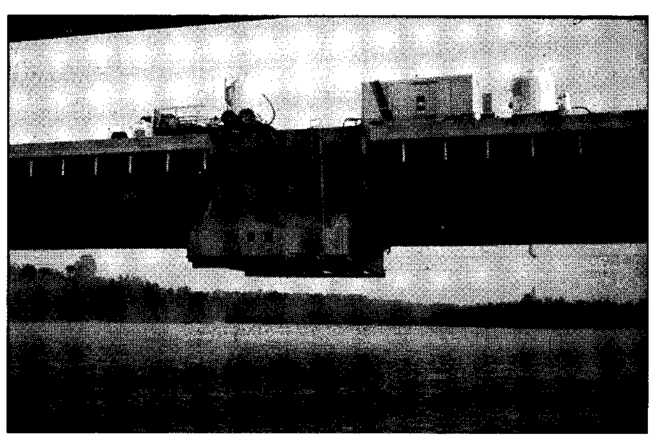


FIGURE 26 Containment for full removal.

DOTs have increasingly required containment designs stamped by a licensed professional engineer with calculations on wind load in addition to the effect of dead load on the containment and the bridge.

Containment Guide

The industry standard for containment types is SSPC Guide 6, *Guide for Containing Debris Generated During Paint Removal Operations.* The revised version of this guide defines four different levels of containment with Class 1 being the most protective. There are also different containment definitions for removal methods (e.g., A = abrasive, P = power and hand tool cleaning, C = chemical cleaning and W = wet blast methods). Unfortunately, there is some confusion between the current Guide 6 and the old version Guide 6I; the latter included five levels of containment for abrasive blasting designated Classes 1 through 5 while the new version has four levels for abrasive blasting designated Classes 1A through 4A. The containment guide defines requirements for the enclosure and ventilation system. The items specified include containment system, materials (rigid or flexible), penetrability, air flow, and other variables.

Many of the specifications still refer to the Guide 6I and require clarification by the DOT that this is the standard referenced. A majority of the DOTs reference the SSPC Guide for Containment with some modifications:

- New Hampshire has used the Class 3 (6I) but made it more stringent by requiring impermeable materials only and forced air for ventilation (natural air not permitted).
- Massachusetts DOT requires Class 1 containment for dry blasting and Class 3 containment for vacuum or wet blasting. The DOT also requires a Class 3 (Guide 6I) containment with impermeable material only.
- New York State has redefined the SSPC Classes as Class A, B, and C with some modifications in the definitions. For example, the DOT defines a "Class B" containment which includes flexible materials, and overlapped seams. It does not require forced air ventilation or air filtration. It is equivalent to Class 3P from Guide 6. The removal method is vacuum-shrouded power tools. The DOT does not require containment if 1 m^2 (10 ft^2) or less is being disturbed.
- Iowa DOT requires Class 4 containment (Guide 6I) for wet blast or high-pressure water jetting.

Other Requirements for Containment

- California DOT requires forced-air ventilation of containment to produce negative pressure. This is verified visually by the concave nature of the flexible containment screens.
- Washington DOT permits only one-half of the bridge to be enclosed at any one time to minimize wind stress.
- Minnesota DOT requires that tarpaulins extend a minimum of 8 m (25 ft) beyond the exterior of the steel surface being cleaned. The agency also designates minimum overlaps for tarps and that the tarp be weighted or secured on the bottom edge.
- Illinois DOT requires a minimum of 30 footcandles of artificial lighting for blasting and painting where natural light is inadequate.
- North Carolina DOT requires a minimum of 50 footcandles. The agency also requires detailed information on the type of dust collector to be used, the type of tarpaulins, and the type of bracing material and connections. They also require a solid floor for containments completely in the air.
- Connecticut DOT requires contractor to furnish DOT inspector with a portable anemometer to verify negative pressure and with light meters to verify the 50 footcandles of light specified.
- Pennsylvania DOT requires contractor to provide the department's representative with two portable light meters with a scale of 0 to 50 footcandles.
- Ohio Turnpike Authority requires a minimum of 10 footcandles for surface preparation and painting, and a minimum of 30 footcandles for inspection.
- Pennsylvania DOT requires submittal of provisions for dropping the containment in inclement weather and of methods of attachments that will be used. In addition, contractors must verify that the platform can support four times its intended load and that wire cables can support six times their intended load.
- Ohio Turnpike Authority requires bridge structure to be analyzed by licensed engineer from the state of Ohio and prequalified with Ohio DOT for design of complex structures.

Containment for Overcoating

Full containments are used most often for full removal, although some agencies require essentially full containment for overcoating projects as well. For most overcoating projects, the requirements for containment are much less stringent, as less dusty surface preparation methods are normally used. Figure 27 shows an example of containment for overcoating. One of the reasons for specifying overcoating is the expected reduction in the initial cost, and one major factor in that reduction is less expensive containment. This subject is discussed in greater detail in an FHWA report (*39*). Examples of containment for overcoating are as follows:

FIGURE 27 Containment for overcoating.

• Iowa DOT requires the following for containment during vacuum blasting and hand and power tool cleaning:

—the area under the structure must be level and cleaned,

—edges of the ground containment must be turned up to form a 300 mm (1 ft) berm,

—a 1-m (3-ft) overlap is to be formed between the seams of the containment,

—it does not need to be submitted in advance or approved by a professional engineer.

• California accepts drapes along the side of the structure and tarps under the structure for vacuum-shrouded surface preparation.

• Illinois DOT requires tarpaulins beneath all power tool cleaning to extend at least 3 ft from operating area. For cleaning containment, the HEPA vacuum must develop a minimum of 2.5 m (100 in) of water lift at 3.5 cubic meter per minute (m^3/m (100 CFM)) air flow.

• New Hampshire DOT requires dust collectors to have a pressure gauge to measure static pressure across the dust filter bank.

Evaluating and Inspecting Containment

Containments are intended to prevent emission of lead dust and debris. The effectiveness can be measured by monitoring the dust in the air with instruments, visually, or by measuring the lead or debris on the ground (see next section). The containment (including ventilation) is also designed to allow the surface to be cleaned and painted effectively while protecting the health and safety of the worker and inspectors. Additional information on containment is given in Appendix E.

Guidelines for Reviewing and Inspecting Containment

New York State has developed two sets of guidelines to assist agency personnel in evaluating the effectiveness of containment.

• "Guidelines for reviewing Class A containment plans" sets out specific questions to be asked and items to be checked during review of a contractor written containment plan. Items covered include minimizing obstructions, type of containment material, support structures, details of joints and seams, air flow minimum and maximum in ducts, air flow in containment, fan requirement, dust or collector materials, and air make-up points in ducts.

• "Guidelines for monitoring operation of Class A containment enclosures" is intended for DOT inspectors and engineers to check out the containment enclosure before work is started and to guide them on how containment operations should be conducted during the work. It describes the following:

—smoke tubes and instruments for measuring air flow and velocity,

—review of working drawings,

—installation of enclosure,

—directions for a trial run in which dust collector is started prior to blasting,

—means to verify that dust filters are periodically cleaned.

Connecticut DOT has developed a detailed series of guidelines for containment for surface preparation prior to painting, welding, or steel rehabilitation. There are four levels, depending on the method of removal and the sensitivity of the area around the bridge. The guidelines address materials and methods of construction for the enclosure, requirement for drawings, requirement for cleaning up spills, disassembly of enclosure if wind exceeds 70 kph (40 mph), and waste storage requirements.

MONITORING EMISSIONS (AIR, SOIL, WATER)

Monitoring of air, soil, and water were not considered in bridge painting specifications until the early 1990s by most agencies. There is still some discussion about how important it is to include these items. The industry has developed several documents detailing the "how" for these activities (*3,13,14*). There is widely diversified opinion among transportation agency and industry representatives about the need for these types of monitoring, the criteria for acceptance, and how often and with what specific method they should be done.

Air Monitoring

High-Volume Sampling

As discussed previously, lead paint removal can result in exceedance of EPA National Ambient Air Quality Standards (NAAQS) for lead and particulate matter. Most practitioners have recognized that application of these standards to lead paint removal from bridges is not well defined and that the results are often imprecise and unreliable (*41*).

Some have argued that air monitoring for TSP lead (total suspended particulate of lead) or PM-10 (suspended particulate matter with diameter of 10 micrometers or less) is primarily a means to verify the adequacy of containment and not necessarily a means to comply with the NAAQS. FHWA has commissioned a study to determine if there are alternative methodologies and strategies for verifying this without the expense of the ambient air monitoring (*42*). Figure 28 shows a high-volume monitor for PM-10.

PM-10 versus TSP

There is also some question about whether it is necessary to monitor for both TSP lead and for PM-10. A case can be made for not requiring PM-10 monitoring except in unusual circumstances.

• Lead is much more recognizable as a hazard to the public than dust. Dust producing operations, other than lead paint removal, are very common at construction sites. The nuisance

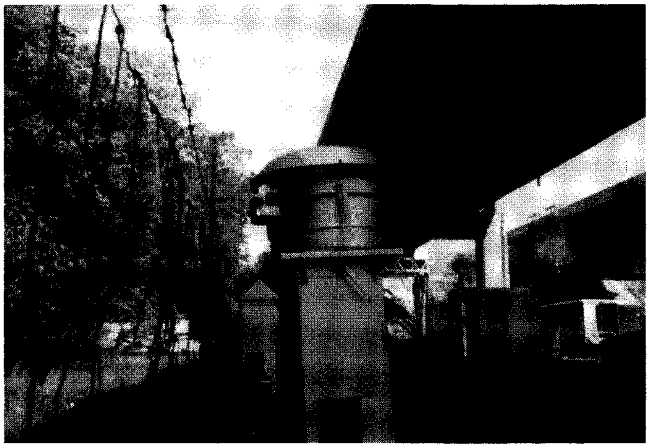


FIGURE 28 High-volume monitor for PM-10.

factor is important even when lead is not present. Recently, OSHA has started paying more attention to potential hazards of these sorts, particularly when the dust contains silica.

- The source of the dust (PM-10 particulates) is the same as the source for the TSP lead particulates (i.e., blast cleaning done inside containment). This dust is typically controlled to a much greater extent than other construction operations.
- The lead NAAQS requires averaging over 90 days, which takes into account the erratic nature of emissions, which may be very high for short periods of time. The PM-10 requirement is a 24-hour average. Short-term emissions may not have a long-term effect on the public.
- When blast cleaning lead, there is a higher likelihood on a daily basis of exceeding the TSP lead levels of 1.5 μg/m^3 than the PM-10 level of 150 μg/m^3 (*50*).

DOT Approach

States have chosen various alternatives to ambient air monitoring using high-volume samplers:

- Iowa — Monitoring is required for TSP lead and for total or hexavalent chromium. Also, Iowa has a statement about the possible need to monitor for PM-2.5 based on the proposed EPA rules of December 1996. See Appendix C.
- New York City DOT — This agency requires numerous monitors of both PM-10 and TSP lead for power tool cleaning as well as for abrasive blast cleaning.

— PM-10/TSP lead: An independent hazardous waste management company is required to measure PM-10 and TSP lead at four fixed stations and at a background station one-half mile away. The levels measured are corrected by subtracting twice the background μg/m^3 levels. Corrective action is needed if the adjusted levels exceed 450 μg/m^3 for PM-10 or 4.5 μg/m^3 for TSP lead (both are 8-hour time weighted averages).

— New York City DOT also requires realtime monitoring of particulates; this is required on a regular schedule and whenever there are suspected lapses in containment. The criterion for action is 450 μg/m^3. Any reading above 250 μg/m^3 requires reassessment.

- Triboro Bridge & Tunnel Authority, NY—Requires three TSP lead and three PM-10 monitors.
- New Hampshire DOT—This agency requires the compliance with the TSP lead NAAQS, but not PM-10. Personal air samplers (e.g., conforming to NIOSH Method 7082) are used to monitor the area in three locations (inside containment, outside containment within regulated area, and at the property line). It also requires an "Air Emission Permit" before performing work, which involves a $900 fee to the NHDES (New Hampshire Dept. of Environmental Services). This fee may be waived for a small project.
- Illinois DOT requires two TSP monitors (windward and leeward), placed to capture the maximum amount of pollutants for 5 days. The criterion for acceptable emissions is less than 5 μg/m^3 based on 24-hour time weighted average.
- New York state DOT presently conducts TSP monitoring on representative bridges (about 10 per year). The monitoring is done under separate contract paid directly by the DOT.
- New York State DOT has done extensive monitoring by several methods on numerous bridges including total lead, total PM-10 and PM-10 lead (*43*). They conclude that the most important quantity to measure is TSP lead, but even that only rarely exceeded the EPA NAAQS limit. Agency representatives observed that lead dust (TSP) exceedance occurred most frequently during blasting or blowdown, at or near air intakes, tarpaulin seams, containment entrance/exit, and at point of irregular seals (*43*).
- Colorado DOT stipulates PM-10 with contractor required to shut down operations if levels exceed 150 μg/m^3 for 24 hours or 450 μg/m^3 for 8 hours.
- Massachusetts DOT requires both TSP lead and PM-10 monitoring. Background levels are checked by monitoring upwind or before the project starts. PM-10 monitoring is done 4 of the first 8 days. The job is shut down if emissions exceed 400 μg/m^3 over 8 hours or exceed the background level by 150 percent or more. For TSP lead, the maximum for an 8-hour day is 13.5 μg/m^3 based on a 30-day project.
- New Hampshire DOT requires TSP lead but not PM-10 monitoring.
- Pennsylvania DOT requires TSP lead and PM-10 monitoring (at least one per site) to be done for 1 week prior to blasting and up to 2 weeks after blasting starts as a minimum.
- Maryland DOT requires daily ambient air monitoring 3 days prior to beginning work and during the first 5 days of work for hand tool cleaning, power tool cleaning and water blast cleaning.

The results of the survey showed that 50 percent of the respondents required ambient air monitoring for TSP lead and PM-10.

Monitoring Visible Emissions

Visible dust clouds or billowing are evidence that containment is inadequate. As discussed in Guide 6 and Appendix D, it is also possible to determine the effectiveness of containment by monitoring the visible emissions. This approach is typically less rigorous than instrumental monitoring but is often more practical and less costly. Visible emission criteria may be used to avoid expense and to get immediate feedback. Monitoring PM-10 and TSP lead can be used when disagreements arise.

Examples of state practice for visible emission monitoring are as follows:

- Colorado DOT evaluates visible emissions via EPA Method 22 (time of visible emissions). Emissions are permitted for a maximum of 10 percent of the work day (e.g., 48 minutes in 8 hours). This is in addition to instrumental monitoring described above.
- Ontario Ministry of Transportation requires no visible emission for a distance to be stipulated in the contract.
- Massachusetts Turnpike monitors visible emissions by Method A of SSPC Guide 6, which defines five levels based on the percent of time that emissions are visible.
- New York City DOT uses the New York State limit of 20 percent opacity for no more than 6 minutes per hour. At no time can opacity exceed 57 percent.
- Ohio Turnpike Authority requires visible emissions monitoring in accordance with Method 22, using SSPC Level 1 (no more than 1 percent of the work day).
- Pennsylvania DOT requires a written program for assessment of visual observation including: frequency of observations, areas of work activities that will be observed, and methods of observation. Visual emissions are to be done in accordance with Method 22. This method allows no greater than 1 percent of work day in accordance with SSPC Level 1. Contractor must shut down emission producing activities if emissions exceed the criteria based on ambient air monitoring or visible emissions. Visible emissions are to be conducted at least three times a day. The specification references Method Pb/Lead A4 from SSPC 95-06.
- Maryland DOT requires TSP monitors to be placed downwind adjacent to homes, businesses, parks or pedestrian walkways that are within 150 meters (500 ft) of the bridge during blast cleaning operations. These are to be done in conformance with Method D1 of SSPC Guide 6.

Water and Sediment Monitoring

This has become an issue when blasting or working over or near a stream or other body of water (the issue of lead contamination of water used for paint removal or hygiene is discussed under waste handling). It is clearly a violation of the Clean Water Act and RCRA if lead-containing waste is discharged into the water. This is an event that may occur unavoidably, even when the most conscientious contractor is working, or it may occur frequently (and avoidably) for less conscientious contractors.

There are no defined EPA procedures for controlling discharges of pollutants into waterways. Rather, EPA allows states to use best management practices (BMP) for these purposes. These are defined as management practices to prevent or reduce introduction of pollutants into receiving waters. The federal hazardous waste regulation stipulates that the contractor immediately report any such spills and correct the breach in the containment if possible. Attempts should be made to clean up the spill, but this may be difficult in moving water.

SSPC, ASTM, and other groups have defined methods for sampling and monitoring the water and sediment. These methods typically measure general water and sediment quality and may not detect discharge from a paint removal operation. For example, periodic monitoring of the water is not likely to detect occasional discharges (*1,44*). In almost all cases the dilution factor of the moving water quickly reduces the lead level to below measurable levels. Sediments are likely to retain the lead particles for a longer period of time. Tests by Oregon DOT found no detectable levels of lead in sediments even years ago when open blasting was performed.

New York State DOT defines the requirements of the New York State Department of Environmental Conservation including: no increase in turbidity, no suspended colloidal and settleable solids, no residue from oil or floating substances, and special precautions near wetlands. The DOT notes that some bridge washing contractors have been cited for water quality violations.

Iowa DOT provides criteria for when river sediment or soil are contaminated but sampling procedures are not provided. Maryland DOT requires testing water and sediment for heavy metal content on the bridges within 150 meters (500 ft.) of a stream or other body of water. Testing is to be done before, during, and after the work operations are completed.

Other agencies requiring water and sediment monitoring are: New York City DOT, Connecticut DOT, and New Jersey DOT.

Containment Booms

It is common practice to use containment booms and skirts to prevent surface debris from being transported downstream. This practice is only partially effective as the booms easily become clogged or breached and cannot withstand heavy current flow. For bridge paint removal over water, the Ontario Ministry of Transportation requires a skimmer on the water, which must be cleaned out at midday and at the end of each day.

Soil Monitoring

Unlike lead in water, lead in soil is likely to remain in place for long periods of time. Therefore, monitoring is an effective means to determine if a leak or emission has occurred. It is important to recognize the other sources of lead in soil, primarily from previous lead paint removal or application, abrasion of yellow traffic stripes, and from use of leaded gasoline.

Soil Sampling

In order to determine the amount of lead in the soil, it is necessary to take representative samples. It is a challenge to acquire adequate samples to provide valid soil levels. Highway agencies typically require four to 10 samples spread from areas beneath and adjacent to the bridge surface. Because of the variability in the level of lead in the soil, this may not provide an adequate number to give precise results. In general, this may be valid for the gross amount of lead contamination. This number of samples may be suitable for determining if there is a very low lead level (e.g., less than 100 PPM) or a very high level (e.g., greater than 1,000 PPM). Figure 29 shows a soil sample being taken.

One of the main purposes of specifying sampling and analysis of lead in soil is to determine if the contractor has allowed significant quantities of lead to be deposited on the soil. If the lead in the soil is greatly increased after the project, the owner can turn to the contractor to clean the soil. Or if the level was high to begin with, the contractor has a legitimate claim that the lead contamination was not his responsibility. Therefore, this protects both the transportation agency and the contractor. Based on small samplings, it may be difficult to attribute increases in lead to the contractor unless these are significant (e.g., 500 to 1,000 PPM) total increases or a 100 percent relative increase. SSPC, ASTM, and NIOSH have established methodologies to collect and analyze the samples (the weak link in the process is the sampling procedure itself). A large amount of data has been published showing the high variability in lead levels in soil under and adjacent to bridges and the difficulty in comparing pre- and post-project results (*45,46*).

DOT Practices

Typical examples of criteria for contractors to sample and clean up the lead in soil are as follows:

- California—Soil sampling requires up to 20 samples within 36 hours of cleaning. The method is similar to that in the SSPC Guide 6 requiring five plugs in a 300 mm x 300 mm (1 ft x 1 ft) area. No increase in soil concentration is allowed.
- Colorado DOT allows a maximum increase in soil of 200 ppm.

FIGURE 29 Soil sampling.

- Illinois DOT requires one soil sample for every 100 m (300 ft) of bridge length prior to cleaning and at completion of project.
- Maryland DOT requires a soil analysis for lead and other hazardous elements in accordance with Method E of SSPC Guide 6. Four soil samples are to be taken and analyzed, one at each corner of the bridge. Locations of soil samples are to be marked or recorded as approved by the engineer. The analysis is performed prior to, during, and at the completion of the work. If the post-job analysis indicates an increase of 500 PPM or greater, the contractor is required to clean the site to reduce the lead content to preexisting conditions.
- Maryland Transportation Authority (responsible for toll bridges) requires submitting soil sampling results to state environmental agency to determine if clean-up is needed.
- New York City DOT—Contractor remediates the soil showing any increased levels of lead in excess of 500 PPM. In addition, the independent hazardous waste management company must submit a plan for sampling, analysis, and evaluation, along with a map.

— sample to be taken directly under the bridge and every 16 m (50 ft) up to 65 m to 100 m (200 to 300 ft) in four directions from bridge;

— five samples at each site forming 16 m (50 ft) grid;

— samples to be collected: one week before start-up, upon 50 percent completion, upon 100 percent completion and if work is suspended because of air emission;

— no specific criteria are given for when contamination has occurred, to be determined based on analysis.

- Ohio Turnpike Authority requirement is as follows:

— if initial lead in soil is less than 200 ppm, an impact has occurred if final lead concentration exceeds initial lead concentration by 100 ppm or two standard deviations,

— if initial lead in soil is greater than 200 ppm, an impact has occurred if final lead concentration exceeds initial lead concentration by 200 ppm.

TRAFFIC CONTROL

Traffic control is an important consideration because it directly impacts the completion time and cost of a project. Figure 30 shows traffic control on a bridge being repainted. The DOT must balance inconvenience to the public (e.g., traffic delays) with the need to expedite the work and reduce cost. Safety is also a consideration as fatalities and other accidents may result from improper traffic control. The presence of containment and the use of large equipment for air makeup, dust control, abrasive recycling, and industrial hygiene trailers and regulated areas are common. The contractor is both seen and heard. As a result, lead removal projects have become major road construction activities.

Large equipment must be placed somewhere (e.g., on or adjacent to the roadway, below the deck, or on a barge for work under water). The more access the contractor has, the more efficiently the work can proceed. Conversely, if the contractor can only close traffic lanes for a limited time during the day, the cost of starting and stopping the work can be enormous. This is an important subject to be discussed with contractors during a

FIGURE 30 Traffic control on bridge being repainted.

prebid conference, or preconstruction, or even earlier in the project planning stage.

The DOTs can reduce variability in bid costs for traffic control by clearly stating the specific requirements in the bid documents. Traffic control considerations may also impact the specific type of containment and removal system selected by the contractor. Information on traffic control devices is available from the Manual of Uniform Traffic Control Devices (MUTCD) (*47*). Examples of traffic control provision and specifications are as follows:

- New Jersey DOT requires a detailed equipment storage plan. The DOT must be notified prior to any ramp or lane closures. The DOT also gives specific requirements for nighttime work.
- Washington DOT designates requirements for lane restrictions, (e.g., no interruptions on holiday weekends), portable message signs, and use of traffic cones, flagging signs, and other control devices. Also, a traffic control manager is required.
- Connecticut DOT provides the following information: charts showing which lanes can be closed; guidelines for removing signs; requirements for taper length related to speed; directions on establishing buffer space adjacent to the transition taper; and when there is a need for crash trucks or state police (e.g., on limited access highway).
- Oregon DOT includes traffic control as a major discussion topic in the prebid conference.
- Maryland DOT requires that contractor complete a traffic control plan certification, approved and signed by the DOT. The contractor is subject to a daily fine of $1,000 for failure to properly maintain traffic. Fines for failure to maintain traffic flow are assessed at $50 for the first 5 minutes and $50 per each minute thereafter.

WORKER PROTECTION FOR CONTRACTOR EMPLOYEES

Protecting Contractor Employees

An area that has generated some differences of opinion is the extent of requirements the DOT should impose on the contractor for worker protection. Some states (e.g., Connecticut, New Jersey) have included very stringent requirements for worker health and safety. In some instances these requirements exceed those established by OSHA. For example, several states require more frequent monitoring of worker blood levels (e.g., monthly) compared to OSHA requirements (bi-monthly). Also, some states have a lower threshold for removing a worker from lead exposures (e.g., 25 to 35 μg/dl versus OSHA's 50 μg/dl). Other agencies (e.g., Ohio, West Virginia, New York City) have taken the posture that protecting the workers (employees) is strictly the responsibility of the employer (contractor). This issue is also discussed under the section on contracts. Figure 31 shows a worker wearing protective equipment.

Some of the largest citations issued by OSHA for failure to comply with 29 CFR 1926.62 have been issued to bridge painting contractors. This can result in delays to projects as the contractor focuses on compliance in addition to the health issue concerns.

Model Specification For Lead Health and Safety

In 1993 the Center to Protect Worker Rights (CPWR) developed a model specification for protecting bridge workers removing lead-containing paint (*48*). This document provided procedures and criteria that in several instances were more stringent than the OSHA Lead in Construction Standard. The group believed that the OSHA standard provided a minimum set of criteria and that through stricter control and monitoring, a public agency like a DOT could achieve greater protection of the workers by assigning responsibilities to the DOT. The CPWR argues that better control can be exercised over the contractor when lead health and safety is enforceable under the contract, rather than other under OSHA. This specification was evaluated at a NASA facility in Cleveland and, based on those and other assessments, a revised version was issued in 1995 (*49*). It is very similar to the specification used by Connecticut DOT and the requirements of New Jersey DOT.

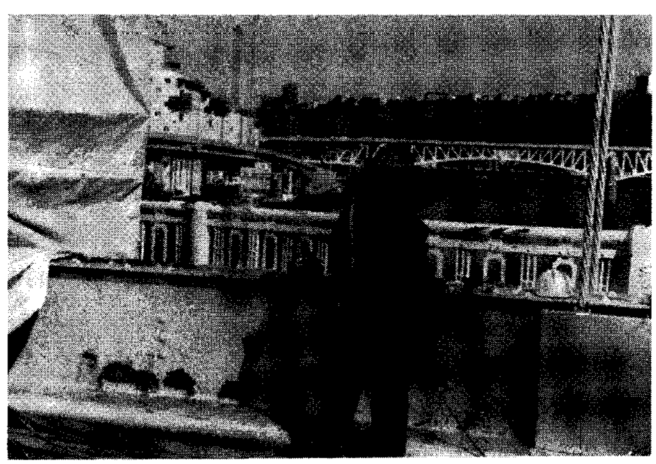


FIGURE 31 Worker wearing protective equipment.

Connecticut DOT Initiatives

Results from Connecticut Road Industry Surveillance Program (CRISP) (now CLINIC—Connecticut Lead Intervention Network in Construction) have demonstrated that stringent programs with participation by several agencies (e.g., Connecticut DOT, OSHA, Connecticut DOH) can result in dramatic improvements in worker protection, as judged by blood levels.

Connecticut DOT is also investigating the use of wipe samples. This is a procedure in which surfaces are wiped with a damp cloth (e.g., baby wipe) and the cloth is analyzed for lead picked up from the surface. Criteria for wipe samples are included in the OSHA compliance directive (developed as a guide for OSHA field inspectors enforcing the lead standard), though not in the standard itself. Connecticut DOT has hired an independent industrial hygienist to collect wipe samples in various locations including clean and dirty side of decontamination trailers, the lunch room, and hands of workers. Connecticut DOT uses these data as means to determine whether the contractor is observing good hygiene procedures.

Examples where DOT requirements go beyond those of the OSHA lead standard include the following:

- Connecticut DOT defines who shall use the decontamination facility and designates number of showers (one per 10 employees of each sex) and defines a schedule and procedure for recleaning the decon. For the portable hand wash facility, the agency requires hot water heater, eye wash station, light for night use, and a lead filtration system.
- Massachusetts Turnpike has developed a comprehensive guidance document on the contractor's health and safety plan that includes details of engineering and work practice controls, including procedures on how to reduce exposure limits and how to measure velocities and pressure inside containment. The contractor must also identify staff positions and responsibilities and submit a detailed written plan conforming to the guidelines. In addition, personal air monitoring for workers must be done every 60 days, whereas OSHA does not designate a time limit if the task has not changed. Also, the competent person must be a certified industrial hygienist.

FIGURE 32 Regulated area for protecting adjacent workers.

- New Hampshire DOT requires qualitative and quantitative fit testing for negative pressure respirators (OSHA requires qualitative fit testing of half-mask respirators and quantitative fit testing of full-face respirators). The DOT also establishes a medical removal criterion based on zinc protoporphyrin (ZPP) as well as blood lead, whereas OSHA's medical removal is based only on blood lead levels.
- North Dakota DOT stipulates that the American National Standards Institute (*50*) and SSPC minimum velocities in containment are not appropriate, but that 29 CFR 1926.62 must be observed.
- Maryland DOT requires that the project supervisor be trained and certified in accordance with requirements of the Maryland Department of the Environment.
- Maryland DOT requires worker exposure monitoring to be conducted once per shift for at least the first 3 days of cleaning and monthly thereafter, and if work operations change.
- Maryland DOT provides a sample lead-based paint removal and inspection "daily checklist" to be completed by the contractor and furnished to the project engineer. Items included are: contractor's crew (number and type of workers for whom personal monitoring is conducted), equipment used, barriers for containment, visible emissions, work area practices, e.g., the availability of personal protective equipment (PPE), worker decontamination and work habits (e.g., where the workers wash hands upon leaving work area).

Protecting Adjacent Workers

A related issue is the protection of adjacent workers who are not employees of the painting contractors. These may be workers of another trade (e.g., iron workers or DOT employees). As the owner of the structure, the DOT may be held responsible for exposures of workers who are not properly protected against lead. Unlike the workers employed by the painting contractor, these employees would not be covered by the painting contractor's worker compensation provisions. Figure 32 shows a regulated area that helps to protect adjacent workers.

A New York City public agency reported that several electrical workers sued the agency because they were exposed to fumes from coating application by a painting contractor (hired by the agency) working in the same vicinity (*personal communication, L. Bowker, New York City DEP, March 1997*).

Protecting Transportation Agency Employees

Contractor Responsibility

Under OSHA the DOT is responsible for protecting inspectors, field engineers and others who may be present at lead removal sites. Many DOTs, however, require that contractors provide equipment and facilities to the DOT employees as part of the contract.

Examples are as follows:

• Minnesota DOT requires contractors to provide protective clothing and use of facilities to all DOT inspectors.

• Massachusetts DOT requires contractors to test blood of three DOT employees with data furnished to the Massachusetts blood lead registry.

• New Hampshire DOT requires contractors to furnish PPE and training for two DOT employees.

• Maryland Transportation Authority requires proper respirators to be supplied by the contractor, but fit testing and respirator training are performed by the Authority's own safety department.

Transportation Agency Responsibility for Protecting Its Own Employees

As noted, several transportation agencies require contractors to assist them in protecting the agency employees who may be exposed to lead paint during lead removal projects. If desired, this must be included in the contract documents. However, the agency still has the full responsibility for the health and safety protection of the employee. Many agencies are encouraged to institute their own training program to ensure compliance with the Lead in Construction Standard. As with contractor employees, the key criterion is whether the employee will be exposed to a level of airborne lead at or exceeding 30 $\mu g/m^3$ on an average of 8 hours for any day.

Maryland DOT includes the following statement: "The Administration assumes full responsibility for the safety and health of its own employees and for complete compliance, as an employer, with the above noted [Federal and Maryland state] regulations."

QUALITY ASSURANCE (INSPECTION AND MONITORING)

Assuring Quality of Contractor's Work and Materials

Quality assurance and quality control of a paint removal project may involve a number of different activities, including the following:

• Submittal of contractor plans such as:
— containment and ventilation system designs (e.g., by professional engineer)
— site work plan
— waste handling and disposal
— site-specific air, soil, or water sampling and monitoring plan
— site contingency plan for waste emergency, including evaluation plan
— site health and safety
— employee training.

• Materials and quality control
— manufacturer's verification of compliance with composition and performance requirements
— submittal of retained samples of paint or abrasive.

• Submittal of test results
— prejob soil or paint testing
— analytical test of lead in waste soil, air, or water.

• Inspection and verification
— painting portion of work (e.g., surface preparation, application materials dry film thickness (DFT))
— environmental and safety compliance (e.g., by industrial hygienist or environmental professional)
— engineering assessment of containment and ventilation submitted by contractor
— assessment of other plans submitted by contractor.

• Others including:
— request for approval of waste TSD facility
— requiring on-site support of coating manufacturer technical representative (required by Iowa and New Jersey DOTs)
— certification of equipment decontamination (required by Iowa DOT).

Expertise Required by Transportation Agency

In order to properly plan, manage, and evaluate the numerous elements of a paint removal and repainting project, a variety of professionals may be needed by the transportation agency. These go beyond traditional requirements of earlier painting projects where maintenance and construction staff could reasonably be expected to oversee all aspects of the projects.

Among those needed are:

• Materials, coatings, or corrosion specialist or engineer—to determine the need for painting and the most suitable repaint strategy.

• Structural engineer—to determine the structural integrity of containment (and its effect on the bridge) as a result of wind and dead loads on the bridge.

• Environmental scientist or engineer—to determine the means to protect air, soil, and water from contamination and to ensure compliance with environmental regulations.

• Industrial hygienist—to ensure the adequacy of the contractor health and safety plan, to verify adequacy of ventilation of containment, to establish procedures to protect DOT or other workers who may be exposed to health and safety hazards, and to assess the possible presence of other health and safety hazards (e.g., exposure to cadmium, solvents, noise).

• Traffic or safety engineer—to minimize risks and costs to the driving public.

• Community relations specialist—to ensure that nearby residents and businesses understand what is being done and are able to get their questions answered and fears allayed.

DOTs may be weak in expertise in the industrial hygiene and environmental engineering areas as well as community relations. Also, structural, traffic, or safety engineers may not be available to participate in review of deleading plans or to plan deleading projects.

The most widely used current practice is to continue to assign the planning of lead paint removal projects to a materials, maintenance, or construction specialist within the DOT. The DOT hopes that this person can learn enough about the other disciplines to provide an effective and appropriate specification. Similarly, the execution of the project is left to the field staff who are expected to learn what is necessary to allow the work to proceed without undue delays in the production and without incurring undue risks of adverse health or environmental effects, risks, or citations.

When the impact and cost of lead paint removal became more widely recognized, numerous transportation agencies established an internal task group to deal with the issue. Typically, these groups include representatives from management (e.g., chief engineer's office, construction, environmental, and materials and maintenance divisions). These groups greatly facilitate communication and more informed decision making. It is important that such groups be continually supported by the agencies, as conditions, regulations, and technologies are changing rapidly. Procedures and policies that were appropriate 5 years ago may need to be substantially revised or at least periodically reassessed.

Oregon DOT has developed a position that is responsible for planning, writing specifications, training inspectors, and all other aspects of such projects, plus overseeing technical aspects once a job is set.

CHAPTER FIVE

CONTRACT DEVELOPMENT AND ADMINISTRATION PRACTICES

INTRODUCTION

This chapter describes the means by which transportation agencies develop and administer contracts for lead paint removal and how they interact with contractors.

Contracts are legal agreements that govern what work will be done, how the work will be performed, when the work will be done, the cost, the means of verifying a specification, and the provisions for nonconformance. All agencies are governed by state-specific regulations of varying complexity and diversity and with different formats and contents. In this section, we will primarily address those issues that directly impact lead paint removal from bridges. These include the following:

- Qualifying contractors and applicators
- Insurance and bonding
- Prebid conferences
- Liabilities for environmental or safety violations
- Type of contract (e.g., lump sum, fixed price, pay items)
- Special contracting practices (partnering, warranties)
- General and subcontractors
- Impact on public (public relations).

QUALIFYING CONTRACTORS

Bridge painting in general, and removing and disposing of lead paint in particular, are operations that require a high degree of skills, successful experience, and thorough understanding of regulations.

There are several types of procedures for qualifying contractors, including:

- Transportation agency (internal) programs
- Industry programs
- Regulatory agency requirements.

Transportation Agency (Internal) Programs

Almost all agencies have some type of requirement for the contractor to be included on the bid list. Typically, the requirement is that the contractor is able to become bonded by a bonding company. This assures that the contractor has sufficient resources to complete the contract (see discussion below under bonding).

Some agencies also require that the contractor demonstrate some technical expertise and experience. This is to assure that the contractor understands the technical complexities and sensitivities of a lead paint removal project. For example, in Pennsylvania, contractors must submit evidence that they are capable of applying high-performance coatings to be qualified for bridge maintenance painting.

Highway agencies maintain bidders lists based on such criteria. Although most agencies have provisions for removing contractors from the list, this is rarely done. The requirement for open bidding of public agency projects makes it difficult to exclude a contractor from the highway agency approved list. In addition, most agencies don't have adequate staff to thoroughly observe or monitor the work done by painting contractors. Even if a contractor has performed poorly in the past, it is not always easy to remove that contractor from the list of approved bidders. Some reasons for this difficulty are poor specifications, unrealistic cost estimates, poor inspection, state statutes, and political considerations (see chapter 6).

New York State Thruway Authority requires that a contractor have a minimum of 5 years experience in applying the specific type of coating system, with at least one similar project in the last 2 years. A list of previous clients and projects is submitted as part of the contract bid proposal.

Industry Programs: SSPC Certification Program

In 1989, SSPC developed a program to prequalify industrial painting contractors based on a consensus standard. This is designated as SSPC-QP 1, *Standard Procedure for Evaluating Qualifications of Painting Contractors (Field Application to Complex Structures).* Under this program, contractors are evaluated in a field audit for conformance to criteria in four areas (quality control, safety procedures, technical capabilities, and management/financial procedures). Contractors who meet the minimum criteria become certified SSPC contractors. This certification must be renewed annually based on an audit at an active painting or paint removal project.

This program was expanded in 1992 to include contractors who have special expertise in removing lead or other hazardous coating from structures. This is known as SSPC-QP 2, *Standard Procedure for Evaluating Qualifications of Painting Contractors To Remove Hazardous Paint.* To meet the requirements of SSPC-QP 2, contractors must demonstrate specific knowledge of environmental and health and safety regulations and have on staff a competent person. They must also demonstrate the capability of developing plans for lead health and safety and environmental compliance.

The program is paid for by the contractor and is free to facility owners such as transportation agencies. A number of agencies have adopted the program in one form or another.

Connecticut DOT, Maryland DOT, West Virginia DOT, Indiana DOT, New York State Thruway Authority, and Ohio Turnpike Authority require SSPC-QP 1 and QP 2 for almost all lead paint removal projects. Other states and agencies use certified contractors for special projects.

For example, Georgia DOT offered SSPC-QP 1 as an alternative to a state administered training program. Oklahoma DOT offers contractors a $3,000 bonus if they are SSPC certified. This program has been endorsed by several groups including the Center To Protect Worker Rights (*48*), The Alliance To Prevent Lead Childhood Poisoning (*51*) and in the AASHTO Bridge Painting Guide (*33*). To date, no other industry group has established a general program to prequalify industrial painting contractors.

Applicator Qualification

It is often argued that the success of a painting or paint removal project depends on the skill of the applicator or operator rather than on the qualification of the firm. In the United States, there is no national program to qualify applicators because of the historic transience of individuals in the paint trade. Some DOTs have established programs to qualify paint applicators, such as New Hampshire and Utah (*52*).

Regulatory Agency Requirements

Because of concern about the effects of exposure to lead on the general public and the environment, the United States Congress, in 1992, directed the EPA to establish training and certification requirements for contractors engaged in lead paint activities on bridges and other structures (see discussion under regulations, Title X, Section 402 of Toxic Substances Control Act).

EPA issued a draft proposal that included requirements for training and certification in September 1994 (*53*). However, in the final EPA Title X rule of August 1996, bridges (and other steel structures) were not included in the proposal, but were deferred to a later rule making (*54*). When this rule is finalized, it is anticipated that the states will be required to issue licenses to verify the qualifications of painting contractors to perform lead paint removal and related work. This rule is not expected to be in place until 1999 or later.

Several states, however, have established their own requirements for licensing, certification, or training for painting contractors doing bridge work. Among these are New Jersey, Virginia, Maryland, Vermont, and Missouri. Programs are under development in Maine and Massachusetts. Typically, these states require that the contractor inform the regulatory agency in writing that the supervisors and lead workers are properly trained by a training program provider that is certified by the state. Also the contractor must agree to conform to the appropriate EPA, OSHA, and state rules. In addition, a contractor is required to pay a fee, and in some instances notify the state regulatory agency in advance of any projects that will remove or disturb lead.

One of the critical issues for the state certification program is reciprocity among states. A large proportion of painting contractors do work in multiple states, so the potentially excessive costs for becoming certified in numerous states would be ultimately passed on to the transportation agencies and other owners.

Training and Certification for Lead Workers and Supervisors

Under The Residential Lead Based Paint Reduction Act, EPA has been mandated by Congress to certify contractors engaged in lead paint activities (*7*). The industrial version of that rule is still under development. Under the residential version of the rule, EPA has identified five types of individuals requiring training or certification, including: inspectors, risk assessors, planner/designers, supervisors, and workers. In the proposed industrial rule, the EPA designated training and certification of supervisors and training (but not certification) for workers. The final rule, expected in about 1999, will almost certainly require certification and training of supervisors. It has not yet been determined whether training will be required for workers. However, several states have already established programs to certify and train these individuals.

Requirements For Shops Rehabilitating Lead-Coated Steel

Shops that refurbish lead-coated steel beams must be thoroughly familiar with the appropriate regulations concerning handling and disposal of the waste. The steel members are not considered hazardous waste because they are not being discarded and hence are exempt from subtitle C of RCRA. However, the lead on the steel is still a hazardous material and all individuals handling the lead-coated steel would be subject to the requirements of the General Industry Lead Standard 29 CFR 1910.1025. This rule is comparable to the Lead in Construction Standard 29 CFR 1926.62 for manufacturing facilities. Under this rule, the shop is required to undertake air monitoring for individuals who may be exposed to airborne lead. These exposures may result from abrasive blasting using a centrifugal wheel machine or air blast equipment or other mechanical removal methods. Blast cleaning equipment operators and those in adjacent work areas should be monitored to determine the level of dust generated during paint removal. If the shop does any hot work or mechanical work on the steel before the lead paint is removed, this can also be a source of lead exposure. Figure 33 shows a bridge demolition site. Figure 34 illustrates how torchcutting is used for bridge demolition.

Residue from the abrasive blasting will contain lead and must be tested to determine if it is a hazardous waste. If steel shot or grit was used, it is likely that the waste will test as nonhazardous. However, as discussed earlier, the lead-contaminated debris should be disposed of as a hazardous waste to avoid potential problems in a landfill, when the stabilizing effect of the iron is diminished because of oxidation.

It is also important for the operator to ensure that the equipment used for abrasive blasting does not become contaminated

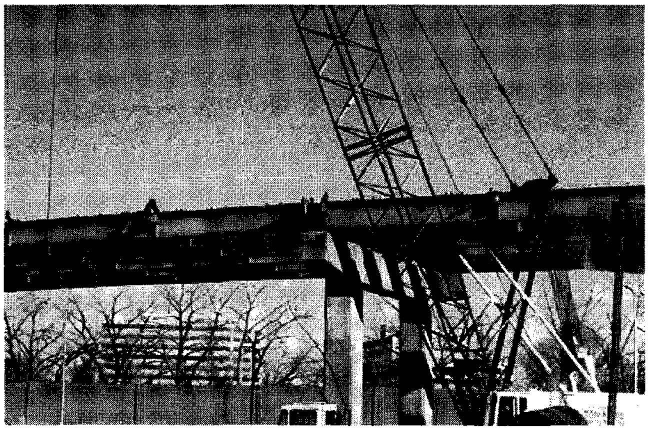


FIGURE 33 Bridge demolition site.

with lead dust. Lead wipe sampling would be a good way to verify this.

Individuals handling and disposing of the waste would also be subject to training requirements as specified under OSHA (29 CFR 1926.62), EPA (for hazardous waste handling), and anticipated state regulations for supervisors and workers engaged in lead paint activities. Also, if any steel member is found to be unsuitable for rework, its disposal would then be subject to Subtitle C of RCRA.

Maryland DOT requires a cleaning containment system plan for containing blast residue and other debris for work done in removing lead paint from existing steel in shops.

Because of the added responsibility and potential liability, it has been suggested that some type of certification may be appropriate for shops undertaking this type of work. The certification could be modeled after the SSPC-QP 2 and QP 3 program (*55*). SSPC-QP 3 is a recently introduced standard and qualification program designed to verify the qualifications of a shop that does painting. It would probably need to be modified to give more focus on compliance with lead regulations. For example, an individual would be designated as the competent person, responsible for ensuring that the lead health and safety and environmental controls are done correctly. Alternately, other programs such as the AISC sophisticated paint endorsement (*56*) could be modified or new programs developed.

BONDING AND INSURANCE

Bonding

Most agencies require that the contractor provide a bond or obtain bonding from a bonding agency. There are several types of bonds that may be required:

- A *bid bond* compensates the owner if the low bidder decides not to undertake the work. A typical amount is 10 to 20 percent of the bid.
- A *payment bond* provides for the bonding company to pay the subcontractor if the general contractor fails to pay after the general has been paid by the owner.
- A *performance bond* provides for the bonding company to pay to complete the work or to undertake the completion (e.g., by another contractor). This would occur if the original contractor is unable to perform the work because the contractor abandoned the job or was fired by the DOT. Performance bonds are normally required by state law. There have been several instances of bonding companies taking over lead removal projects. A warranty, which is also a type of performance bond, is discussed later in this chapter.

Insurance

State agencies usually require that the contractor have a comprehensive and general liability (CGL) insurance policy that covers claims for bodily injury or property damage (e.g., from auto accidents) caused by the contractor during the course of the project.

However, it is important to note that most CGL policies have a "pollution exclusion" clause (*57*). This excludes coverage for any claim arising out of the release of any contaminants or pollutants into the ground, air, or water. In other words, cleanup of a nearby yard or home contaminated with lead debris would not be covered under most CGL policies. (Figure 35

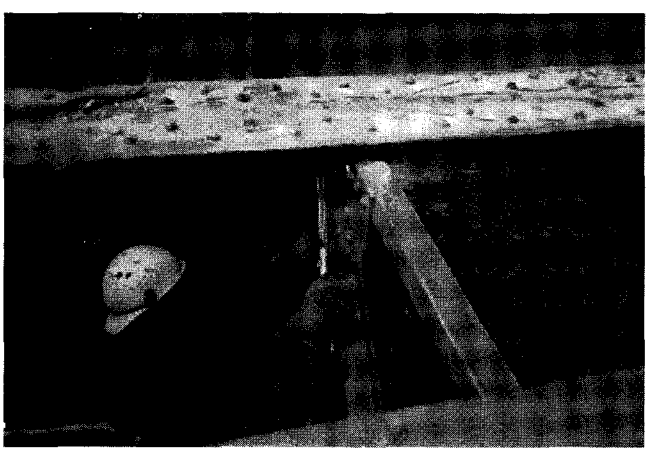


FIGURE 34 Bridge demolition by torchcutting.

FIGURE 35 Lead-containing abrasive contamination on property.

is an example of property contaminated by lead and abrasive.) This is a major gap in the coverage of painting contractors that has been recognized but not properly rectified. Some insurance companies have been offering this type of coverage at additional cost. In other regulated industries (e.g., asbestos and residential lead abatement), states have required contractors to acquire pollution coverage.

Surveys by SSPC and others have indicated that a large proportion of painting contractors do not have pollution coverage and are therefore assuming the risk if there is an environmental incident. As noted in the discussion on waste generation, the owner (DOT) shares the liability for incidents related to handling, disposal, or transportation of hazardous waste.

Illinois DOT indemnifies contractors for any lead pollution claims. This is paid for by withholding 5 percent of the price and placing it in an insurance pool. Massachusetts Turnpike requires pollution liability insurance. New Jersey DOT requires pollution liability insurance, at $5 million per incident and $10 million total coverage.

Maryland DOT requires the contractor to hire an industrial hygienist having $1million insurance coverage for errors and omissions. The hygienist is to monitor worker exposure and ambient air and collect waste samples.

PREBID AND PRECONSTRUCTION CONFERENCES

Prebid Conferences

A prebid conference is a means to inform potential bidders about the nature and scope of the project. Typically, the transportation agency engineer or project manager describes the contract requirements, which may include what the agency requires in terms of traffic control, access, staging, the degree of cleaning, the type of containment, the level of monitoring for air, soil, water, waste handling, etc. It explains what is written in the bid package and offers the bidder the opportunity to ask any questions. It may involve a site visit so that the contractors can determine site conditions for themselves.

An important issue is whether contractors should be required to attend a prebid meeting as a condition for submitting a bid. One criticism of this is that it penalizes contractors who must travel long distances and small contractors who don't have the resources to send representatives to a lot of meetings. As reported in NCHRP Synthesis 176, a majority of DOT representatives and contractors were in favor of a mandatory prebid conference, because they help avoid any misunderstanding and create a level playing field.

Based on this and other input, in 1993 FHWA issued a memorandum (*58*) requiring mandatory prebid conferences for federally assisted projects involving lead paint removal. However, in April 1994 this requirement was rescinded because it could not be enforced in several states and because OSHA representatives were unable to participate (*58*). FHWA's current policy recommends that a state conduct prebid conferences for large and unusual projects.

Overall, a prebid conference is a very useful means to establish good early communications with the potential bidders. The amount of change in practice and requirements over the last 5 to 10 years for lead paint removal has been enormous. Mandatory participation at these meetings helps assure that the bidders are at least made aware of some of the changes. It forces them to give more thought to what is involved in submitting a responsible bid. Prebids also provide an opportunity for contractors to point out possible problem areas or items not anticipated by the owner. Some states have required contractors to attend a yearly prebid meeting to discuss that year's projects and changes in the specification.

Typical items included in a prebid conference are as follows (*59*):

- Discussion of project scope, describing the extent of lead paint removal and general level of exposure control required.
- Review of contract documents, painting specification, worker and environmental protection specification.
- Review of performance criteria for controls over worker protection, environmental emissions, handling and disposal of waste streams, and containment and ventilation system design.
- Discussion of prebid, preconstruction, and construction time submittal requirements.
- Levels of project monitoring and specification enforcement procedures.

States that still conduct mandatory prebid conferences include North Carolina (for total removal only) and Oregon. North Carolina DOT refers to their program as a "Constructibility Conference." The contractor's plans for containment, waste disposal, environmental monitoring, and worker protection are reviewed, along with other specific concerns and requirements.

Preconstruction Conferences

These conferences are held after the contract has been awarded and before the work is started. They are intended to define the scope and schedule of work, and establish the ground rules for the working relationship between the contractor and the DOT. The conference normally includes: the engineer, the inspector, a representative from the environmental monitoring firm, and the key personnel from the contractor and subcontractors. For example, Washington DOT requires the contractor to submit for approval the method for removal of overspray on traffic.

LIABILITIES FOR ENVIRONMENTAL OR SAFETY VIOLATIONS

A major concern of the highway agencies and the contractors is their specific liability in incidences of alleged violations or other misconduct. An important distinction can be made between issues related to environmental statutes and regulations versus issues related to safety and health.

Safety and Health Liabilities and Violations

OSHA has assigned the responsibility for the protection of employee health and safety to the employer (the contractor).

As noted previously, OSHA has established definitive rules and requirements for employees exposed to lead as well as to employees working on scaffolding, wearing respirators, handling solvents, etc. Also, under state worker's compensation programs, the employee is directly compensated for injuries or illnesses incurred on the job.

There have been a few instances where an employee has attempted to hold a facility owner responsible for the worker's exposure to lead. This may occur where the exposure is to the worker's family, which is not covered under workers compensation laws (*60*). In these instances, a contractor is still primarily liable, but if the contractor is unable to pay, the owner and other parties may be brought into the suit. It is not known in any of these instances if the court has ruled in the employee's favor. However, there is nothing to prevent an employee from suing the highway agency.

One area in which DOTs may have liability is when adjacent workers, employed by the DOT, are exposed to or injured by lead. In New York City DOT, electrical workers have sued employers (a public agency) because of adverse health reactions from paint solvent fumes (*personal communication, L. Bowker, New York City DEP, March 1997*).

In some instances, transportation agencies (Connecticut DOT, New Jersey DOT) have established very rigorous health and safety requirements for their contractors that go beyond what OSHA requires (e.g., in the frequency of blood lead monitoring or the level of blood lead requiring worker removal from areas of lead exposure). There is some question as to whether an employee could successfully sue the agency if such provisions were not complied with.

Several arguments have been put forth in favor of DOTs requiring some level of worker health and safety in the contract. With such an arrangement, worker health and safety could be enforced under the provisions of the contract, rather than under OSHA. This would help assure that the contractor follows the provisions because there is much greater likelihood of a DOT inspector on the job than an OSHA inspector. In addition, the owner can shut down the project if the contractor is not in conformance. This position has also been taken by two health and safety advocacy groups, the Center To Protect Worker Rights (*48*) and The Alliance to Prevent Childhood Lead Poisoning (*51*). In addition, some agencies believe that facility owners have an obligation to ensure a safe working environment for all personnel associated with the project including contract personnel. Others argue, however, that the DOT inspectors are usually not trained in lead. They could be held personally liable if a worker or worker's family member became lead-poisoned from the project.

Environmental Violations

State agencies have a much more direct responsibility when it comes to violations of environmental regulations. One example is the responsibility of generating hazardous waste. In the Federal Register of August 29, 1996 (*61*), EPA confirmed that the owner and contractor are co-generators of hazardous waste, equally responsible for the handling and disposal of this waste. So if the contractor illegally disposes of waste or fails to properly store, record, or label the waste, the owner can also be held liable. Of course the owner may be able to compel the contractor to pay for the remediation or fines under the terms of the contract. But if the contractor does not have the resources, the owner may be required to assume the fiscal responsibility. Contracts should be specific as to the responsibilities of all parties and what criteria will be used to determine conformance.

It is not clear which party (i.e., contractor or owner) has primary responsibility for pollution of the air, water, or soil. However, as the DOT is still the "owner" of the waste (at least under one interpretation), it is prudent to assume that the owner will also have liability for other forms of lead contamination.

Soil Contamination

In the case of soil, it is often difficult to prove when the soil became contaminated. The contractor may claim that the lead was in the soil prior to any lead removal work. Contractors are typically advised to measure the lead content in the soil before doing any lead removal to protect themselves from the responsibilities for preexisting lead. Facility owners also need to be aware of what is present before project start-up. Transportation agencies are therefore advised to require pretesting as well as post-job testing of soil for lead.

It must be recognized that in many instances there is significant residual lead in the soil from previous paint application or removal from degraded yellow traffic markings or from leaded gasoline. In several instances, highway agencies have paid substantial sums for cleaning up lead-contaminated soil in yards or playgrounds (e.g., Port Authority of New York/ New Jersey, New Jersey DOT, and the Golden Gate Bridge Authority). These situations arise from paint chips or debris that have eroded or fallen off a structure during normal aging of the structure or under any activities that cause the structure to vibrate. These represent a clear case of responsibility belonging to the agency.

TYPES OF CONTRACTS/PAY ITEMS FOR LEAD PAINT REMOVAL

Transportation agencies have used several types of contracts for bridge painting. This normally depends on the standard procedures used by the agency. For bridge paint removal contracts, the most common type of contract is a fixed-price contract (e.g., the contractor agrees to perform the work for a predetermined amount of money, which is established by the bidding process). Occasionally, a contractor is given work on a time and materials basis if the work could not be well defined or it is performed under special circumstances.

Lump Sum Versus Separate Pay Item

In some instances the work for a lead paint removal project may be divided into several components rather than being bid as a single entity (e.g., lump sum).

Basis of Payment

The trend in lead paint removal projects is to include the various elements of the project (e.g., containment, cleaning and painting, waste disposal) under a lump sum. Several items are, however, often issued as separate payment items, such as lead health and safety program, waste testing or disposal, and environmental monitoring (see result of survey in chapter 6). Containment/environmental protection has also been broken out as a separate pay item by some agencies.

Some examples are as follows:

- Lead health and safety plan—If a transportation agency wants to ensure that adequate resources are devoted to this item, it can be separately priced. Connecticut DOT used this practice when first implementing its program to control the blood lead levels of workers.
- Industrial hygiene or environmental monitoring—A separate subcontract may be desired for assessing the extent of air or soil emissions or worker exposures.
- Waste disposal—In some instances, a transportation agency agrees to pay the contractor based on the amount of waste collected for disposal. This practice was established because of the uncertainties in the cost for disposing of waste which might turn out to be hazardous or nonhazardous. This procedure, however, may reduce the contractor's incentive to minimize the waste.
- Minnesota DOT pays for the work based on the square feet of surface cleaned and painted. All the TCLP tests (but not the collection of the samples) is paid for separately.
- North Carolina DOT includes pollution control as a separate item.
- California DOT pays for spot cleaning and priming by the square foot, then by lump sum for the full undercoat and full finish coat.
- Ohio Turnpike Authority pays for spot washing based on surface area washed.
- Connecticut DOT and the New York State Thruway Authority pay for the decontamination facility based on the number of months or weeks that the facility is operational.
- New York State DOT includes worker health and safety as a special pay item, but the contractors tend to bid it at a very minimal level (e.g., about \$1,000-\$2,000 per bridge). Other separate pay items include lead exposure control plan (which includes waste management) and medical monitoring and exposure testing.
- Illinois DOT includes three pay items: cleaning and painting steel bridges; containment and disposal of lead paint blasting residues; and containment and disposal of lead paint power tool cleaning residues.
- New Jersey Turnpike Authority divides pay items into cleaning and painting, lead health and safety plan, containment plan, and waste reclaiming plan. Ambient air monitoring is also bid as a separate item based on a daily rate for a specified number of days. Having a daily rate gives the Authority some latitude in knowing the cost of additional air monitoring, if needed.

NEW APPROACHES AND CONCEPTS IN CONTRACTING

In an effort to ensure best long-term performance and to manage finite resources, transportation agencies have investigated some innovative approaches for contracting. These include partnering, warranties, and single source responsibilities.

Partnering

The traditional purchaser/seller relationship can be modified to minimize the adversarial relationship between the two parties. In one version, the contractor is given a financial incentive to work with the owner in reducing cost and expediting the project. This, of course, is not unique to bridge painting or paint removal, but has been tried on several recent lead removal projects. Examples are the Gold Star Bridge in Connecticut and several bridges in Pennsylvania. It has also been offered on at least one bridge in Maryland. In order for this approach to be successful, commitments must be made at the highest levels in the transportation agency. In some instances, a neutral facilitator is used to ensure good communication and adequate procedures for resolving differences.

Warranty

Warranties are assurances that a product (e.g., bridge painting job) will meet a given level of performance for a given period of time. Painting contractors have been reluctant to warrant their work because they don't have control of the painting materials or the general specification. The transportation agencies have been suspect about their ability to compel a contractor to return to a project months or years after completion to correct deficiencies. Even if some money had been held back from the original contract, the contractor might choose to forego that additional revenue if the re-work was excessive.

- Maryland DOT was one of the first DOTs to use such a program. For several years Maryland DOT has included a 1-year warranty as part of the bridge painting contract. Under this program a contractor must repair the bridge for any rust or paint breakdown in excess of 1 percent of the surface area painted. Maryland DOT withholds a portion of the project fund for this purpose.
- Maryland DOT has developed a new procedure for bridge warranty that is being used for a bridge over I-695 in Baltimore. The contractor is required to submit a bid for a 5-year warranty. The contractor is also given an option of extending the warranty for up to an additional 5 years. For each year above 5, the contractor's bid (for comparison purposes) is reduced by \$35,000. In other words, if the contractor bids \$1 million and provides a 7-year warranty, the DOT will use \$1 million minus 2 times \$35,000 or \$930,000 for comparison against other contractors. The actual amount to be paid to the contractor would still be the full amount of \$1 million.
- Maryland DOT requires a warranty performance bond equal to 100 percent of the total contract. The paint system is

considered to be defective if visible or rust breakthrough, paint blistering, peeling, or scaling conditions occur over 1 percent of the surface area or greater during the warranty period. Effects such as chalking, peeling, or rust degree less than 1 percent are not considered failures. The agency provides a chart listing performance criteria for repair.

- Oklahoma DOT requires the contractor to submit an unconditional warranty that the paint system will be free of defects for 2 years from the acceptance date. It is defective if it contains visible rust, blistering paint or improper paint thickness. In addition, the contractor is required to post a maintenance bond of 20 percent.
- Maryland Transportation Authority required a 25 percent performance bond for 10 years for repainting a portion of the Chesapeake Bay Bridge, a $40 million dollar project (including warranty).
- Oregon DOT requires contractors to warranty that the coating system is free of defects for the first full winter. The contractor has 105 days to make the repair. A 10 percent warranty performance bond is also required.
- Michigan DOT started a program in 1991 under which 15 bridges in the state were painted under 2-year warranties (supplemental performance bonds). The DOT reported that the costs for the warranty projects are consistent with comparable projects without warranties. The performance of the projects were also judged to be about equal to those projects not under warranty. The contractor was held responsible to repair some localized peeling on several of the bridges (*62*).
- Buffalo and Ft. Erie Public Bridge Authority required a 10-year warranty for repainting the Peace Bridge (Figure 36), and limited bidding to coatings manufacturers as the prime contractor.

Warranties will typically require additional funds, which must be escrowed or paid out in future years. This is a practice that would have been very unlikely in the past by DOT contracting officials. However, DOTs are becoming very open and receptive in their efforts to improve the efficiency of the construction process.

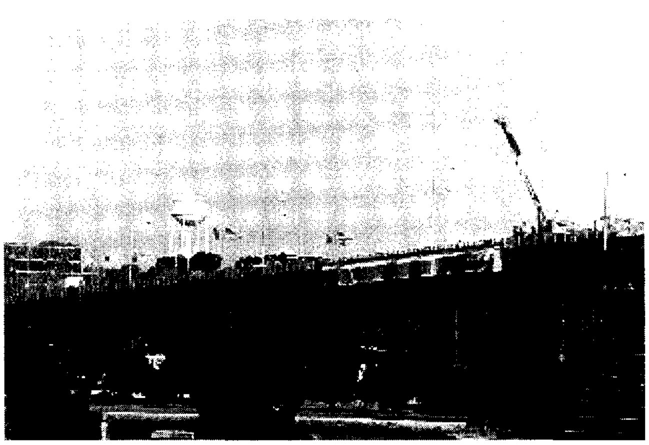


FIGURE 36 Peace Bridge being repainted under partnership.

Bridge Painting Warranties In Europe

According to the recent FHWA report (*63*), there is a more cooperative relationship between bridge agencies and painting contractors, and paint suppliers in Europe than in the United States. In addition, many of the bids for work are distributed to a limited number of qualified vendors. The focus of the limited bidder's lists used for competition of contracts is to ensure financial viability of potential contractors. A second emphasis is to ensure quality. Quality is ensured by basing the qualified contractors list on past performance on similar jobs.

Warranties on bridge painting contracts are also common among European bridge owners, contractors and paint vendors. Most were typically held liable for field performance for a 5-year period. The system in Holland is described as follows:

> After letting of a painting contract, the owner, contractor, and paint supplier meet on-site and the contractor applies the specified surface preparation/coating system to selected areas of the bridge. Once all parties agree the specification was properly followed in the selected areas, these areas are designated for evaluation for warranty conformance. The entire bridge is painted following the specification. If failure occurs first on the structure, while the "warranty areas" remain intact, the contractor is considered liable for the failure. If failure occurs on the warranty areas, the coating manufacturer is held liable since they were present at application of these areas and "signed-off" that they were properly applied. The warranty generally applies for a five-year period.

GENERAL AND SUBCONTRACTORS AND THIRD PARTY CONTRACTORS

Frequently there is more than one contractual arrangement associated with a bridge painting project. The bridge painting may be a subcontract to a bridge rehabilitation project. Other subcontractors may include industrial hygiene or environmental monitoring firms.

Subcontracting

Large general or construction contractors are hired to perform major bridge rehabilitation projects (e.g., including deck replacement). These often include adding new structural steel, which must be repainted, and also repainting the existing structural steel. Based on survey responses, rehabilitation accounted for about 30 percent of the lead-paint removal work over the last 4 years. Figure 37 shows a bridge deck replacement project.

Painting contractors often complain that general contractors don't understand the requirements for paint removal or for repainting. Frequently, general contractors are not as knowledgeable about the special requirements for lead health and safety plans, and environmental controls and regulations as are specialty painting contractors. It is important for the transportation agency to ensure that the general contractor gives adequate attention to these aspects. Because of the potential for lead release or improper handling of waste, it is beneficial for the general contractor to have someone available who is knowledgeable in the design and specification of containment, dis-

FIGURE 37 Bridge deck replacement project.

posal, worker monitoring, and other crucial aspects of lead paint removal.

In some instances, the general contractor will undertake lead paint removal and repainting with its own crews or supervisors. In those circumstances, it may be in the transportation agency's best interest to require the same prequalification of the supervisor and crew of the painting subcontractor or general supervisor it would require if hiring the subcontractor directly.

For some projects, the paint portion of the work (removal and repainting) represents a larger cost than the steel work (rehabilitation), so the painting contractor becomes the prime contractor. The same provisions should apply (e.g., the painting contractor should be required to use qualified and trained steel and iron workers). An upcoming paint removal project in Portland, Oregon (Hawthorne Bridge) requires the prime contractor to be the coatings contractor, with steel repairs to be subcontracted. This is to assure that the prime contractor is most knowledgeable in the lead aspects of the project.

Washington DOT requires the contractor to submit to the engineer a certification of any subcontract for work performed on a federal-aid contract. New Jersey DOT requires that the subcontractor meet the same prequalifications as the prime, if the subcontract is for $200,000 or more. For certain special projects Maryland DOT requires approval of any subcontractors.

Industrial Hygiene and Environmental Monitoring Firm

Many contractors (at least until recently) have had relatively little experience in industrial hygiene (e.g., lead, air sampling, regulated areas) or environmental monitoring (e.g., ambient air collection and testing). So, there may be a need to hire an independent firm to verify that the work conforms with the regulations. In such cases, it is preferable if the industrial hygiene or environmental firm works directly for the transportation agency, rather than for the contractor. This helps to ensure that the report and data are unbiased and to protect the owner from liabilities, as discussed previously.

An alternative that may be cost effective is for the contractor to perform its own monitoring, and have an agency inspector verify that proper sampling and other procedures have been employed. This may require some investment by the transportation agency in training or hiring inspectors knowledgeable in these areas, but it would appear to be a worthwhile investment.

IMPACT ON PUBLIC (PUBLIC RELATIONS)

As noted above, a lead paint removal project (including containment trailers and workers dressed in protective suits) is a highly visible public activity. Because of several well-documented "horror stories," news media and health and regulatory officials as well as community leaders are well aware of the potential problems that can arise from lead in various forms. For example, at a recent SSPC conference in Connecticut, examples were presented on two alternate approaches to dealing with the public. The public can be a formidable adversary in the form of an aroused media, indignant community activist groups, and sympathetic regulators. Poor communication with the public can result in lawsuits, project shutdowns, and embarrassing media coverage. A prime example is the experience of the New York City DOT where the entire program of blast-cleaning projects was put on hold for more than a year because of problems with the community (*64*). Improved procedures described below are now in place.

The bulk of this responsibility lies with the transportation agency to inform and assure the public that the work is necessary and will not have adverse economic, environmental, or health impacts on the community.

The contractor also has an important role in dealing with the public. The contractor may be required to provide a spokesperson to relay exactly what is occurring, or to explain delays in the progress of the work. The spokesperson must be able to discuss any real or apparent problems or incidents that might produce personal or environmental exposures. Figure 38 shows

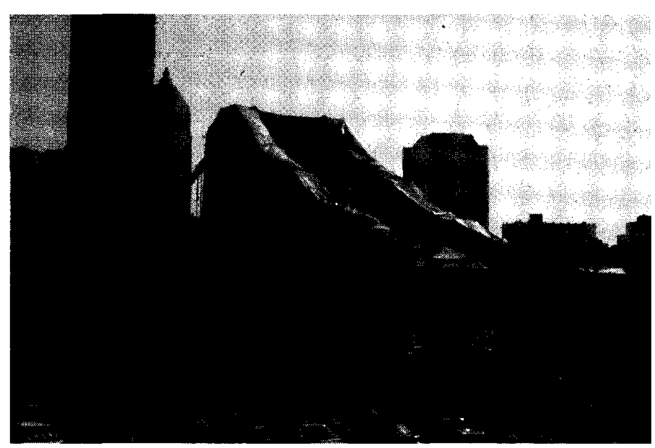


FIGURE 38 Bridge repainting project in sensitive area.

the kind of steps that should be taken when a bridge repainting project occurs in a sensitive area.

- The New York City community notification procedure (developed for abrasive blasting projects) includes the following sections:
  - — When will the community be notified?
  - — What information will be included in the notification?
  - — In which languages will the notification be provided?
  - — Who will receive the notification?
  - — What types of information will be posted on site?
  - — Will community boards meet with DOT representatives?
- Oregon DOT organized a series of meetings with various citizens groups to discuss options for a bridge rehabilitation project. The community and DOT ultimately agreed on a 12-month complete closure rather than a 24-month extended closure.
- Connecticut DOT has established a public outreach program that was successfully implemented on a large multiyear bridge repainting project (*65*). The outreach program includes the following elements: adequate notice, public input, informing the public, and addressing the public's comments. Communication vehicles included project newsletter and brochure, video, speakers bureau, flyer for school children, residence information meetings, newspaper advertising, and other media contacts. The estimated cost was $1.30/sq. m ($0.12/sq. ft.) for 4 years, a portion of which was paid voluntarily by the contractor.

CHAPTER SIX

RESULTS OF TRANSPORTATION AGENCY SURVEY

INTRODUCTION

A survey form was developed and distributed to identify practices and costs for lead paint removal from bridges for 1993 to 1996. The survey for transportation agencies is shown as Appendix A-1. Responses were received from 38 of 51 state DOTs, four Canadian provinces, and seven other bridge agencies (cities, bridge, and port authorities) (see Appendix A-2). Some agencies only furnished data on costs (see Part I below).

The survey was organized into three sections. Part I requested information on the overall agency costs for bridge painting over the past 4 years. Part II sought specific case histories. Agencies were asked to select up to three representative bridges, one for which full removal had been undertaken, one for which overcoating had been undertaken, and one for which steel replacement had been performed. The level of response for steel replacement was very low, so this category was not included in the tabulations. Part III of the survey addressed contracts and the contracting process.

PART I: OVERALL BRIDGE PAINTING COSTS FROM 1993 TO 1996

Each agency was asked to provide information on the number of bridges painted and bridge-painting costs from 1993 through 1996, under four categories: full removal as maintenance painting, overcoating as maintenance painting, full removal as part of deck rehabilitation, and overcoating as part of deck rehabilitation. In addition, information was requested on the number of bridges coated with lead paint and total number of bridges (including lead paint and nonlead paint) in the agency's jurisdiction. The results of Question 1 of Part I are presented in Table 4. This table shows that, as a group, the 36 agencies that reported data spent a total of more than $900 million over the last 4 years on bridge painting. If estimates for the nonresponding agencies are factored in, the total is probably close to $1.2 billion or $300 million per year. More than 90 percent of this was spent for bridges that contained lead paint. It is interesting to contrast this information with the results of the survey conducted as a part of NCHRP Synthesis 176 (*1*), which estimated a total expenditure of $100 to $120 million a year on bridge painting. However, the results may not be entirely comparable because the questions were asked slightly differently in the two surveys. The earlier survey did not specifically ask for amounts spent on bridge repainting as part of a rehabilitation project.

Figure 39 shows the full removal and overcoating costs for all agencies combined for each of the 4 years for which the survey sought information. There is no consistent trend for the proportion of the cost spent on overcoating versus full removal. This may be due, in part, to differences in cost for different types of bridges (girder versus truss) or costs associated with traffic impact (limited work hours/lane closures versus no limitations). The amount of money spent by each state varies significantly, even when taking into account the number of bridges within the state (Figure 40). Particularly noteworthy is New York State, which spent more than $300 million over the last 4 years on overcoating. Sixty percent of that

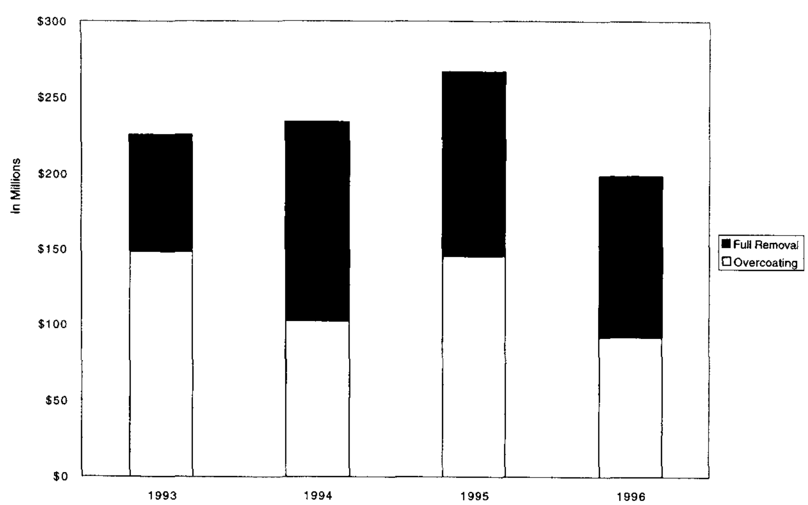


FIGURE 39 Total spending for overcoating & full removal.

TABLE 4
Transportation Agency Repainting Costs: 1993 - 1996

	1	2	3	4	5	6
Agency*	# Overcoated	# Full Removal	% Full Removal	Spent on Overcoating 93-96	Spent on Full Removal	% Spent on Full Removal
AK	3	4	57%	$2,500,000	$700,000	22%
AR	5	45	90%	$2,900,000	$32,300,000	92%
AZ	0	1	100%	$0	$100,000	100%
CA	51	4	7%	$37,700,000	$7,800,000	17%
CT	0	108	100%	$0	$51,600,000	100%
DC	0	3	100%	$0	$5,100,000	100%
GA	0	532	100%	$0	$29,200,000	100%
IA	218	1	9%	$5,100,000	$7,200,000	59%
IL	299	6	3%	$21,200,000	$440,000	2%
IN	4	125	97%	$2,200,000	$14,000,000	86%
MA	137	7	5%	$17,000,000	$2,800,000	14%
MD	58	31	35%	$7,200,000	$13,800,000	66%
MN	8	13	62%	$144,000	$11,121,000	99%
MO	237	82	26%	$21,100,000	$27,020,000	56%
MS	1	0	0%	$100,000	$0	0%
ND	1	4	80%	$100,000	$700,000	88%
NH	21	1	5%	$1,200,000	$600,000	33%
NJ	0	135	100%	$0	$27,500,000	100%
NYS	827	0	0%	$307,100,000	$0	0%
OH	0	405	100%	$0	$47,400,000	100%
OK	11	29	73%	$1,500,000	$3,600,000	71%
OR	13	7	35%	$4,500,000	$19,500,000	81%
TN	49	17	3%	$3,650,000	$6,900,000	7%
UT	0	3	100%	$0	$200,000	100%
VT	0	5	100%	$0	$7,346,000	100%
WA	16	1	6%	$8,100,000	N/A	0%
WI	0	43	100%	$0	$13,963,236	100%
Chic	0	8	100%	$0	$3,260,000	100%
GG	0	4	100%	$0	$14,129,000	100%
NJT	50	1	2%	$7,300,000	$500,000	6%
MAT	0	28	100%	$0	$33,917,000	100%
Ont	0	42	100%	$0	$17,500,000	100%
NYC	5	5	50%	$12,600,000	$27,800,000	69%
NYCT	409	0	0%	$21,500,000	$0	0%
DE Riv	1	0	0%	$4,900,000	$0	0%
NY&NJ	3	9	75%	$900,000	$11,000,000	92%
Totals	2427	1709	41%	$490,494,000	$438,396,236	47%

*** See Appendix A for abbreviations code**

TABLE 4 (*continued*)
Transportation Agency Repainting Costs: 1993 - 1996

	7	8	9	10	11	12
Agency*	Total Spent	Avge Cost For Overcoating	Avge Cost for Full Removal	# of Maint. Painting	# of Deck Rehab.	% of Maint. Painting
AK	$3,200,000	$833,333	$175,000	0	7	0%
AR	$35,200,000	$580,000	$717,778	46	4	92%
AZ	$100,000	N/A	$100,000	0	1	0%
CA	$45,500,000	$739,216	$1,950,000	55	0	100%
CT	$51,600,000	N/A	$477,778	94	14	87%
DC	$5,100,000	N/A	$1,700,000	0	3	0%
GA	$29,200,000	N/A	$54,887	528	4	99%
IA	$12,300,000	$23,394	$7,200,000	219	0	100%
IL	$21,640,000	$70,903	$73,333	156	149	51%
IN	$16,200,000	$550,000	$112,000	129	0	100%
MA	$19,800,000	$124,088	$400,000	144	0	100%
MD	$21,000,000	$124,138	$445,161	89	0	100%
MN	$11,265,000	$18,000	$855,462	21	0	100%
MO	$48,120,000	$89,030	$329,512	290	29	91%
MS	$100,000	$100,000	N/A	1	0	100%
ND	$800,000	$100,000	$175,000	1	4	20%
NH	$1,800,000	$57,143	$600,000	2	20	9%
NJ	$27,500,000	N/A	$203,704	135	0	100%
NYS	$307,100,000	$369,333	N/A	700	127	85%
OH	$47,400,000	N/A	$117,037	405	0	100%
OK	$5,100,000	$136,364	$124,138	40	0	100%
OR	$24,000,000	$346,154	$2,785,714	20	0	100%
TN	$10,550,000	$74,490	$405,882	38	28	58%
UT	$200,000	N/A	$66,667	3	0	100%
VT	$7,346,000	N/A	$1,469,200	2	3	40%
WA	$8,100,000	$506,250	N/A	17	0	100%
WI	$13,963,236	N/A	$324,726	43	0	100%
Chic	$3,260,000	N/A	$407,500	8	0	100%
GG	$14,129,000	N/A	$3,532,250	4	0	100%
NJT	$7,800,000	$146,000	$166,667	53	0	100%
MAT	$33,917,000	N/A	$1,211,321	28	0	100%
Ont	$17,500,000	N/A	$416,667	42	0	100%
NYC	$40,400,000	$2,520,000	$5,560,000	10	0	100%
NYCT	$21,500,000	$52,567	N/A	409	0	100%
DE Riv	$4,900,000	$4,900,000	N/A	1	0	100%
NY&NJ	$11,900,000	$300,000	$1,222,222	12	0	100%
Totals	$929,490,236	$202,099	$256,823	3745	393	91%

* See Appendix A for abbreviations code

TABLE 4 (*continued*)
Transportation Agency Repainting Costs: 1993 - 1996

	13	14	15	16	17	18
Agency*	Spent on Maint. Painting	Spent on Deck Rehab.	% Spent on Maint. Painting	Total Spent	# of Bridge w/PB	Total Bridges
AK	$0	$3,200,000	0%	$3,200,000	5	7
AR	$32,900,000	$2,300,000	93%	$35,200,000	48	50
AZ	$0	$100,000	0%	$100,000	0	1
CA	$45,500,000	$0	100%	$45,500,000	55	55
CT	$47,300,000	$4,300,000	92%	$51,600,000	117	117
DC	$0	$5,100,000	0%	$5,100,000	0	3
GA	$25,600,000	$3,600,000	88%	$29,200,000	568	568
IA	$12,300,000	$0	100%	$12,300,000	194	219
IL	$5,840,000	$15,800,000	27%	$21,640,000	305	305
IN	$16,200,000	$0	100%	$16,200,000	57	186
MA	$19,800,000	$0	100%	$19,800,000	200	200
MD	$21,000,000	$0	100%	$21,000,000	89	89
MN	$11,265,000	$0	100%	$11,265,000	22	22
MO	$20,000,000	$28,120,000	42%	$48,120,000	207	319
MS	$100,000	$0	100%	$100,000	1	1
ND	$100,000	$700,000	13%	$800,000	5	5
NH	$900,000	$900,000	50%	$1,800,000	22	22
NJ	$27,500,000	$0	100%	$27,500,000	133	135
NYS	$191,200,000	$115,900,000	62%	$307,100,000	827	827
OH	$47,400,000	$0	100%	$47,400,000	405	405
OK	$5,100,000	$0	100%	$5,100,000	40	40
OR	$24,000,000	$0	100%	$24,000,000	20	20
TN	$2,500,000	$8,050,000	24%	$2,500,000	18	56
UT	$200,000	$0	100%	$200,000	2	2
VT	$2,625,000	$4,721,000	36%	$7,346,000	5	5
WA	$8,100,000	$0	100%	$8,100,000	16	16
WI	$13,963,236	$0	100%	$13,963,236	43	43
Chic	$3,260,000	$0	100%	$3,260,000	8	8
GG	$14,129,000	$0	100%	$14,129,000	3	4
NJT	$7,800,000	$0	100%	$7,800,000	51	51
MAT	$33,917,000	$0	100%	$33,917,000	28	28
Ont	$17,500,000	$0	100%	$17,500,000	42	42
NYC	$40,400,000	$0	100%	$40,400,000	10	10
NYCT	$21,500,000	$0	100%	$21,500,000	503	503
DE Riv	$4,900,000	$0	100%	$4,900,000	0	1
NY&NJ	$11,900,000	$0	100%	$11,900,000	12	12
Totals	$736,699,236	$192,791,000	79%	$921,440,236	4061	4377

*** See Appendix A for abbreviations code**

TABLE 4 *(continued)*
Transportation Agency Repainting Costs: 1993 - 1996

	19	20	21	22
Agency*	% Bridges w/PB	Spent on Bridges w/PB	Total Spent on Bridges	% Spent on Bridges w/PB
AK	71%	$1,300,000	$3,200,000	41%
AR	96%	$33,600,000	$35,200,000	95%
AZ	0%	$0	$100,000	0%
CA	100%	$45,500,000	$45,500,000	100%
CT	100%	$51,600,000	$51,600,000	100%
DC	0%	$5,100,000	$5,100,000	100%
GA	100%	$29,200,000	$29,200,000	100%
IA	89%	$7,200,000	$12,300,000	59%
IL	100%	$21,640,000	$21,640,000	100%
IN	31%	$3,200,000	$16,200,000	20%
MA	100%	$19,800,000	$19,800,000	100%
MD	100%	$21,000,000	$21,000,000	100%
MN	100%	$11,265,000	$11,265,000	100%
MO	65%	$30,220,000	$48,120,000	63%
MS	100%	$100,000	$100,000	100%
ND	100%	$800,000	$800,000	100%
NH	100%	$1,800,000	$1,800,000	100%
NJ	99%	$22,300,000	$27,500,000	81%
NYS	100%	$307,100,000	$307,100,000	100%
OH	100%	$47,400,000	$47,400,000	100%
OK	100%	$5,100,000	$5,100,000	100%
OR	100%	$24,000,000	$24,000,000	100%
TN	32%	$3,375,000	$11,550,000	29%
UT	100%	$200,000	$200,000	100%
VT	100%	$7,346,000	$7,346,000	100%
WA	100%	$8,100,000	$8,100,000	100%
WI	100%	$13,963,236	$13,963,236	100%
Chic	100%	$2,441,000	$3,260,000	75%
GG	75%	$10,614,000	$14,129,000	75%
NJT	100%	$7,800,000	$7,800,000	100%
MAT	100%	$33,720,000	$33,917,000	99%
Ont	100%	$17,500,000	$17,500,000	100%
NYC	100%	$36,400,000	$36,400,000	100%
NYCT	100%	$26,500,000	$26,500,000	100%
DE Riv	0%	$0	$4,900,000	0%
NY&NJ	100%	$11,900,000	$11,900,000	100%
Totals	93%	$869,084,236	$931,490,236	93%

* See Appendix A for abbreviations code

total was for maintenance painting contracts and the remaining 40 percent was for painting done as part of deck rehabilitation.

Other states having significant expenditures for bridge painting over the 4 years surveyed included:

- Connecticut—$51.6 million (100 percent on full removal);
- Missouri—$48.1 million (56 percent on full removal);
- Ohio—$47.4 million (100 percent on full removal);
- California—$45.5 million (17 percent on full removal);
- Arkansas—$35.2 million (92 percent on full removal);
- Georgia—$29.2 million (100 percent on full removal);
- New Jersey—$27.5 million (100 percent on full removal);
- Oregon—$24 million (81 percent on full removal);
- Illinois—$21.6 million (2 percent on full removal);
- Maryland—$21 million (66 percent on full removal).

Of nonstate DOTs, the transportation agencies with the highest expenditures for bridge painting were:

- New York City DOT—$40.4 million (69 percent on full removal);
- Massachusetts Turnpike—$33.9 million (100 percent on full removal);
- New York City Transit—$21.5 million (100 percent on overcoating);
- Ontario Ministry of Transportation—$17.5 million (100 percent on overcoating);

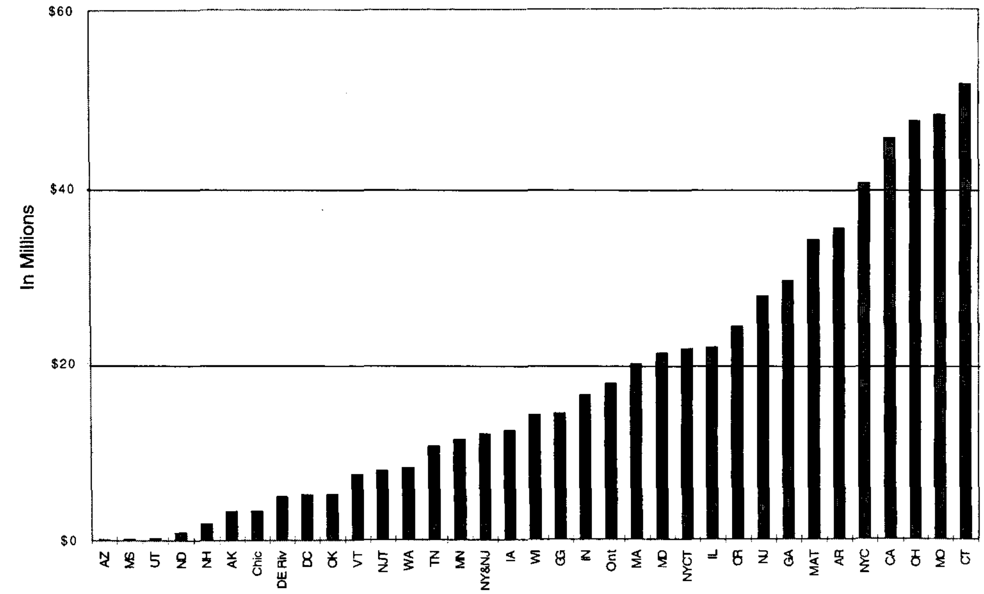


FIGURE 40 Total bridge repainting expenditure for full removal and overcoating by agency, 1993-1996.

- Golden Gate Bridge Authority—$14.1 million (100 percent on full removal);
- Port Authority of New York/New Jersey—$11.9 million (92 percent on full removal).

The total number of bridges painted by the responding agencies was 4,377. Ninety-three percent (4,016) were coated with lead paint. In Indiana, Missouri, and Tennessee, less than 50 percent of the bridges had been coated with lead. The number of bridges painted by each state is given in Figure 41. As reported in Synthesis 176 (*1*), about 6,000 bridges were painted between 1986 and 1989. So, even though the total amount spent on bridges has more than doubled, fewer bridges are being painted each year than in the late 1980s.

Overall, about 47 percent of bridge painting costs were for full removal and 53 percent for overcoating. Correspondingly, the total number of bridges that underwent full removal was 1,709, while the total overcoated was 2,427. The average cost per bridge for overcoating was $202,000, somewhat less than that for full removal ($256,000). Since the average price per square meter for overcoating is about half that for full removal, these data suggest that the overcoating projects had about twice as much surface area as the full removal project. The data indicate that about half the states undertake full removal almost

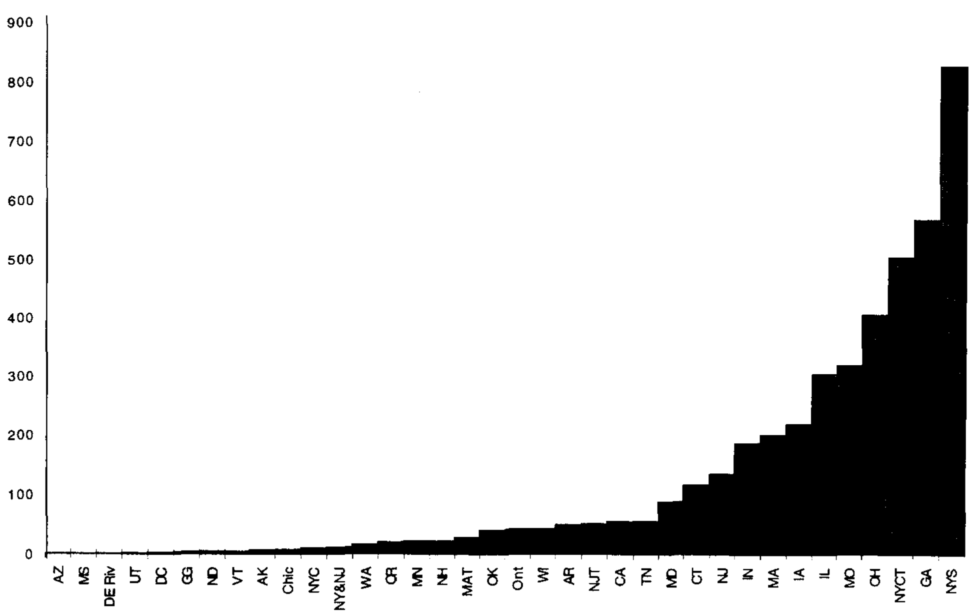


FIGURE 41 Total bridges repainted by agency, 1993-1996.

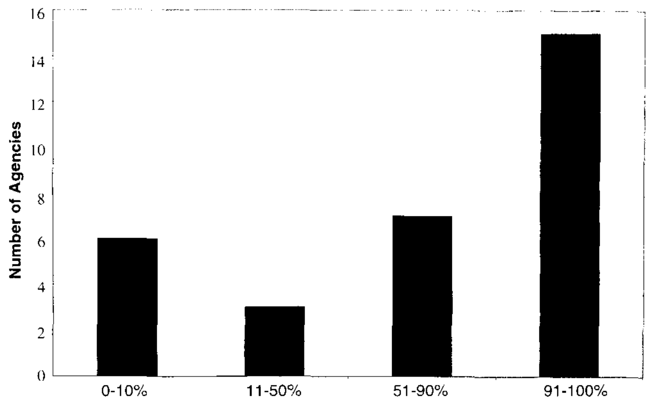


FIGURE 42 Percent spent on full removal, 1993-1996.

exclusively (90 percent or greater of funds), about one-fifth undertake overcoating almost exclusively, and one-third do moderate amounts of both (Figure 42).

Also noteworthy were several states that spent relatively little on bridge painting over the 4-year period, e.g., Arizona and Mississippi, which spent just $100,000 each.

The second question of Part I requested information on the number and costs of bridges replaced or that had undergone major steel rehabilitation. For many agencies, it was not possible to separate paint related costs from the overall costs.

PART II: FULL REMOVAL CASE HISTORIES

Agencies were asked to provide data for representative projects of three different types: full removal (Question 3), overcoating (Question 4), and steel replacement (Question 5). Because of the low level of response to Question 5, this category was not included in the survey analysis.

The data for full removal case histories are compiled in Table 5, which shows that there is great variation in the cost per unit area for full removal. As shown in Figure 43, cost per unit area ranges from $29.27/m^2 ($2.72/sq. ft.) in Illinois to $243.80/m^2 ($22.67/sq. ft.) in Maryland. The average is $112.58/m^2 ($10.46/sq. ft.) and the median is $115.35/m^2 ($10.72/sq. ft.). Also, from Table 5 it can be observed that a wide variety of bridge types are included in the survey, including rolled girder, plate girder, bascule bridge, various types of trusses, and a steel arch bridge. The bridges were categorized into two major groups: Group 1, girder and plate girder bridges (including rolled beam); and Group 2, truss bridges (including arches and suspension bridges). The surface areas are shown in Table 6. The analysis showed that the cost for full removal from truss bridges was greater than the cost for full removal from girder bridges (Table 7).

Subparts C and D of Question 3 requested information on containment. The results of these questions showed that the projects were about equally split between suspended platform and bridge-to-grade type containments. A few mentioned specific types. The sidewalls of nearly all containments were constructed of impenetrable tarps; only one used solid construction (i.e., fiberglass and aluminum panels). Four of the respondents used grate floors. Approximately one-fourth used solid floors, primarily plywood. As expected, all of those who used bridge-to-grade containments used ground covers as the primary flooring material. Closure of containments was primarily accomplished by overlapping the tarps or ground covers. Approximately 20 percent used clips. Other closures cited in-

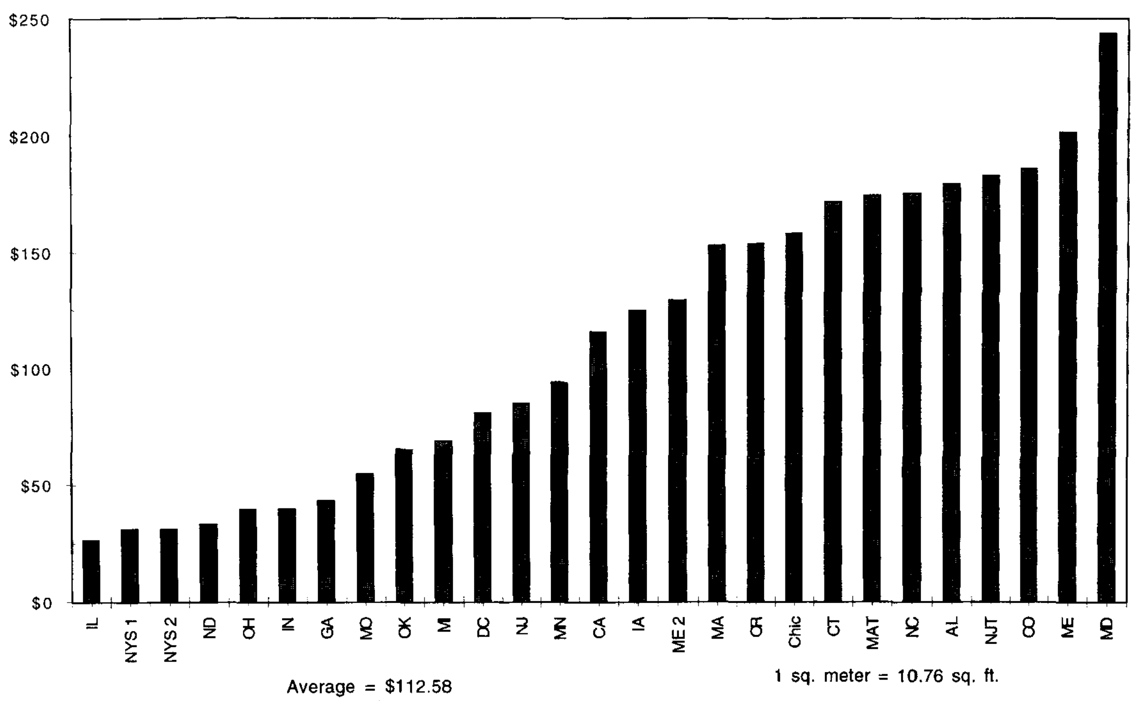


FIGURE 43 Cost per square meter—full removal from case histories.

TABLE 5

Summary of State Responses on Full Removal Case Histories

			Containment				Assessments							
Agency	Type of Bridge	Total Sq. Meter*	Type	Side Walls	Floors	Closures	Prevent Spills	Collect Spills	Air Emission	Neg. Pressure	Waste Disp. Cost/Mg	Air Monitored	Final Agency Cost	Price Per Sq. m.
AR	Long plate girder		Suspended Platform Bridge to Grade	Penetrable Tarps	Ground Covers-Tarps		3	4	3	2		No	$553,843	
AK	Steel stringer, laminated timber deck	2,232	Bridge to Grade	Impenetrable Tarps		Overlaps	4	4	5	1			$400,000	$179.76
CA	Steel through truss	10,230	Bridge to Grade	Impenetrable Tarps								Yes	$1,179,480	$115.39
DC	Simple span w/cross girders	46,500	Bridge to Grade (ARK)	Impenetrable Tarps	Grate/ground covers	Zippers/overlaps	4	5	5	5	$220.40	Yes	$3,745,000	$80.62
IA	Truss	77,655	Suspended Platform	Impenetrable Tarps	Solid/ground cover	Overlaps	4	4	4	4		Yes		$124.86
MA	Steel cantilevered through truss	7,905		Impenetrable Tarps	Grate	Overlaps	5	5	3	4		Yes	$1,200,000	$152.85
MD	Steel arch	5,124	Bridge to Grade	Impenetrable Tarps	Solid-plywood ground covers	Overlaps	5	5	5	5		Yes	$1,249,000	$243.80
ME 1	Truss	2,829											$570,124	$201.72
ME 2	Steel girder Buckfield - Hall	670	Suspended Platform	Other	Solid		5	5	5	5	$16.53	Yes	$83,000	$129.17
MI	Plate Girder-Cantilever spans	3,348		Impenetrable Tarps	Ground Covers	Clips and overlaps	4	4	4	4		Yes	$230,000	$68.78
MO	Continuous I-Bm + Pl Girder		Suspended Platform(ARK)	Impenetrable Tarps	Grate, Ground covers/tarps	Clips-tarp snaps + Overlaps	3	4	4		$88.16	Yes	$167,500	$54.57
NC	Turn Span Plate Girder	1,691	Suspended Platform	Impenetrable Tarps	Solid						$640.00	Yes	$295,000	$174.45
ND	Rolled girder	2,334	Suspended Platform	Impenetrable Tarps	Solid/Cone	Overlaps	4	4	4	4		No	$77,000	$33.05
ND	Rolled girder, 77 meters total length		Suspended Platform	Impenetrable Tarps	Solid/Cone	Overlaps	4	4	4	4		No	$77,000	
NH	1 span truss 107m long, 16m high		Susp. Plat., Bridge to Grade (ARK)	Impenetrable Tarps	Grate	Velcro	5		5	5		Yes		
NJ	Highway overpass or interstate	1,674	Bridge to Grade	Impenetrable Tarps	Ground Covers	Overlaps	5	5	4	4	$330.60		$838,543	$84.82
NYS	Built up plate girder	1,953	Bridge to Grade	Impenetrable Tarps	Ground Covers	Clips/Overlaps	4	4	3	3	$3.67	No	$60,247	$30.89
OH	4-span rolled beam	1,720	Bridge to Grade	Impenetrable Tarps	Ground Covers	Overlaps	4	5	5	5		No	$67,539	$39.29
OR	Deck Truss	26,040	Suspended Platform	Other-fiberglass & aluminum panels	Solid/Plywood	Overlaps Latched doors	5	4	4	3	$55.10	No	$4,000,000	$153.71
SC	Steel beam 3-span		Bridge to Grade	Impenetrable Tarps	Ground Covers	Overlaps	2	4	2	2		No	$68,552	
Chic	single level, double leaf bascule	2,543	Bridge to Grade	Impenetrable Tarps	Barge and Ground covers/tarps	Clips	4	4	4	4		Yes	$401,300	$157.91
GG	Suspension	930,000	Bridge to Grade	Penetrable Tarps	Solid	Overlaps	3	3	2	1	$335.01	No		
Ont	Welded steel plate girders	3,303	Bridge to Grade	Impenetrable Tarps	Solid	Overlaps	1	1	2	2		Yes		

*Metric to English Conversions
1 sq. meter = 10.76 sq. ft
1 Mg = 1.1 Ton
1 meter = 3.28 ft

TABLE 5 (continued)
Summary of State Responses on Full Removal Case Histories

			Assessments								
Agency	Type of Bridge	Total Sq. Meter *	Prevent Spills	Collect Spills	Air Emission	Neg. Pressure	Waste Disp. Cost/Mg	Air Monitored	Final Agency Cost	Price Per Sq. m.	Price Per Sq.Ft.
AR	Long plate girder		3	4	3	2		No	$553,843		
AK	Steel stringer, laminated timber deck	2,232	4	4	5	1			$400,000	$179.76	$16.70
CA	Steel through truss	10,230						Yes	$1,179,480	$115.39	$10.72
DC	Simple span w/cross girders	46,500	4	5	5	5	$220.40	Yes	$3,745,000	$80.62	$7.49
IA	Truss	77,655	4	4	4	4		Yes		$124.86	$11.60
MA	Steel cantilevered through truss	7,905	5	5	3	4		Yes	$1,200,000	$152.85	$14.20
MD	Steel arch	5,124	5	5	5	5		Yes	$1,249,000	$243.80	$22.65
ME 1	Truss	2,829							$570,124	$201.72	$18.74
ME 2	Steel girder Buckfield - Hall	670	5	5	5	5	$16.53	Yes	$83,000	$129.17	$12.00
MI	Plate Girder-Cantilever spans	3,348	4	4	4	4		Yes	$230,000	$68.78	$6.39
MO	Continuous I-Bm + Pl Girder		3	4	4		$88.16	Yes	$167,500	$54.57	$5.07
NC	Turn Span Plate Girder	1,691					$640.00	Yes	$295,000	$174.45	$16.21
ND	Rolled girder	2,334	4	4	4	4		No	$77,000	$33.05	$3.07
ND	Rolled girder, 77 meters total length		4	4	4	4		No	$77,000		
NH	1 span truss 107m long, 16m high		5		5	5		Yes			
NJ	Highway overpass or interstate	1,674	5	5	4	4	$330.60		$838,543	$84.82	$7.88
NYS	Built up plate girder	1,953	4	4	3	3	$3.67	No	$60,247	$30.89	$2.87
OH	4-span rolled beam	1,720	4	5	5	5		No	$67,539	$39.29	$3.65
OR	Deck Truss	26,040	5	4	4	3	$55.10	No	$4,000,000	$153.71	$14.28
SC	Steel beam 3-span		2	4	2	2		No	$68,552		
Chic	single level, double leaf bascule	2,543	4	4	4	4		Yes	$401,300	$157.91	$14.67
GG	Suspension	930,000	3	3	2	1	$335.01	No			
Ont	Welded steel plate girders	3,303	1	1	2	2		Yes			

*Metric to English Conversions
1 sq. meter = 10.76 sq. ft
1 Mg = 1.1 Ton
1 meter = 3.28 ft

TABLE 6
Number of Square Meters per Bridge from Case Histories, Full Removal

Agency	ALL BRIDGES Square Meter	GIRDER BRIDGES Square Meter	TRUSS BRIDGES** Square Meter
ME2	670	670	
GA	958	958	
OK	1,116	1,116	
NJ	1,674	1,674	
NC		1,691	
OH	1,720	1,720	
NYS 1	1,953	1,953	
NYS 3	1,953	1,953	
AK	2,232	2,232	
CO	2,325		2,325
ND	2,334	2,334	
Chic	2,543		2,543
UT	2,550	2,550	
CT	2,595	2,595	
NJT	2,790	2,790	
ME	2,829		2,829
Ontario	3,303	3,303	
MI	3,348	3,348	
IL	4,929	4,929	
MD	5,124		5,124
MA	7,905		7,905
CA	10,230		10,230
IN	10,602		10,602
CR	26,040		26,040
MAT	40,920	40,920	
DC	46,500	46,500	
IA	77,655		77,655
Average*	10,261	6,846	16,139
Median	2,693	2,283	7,905

*Golden Gate excluded from Average
**Includes Bascule, etc.
1 Sq. meter = 10.76 Sq. ft.

TABLE 7
Comparing Full Removal Costs for Truss and Girder Bridges in $\$/m^2$ ($/sq.ft.)

Type	Low Cost		High Cost		Average		Median	
Truss	40.35	(3.75)	247.48	(23.00)	145.69	(13.54)	152.79	(14.20)
Girder	29.24	(2.72)	177.54	(16.50)	83.39	(7.75)	65.10	(6.05)
All	29.27	(2.72)	247.48	(23.00)	110.18	(10.24)	104.59	(9.72)

cluded aluminum runners, velcro, duct tape and C-clamps, tarpaulin snaps, and latch doors. The containment was ventilated approximately 50 percent of the time. Fewer than half of the ventilated containments used instruments to verify air flow, based on the responses. Respondents were also asked to assess the adequacy of containment on a scale of 1 to 5 (5 = best) in four areas.

As shown, overall, the agency representatives considered the containments to be very successful in each of the four areas (Table 8). The greatest problem described was in maintaining negative pressure.

Based on this study, the most commonly specified containment class is SSPC Guide 6I (CON) Class 3 (which is equivalent to the present Guide 6 (CON) Class 2A). As expected, because of their greater complexity, a higher percentage of the

TABLE 8
Assessing Adequacy of Containment

Quantity Assessed	Average Ranking
Preventing solid spills	3.84
Collecting solid spills	4.00
Preventing air emissions	3.84
Maintaining negative pressure	3.53

Scale 1 to 5 (5 = best)

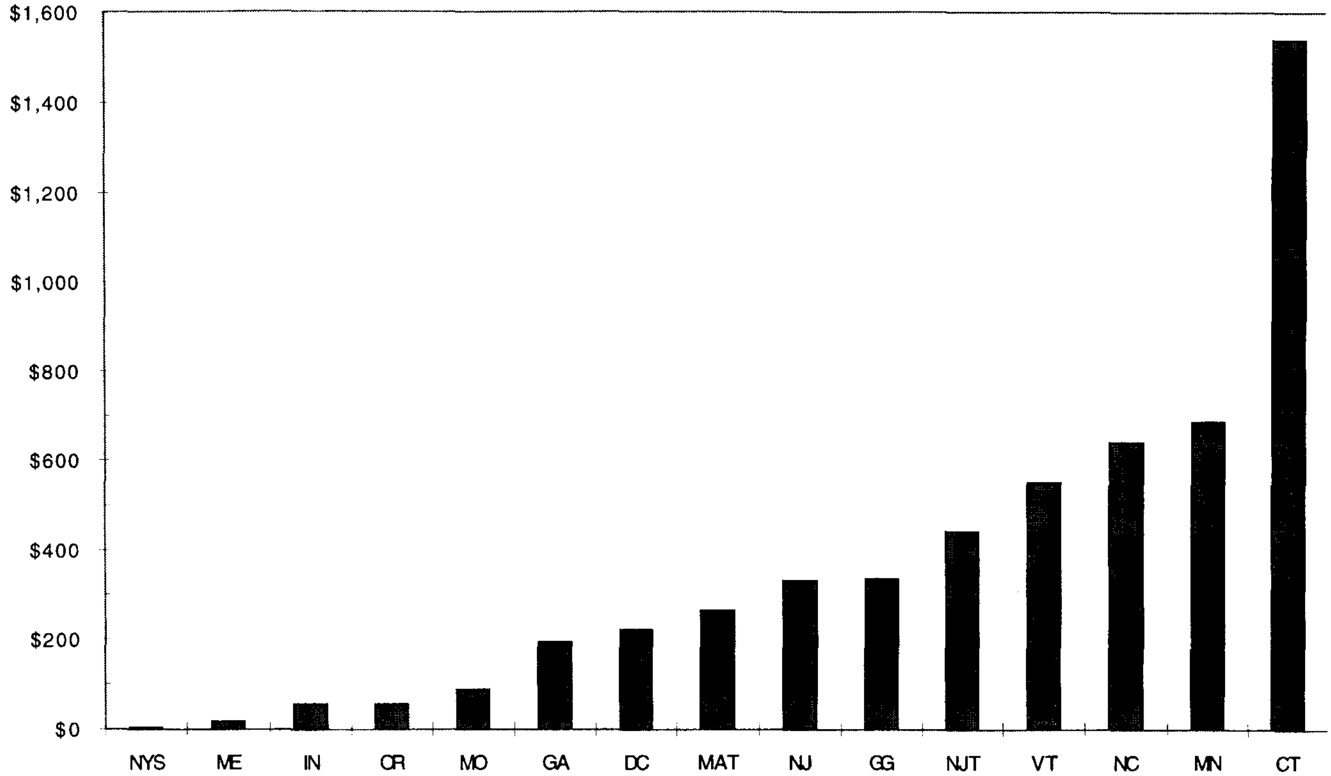


FIGURE 44 Hazardous waste disposal costs per megagram (metric ton).

truss bridges required Classes 1 or 2 (per Guide 6I) compared to girder bridges.

The waste disposal costs are shown in Figure 44. This also shows a very large range in cost from about \$80/Mg (\$72/ton) to \$1400/Mg (\$1,300/ton). This subject is discussed more fully in chapter 3 on waste disposal. Air monitoring was performed for approximately two-thirds of the bridges for which an answer was provided.

OVERCOATING CASE HISTORIES

The responses to Question 4 on overcoating case histories are presented in Table 9. There were a total of 19 responses. The cost per unit area also shows a great variation from \$12.37 m^2 (\$1.15/sq. ft.) in Illinois to about \$137.83/m^2 (\$12.81/sq. ft.) in Chicago (Figure 45). The average is \$54.84/m^2 (\$5.10/ sq.ft) and the median \$49.50/m^2 (\$4.60/sq.ft.). The costs per unit area are about 50 percent of the costs per unit area for full removal. A comparison of costs between girder and truss bridges is shown in Table 10. The range of surface area for girder and truss bridges overcoated is shown in Table 11. It is of interest to compare the costs per unit area to similar costs derived from a survey conducted in 1992 and 1993 (*39*). The range of costs for 20 bridges that underwent full removal was \$53.26/m^2 (\$4.95/sq. ft.) to \$129.12/m^2 (\$12.00/sq. ft.). The average was \$83.28/m^2 (\$7.45/sq. ft.) and the median \$80.70/ m^2 (\$7.50 sq. ft.). The range of costs for nine bridges that were overcoated was \$11.30/m^2 (\$1.05/sq. ft.) to \$53.80/m^2 (\$5.00/ sq. ft.). The average was \$29.70/m^2 (\$2.76/sq. ft.) and the median was \$29.59/m^2 (\$2.75/sq. ft.) Figure 46 shows a structure to be overcoated.

Based on these data, the median cost for overcoating has increased by about 65 percent and the average cost by about 85 percent compared to the 1993 data. For full removal the median costs increased by 37 percent and average costs by 30 percent. A recent FHWA report (*21*) using data derived from 1990 to 1993 estimated a range for full removal projects of \$4 to \$18/sq.ft with an average cost of \$7.50/sq.ft.

For structures that were overcoated, information was requested on the percent degradation of the existing coating. Results show that two-thirds of these structures had coating degradation of 10 percent or less. About 20 percent had degradation between 10 percent and 25 percent, and 15 percent had more than 25 percent degradation. This indicates that most agencies are observing the industry rule of thumb, which states that overcoating is best accomplished when the existing coating degradation is less than 15 percent to 20 percent.

Table 12 provides a summary of the surface preparation and coating systems used for overcoating. Approximately two-thirds of the structures were pressure washed prior to mechanical surface preparation. The range of pressures used is shown in Figure 47. The median pressure is 21 MPa (3,000 psi). It is interesting to compare this number with a survey of DOTs conducted by SSPC as part of a Federal Highway project (*66*). In that survey, the water pressures were found to be in the range of

TABLE 9
Summary of State Responses on Overcoating Case Histories*

				Surface Preparation				
Agency	BridgeType	Area Painted sq. meters	Condition	Prewash MPa	Prewash % Cleaned	Degree of Cleaning	% Mechanically Cleaned	SSPC Class
AK	Continuous Steel Plate Girder	23,994	0-10%	21	100%	SSPC-SP 6 Commercial Blast	90%	
AR	Overpass		0-10%	24	100%	to Bare metal	9%	Vacuum hand tools
CA	Rolled Steel Beams	7,533	0-10%		100%		5%	
CO	WGCK	2,990	0-10%			SSPC-SP 2 Hand Tool Cleaning	5%	
IL	Rolled Beams	2,325	0-10%	10	100%	SSPC-SP 3 PowerTool Cleaning	20%	Vacuum shrouds on power tools
IN	Truss		0-10%	10	100%	SSPC-SP 2 Hand Tool Cleaning	20%	
MA	Steel Stringer		0-10%	1.4	100%	SSPC-SP 6 Commercial Blast, or SP 3	10%	3
MD	Steel Beam	12,000	0-10%, 10-25	28	100%	SSPC-SP 2 Hand Tool Cleaning, SSPC-SP 3	100%	4
ME	Girder	277	0-10%					
MO	Continuous I-Beam		10-25%				95%	
ND	Rolled Beam		10-25%	21	100%	SSPC-SP 2 Hand Tool Cleaning, SSPC-SP 3	25%	none
NH	Arch	3,070	> 25%		100%	SSPC-SP 3 PowerTool Cleaning	70%	3
NYS	Built Up Plate Girder		0-10%			SSPC-SP 6 Commercial Blast/SSPC-SP 7 Brush-off Blast	90%	2A
OK	Overhead Truss		0-10%					
OR	Through Truss	5,860	0-10%	34	100%	SSPC-SP 11 Power Tool Bare Metal	5%	
VT	Multi span		> 25%	14	100%		100%	all
WA	Steel truss		0-10%	21	100%	SSPC-SP 6 Commercial Blast	10%	4
Chic	Double leaf, movable	2,250	> 25%	79	100%	SSPC-SP 6 Commercial Blast	40%	Full
NJ Turn	Steel Beam	6,050	10-25%		100%	SSPC-SP 6 Commercial Blast	100%	3

* Data on Coating Materials given in Table 11

TABLE 9 (continued)
Summary of State Responses on Overcoating Case Histories*

	Containment		Assessments					
Agency	Other Class	Type	Spill Prevent	Spill Collect	Air Emissions	Final Agency Cost	Price/Sq.m.	Price/Sq.Ft.
AK		Bridge to Grade	3	3	1	$1,193,000	$49.50	$4.60
AR			3	3	3	$66,660	$44.87	$4.17
CA		Bridge to Grade				$255,150	$33.89	$3.15
CO	power tool supplied/vacuum	Other - power tool w/vacuum attachment	3	3	2	$89,500	$29.91	$2.78
IL	Tarps within 8′ to power tool cleaning	Suspended Platform	4	4	4	$28,800	$12.37	$1.15
IN						$1,100,000		
MA		Bridge to Grade	4	4	3	$40,000	$52.72	$4.90
MD		Bridge to Grade, Suspended Platform	4	4	5	$476,181	$39.70	$3.69
ME		Suspended Platform	5	5	5	$112,000	$118.36	$11.00
MO	Ground + side tarps	Suspended Platform	5	5	4	$18,600	$19.94	$1.85
ND		Bridge to Grade/none				$40,000		
NH		Bridge to Grade (ARK), Susp. platform	4		4	$315,000	$102.22	$9.50
NYS		Bridge to Grade	4	4	3	$15,005	$15.92	$1.48
OK			2	2	2	$344,961	$69.15	$6.43
OR	vacuum power equipment w/tarps		5	4	4	$322,000	$54.98	$5.11
VT		Suspended Platform	5	5	5	$950,000		
WA		Suspended Platform	4	4	3	$196,000	$57.03	$5.30
Chic		Suspended Platform- down to barge in river	4	4	4	$310,000	$137.83	$12.81
NJ Turn	5	Bridge to Grade	4	4	5	$380,000	$64.56	$6.00

* Data on Coating Materials given in Table 11

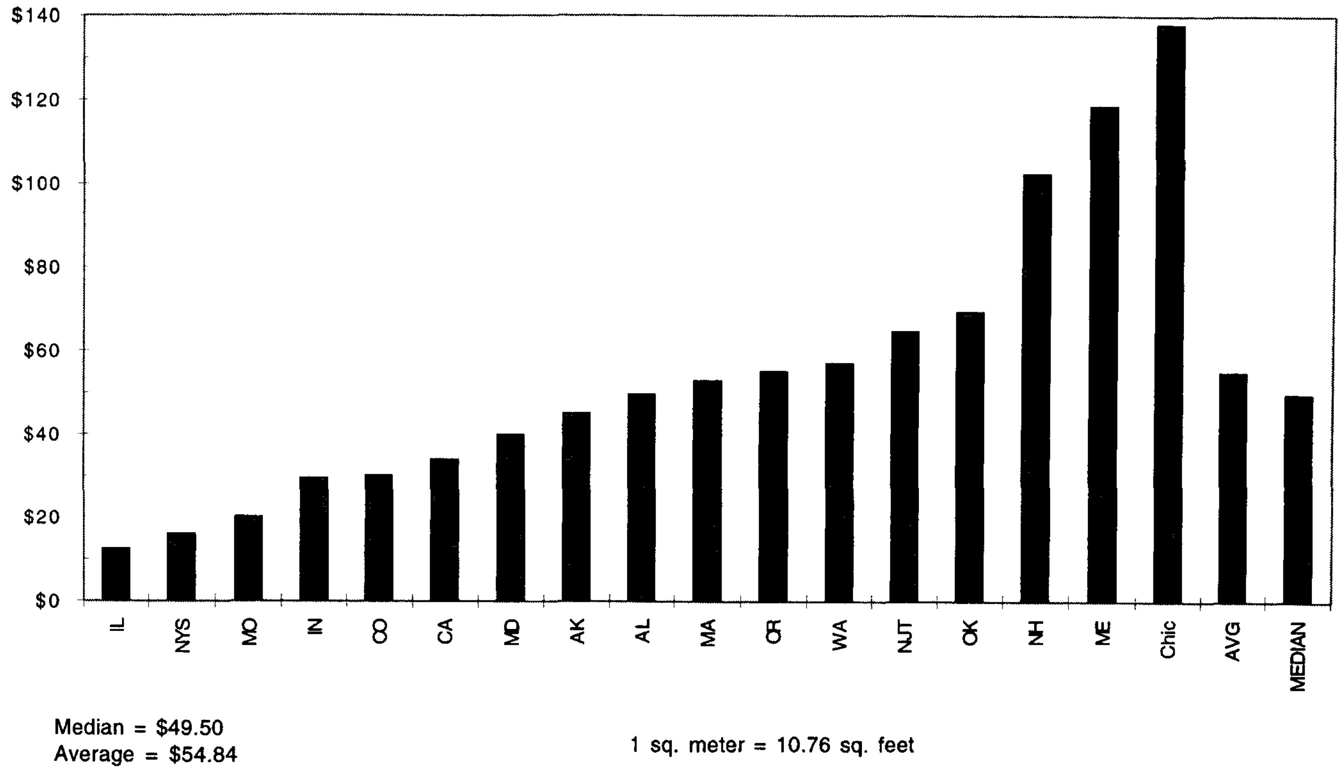


FIGURE 45 Cost per sq. meter—overcoating from case histories.

TABLE 10
Comparing Overcoating Costs and Units in $/m^2$ ($/sq.ft.)

Type	Low		High		Average		Median	
Truss	29.27	(2.72)	102.22	(9.50)	62.52	(5.81)	57.03	(5.30)
Girder	12.37	(1.15)	118.36	(11.00)	46.59	(4.33)	36.80	(3.42)
All	12.37	(1.15)	137.73	(12.80)	54.88	(5.10)	49.50	(4.60)

TABLE 11
Number of Square Meters per Bridge, Overcoating from Case Histories

Agency	ALL BRIDGES Square Meter	GIRDER BRIDGES Square Meter	TRUSS BRIDGES Square Meter
MA	763	763	
ME	977	977	
AR	1,488	1,488	
NYS	1,893	1,893	
Chi	2,251	2,251	
IL	2,325	2,325	
CO	2,990	2,990	
NH	3,069		3,069
WA	3,418		3,418
OR	5,859		5,859
NJT	6,045	6,045	
CA	7,533	7,533	
MD	11,997	11,997	
AK	23,994	23,994	
IN	37,665		37,665
AVERAGE	7,484	5,660	12,503
MEDIAN	3,069	2,325	4,639

1 Sq. meter = 10.76 Sq. ft.

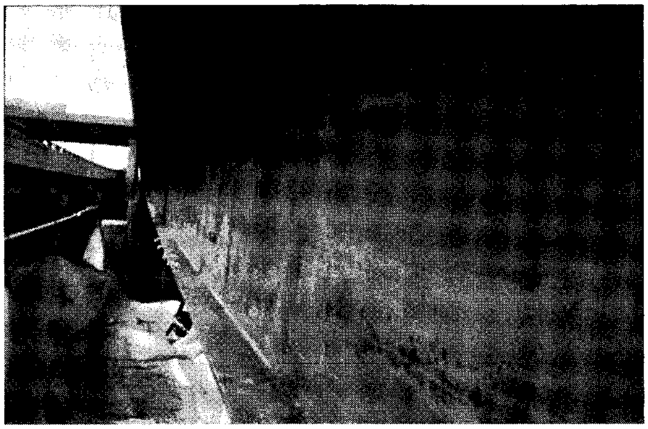


FIGURE 46 Structure to be overcoated.

2.1 MPa to 10.5 MPa (300 to 1,500 psi). Figure 48 shows the percentage of the surface that was mechanically cleaned following the prewash and before application of the first spot primer. The proportion of area cleaned ranges from 5 percent all the way to 100 percent. The median is about 20 percent or 25 percent. This is about twice as much as the amount of surface degraded, which is reasonable considering that in almost all cases it is necessary to clean several centimeters beyond the degraded area when using mechanical preparation such as power tools or spot abrasive blasting. The methods for mechanical cleaning consisted of hand- or power-tool cleaning (most common system), followed by abrasive blast cleaning to SSPC-SP 6 (commercial) or SSPC-SP 7 (brush blast). In many cases, the contractors used a combination of spot blasting to SP 6 and hand- or power-tool cleaning for small areas of paint degradation. Various tools were described, including needle guns, abrasive wheels, abrasive disks, and vacuum shrouds.

The coating material results show that the agencies responding had a strong preference for moisture cured urethane (polyurethane) systems. More than half of the agencies used all three coats of a moisture cured urethane. The primer included zinc or micaceous iron oxide (MIO). The first full coat (applied to the entire surface) typically included an aromatic polyurethane, and the topcoat an aliphatic polyurethane to provide enhanced weather resistance. The second most common system was epoxy mastic, usually with a polyurethane topcoat. Other systems specified included the SSPC lead free alkyd

TABLE 12
Summary of Systems Used for Overcoating

	Summary of Responses for Agencies Engaging in All Possible Phases of Spot Cleaning and Priming								
Agency	**Surface Preparation Degree of Cleaning**	**Surface Preparation Method**	**Percentage of Surface Cleaned**	**Primer Coat - Material**	**Percent Coverage - Primer Coat**	**First Full Coat Material**	**Percent Coverage - First Full Coat**	**Second Coat Material Type**	**Percent Coverage - Second Coat**
AR	SSPC-SP 11	Power Tools	9%	Urethane/Epoxy Mastic	10%	Urethane/Epoxy Mastic	100%	N/A	N/A
AK	SSPC-SP 6	Abrasive Blasting	100%	MCU - MIO	100%	MCU	100%	MCU	100%
CO	SSPC-SP 2	Vacuum Shouded Tools	5%	MCU Primer	N/A	MCU	N/A	MCU	N/A
IL	SSPC-SP 2, SP 3	Hand & Power Tools	20%	Alkyd Primer Long Oil	20%	Alkyd Primer Long Oil	20%	Silicone Alkyd	100%
IN	SSPC-SP 2, SP 3	Hand & Power Tools	20%	Calcium Sulfonate Alkyd	20%	Calcium Sulfonate Alkyd	20%	N/A	N/A
MA	SSPC-SP 6	Power Tools and Wet Abrasive Blasting	10%	Epoxy Mastic	10%	Epoxy Mastic	100%	Polyurethane Acrylic	100%
MD	SSPC-SP 2, SP 3	Hand & Power Tools	100%	MCU Aluminum	100%	MCU	100%	MCU Aliphatic urethane	100%
MO		Hand Tools	100%	Spot prime ends	80%	Prime solid over traffic	100%	N/A	N/A
ND	SSPC-SP 2, SP 3	Hand & Power Tools	25%	MCU Zinc Rich	25%	MCU	100%	MCU	100%
NH	SSPC-SP 3, SP 7	Power Tools, Brush Blast	70%	MCU Sealant	100%	MCU	100%	MCU	100%
NYS	SSPC-SP 6, SP 7	Abrasive Blasting Only	90%	MCU Aluminum	10%	MCU	100%	MCU	100%
OR	SSPC-SP 11	Vacuum Shrouded Power Tools	5%	MCU Zinc Rich	5%	MCU	5%	MCU	100%
VT	SSPC-SP 11	Abrasive Blast & Vacuum Tools	100%	MCU	N/A	MCU	N/A	MCU	N/A
WA	SSPC-SP 6	Abrasive Blasting Only	10%	MCU Zinc Rich	10%	MCU	100%	MCU	100%
Chic	SSPC-SP 6	Abrasive Blasting Only	40%	Alkyd Primer Long Oil	40%	Alkyd Primer Long Oil	50%	Silicone Alkyd	100%
NJT	SSPC-SP 3	Hand & Power Tools	100%	Epoxy Mastic Aluminum	15%	Epoxy Mastic Aluminum	100%	Polyurethane Acrylic	100%

Note - Few Agencies engage in Pre-Cleaning with Water at moderate pressures (21 MPa)
Types of Coatings - Key: MCU - Moisture Cured Urethane, Alkyd Primer - SSPC-Paint 25 Red Iron Oxide Primer, MIO - Micaceous Iron Oxide

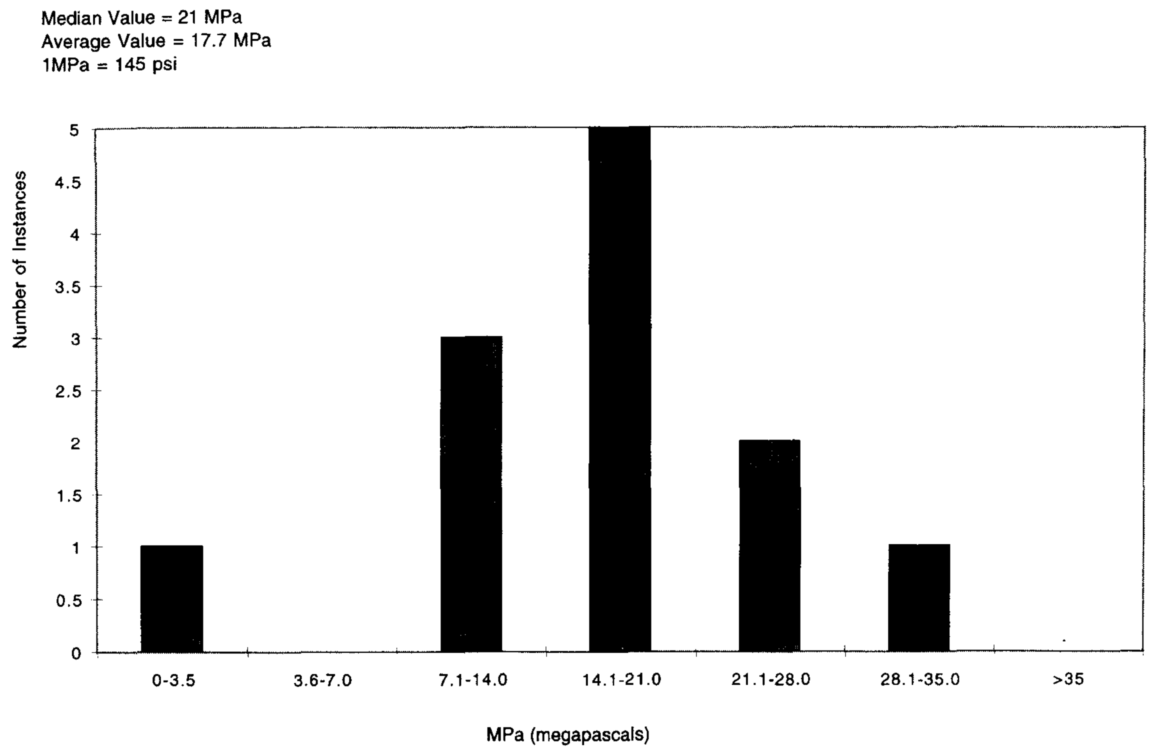


FIGURE 47 Typical prewash pressures for overcoating.

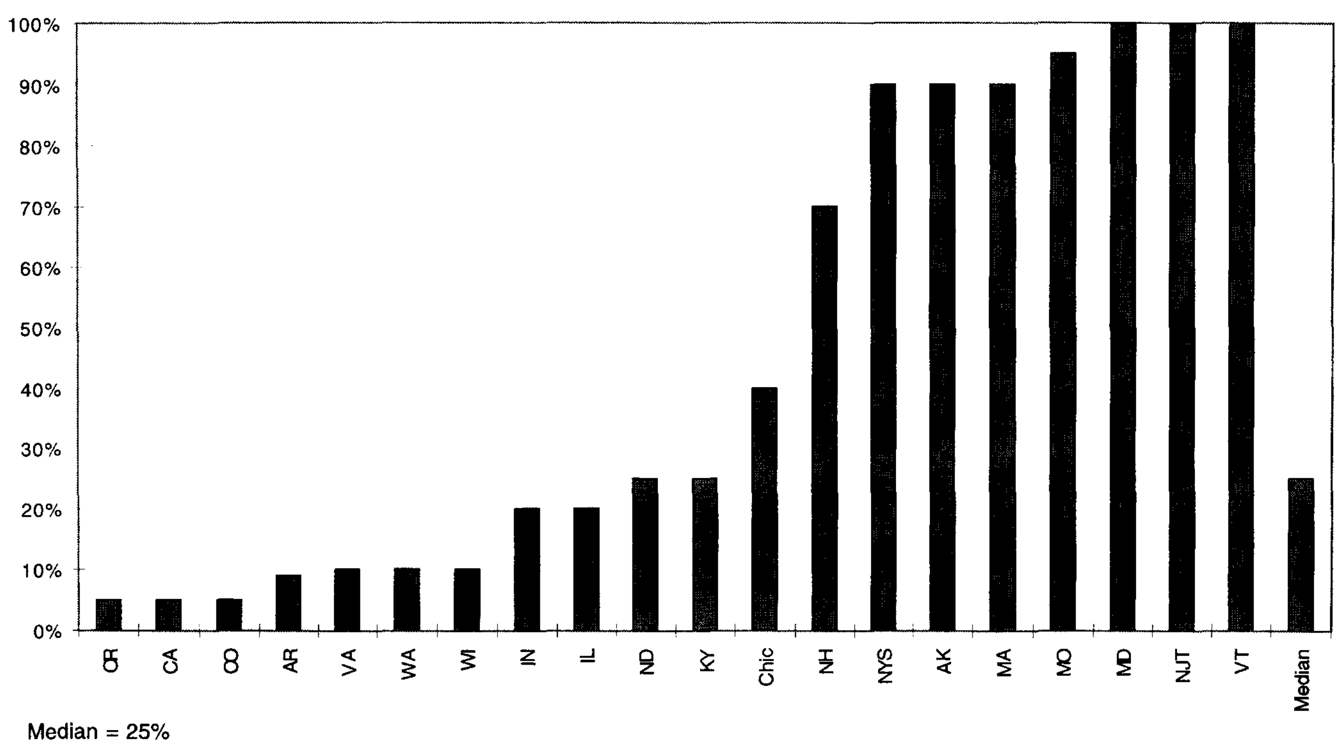


FIGURE 48 Percent of surface mechanically cleaned prior to overcoating.

(Paint 25) and silicone alkyd (Paint 21), calcium sulfonate alkyd, and a waterborne system including an iron oxide primer and an aluminum acrylic finish coat. Surprisingly, one state reapplied a lead-containing primer and intermediate coat.

PART III: CONTRACTS AND CONTRACTING

Data for Part 3 are summarized in Table 13. One part of Question 7 addresses the maximum percent of degradation allowed before a bridge can be overcoated. The results are given in Figure 49. The most common range is 11 percent to 20 percent, followed by 21 percent to 30 percent. This range is considerably higher than the range of the percent degradation that was estimated for the case histories of the bridges that were overcoated.

In Question 8, agencies were asked to rate the importance of several factors in estimating costs for lead paint removal projects. The most important factors were found to be data from past DOT projects and engineering analysis of cost elements, such as surface preparation, containment, and lead health and safety. Data from neighboring states were not important. In Question 9, agencies were asked how accurate estimates are compared to actual bids. Results are shown in Table 14. These data show that engineers' estimates are accurate to within plus or minus 15 percent about half the time and to within plus or minus 30 percent about two-thirds to three-fourths of the time. Also, about half the time the estimated costs are higher than the actual contract cost, ranging up to 90 percent higher. The final part of this question addresses the amount of extra contractor costs computed as a percentage of the initial contract cost. These percentages range from 0 percent (the response given by about half of the respondents) to 100 percent. The median was 10 percent.

Several agencies have also submitted data comparing the bid prices with the engineer's estimate. The results are shown in Table 15. The range of bids for a given project is often enormous, with the high bid often exceeding the low bid by 300 or 400 percent. Also, there are often huge discrepancies between the engineer's estimate and the low bid, which is usually the award price. Data submitted by Chicago DOT showed contracts awarded for which the bid price was less than 30 percent of the engineer's estimate. For an Ohio DOT project, the bid price was one-third lower than the engineer's estimate. And in at least one West Virginia project, the engineer's bid was twice as high as the lowest bid. It is not clear whether these results reflect deficiencies in the estimating process, or the differences among contractors in their ability to produce estimates or their willingness to do the work for a very low fee. However, this has been a major concern among transportation agency owners

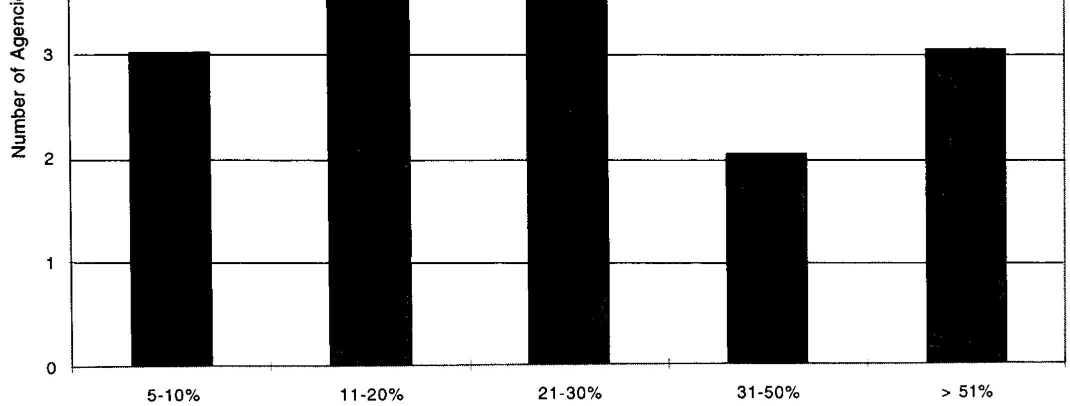


FIGURE 49 Maximum percent of degradation before overcoating.

TABLE 13
Summary of Responses on Contracts and Contracting

Agency	Max Degraded Area	Minimum Adhesion	Other Criteria	How Determined	Criteria Past Project	Engineering Analysis	Current Projects	Other Specifications
ND	10-20%	1A/1B-2A/2B		Survey	4	5	1	
Ont					4	4	1	MTO Estimating procedures
MI					5	5	1	
MO	20-30%				4	3	1	
SC		3A/3B-4A/4B		Survey	3	3	2	
NYS	50%	not removed with dull putty knife	location, type of structure	Survey	5	5	1	
OR	5-10%	1A/1B-2A/2B	if coating is still flexible	Survey	5	5	1	discussion w/contractors
Man								
AZ								
GG	Not established to date	N/A	No overcoating projects	Survey	1	none to date	1	vacuum blast if feasible
Chic				Survey	5	5	2	
NJ					4	5	1	n/a
ME					1	3	1	life cycle cost
DC					5	5	4	
CA	20-30%		Type of surface preparation needed	engineer estimate	1	5	1	Traffic control
OH					5	1	1	
MD	10-20%			engineer estimate	5	4	3	
MI 2		N/A			3	3	1	
IA					4	3	3	
NE	20-30%	N/A		Estimate/ Survey	5	4	4	
NV								
WI								
AK					5	4	1	
AL	5-10%	N/A	Type of existing paint to be overcoated	Survey	5	3	3	
NH	20-30%		Cost	engineer estimate	4	3	3	
MA	10-20%	3A/3B-4A/4B		engineer estimate	3	4	2	
MAT								
IN	5-10%			Survey	3	3	2	
IL		N/A	Policy to blast 2 meters from joints overcoat rest of structure	Survey	5	5	1	
CO	10-20%	N/A	Paint system compatibility considered	Survey	4	2	4	
UT					5	5	2	
MN								
NJT	10-20%			Survey engineer estimate	5	5	2	
VT								
OK		1A/1B-2A/2B	elcometer pull test > 1000 KPa (150 PSI)	by contractor	4	1	1	
WA	20-30%	N/A		engineer estimate	5	4	1	
CT					5	2	2	
GA					5	5	1	

TABLE 13 (continued)
Summary of Responses on Contracts and Contracting

Agency	Other Rating	Accuracy of Bid ± 15%	Accuracy ± 30%	Estimated Costs Higher	Percent of Extras	Qualifications Pollution	Pre Bids Often	Pre Bids Degree of Participation
ND		0%	0	0		No	100%	High
Ont	5	73%	0.91	0.63	0.03	No	10%	High
MI		90%	1	0.15		No	10%	High
MO	1			1		No		Medium
SC	2					No	100%	Medium
NYS		65%	0.875	0.225	0.075	No	1%	Medium
OR	4	84%	0.99	0.5		Yes	100%	High
Man								
AZ								
GG	5	n/a						
Chic		10%	0.4	0.05	0.1	Yes	30%	Low
NJ		25%	0.7	0.9	0.1	No	5%	High
ME	5							
DC						Yes		High
CA	5					No		Medium
OH		90%		0.5		No		
MD		10%	0.9	0.9		Yes	100%	Medium
MI 2						No		
IA								High
NE						No	100%	High
NV						No	75%	Medium
WI								
AK		95%	1	0.05		No	0%	
AL		50%	0.5	0.5	0.25	No	0%	Low
NH		90%				No		High
MA		60%	0.8	0.15			0%	
MAT		100%	1	0.19		Yes		Medium
IN		100%	0.9	0.05	0	No	100%	Medium
IL		80%	0.2	0.9	0	No	10%	High
CO		0%	0.2	0.5		No	10%	Medium
UT		75%	0.25	0.9	0.1	No		
MN								
NJT		50%	1	0.5	1	Yes		
VT							10%	High
OK						No	100%	Low
WA		80%	1	0.1		No	10%	Medium
CT		90%	0.1	0.75	0.15	No	0%	
GA				1		No		

TABLE 14
Accuracy of Agency Cost Estimates

Agency	Bid ±15 %	Bid ± 30%	Low Bid Exceeds Est. by (%)	Extras as % of Award
IN	10	90	5	n/a
MA	60	80	15	n/a
NH	90	90	0	n/a
Chicago	10	40	5	10
MD	10	90	90	n/a
NJ	25	70	90	10
AL	50	50	50	25
NJT	50	100	50	100
NYS	65	88	23	8
Ontario	73	91	63	3
UT	75	100	90	10
IL	80	100	90	10
WA	80	100	10	n/a
OR	84	99	50	n/a
CT	90	100	75	15
MI	90	100	15	n/a
OH	90	90	50	n/a
AK	95	100	5	n/a
MAT	100	100	19	n/a
Median	75%	91%	50%	10%

TABLE 15
Comparing Engineer's Estimates to Bid and Final Costs

Agency - Chicago DOT								
Bridge	Year Painted	Megagrams (Mg)	Engineer's Est	Bid Range Low	Bid Range High	Final Cost	% diff Eng Est.	Cost/Mg
18th St	1994	1088	$720,000	$443,000	$653,333	$443,000	-38%	$407
State St	1994	1905	$713,000	$817,000	$1,571,000	$817,000	15%	$429
Lake St	1995	1905	$898,000	$246,000	$1,027,200	$250,000	-72%	$131
Van Buren St	1996	1542	$569,000	$228,000	$455,000	$228,900	-60%	$148
Dearborn St	1996	1905	$433,000	$276,400	$561,000	$310,000	-28%	$163
Grand Ave	1997	907	$450,000	$189,000	$374,000	$189,000	-58%	$208
Harrison St	1997	1361	$270,000	$247,400	$388,737	$240,000	-11%	$176
Total			$4,053,000	$2,447,799	$5,030,270	$2,477,900		
						Avg.	-0.36	$237
Agency - West Virginia DOT								
	Bid Date							
#3014.1	1996		$206,924	$107,300	$391,558			
#1899.2	1995		$3,558,774	$2,348,840	$25,675,200	$2,795,110	-21%	
#1764.1	1996		$1,211,541	$1,448,370	$2,965,000			
#3016.1	1996		$174,850	$107,300	$436,450			
Total			$5,152,089	$4,011,810	$29,468,208			
Agency - Ohio DOT								
41575			$755,000	$490,976	$1,079,652		-35%	
41602			$360,000	$244,770	$560,905		-32%	
Total			$1,115,000	$735,746	$1,640,557	Avg.	-34%	
Agency - Mass Public Works								
Merrimack River			$1,698,300	$1,256,000	$2,880,000		-26%	
1 Megagram = 1.1 Tons								

and industry representatives. These huge discrepancies between the engineer's estimate and the low bid make it difficult for conscientious contractors to compete in the bridge painting arena, which is shown to be an extremely large-volume business.

On a related topic, agencies provided information about the approach they take when they receive a very low (perhaps unrealistically low) bid for a bridge painting project. In Question 13, the respondents were asked about the frequency of throwing out a bid or requiring re-bidding for each of six potential reasons. The results are summarized in Table 16. For five of the reasons, a majority of the agencies gave a ranking of 1, meaning that the bid is thrown out very infrequently. Based on the survey responses, the main reason for throwing out a bid is that the low bid exceeds the agency's estimate. This indicates that the overriding concern of the agencies is minimizing the cost and keeping within the cost estimate. When a cost is below the engineer's estimate (even by 50 percent or more) the agency will not normally question the validity of the bid. A discussion on this topic is given by Lyras (*67*).

Another subject of interest to contractors and owners is the prebid conference. In NCHRP Synthesis 176, the contractors were almost unanimous in their support for a mandatory prebid conference. Many of the coating specialists among the owners

TABLE 16
Summary of Responses on Reason for Rejecting Bids

Agency	Bid Below DOT Estimate Floor	Bid Below Other Bidders	Low Bid Exceeds Estimate	Unapproved Contractor	Contractor Already Perfoming Badly	Prior OSHA or EPA Violations
ND	1	1	2	1	1	1
MI	1	1	1	1	1	
MO	1	1	5	1	1	1
SC	1	1	3	1	1	1
NYS	1	1	1		1	1
OR	1	1	1	1	1	1
NJ	1	1	3	5	2	3
CA	1	1	1	1	1	1
OH	1	2	4	1	2	1
MD	1	1	1			
MI	1	1	1	1	1	1
NE	1	1	5	1	1	1
NV	1	1	5	1	1	1
AK	1	1	4		4	
AL	1	1	1	1	1	1
MA	1	2	3	5	1	2
IL	1	1	5	2	2	1
CO	1	1	3	3	2	2
UT	1	2	2	1	2	1
OK	1	1	3	1	2	1
WA	1	2	2	1	1	1
CT	1	1	3	5	3	3
GA	1	1	5	5	4	1
DC	2	1	3	1	1	1
IN	2	2	1	5	3	2
IA	3	3	4	4	4	3
Chic				1		
Median	1.0	1.0	3.0	1.0	1.0	1.0
Average	1.2	1.3	2.8	2.1	1.8	1.4

Scale 1 to 5, 5 = Highest

also endorsed this concept. However, after initially mandating prebid conferences on federal work, FHWA rescinded the mandate based on comments from some DOTs (see chapter 5). In Question 12, DOTs were asked about prebid conferences. The results are somewhat contradictory. Most agencies reported that prebid conferences are not mandatory and are held relatively infrequently. However, they were given a high rating with regard to their usefulness.

Another question (Question 10) addressed the payment basis for lead paint removal projects. Previously, a number of agencies had provided breakdowns of the total cost of a lead paint removal project. Major items or activities include paint removal, paint application, materials, containment, health and safety measures, environmental monitoring, and waste handling. Many agencies base their estimates on an analysis of each of these components. They were asked if each of these is covered by a separate pay item (i.e., paid as a separate fee) or is paid as a lump sum for the entire project. The data indicate that separate pay items are most frequently called out for paint application and paint removal, but even these were included as separate items only about 20 percent of the time. Thus, the majority of the time the DOTs issue a contract as a single lump sum, which includes all the items identified above. An analysis of cost breakdowns is also given (*39*).

CHAPTER SEVEN

STRATEGIES AND DECISION MAKING

Transportation agencies must consider many factors when deciding what to do about lead-painted bridges. The basic dilemma is that the lead-containing coatings will not function indefinitely as a means of corrosion protection. If the bridge is not rehabilitated, the possible consequences are:

- The bridge coating will deteriorate and the steel condition will become worse. This increases the cost of repainting because of the increased surface preparation costs.
- As the coating condition worsens, the likelihood of the lead paint eroding into the environment increases.
- If the corrosion is allowed to proceed unchecked, the bridge could require extensive steel repairs and possibly suffer reduction in load strength or threats to structural integrity.

ALTERNATIVE STRATEGIES

If the bridge is to be rehabilitated, several choices can be considered. The steel can be repainted or it can be replaced. In addition to these two broad options, there are several specific options, including taking no action at all. These options are abstracted from a 1993 special report from the *Journal of Protective Coatings and Linings (JPCL)* (*71*).

- Ignore the problem of lead paint—This strategy represents a lack of recognition of the problem or an unwillingness to address it. Because of broad publicity on lead paint, it is difficult to claim ignorance of the problem.
- Defer painting and maintenance—As with ignoring the problem, deferring painting and maintenance does not involve any action, but the decision is made with some knowledge of the consequences. For example, deferral may be part of a strategy that includes painting the most critical bridges, and leaving the others for subsequent years. Deferral may also simply be a result of the recognition that there is not adequate funding to repaint.
- Full removal and repainting—This strategy entails completely removing the existing paint and applying a lead-free system designed to give long-term protection.
- Spot cleaning and repainting—Spot cleaning and repainting is intended to retain the intact, sound paint. Workers clean corroded or deteriorated areas with hand or power tools or other methods and repaint the cleaned areas.
- Spot cleaning and priming with full overcoat—This strategy is a modification of spot cleaning and repainting. Workers lightly clean the intact paint by power water washing or solvent wiping and give it one or more coats of paint in addition to preparing the corroded and deteriorated areas. Spot cleaning and priming may be omitted when degraded areas are limited or scattered, making it impractical to clean them separately. This strategy is called "overcoating" throughout this report.
- Zone painting—This hybrid approach targets sections or zones of structures (e.g., bridge bearing areas or splash zones) to receive greater protection than the remainder of the structure. This approach is often used for painting weathering steel bridges, where only the zones within 6 or 10 ft (2 or 3 m) of the joints are painted, to prevent damage from deicing salts.
- Replacement of steel—This strategy entails removing the steel beams or plates from the structure. The steel is replaced with newly fabricated members or with deleaded, cleaned, and recoated old members.

Selecting a specific strategy entails a careful assessment of many factors, and a balancing of needs for corrosion protection, environmental protection, worker protection, legal protection, aesthetics, public perception, and short- and long-term economics.

As is evident by the variation in practice and cost among transportation agencies over the last 4 years, there is no single strategy for the rehabilitation of a lead-painted bridge that has become a consensus for the transportation industry. Each of the options identified above has its merits as well as some limitations. There have been several attempts to develop a systematic approach to selecting an appropriate option for an agency. For the most part, however, each agency has determined its strategy based on short-term goals. In some instances, the agencies have deferred a thorough analysis because of a limited understanding of the options, concern about the liability of lead exposures, or lack of funding. Some published approaches are reviewed in the following section.

1993 SSPC/JPCL Report

In this 1993 report (*71*), the major options considered are overcoating and full removal and repainting. They are compared on the basis of cost, performance, and risks. Costs are known to be highly variable, which is further illustrated in this report. It is important to consider the fundamental importance of surface preparation in assessing the expected life of overcoating systems. The lifetimes of coatings applied as part of a full-removal project are more predictable and consistent, with coatings typically expected to last for 15 to 25 years of service. For overcoating, which entails applying a coating over a sometimes unpredictable substrate, the lifetimes are considerably more variable. This report emphasizes that coating lifetimes are directly dependent on the quality of cleaning, with coatings on blast-cleaned steel lasting three to four times as long as coatings on rusted or otherwise contaminated substrates. The importance of quality surface preparation for overcoating lifetime is supported in the conclusions of FHWA report RD-96-058, *Guidelines for Repair and Maintenance of Bridge Coatings: Overcoatings* (*72*).

FHWA Guidelines

Appendix 2 of FHWA report RD-96-058 (*72*) presents guidelines for maintenance painting and overcoating. The guide is in the form of answers to four questions typically asked by maintenance engineers:

- Question 1: How does an engineer determine if a steel structure is overcoatable?

  It must be recognized that while overcoating is the lowest initial cost maintenance painting strategy, it is not necessarily the lowest life cycle cost strategy. Key factors that need to be assessed include:

  — Severity and distribution of corrosion
  — Adhesion of coatings
  — Environment of the structure
  — Age and history of the structure
  — Consequences of coating and structural failure.

- Question 2: What surface preparation should be specified?

  The most common procedure is pressure washing followed by spot mechanical cleaning. The authors point out that thorough cleaning of pitted and rusted areas is the key to long service life.

- Question 3: What type of coating system should be specified?

  Moisture-cured urethanes, alkyds, and sealer/epoxy systems are identified as being among the better performing systems. A multicoat system of 200 micrometers (8 mils) minimum and a patch test to determine compatibility are recommended. The coating, however, is considered less important than the surface preparation in determining service life.

- Question 4: What performance life should be expected?

  Two basic failure modes are identified: incompatibility between new and existing coating, and breakdown of paint applied over salt-contaminated rust. In the latter, most coatings provide only 2 to 4 years of service, whereas in less severe areas, lifetimes of 10 or more years may be expected when new and old systems are compatible. Additional information may become available when longer exposures of the FHWA test program are documented.

REPLACING VERSUS REPAINTING STEEL

Several DOTs have reported data on the comparative costs for replacing lead-coated steel bridge members versus repainting these members. A recent article (*73*) describes a generalized approach to analyzing steel bridge replacement versus painting and repairing steel.

Case Histories of Cost Analyses

- Case 1: Based on 1986 painting costs, the painting option is less expensive than replacing the steel: \$16.1 million versus \$16.6 million. Using 1992 painting costs, the same approach—with structural steel widening, repairing existing steel, jacking girders and painting—is \$19.2 million, which is \$2.6 million higher than the total cost of a new structural steel bridge (which interestingly had not increased in the 6 years from 1986 to 1992).
- Case 2, Option A: Steel repairs, new steel for widening, blast cleaning, containment, lead health and safety program, inspection of deck joints, for a total of \$7.5 million. Option B, New steel: removing existing steel, lead health and safety programs (for removing existing steel), touch-up paint, for a total of \$6.4 million.
- Case 3, small railroad bridge crossing, Option A: Blast cleaning, containment, paint disposal, lead health and safety program, repair existing steel: \$140,000. Option B, New steel: \$105,000.
- Case 4, Route 183 bridges: Minor repair of existing steel. Repainting less expensive than new structural steel for both bridges—25 percent less for one bridge, 75 percent less for a second bridge.

A second article (*74*) analyzed the option of a structure undergoing the following repair: deck removed, six-beam structure raised by 9 inches, bearings replaced, and bridge widened.

Option A: Saving existing steel with partial removal: \$152,000 = \$11.33/ft^2 (\$122.00/m^2)

Option B: Saving existing steel, complete removal: \$13.35/ft^2 (\$143.70/m^2)

Option C: New steel: \$10.24/ft^2 (\$110.20/m^2)

The authors conclude that, for a deck replacement project, steel replacement becomes a viable option when paint removal and repainting costs exceed \$110/m^2 (\$10/ft^2).

North Carolina DOT provided data comparing the cost of rehabilitating bridges (including deck replacement and coating replacement) with the cost of constructing new bridges. The rehabilitated structure cost as much as \$700/m^2 (\$65/ft^2) of deck surface area. Most new bridges with regular foundations cost less than \$650/m^2 (\$60/ft^2) (*75*).

Repainting Steel Off-Site

One option for repainting bridges is to dismantle the steel beams and ship them to a fabricating or painting shop. They are then cleaned and repainted, shipped back to the bridge site, and erected, followed by paint touchup. When lead-coated steel is dismantled, the requirements for handling it may be different from steel that is cleaned for repainting.

Connecticut DOT, in conjunction with the state Department of Environmental Protection, developed some general guidelines for transporting lead-coated steel members to a fabricating shop for repainting or other reuse (*76*).

- On-site stripping of paint necessary to remove members would remain a regulated activity and the DOT would be responsible for proper disposal of the waste.

• Transporting of bridge members to a shop would be exempt from regulations because the members are not waste. They are only being refurbished.

• The shop will have to comply with appropriate regulations for the handling and disposal of the waste generated from removing the lead. Many shops are familiar with handling hazardous wastes and this should not be a problem.

• Restrictions may be imposed on the shop.

• The shop may be considered the owner and generator of the waste.

DECISION PROCESS

An SSPC training program (*77*) discusses a decision-making process based on examination of four principal types of data: technical data, cost data, data on performance of coatings systems, and data on the risks and uncertainty; this training program notes that the quality and reliability of data will vary significantly and that no one will ever have complete data.

Technical data discussed include structure/plant data, coating system data, and environmental factors. Cost data include direct costs (e.g., contractor labor and materials, outside survey or engineering, inspection, environmental monitoring, and industrial hygiene) and indirect costs (e.g., internal planning, engineering, traffic delays, and insurance). The text for this training program reviews standard repaint cost elements (e.g., surface preparation, application/set up, materials, and profit/overhead) and additional costs due to lead (e.g., environmental protection, containment, monitoring, disposal, enhanced worker protection, training, regulatory awareness, added paperwork, and insurance). Examples are given of cost breakdowns for full removal, overcoating, and steel replacement.

Performance data are considered next. Concepts discussed include coating lifetime, repaint intervals, and sources and reliability of historical data.

In the section on risk and uncertainty, it is noted that all of the options being considered for bridge-paint maintenance have certain risks for the owner, specifier, and contractor. Risks discussed are early coating failure, environmental contamination, lead poisoning, litigation, and adverse publicity.

This training program stresses that the above data must be organized to effect a decision. Important factors include budget, future plans for the structure, time to make the decision, willingness to assume risk, and company policy. For each option, pros and cons are reviewed, risks and costs are discussed, and examples are given.

Consultant Decision Tree

In a recent presentation (*73*), a decision tree for selecting options for rehabilitation of lead-coated beam or girder span bridges was presented. The decision tree included the following elements:

• Remaining service life of structure
  Two branches were established: one for a short life (less than 15 to 20 years), one for a longer life (greater than 20 years).

• Need for deck replacement
  A major factor is whether the deck is being considered for replacement. When the deck is being replaced, consideration is given to replacing the steel (as described above). Several alternatives are given for replacing the steel, including cleaning and painting at a remote site (e.g., fabricating shop), replacing the steel with painted carbon steel, or replacing the steel with unpainted weathering steel. If the deck is not being replaced, removing steel beams is not considered a viable option.

• Alternatives to full removal
  Another question is whether there is an agency that requires full removal (i.e., does not allow overcoating). If there is no such policy in effect, the specifier must decide between the options (overcoating, zone painting, full removal, or no painting required). This is based on a condition assessment. The decision tree is illustrated in Figure 50.

Decisions Based on Risk Analysis

Another approach to managing the complex issue of protecting the structure, the environment, and the workers is a formal risk analysis program. Such an approach is presented in the book *Project Design* (*14*). In the preface, the authors explain:

> The challenge to the designer of a hazardous paint removal project is to develop a means to properly assess the public health risk, environmental impact, and emission potential of the operation so that the appropriate level of protection is provided. Furthermore, based on the same variables, the designer must consider methods to monitor containment system performance to ensure that the public health risks and environmental impacts are indeed being satisfactorily controlled. Finally, the hazards to the workers performing the work as well as those working near the project must be adequately assessed in order to properly protect them.

The book addresses these issues by establishing a decision path that project designers can follow when selecting the appropriate level of emissions control for individual projects. The design of lead (hazardous) paint management projects in industrial applications requires consideration of the following stages:

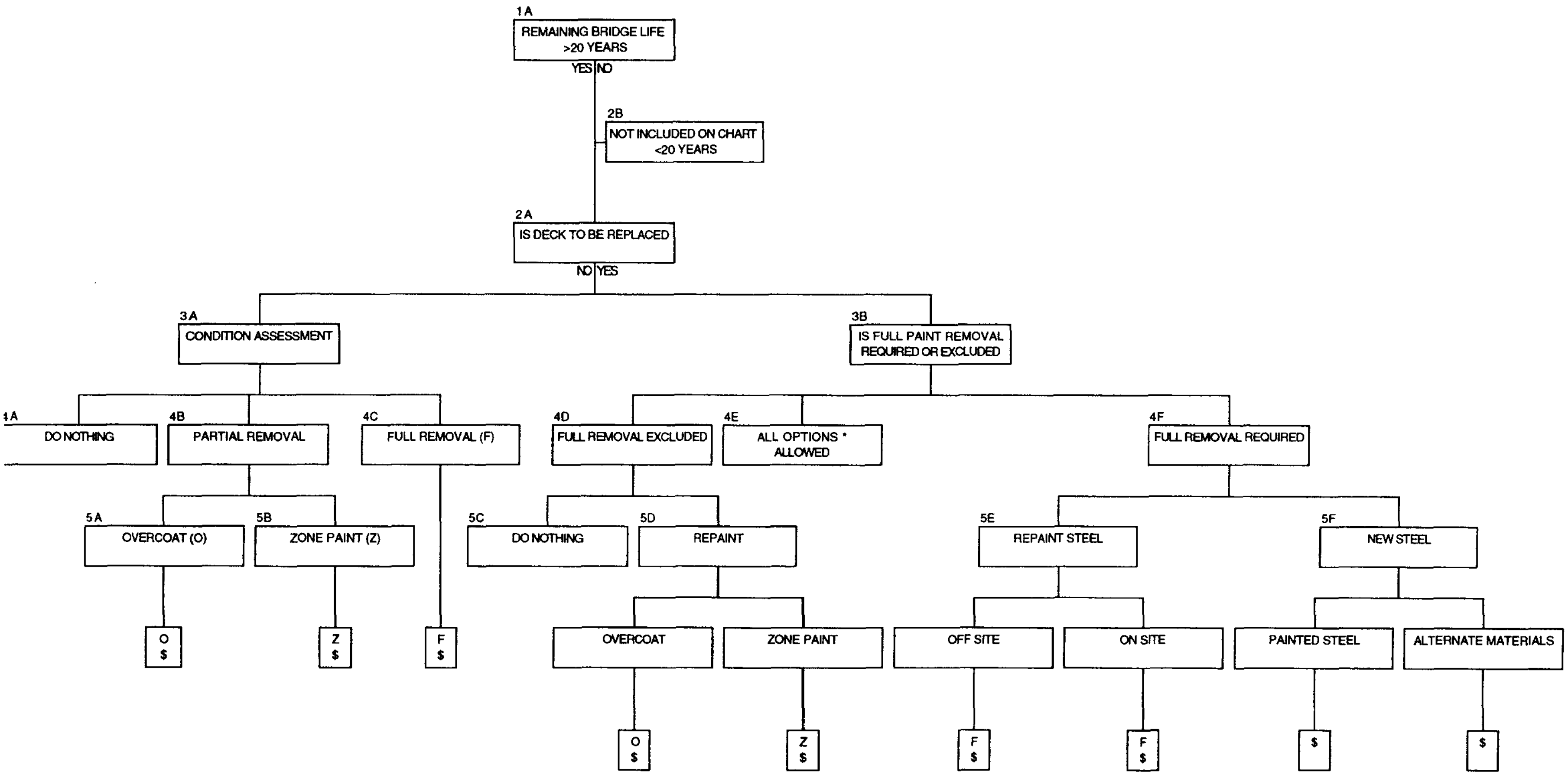
• Phase 1: Assessment for the presence of lead and other toxic metals.

• Phase 2: Determination of the painting strategy, similar to those strategies defined in the previous section. The analysis is based primarily on assessment of coating condition.

• Phase 3: Assessment of project risks to the public, environment, and other workers.

• Phase 4: Establishment of limitations on emissions based on characteristics of the specific site.

• Phase 5: Selection of the appropriate paint removal/containment system combinations consistent with the selected maintenance strategy and the necessary level of emission control. (Phases 5 and 6 are discussed in Appendix E of this document.)



* Consider 5C, 5D, 5E, 5F

FIGURE 50 Decision tree for lead-coated beam or girder span bridges.

- Phase 6: Selection of the appropriate monitoring systems to verify that emissions are properly controlled.
- Phase 7: Establishment of appropriate worker protection requirements.
- Phase 8: Establishment of appropriate waste management requirements.
- Phase 9: Determination of project clearance requirements for releasing the contractor. This is to verify that no environmental contamination has occurred.
- Phase 10: Preparation of project cost estimates.
- Phase 11: Collection of all site-specific information needed to prepare a comprehensive specification to address all of the above.

The book also includes some examples of how this program approach can be applied to specific projects, including a highway bridge. The National Highway Institute (NHI), in conjunction with FHWA, is developing a training program based on these concepts for DOT engineers, project managers, specifiers, and others.

CHAPTER EIGHT

CONCLUSIONS

Numerous detailed reports and studies on the subject of lead paint removal from bridges and other structures have been published in the last few years. The conclusions presented below reflect input from these and other sources noted earlier, as well as from the results of the surveys.

ENVIRONMENTAL REGULATIONS

Waste Regulations

- RCRA is still the major driving force for requiring control of emissions from bridge painting. These rules have not been substantially modified in the last 5 years. Changes have been incremental.
- EPA has clarified the shared-generator responsibility between owner and contractor.
- The proposed new treatment standard for waste (reducing lead treatment from 5 mg/l to 0.037 mg/l) is considered to have a minor impact on the industry.
- Overall, DOTs are well aware of the provisions of the waste regulations and the consequences of noncompliance. One reason is that lead paint is not the only bridge or highway waste product.
- Waste generated from recyclable steel grit, even though testing as nonhazardous, requires treatment as if it were a hazardous waste.
- Except in rare instances, chromium has not exceeded levels to be classified as hazardous waste.
- Innovative approaches have been developed for handling and disposal of lead-containing waste. One notable example is a proprietary material mixed with an abrasive to render waste nonhazardous.
- Restrictions on zinc are considered very unlikely; this material is expected to be available indefinitely. However, California and Michigan are currently controlling zinc.
- Recovering the lead from paint chips (hand- or power-tool cleaning or steel grit blasting), or using debris for cement manufacture from blasting with expendable abrasives, eliminates the long-term liability associated with disposal of lead-containing wastes.

Air Quality

- About half of the transportation agencies that responded to the survey are now requiring ambient air monitoring using high-volume samplers.
- The need for extensive ambient air monitoring on bridge paint removal projects has been questioned.
- There is an emerging consensus that these measurements are undertaken not to comply with the EPA air quality standards, but as a means to evaluate the effectiveness of containment. (No evidence of citations for exceeding EPA air standards has been identified.)
- The current procedures provide erratic results because of the effect of site or bridge configuration, wind monitor placement, and other variables.
- Alternate means are sought to verify containment efficiency (a current FHWA research project is addressing this task).

Soil Quality

- The EPA has not yet issued guidelines for cleaning up lead in soil. EPA is required to define hazardous levels of lead in soil by Title X.
- Soil quality may also primarily be used for determining efficiency of containment.
- The methodologies for collecting samples and testing soil are well established.
- The procedures and practice for selecting sampling locations are the weak links in this process. A major problem is high variability of lead in soil.
- Overall, soil measurements are a suitable means to determine gross contamination.
- The highway right-of-way has lead concentrations that are usually significantly above the national average of lead in soil. Pre-job sampling is needed to determine if the contractor contaminates the soil.

Water Quality

- There is greater interest in water discharge requirements because of the increased use of water for prewash, paint removal, and hygiene.
- Collecting and filtering of such water is often required before discharging the wastewater into sanitary sewers.
- The EPA rules are very general, so state and local agencies have their own requirements. This has resulted in a wide variability in the scopes and responsibilities for regulating water quality. A worthwhile effort would be to sort out these regulations and their application to bridge painting activities.

WORKER PROTECTION

Worker Protection for Lead

- The major change in the industry in the last 5 years has been the promulgation and implementation of the OSHA Lead in Construction Standard. This standard is generally very well recognized and for the most part observed, and has caused a measurable improvement in the practice of lead paint removal from bridges.

- OSHA enforcement, although sometimes dramatic and highly visible, is sporadic and sparse.

Worker Protection for Other Metals

- Cadmium is present in some paints and abrasives in very small quantities and occasionally may exceed the action level requiring contractors to observe OSHA's cadmium standard.
- Chromium is present in the form of corrosion-inhibiting chromate pigments. For these types of coatings the action level may be exceeded.
- An assessment of the presence of these metals should be made in the early stages of project planning.

Other Worker Protection Issues

- OSHA has given increased attention to issues such as fall protection and confined space. Also, there are more frequent citations for noise exceedance and for not observing HAZCOM (the hazardous communication standard).

Worker Protection for Transportation Agencies

- Some transportation agencies have sought contractor assistance in obtaining protective equipment and training for the agency's employees. However, under OSHA, the highway agencies are still responsible for protecting their employees.
- FHWA is developing a National Highway Institute (NHI) training course on preparing painting specifications that includes issues related to lead removal.

Training and Certification

- A few states currently have requirements for licensing, certifying, and training industrial deleading contractors, including bridge paint workers and supervisors.
- EPA's final issuance of training and certification requirements under Title X for industrial structures will likely occur in 1998 or 1999, with implementation by 2000. All states will have to develop training courses and certify those involved in lead disturbance.
- A major concern is reciprocity among states with regard to training and third party exams. Also, the multiplicity of fees may increase the cost to contractors. Efforts are underway to address this issue.

SPECIFICATIONS

- These vary widely in format, organization, and level of detail.
- Some good models are available (e.g., AASHTO, SSPC, industry, and a few DOTs).
- There are various examples of prescriptive and performance specifications, but the general preference of owners, contractors, and material suppliers is for performance specifications.
- Specifications and special provisions for lead paint removal appear to have deficiencies that could be corrected by a greater review within the coatings/corrosion community or among peers within the agency or from other transportation agencies.
- States could benefit by gaining access to specifications from other states (e.g., through some type of clearinghouse).

CONTRACTS

- There is also a great variability in contracting practice, due partly to state agencies and statutory differences.
- Bid prices are extremely variable, which may indicate deficiencies in the bidding process or contractors' understanding of the specification requirements. For example, the agencies have very limited options for excluding unrealistically low bids.
- Insurance of lead removal projects is a concern because most contractors don't have pollution insurance. It is an issue that may be worth investigating.
- In addition, transportation agencies may need clarification on the issue of liability for contractors, consultants, hygiene firms, and inspectors.
- The SSPC contractor certification program has increased awareness of the level of quality achievable, which gives it an impact beyond its use by the eight or ten transportation agencies currently specifying it. No viable alternatives for qualifying contractors have been proposed. Qualifications of shops that rehabilitate lead-coated steel members may also be worthwhile.
- Partnering and performance warranties are new concepts being applied to bridge painting.
- Overall, contractors incur high risks for bridge painting, which may reflect the variability in cost and in performance.
- Paradoxically, bridge painting has become very competitive. This is a factor that can also affect quality as costs decrease.

COSTS

- Funding of bridge painting has traditionally been inadequate to meet agencies' needs for regular maintenance. This is expected for the indefinite future.
- States seek FHWA financial assistance: some have started to allocate major resources from 100 percent state funds.

• Several states are trying to significantly reduce their backlog of lead-coated bridges. However, if adequate funding is not made available, this may result in questionable quality and environmental control.

• Transportation agencies are increasingly looking at using overcoating, but often do not have sufficient data on performance or long-term costs. The focus is primarily on construction cost.

• Opportunities may exist to reduce costs by improved planning and by partnering with contractors.

• Costs have increased substantially since Synthesis 176 was published in 1990, but appear to have stabilized in the last 2 years for full removal and containment.

• There is a large variation of costs among states differing by a factor of two to three for nominally similar work. These differences may be attributed to the degree of inspection and control over emissions and enforcement of specifications.

• Replacement of steel members is a viable alternative to repainting for bridges undergoing deck replacement.

SELECTING STRATEGIES

• There is a tremendous inventory of lead-coated bridges. Although some agencies have made substantial reductions in their inventory, most agencies paint only a small percentage (typically 2 to 5 percent) every year. Therefore, lead paint removal will continue to be required for many years, perhaps decades.

• There has been a large amount of testing, research, and evaluation of overcoating within the last year or two. Overcoating is becoming more widely used as a means of maximizing bridge painting budgets. Improved guidelines for assessing the viability of overcoating are becoming available based on considerations of extent of coating failure, adhesion, thickness, and presence of millscale.

• Accordingly, improved means are needed for documentation of field applications, assessment of design and performance of containment, performance of coatings, etc. Such protocols would help ensure that in 10 years or so, the merits of alternative techniques and strategies can be better determined.

• Models based on risk analysis have potential to aid transportation agencies in decision making.

• Top managers and administrators of transportation agencies have an increased awareness of the problems and potential liabilities for lead paint removal.

• Increased education and promotion are still needed so that money spent on bridge painting can be seen as an investment in the long-term protection of structures.

CONTAINMENT

• The SSPC Containment Guide is an effective guidance document for containment. It is used by most transportation agencies for specifying containment types and means of monitoring.

• Innovative, comprehensive approaches to implementation of containment, ventilation, and monitoring systems have been developed. Many contractors are becoming very proficient in this area.

• Better means are needed for determining the efficiency and effectiveness of containment.

• However, levels of lead dust during abrasive blasting are still extremely high. Ventilation dilution is not adequate as an engineering control to reduce the level of worker exposure to below the personal exposure limit. Properly designed ventilation of containment is essential for improving visibility and clearing the dust after blasting.

• Better definitions are needed of what containments are required for overcoating, as there is great variability among transportation agencies. There is also little data on the performance or effectiveness of containment for overcoating projects.

SURFACE PREPARATION

• Dry blasting is still the most effective means for removing paint, with expendable and recyclable abrasives being about equally cost effective and productive. The use of a recyclable abrasive, however, results in significant reductions of total waste.

• Almost every preparation method can produce exposures above the personal exposure limit. However, recent data suggest that the use of shrouded power tools and vacuum blasting can control exposure so that minimal respiratory protection is required.

• Alternate tools are several times less productive than blast cleaning and cannot access the entire surface. As a result, several DOTs allow for a lower degree of surface preparation in areas that are difficult to access.

• There is greater use of water as a cleaning method both for preparation (e.g., medium-pressure water washing) and as a primary paint removal method (e.g., high-pressure water jetting and wet blasting).

• A major challenge is collecting or filtering the waste water that otherwise could contaminate the ground or water. Consequently, advances in technology are needed to develop effective means for collecting, channeling, filtering, and treating waste water.

• The cost of the preparation and painting is less than half the total project costs. The additional costs offer a better quality surface preparation (e.g., near-white blasting) and higher quality coating systems, which may result in reduced life-cycle costs.

• There are several new and forthcoming industry consensus standards describing alternate coating removal methods, the effect of soluble salts, and new visual standards.

REFERENCES

1. Appleman, B. R., *NCHRP Synthesis 176: Bridge Paint: Removal, Containment, and Disposal,* Transportation Research Board, National Research Council, Washington, DC, (February 1992) p. 29.
2. Carlson, E. D., Federal Highway Administration, "Risks Posed by Lead Poisoning and Environmental Contamination During Bridge Renovation and Other Construction Work," Statement at Hearing Before the Subcommittee on Health and the Environment, Committee on Energy and Commerce, US House of Representatives (March 3, 1993).
3. Trimber, K. A., *Industrial Lead Paint Removal Handbook, 2nd Edition,* KTA-Tator, Inc., Pittsburgh, Pa. (1993) SSPC Report 93-02.
4. *C-3, Supervisor/Competent Person Training for Deleading of Industrial Structures,* SSPC, Pittsburgh, Pa. (1997).
5. 29 CFR Part 1926.62, Lead Exposure in Construction, Interim Final Rule, *Federal Register,* Occupational Safety and Health Administration, Department of Labor (May 4, 1993).
6. 16 CFR 1303, Consumer Product Safety Act, "Ban of Lead-Containing Paint and Certain Consumer Products Bearing Lead-Containing Paints," section 1303.2 definitions," p. A-7.
7. *The Residential Lead-Based Paint Hazard Reduction Act of 1992* ("Title X"), Section 402 and 404 of the Toxic Substances Control Act, or TSCA (Public Law 15 U.S.C. 2682 and 2684).
8. Leighton, R. I., "Exposure Monitoring on Bridge Maintenance Painting Projects," in *Industrial Lead Paint Abatement: Preparing for the Future,* Proceedings of the 9th Annual Industrial Lead Paint Abatement and Removal Conference, Pittsburgh, Pa. (March 11-13, 1996), SSPC Report 96-01, p. 24.
9. Tinklenberg, G. L. and D.M. Doezema, "Health Concerns for Workers Using Zinc-Rich Coatings," in *Lead and Other Safety, Health, and Environmental Issues: Piecing Together the Critical Issues,* Proceedings of the SSPC 1997 Compliance in Industrial Painting Conference, Stamford, CT (March 3-4, 1997), SSPC Report 97-03, p. 69-83.
10. Zedd, H.C., Y.P. Walker, J.E. Hernandez, and R.J. Thomas, "Lead Exposures During Shipboard Chipping and Grinding Paint Removal Operations," *American Industrial Hygiene Association Journal,* Vol. 54, No. 7, pp. 392-396.
11. Preamble to Lead Exposure in Construction, Interim Final Rule, *Federal Register,* Occupational Safety and Health Administration, Department of Labor (May 4, 1993), pp. 26590-26627.
12. "Lead Paint Removal: Case Histories and Compliance Strategies," TIP-5B, Technical Information Packet Service (TIPS), *Journal of Protective Coatings and Linings,* Technology Publishing Co., Pittsburgh, Pa. (1996).
13. "SSPC Guide 6, Guide for Containing Debris Generated during Paint Removal Operations" in *Systems and Specifications, Steel Structures Painting Manual, Volume 2,* SSPC, Pittsburgh, Pa. (1995).
14. Trimber, K. A. and D.P. Adley, *Project Design: Industrial Lead Paint Removal Handbook, Volume II,* Technology Publishing Company, Pittsburgh, Pa. (1994) SSPC Report 94-18.
15. Gozion, M., "Design and Cost Estimating for SSPC Class 1 Containment Systems," *Journal of Protective Coatings and Linings* (November 1994) pp. 59-68.
16. (a) Mickelsen, L., *Control Technology for Removing Lead-Based Paint from Steel Structures: Chemical Stripping at Columbus Ohio Bridge,* NIOSH, Report # ECTB183-17a (March 1995). (b) Mickelsen, R.L. and O.E. Johnson, "Lead Exposure During Removal of Lead-Based Paint Using Vacuum Blasting," *Journal of Protective Coatings and Linings* (February, 1995) pp. 78-84.
17. Medford, W.M., "Containment and Beneficial Reuse of Blasting Sand in Asphalt Concrete: A Case History," *Journal of Protective Coatings and Linings* (January 1990) pp. 36-44.
18. Hitzrot, H. W., "Lead Paint Removal Using Recyclable Steel Abrasives: Problems and Solutions," Maintenance Tips, *Journal of Protective Coatings and Linings* (July 1991) pp. 39-42.
19. "EPA Issues Memo on Using Filings with Expendable Abrasives for Lead Paint Removal," Regulation News, *Journal of Protective Coatings and Linings* (October 1991) p. 33.
20. Gustavson, C.M. and V.F. Hock, "Evaluation of Chemical Stabilization of Lead Based Paint Using an Engineered Abrasive," *Proceedings* of SSPC Eighth Annual Industrial Lead Paint Abatement and Removal Conference, Chicago, IL (March 13-15, 1995), SSPC Report 95-05, pp.159-166.
21. Smith, L.M, and G.L. Tinklenberg, *Lead-Containing Paint Removal, Containment, and Disposal,* FHWA-RD-94-100, Federal Highway Administration, McLean, Va. (February 1995).
22. "Guide 7, Guide for Disposal of Lead-Contaminated Surface Preparation Debris," in *Systems and Specifications, Steel Structures Painting Manual, Volume 2,* SSPC, Pittsburgh, Pa. (1995).
23. Salt, B.K, R.L.Carrasquillo, R.C. Loehr, and D.W. Fowler, "Recycling Contaminated Spent Blasting Abrasives in Portland Cement Mortars Using Solidification/Stabilization Technology," RR-1315-35, University of Texas; Fed-

eral Highway Administration, Texas Division; and Texas Department of Transportation, Austin (April 1995).

24. *Understanding the Hazardous Waste Rules: A Handbook for Small Businesses—1996 Update,* EPA530-K-95-001, United States Environmental Protection Agency, Washington, DC (June 1996).
25. Christoffer, W.C., "Environmental Lead Laboratory Accreditation," *Proceedings* of SSPC Eighth Annual Industrial Lead Paint Abatement and Removal Conference, Chicago, IL (March 13-15, 1995), SSPC Report 95-05, pp 167-171.
26. Tinklenberg, G. and L. Smith, "The Criticality of Sampling and Quality Control for Hazardous Waste Testing," *Journal of Protective Coatings and Linings* (April 1990) pp. 36-44.
27. Corbett, W. D., "Determining the Toxicity of Liquid Wastes Generated During Coating Removal Operations," *Compliance*, 97/1 (1997) p. 8.
28. *New Jersey Supplement, for C-3, Supervisor/Competent Person Training for Deleading of Industrial Structures,* SSPC, Pittsburgh, Pa. (1997).
29. Rex, J., "The Penalty Box-Missouri," *Pb, SSPC's Lead Paint Bulletin*, Fall 1993, p. 4.
30. Rex, J., "The Penalty Box-Massachusetts," *Pb, SSPC's Lead Paint Bulletin*, 95/2 (1995).
31. Rex, J., "Guilty Pleas in Hazardous Waste Case Could Mean Prison and Fine," *Pb, SSPC's Lead Paint Bulletin,* Summer 1992, p. 2.
32. Appleman, B. R., "Improving Bridge Painting Specifications," *Journal of Protective Coatings and Linings* (September 1988) p. 38.
33. AASHTO *Guide for Painting Steel Structures,* American Association of State Highway and Transportation Officials, Washington, DC, 1995.
34. Rex, J., "SSPC Protests Stoppage of Paint Removal and Repair Activities on NYC Bridges," *Compliance* 96/1 (1996), pp. 3-4.
35. "User's Guide to Selection of Blasting Abrasives," National Shipbuilding Research Program, Project 3-95-7, Award Date: March 1996.
36. "Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating," SSPC-SP 12/NACE No. 5 in *Systems and Specifications, Steel Structures Painting Manual, Volume 2*, SSPC, Pittsburgh, Pa. (1995).
37. Johnson, W.C., "Cost-Effective Extraction of Chlorides from Bridge Steel," *Journal of Protective Coatings and Linings* (January 1997) pp. 82-92.
38. (a) Mickelsen, R.L. *Control Technology for Removing Lead-Based Paint from Steel Structures: Chemical Stripping at Columbus, Ohio Bridge*, ECTB183-17a NIOSH (March 1995). (b) *Control Technology for Removing Lead-Based Paint from Steel Structures: Power Tool Cleaning*, ECTB183-16A, NIOSH (November 1995). (c) *Control Technology for Removing Lead-Based Paint from Steel Structures: Abrasive Blasting Inside Two Ventilated Containment Systems,* ECTB183-14a, NIOSH (December 1994).
39. Appleman, B.R., "Critical Aspects of Overcoating," BIRL Industrial Research Laboratory, Northwestern University, Evanston, IL, Final Draft (June 1995).
40. "Surface Preparation Specifications," in *Systems and Specifications, Steel Structures Painting Manual, Volume 2*, SSPC, Pittsburgh, Pa. (1995).
41. Tinklenberg, G., L. Smith, V. Coluccio, M. Itkin, H. Patel, R. Westman, and J. Morton, "Effectiveness of Air Monitoring on Lead Abatement Projects in Assessing Environmental Fallout," Problem Solving Forum, *Journal of Protective Coatings and Linings* (March 1994) pp. 19-27.
42. Dawson, J. L. , M. Brown, and R. A. Kogler, Jr., "Containment Efficiency: Environment and Worker Exposure," in *Lead and Other Safety, Health, and Environmental Issues: Piecing Together the Critical Issues*, *Proceedings* of the SSPC 1997 Compliance in Industrial Painting Conference, Stamford, Ct. (March 3-4, 1997) p. 34-38.
43. Zamurs, J., and J. Bass, *Air Quality Monitoring Report on Five Class A Containment Projects from 1995 NYSDOT Construction Season*, Environmental Analysis Bureau (June 7, 1996).
44. Snyder, M.K, and D. Benderski, *NCHRP Report 265: Removal of Lead-Based Bridge Paint,* Transportation Research Board, Washington, DC (December 1983).
45. Leighton, R. I. and W. A. McGreevy, "Soil Sampling for Industrial Painting Projects," in *Industrial Lead Paint Abatement: Preparing for the Future*, *Proceedings* of the 9th Annual Industrial Lead Paint Abatement and Removal Conference, Pittsburgh, Pa. (March 11-13, 1996), SSPC Report 96-01, p. 67-71.
46. Arrotti, G., P. L. Manske, and F.H. Moy, "Soil Sampling for Containment Verification Following Lead Paint Abatement of Steel Structures, in *Industrial Lead Paint Abatement: Preparing for the Future*, Proceedings of the 9th Annual Industrial Lead Paint Abatement and Removal Conference, Pittsburgh, Pa., (March 11-13, 1996), SSPC Report 96-01, p. 61-66.
47. *Manual on Uniform Traffic Control Devices for Streets and Highways Work Zone Safety: Guidelines for Municipalities, Utilities, and Contractors,* ANSI D6.1-1971, North Carolina Institute of Transportation Research and Education, September 1993.
48. *Model Specifications for the Protection of Workers from Lead on Steel Structures,* Report No. OSH3-93, The Center to Protect Workers' Rights, Washington, DC (1993).
49. Ventura, J. and P. Susi, "Implementing and Evaluating Model Lead Specifications," in *Industrial Lead Paint Abatement: Preparing for the Future, Proceedings* of the 9th Annual Industrial Lead Paint Abatement and Removal Conference, Pittsburgh, Pa. (March 11-13, 1996), SSPC Report 96-01, p 84-92.
50. "For Exhaust Systems—Abrasive Blasting Operations—Ventilation and Safe Practices," ANSI/ASC Z9.4, American National Standards Institute, New York, NY.
51. Erville, P. R., *Avoiding Lead-Based Paint Hazards on Highway, Bridge and Transit Structures,* Alliance to End Childhood Lead Poisoning, Washington DC, October 1994.

52. Zollinger, B.P., "State Program to Qualify Painters," Maintenance Tips, *Journal of Protective Coatings and Linings* (January 1987) pp. 30, 65.
53. Appleman, B. and J. Rex, "EPA Title X: A Preliminary Summary of the Proposed Rule," *Pb: SSPC's Lead Paint Bulletin,* issue 94/5, p. 1.
54. Appleman, B. "Significance of EPA Title X Rule on Certification and Training for Residential Deleading," *Compliance* 96/5 (1996), p. 1.
55. "Standard Procedure for Evaluating Qualifications of Shop Painting Contractors," SSPC-QP 3 in *Systems and Specifications, Steel Structures Painting Manual, Volume 2,* SSPC, Pittsburgh, Pa. (1995).
56. *Quality Certification Program, Specialty Paint Endorsement,* American Institute of Steel Construction, Inc., Chicago, Ill. (1994).
57. "Gap in Liability Policy Widens with Meaning of Pollutant," News Site, Legal, *Engineering News-Record (ENR)* (May 19, 1997) p. 22.
58. (a) *Lead-Based Paint Removal Worker Health and Safety Issues*, Memorandum from Director, Office of Engineering, Federal Highway Administration, US Department of Transportation to Regional Federal Highway Administrators, Division Administrators, Federal Lands Highway Program Administrator (June 14, 1993); (b) *Pre-bid Conferences on Lead-Based Paint Abatement,* Memorandum from Director, Office of Engineering, Federal Highway Administration, US Department of Transportation to Regional Federal Highway Administrators, Division Administrators, Federal Lands Highway Program Administrator (March 18, 1994).
59. Chirigos, N. and P. Shropshire, "Controlling the Cost of Maintenance Painting from the Contractors' Perspective," in *Industrial Lead Paint Abatement: Preparing for the Future*, Proceedings of the 9th Annual Industrial Lead Paint Abatement and Removal Conference, Pittsburgh, Pa. (March 11-13, 1996), SSPC Report 96-01, p. 49-54.
60. Vink, M. P., "Lead Contamination in Homes and Vehicles of Lead-Exposed Bridgeworkers," *Compliance*, 96/2 (1996) p. 1.
61. 40 CFR Part 745, Lead; Requirements for Lead-Based Paint Activities in Target Housing and Child-Occupied Facilities; Final Rule, *Federal Register*, August 29, 1996 p. 45798.
62. Hancher, D.E., *NCHRP Synthesis of Highway Practice 195: Use of Warranties in Road Construction*, Transportation Research Board, National Research Council, Washington, DC (1994).
63. *FHWA Study Tour for Bridge Maintenance Coatings,* Federal Highway Administration, US Department of Transportation, Washington, DC (June 1996).
64. Rex, J., "SSPC Protests Stoppage of Paint Removal and Repair Activities on NYC Bridges," *Compliance* 96/1 (1996), pp. 3-4.
65. Castler, L. B., "A Positive Approach—Public Outreach on Lead Paint Removal Projects," in *Lead and Other Safety, Health, and Environmental Issues: Piecing Together the Critical Issues*, *Proceedings* of the SSPC 1997 Compliance in Industrial Painting Conference, Stamford, CT (March 3-4, 1997), SSPC Report 97-03, p. 102-107.
66. Appleman, B.R., *Guidelines for Cost Effective Lead Paint Removal,* FHWA-RD-94-YYY, Federal Highway Administration, US Department of Transportation, Washington, DC (January 1996), SSPC Report 96-06.
67. Lyras, L.G., "Cost of Lead Paint Removal: Achieving Realistic Bid Prices," *Journal of Protective Coatings and Linings* (July 1991) pp. 56-63.
68. Appleman, B.R., "Overcoating vs. Removing Lead Paint: A Comparative Analysis, *Journal of Protective Coatings and Linings Special Report: Overcoating Lead Paint* (November 1993).
69. Farschon, C., R. Kogler, and J.P. Ault, *Guidelines for Repair and Maintenance of Bridge Coatings: Overcoating,* FHWA-RD-96-058, Federal Highway Administration, US Department of Transportation, Washington, DC (April 7, 1997).
70. Castler, L. "Replacing Steel vs Replacing Lead: Connecticut's Experience," *Journal of Protective Coatings and Linings* (July 94) pp. 54-62.
71. Copenbarger, D. and A. Humaideh, "Overcoating, Steel Replacement, and Other Strategies for Bridges," *Proceedings* of SSPC's Eighth Annual Conference on Industrial Lead Paint Abatement and Removal, Chicago, Ill. (March 13-15, 1995), SSPC Report 95-05, pp. 95-97.
72. *T-1, Two-Day Tutorial on Industrial Lead Paint Removal and Abatement* (Unit 7), (1994) SSPC, Pittsburgh, Pa.

ANNOTATED BIBLIOGRAPHY

1. Appleman, B.R., Critical Aspects of Overcoating, BIRL Industrial Research Laboratory, Northwestern University, Evanston, IL, Final Draft June 9, 1995.
   This report contains a description of overcoating as a maintenance strategy and how it compares to other bridge painting activities. It describes in detail the technology and practice of overcoating. It provides a comparison of overcoating to full removal and addresses issues such as worker protection during overcoating, environmental regulations, treatment of waste and monitoring of compliance. It describes procedures for evaluating performance of overcoating systems. It describes additional follow-ups needed to better understand overcoating and the means by which highway agencies can take advantage of this technology. Finally, it contains an extensive set of supplementary material including previous reports, review and analysis of DOT practices and specifications, and documentation of presentations.

2. Appleman, Bernard R., Guidelines for Cost Effective Lead Paint Removal, Federal Highway Administration, Washington, DC, 1996. [SSPC 96-06]
   FHWA sponsored a workshop to identify critical issues and to develop guidelines for removing lead paint from highway bridges. About 45 representatives of highway and regulatory agencies and private industry identified, analyzed, and gave recommendations for critical technology and regulatory issues. Guidelines were developed to assist highway and bridge agencies in planning and managing programs to remove lead paint and to maintain bridges both cost effectively and in compliance with environmental and health regulations. The guidelines include the following sections: Developing Strategy and Specification Requirements; Specifying Full Removal and Repainting; Specifying Spot Repair and Overcoating; Contracting and Inspection Practices; Sources of Information; Costs and Funding.

3. Bridge Paint: Removal, Containment, and Disposal, National Cooperative Highway Research Program, Synthesis of Highway Practice 176, Transportation Research Board, Washington, DC, February 1992. [SSPC 92-02]
   A synthesis that is of interest to bridge painting contractors, bridge maintenance and construction engineers, environmental engineers, equipment manufacturers and suppliers, and others interested in bridge paint removal. Information is provided on current practices in bridge paint removal, containment, and disposal, with special attention paid to environmental, health, and cost issues, along with a discussion of current environmental regulations governing paint removal practices.

4. Neal, Tom W., Alternate Methods of Corrosion Protection for Exposed Bridge Steel Surfaces, National Cooperative Highway Research Program, Project 20-5, Topic 26-12, Second Draft March 1997.
   A synthesis was prepared to summarize the state of the practice of state DOTs as well as recently completed and ongoing research (including laboratory and field) for preservation of exposed structural steel on existing bridge structures. The synthesis covers the exposed steel above the splash zone (including bearings, expansion dams, scuppers, downspouts, etc.) as well as new steel necessary for rehabilitative work. The focus of the synthesis is to identify the key issues of concern during the management decision process (and the rationale behind existing and potential strategies) for structural steel corrosion protection of existing bridges. Issues to be addressed include but are not limited to: materials selection criteria; environmental factors and conditions; maintenance prioritization; type and extent of surface preparation; application factors; relative cost factors and their effect; worker safety; quality control/quality assurance; and funding mechanisms.

5. Smith, Lloyd M., and Gary L. Tinklenberg, Lead-Containing Paint Removal, Containment, and Disposal, FHWA-RD-94-100, Federal Highway Administration, McLean, VA, February 1995.
   A comprehensive study is described which evaluated the various factors involved with lead-paint removal. Containment and ventilation systems were studied and recommendations were developed for containment materials, design of joints, design of air inputs, negative pressure, and airflow within containment. Waste disposal is a significant issue due to long-term liability and cost. Tests were performed on hazardous waste characterization, waste minimization, methods of generating non-hazardous waste, and long-term stability of lead-containing wastes and stabilized wastes. Alternate surface preparation methods and costs were evaluated.

6. SSPC, C-3, Supervisor/Competent Person Training for Deleading of Industrial Structures, Steel Structures Painting Council, Pittsburgh, Pa., 1997.
   This four-day course is intended to provide practical information on regulations and technology needed by individuals responsible for supervising and overseeing indus-

trial lead paint removal and other deleading work. The course is designed to meet the requirements of several sets of published qualifications for such individuals, including: EPA Supervisor for Superstructures and Commercial Buildings (40 CFR 745); OSHA Lead Training (29 CFR 1926.62 (l)); OSHA Competent Person (CPL 2-2-58 12/13/93); and SSPC Competent Person (SSPC QP-2, Section 2.1). The course contains approximately 22-24 hours of lecture/review and 8-10 hours of hands-on demonstrations and exercises.

7. Trimber, Kenneth A., Industrial Lead Paint Removal Handbook, 2nd Edition, KTA-Tator, Inc., Pittsburgh, 1993. [SSPC 93-02]
   An essential overview and guide for those who conduct and manage industrial lead paint removal operations. Topics include methods of lead paint removal; designing and implementing a containment system; waste collection, handling and disposal; worker and environmental protection; preparing specifications; and more. Appendices include relevant excerpts from the Code of Federal Regulations, an extensive glossary of terms, and a comprehensive list of resources for information on regulations.

8. Trimber, Kenneth A. and Adley, Daniel P., CIH, CSP, Project Design: Industrial Lead Paint Removal Handbook, Volume II, Technology Publishing Company, Pittsburgh, 1994. [SSPC 95-06]
   Applies the basic information found in the Industrial Lead Paint Removal Handbook (see above) to the more specific job of designing an industrial lead paint removal project. Provides a logical multi-phase approach to gathering and analyzing data, offers strategies for sound and effective decision making, and presents detailed yet easy-to-follow guidelines, methods, and procedures for the performance and completion of related tasks.

KEY INTERNET SITES

EPA

1. Title X (Residential)
http://www.epa.gov/docs/fedrgstr/EPA-TOX/1996/August/Day29/pr-24181DIR/
2. Office of Prevention, Pesticides and Toxic Substances
http://www.epa.gov/internet/oppts/
3. EPA Region Contacts
http://www.epa.gov/epahome/Offices.html#regions
4. Search the EPA Server
http://www.epa.gov/epahome/search.html
5. Search the Federal Register, Environmental Subset
http://www.epa.gov/fedrgstr/search.htm

FHWA

1. Home Page
http://www.fhwa.dot.gov
2 Legislation and Regulations
http://www.fhwa.dot.gov/legsregs/legislat.html
3. Field Offices
http://www.fhwa.dot.gov/field.html

JPCL

1. http://www.protectivecoatings.com

NORTHWESTERN UNIVERSITY'S INFRASTRUCTURE TECHNOLOGY INSTITUTE

1. Bridge Lead Paint Removal Bibliography
http://iti.acns.nwu.edu/clear/bridge/lead.html
2. Bridge Paint Removal
http://iti.acns.nwu.edu/clear/bridge/bri_pai.html
3. Issues Impacting Bridge Painting: An Overview. FHWA/RD/94/098 (Aug 95)
Ch. 3 Worker Protection/Paint Removal
http://iti.acns.nwu.edu/pubs/fhfr/fhfr_ch3.html
Ch. 4 Analysis and Disposal of Lead-Contaminated Debris
http://iti.a cns.nwu.edu/pubs/fhfr/fhfr_ch4.html

OSHA

1. Home Page
http://www.osha.gov/
2. Lead Exposure in Construction; Interim Final Rule,
http://www.osha-slc.gov/OshStd_data/1926.0062.html
3. Standard Interpretations of 1926.62
http://www.osha-slc.gov/OshDoc/Interp_Std_toc/TOC_1926.62.html
4. OSHA Office Directory
http://www.osha.gov/oshdir/

SSPC ONLINE

1. Home Page
http://www.sspc.org
2 Regulatory News
http://www.sspc.org/site/regnews.html
3. Overcoating of Lead-Based Painted Bridges
http://www.sspc.org/site/ro53/RO53SEC1.html
4. Compliance: Environmental, Health and Safety News from SSPC
http://www.sspc.org/site/compliance/comp.html
5. A Summary of EPA Rule on Certification and Training for Residential Deleading
http://www.sspc.org/site/compliance/96_5/EPASummary.html
6. Contractor Certification
http://www.sspc.org/site/cert.html

Other Sources of Related Information

1. National Institute of Standards and Technology (NIST)
http://www.nist.gov
2. Transportation Research Board (TRB)
http://www.nas.edu/trb
3. Fact Sheet on Lead Paint at Military Facilities
http://www.afcee.brooks.af.mil/pro_act/main/fact/fact/May1996/05_9617.htm
4. National Lead Information Center
http://www.nsc.org/ehc/lead.htm
5. Robotic Bridge Paint Removal
http://www.azfms.com/DocReviews/May96/art13.html

ABBREVIATIONS

AAS	Atomic absorption spectroscopy
AASHTO	American Association of State Highway and Transportation Officials
AIHA	American Industrial Hygiene Association
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BDL	Below detectable limit
BMP	Best management practice
CAA	Clean Air Act
CARB	California Air Resources Board
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGL	Comprehensive and general liability
CIH	Certified industrial hygienist
CPWR	Center for the Protection of Workers' Rights
CRISP	Connecticut Road Industry Surveillance Program (Now CLINIC — Connecticut Lead Intervention Network In Construction)
DFT	Dry film thickness
EPA	Environmental Protection Agency
GSA	General Services Administration
HEPA	High efficiency particulate air
ICP	Inductively coupled plasma
ISO	International Organization for Standardization
JPCL	Journal of Protective Coatings and Linings
KPa	Kilopascals
MIO	Micaceous iron oxide
MPa	Megapascals
MUTCD	Manual of Uniform Traffic Control Devices
NAAQS	National Ambient Air Quality Standard
NACE	NACE International (previously the National Association of Corrosion Engineers)
NIOSH	National Institute for Occupational Safety & Health
NHI	National Highway Institute
NCHRP	National Cooperative Highway Research Program
NLLAP	National Lead Laboratory Accreditation Program
NSRP	National Shipbuilding Research Program
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PCCP	SSPC's Painting Contractor Certification Program
PCB	Polychlorinated biphenyl
PCSA	Proprietary calcium silicate additive
PEL	Permissible exposure limit
PM	Particulate matter
PM-10	Particulate matter with diameter of 10 micrometers or less
PPE	Personal protective equipment
PPM	Parts per million
PSI	Pounds per square inch
RCRA	Resource Conservation and Recovery Act
SAE	Society of Automotive Engineers
TCLP	Toxicity Characteristic Leaching Procedure
TRB	Transportation Research Board
TSDF	Treatment, storage and disposal facilities
TSP	Total suspended particulate
ZPP	Zinc protoporphyrin

APPENDIX A
Questionaire

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Project 20-5, Topic 28-04

"Lead Based Paint Removal for Steel Highway Bridges"

QUESTIONNAIRE

Name of respondent/Position: ____________________
Agency: ____________________
Department: ____________________
Phone and FAX No's: ____________________

Part I. Numbers of Bridges and Costs Involving Lead Paint Removal

1. What is the number of existing (previously painted) steel bridges that were repainted under the following programs in each of the last 4 years? How many of these had lead paint?

# Bridges Involved		1993		1994		1995		1996 (Estimated)	
		Total	w/Pb	Total	w/Pb	Total	w/Pb	Total	w/Pb
Maintenance Painting									
Full Removal	#								
	$*								
Overcoating	#								
	$*								
Deck Rehabilitation									
Full Removal	#								
	$*								
Overcoating	#								
	$*								

* Nearest $100K.

2. How many steel bridges were replaced or rehabilitated in each of the last 4 years?

# Bridges Involved		1993		1994		1995		1996 (Estimated)	
		Total	w/Pb	Total	w/Pb	Total	w/Pb	Total	w/Pb
Superstructure Rehabbed	#								
	$*								
Superstructure Replaced	#								
	$*								
Steel Bridge Replaced	#								
	$*								

*Nearest $100K.

Part II. Information on Specific Projects

3. **Full Removal Case Histories**
Select 1 representative project involving full lead paint removal (either maintenance painting or rehabilitation). **Note:** If your agency has not done any, please omit this question.

a. Description
- Type of bridge ____________________
- Location (urban, rural, marine)____________________ age __________
- Total sq. feet __________ No. of tons__________

b. Coating System
- Primer __________ Intermediate __________ Topcoat __________
- Degree of cleaning ________ Abrasive __________ Profile __________

c. Containment System
- Specified: SSPC class ______________, other ______________
- General Type: Bridge to Grade__________, Suspended Platform______________
  Other (Specify)__________, Specific commercial system used: (e.g., ARK) __________
- Side walls: Penetrable Tarps ______, Impenetrable Tarps______, Other__________
- Floors: Grate________, Solid (Describe)__________, Ground Covers __________
- Closures: Zippers __________, Clips __________, Overlaps ______________
- Dimensions of contained space __________, number of times moved __________
- Ventilation: Yes/No ________ Instrument verification: Yes/No __________

d. Assessment of containment (scale of 1 to 5, 5 = Best)
- Preventing solid spills and releases ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Collecting solid spills and release ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Preventing air emissions ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Maintain Negative Pressure ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

e. Waste handling and control
- Waste generated: # Drums ________ # Tons ________ How collected? __________
- Number of samples __________ Results of hazard analysis (TCLP) ______________
- Disposal: $ per Drum/Ton __________ Treatment/Disposal Firm ______________

f. Air, soil and water testing
- Air monitoring done? ________ # monitors; PM-10 ________TSP (lead) __________
- Was soil sampling done? ________; # samples; pre - __________ post- __________
- Water sampling done for work over water __________ Type of sample? __________
- Surface preparation water: Collected? ______ Treated? ______ How disposed? ________
- Hygiene water: Collected? ________ Treated? ________ How disposed? __________

g. Worker Controls by Contractor
- Did contractor submit written lead health & safety plan? ❑ Yes ❑ No
- Were decon trailers used? ❑ Yes ❑ No

Appendix A-1

NCHRP Project 20-5, Topic 28-04
Agency: ____________

- Was Industrial Hygienist used? ❑ Yes ❑ No

h. Costs
- Final agency cost ____________, Price per sq. ft. __________
- Initial contractor bid ____________ Added costs __________
- Other cost data (e.g., costs for waste disposal, lead health & safety) ____________

Note: If available, please provide a list or range of the bid prices on this project.

4. Overcoating Case History

Select 1 representative project involving partial lead paint removal (either maintenance painting or rehabilitation). **Note:** If your agency has not done any, please omit this question.

a. Description
- Type of bridge ____________, age ____________
- Location (urban, rural, marine)____________
- Total sq. feet ____________ Total repainted ________ No. of tons__________

b. Condition & History
- Percent degraded/rusted: 0-10%____; 10-25%_____; more than 25%_________
- Other info on condition: adhesion:___________, thickness______________

c. Surface preparation & coating
- Identify each step in surface preparation and coating and percent of surface cleaned:

	Step	Description	% Cleaned/Coated
*	prewash	Pressure: ____________	______
*	spot/full surface prep	Degree of cleaning:__________ Tool: __________	______
*	spot prime	Material: ____________	______
*	1st full overcoat	Material: ____________	______
*	2nd full overcoat	Material: ____________	______

Note: If available, please attach specification.

d. Containment System
- Specified: SSPC class ____________, other ____________
- General Type: Bridge to Grade__________, Suspended Platform____________
  Other (Specify)__________, Specific commercial system: (e.g., ARK) ________
- Side walls: Penetrable Tarps ______, Impenetrable Tarps______, Other__________
- Floors: Grate________, Solid (Describe)_________, Ground Covers __________
- Closures: Zippers _________, Clips ___________, Overlaps ____________
- Dimensions of contained space __________, number of times moved __________
- Ventilation: Yes/No ______ Instrument verification: Yes/No _________

Appendix A-1

NCHRP Project 20-5, Topic 28-04
Agency: ____________

Assessment of Containment (scale of 1 to 5, 5 = Best)
- Preventing solid spills and releases ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Collecting solid spills and releases ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Preventing air emissions ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

Waste handling and control
- Waste generated: # Drums ________ # Tons ________ How collected? _________
- Number of samples __________ Results of hazard analysis (TCLP)____________
- Disposal: $ per Drum/Ton __________ Treatment/Disposal Firm ____________

Air, Soil, and Water Testing
- Air monitoring done? ________ # monitors; PM-10 ________ TSP (lead) _______
- Was soil sampling done? ________; # samples pre-_________ post-___________
- Surface preparation water: Collected? ______ Tested? _______ Treated? _______
  How disposed? ____________
- Hygiene water: Collected? _________ Tested? ________ Treated? ________
  How disposed? ____________

Worker Controls by Contractor
- Did contractor submit written lead health & safety plan? ❑ Yes ❑ No
- Were decon trailers used? ❑ Yes ❑ No
- Was Industrial Hygienist used? ❑ Yes ❑ No

Costs
- Final agency cost ____________Price per sq. ft. _________
- Initial contractor bid _________ Added costs ___________
- Other cost data (e.g., costs for waste disposal, lead health & safety) ___________

Can you provide a list or range of the bid prices on this project?

Steel Replacement Case Histories

Select 1 representative project involving steel bridge demolition or steel replacement.
Note: If your agency has not done any, please omit this question.

Description, location and size of bridge (e.g., rolled girder bridge,120 ft. long, urban intersection)
____
____

Condition
- Overall condition (1 to 5, 5 = Best) ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Age of bridge ____________

Main reason for removing steel (e.g. structural repairs, bridge no longer needed or functional, cheaper than repainting) ____________________________

d. Methods used to remove steel members
For each indicate **F** for frequently, **S** for sometimes, **O** for occasionally
- torch cutting Tool: ____________________ Frequency: ❑ F ❑ S ❑ O
- rivet busting Tool: ____________________ Frequency: ❑ F ❑ S ❑ O
- mechanical shears Tool: ____________________ Frequency: ❑ F ❑ S ❑ O
- mechanical saws Tool: ____________________ Frequency: ❑ F ❑ S ❑ O
- other (please describe) ____

e. Controlling releases to the environment
- Were any of the following methods used?
  - * removing paint on areas to be burned ❑ Yes ❑ No
  - * tarps or ground covers to collect loose debris ❑ Yes ❑ No
  - * periodic (e.g., daily) clean-up of work area ❑ Yes ❑ No
  - * other ____________________________ ❑ Yes ❑ No
- Were air or soil monitored for lead? ❑ Yes ❑ No

f. Waste handling & disposal
- Were there any special procedures for handling dismantled members?
(e.g., hazard warnings, special area) ____
- How were members disposed? recycling______ discarded______ Other______________
- Were any special instruction provided to waste hauler? ❑ Yes ❑ No

g. Worker Controls by Contractor
- Did contractor submit written lead health & safety plan? ❑ Yes ❑ No
- Were decon trailers used? ❑ Yes ❑ No
- Was Industrial Hygienist used? ❑ Yes ❑ No
- What type of respirator was worn? Half/full face _____ air supplied _____ none _____

Part III. Contracts and Contracting

6. The decision to repaint bridges is made at the: district level ___________ state level ___________

7. Specifications for overcoating systems
- What portions of the structure are given enhanced surface preparation in an overcoating project? (Check all that apply)
Bearings_______; adjacent to joints_______; rusted areas_______; other (specify)_______

For determining if bridge can be overcoated;
- What is maximum % of degradation? 5-10% ____ 10-20% ____ 20-30% ____ other _______
- What is minimum adhesion (ASTM D3359)? 1A/1B-2A/2B ____ 3A/3B-4A/4B ____ N/A ____
- What is maximum thickness? 10-20 mils ____ 20-30 mils ____ >30 mils ____ N/A ______
- What other criteria are used? ____
- How is this determined?
Survey________; engineer estimate_______; by contractor ________; other (describe)_______
- Please attach specifications for the 2 or 3 most common used systems for overcoating.

8. How important are the following criteria in estimating costs for lead paint removal project? (please rate from 1 to 5 with 5 being most important)
- Data from past DOT projects on similar bridges ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

Appendix A-1

NCHRP Project 20-5, Topic 28-04
Agency: ____________________

- Engineering analysis on cost elements ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
(e.g. surf prep, containment, lead health & safety, etc)
- Current projects from neighboring states ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- Other (please specify __________________) ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

9. How accurate are estimates compared to actual (lowest) bids?
- What percent are within 15% of estimate? ____________
- What percent are within 30% of estimate? ____________
- What percent of time are estimated costs higher than initial award cost? ____________
- What is percent of extras based on initial award cost? ____________

10. For each of the following please indicate if it is "separate pay item" or "lump sum" in paint removal/repainting project.
- paint removal Separate ❑ Lump Sum ❑
- paint application and materials Separate ❑ Lump Sum ❑
- containment Separate ❑ Lump Sum ❑
- environmental monitoring (air,water,soil) Separate ❑ Lump Sum ❑
- waste treatment and disposal Separate ❑ Lump Sum ❑
- worker lead health and safety Separate ❑ Lump Sum ❑
- inspection instruments Separate ❑ Lump Sum ❑

11. Which of the following are required for pre-qualification of contractors?
- pollution insurance ❑ Yes ❑ No
- DOT performance criteria ❑ Yes ❑ No
- SSPC contractor certification All bridges ❑ Some ❑ None ❑
- Other (specify) ____

12. Use of pre bid conferences
- How often held? (Percent) ______ Are they mandatory? ❑ Yes ❑ No
- Degree of participation by contractors: ❑ High ❑ Medium ❑ Low
- Usefulness (1 to 5, 5 = highest) ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

13. How frequently does DOT throw out a specific bid, or require re-bidding? (Please rate frequency on a scale of 1 to 5, 5 being most frequent).
- bid too far below DOT's estimate or previous projects ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- one bid too far below other bids ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- lowest bid exceeds estimate ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- contractor not on approved list ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5
- contractor not performing on another project ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

Appendix A-1

NCHRP Project 20-5, Topic 28-04
Agency: ________________

- contractor has received a major OSHA or environmental citation ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5

Please furnish any data on comparing costs for different projects or different bids on a project by multiple contractors.

Also, please furnish copies of specifications or contracts or relevant portions of these documents to amplify responses.

****

THANK YOU FOR YOUR ASSISTANCE!

Please send your response to:

Dr. Bernard R. Appleman
Executive Director
Steel Structures Painting Council
40 24th Street, 6th flr.
Pittsburgh, PA 15222-4643

If you have any questions, please call Dr. Appleman at (412)281-2331, ext. 134 or contact him on E-mail at appleman@sspc.org., or by fax (412)281-9992.

We would appreciate your response by January 15, 1997

****

APPENDIX A-2
Responders to Survey

US STATE DOT'S

Alaska DOT
Arkansas State Hwy. & Transp.
Arizona DOT
California DOT
Colorado DOT
Connecticut DOT
DC DOT & Publ. Works
Georgia DOT
Hawaii DOT
Illinois DOT
Indiana DOT
Iowa DOT
Kentucky DOT
Maine DOT
Maryland DOT
Massachusetts DOT
Michigan DOT
Minnesota DOT
Mississippi DOT
Missouri DOT
Nebraska DOT
Nevada DOT
New Hampshire DOT
New Jersey DOT
New York State DOT
North Carolina DOT
North Dakota DOT
Ohio DOT
Oklahoma DOT
Oregon DOT
South Carolina DOT
Tennessee DOT
Utah DOT
Virginia DOT
Vermont DOT
Washington DOT
West Virginia DOT
Wisconsin DOT

OTHER BRIDGE AGENCIES

Chicago DOT
Massachusetts Turnpike Auth.
New York City DOT
New Jersey Turnpike Auth.
Pennsylvania Turnpike Commission
Port Authority of NY/NJ
Phila. Dept. of Streets Bridge Sect.

CANADIAN BRIDGE AGENCIES

Alberta Transp. & Utility Library
Manitoba Hwy & Transp.
Ontario Ministry of Transp.

APPENDIX B
List of Relevant Standards

AASHTO

1. Guide for Painting Steel Structures (1994)
2. Specification M300-86, Inorganic Zinc Rich Primer

ANSI

1. ANSI Z9.2 1979, "Fundamentals Governing the Design and Operation of Local Exhaust Systems"

ASTM

1. E 1729-95: Standard Practice for Field Collection of Dried Paint Samples for Lead Determination by Atomic Spectrometry Techniques
   1. Scope
   1.1 This practice covers the collection of dried paint samples or other coatings from buildings and related structures. These samples are collected in a manner that will permit subsequent digestion and determination of lead using laboratory analysis techniques such as Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Flame Atomic Absorption Spectrometry (FAAS).
   1.2 This practice is used to collect samples for subsequent determination of lead on an area basis (milligrams of lead per area sampled) or concentration basis (milligrams of lead per gram of dried paint collected or weight percent).
   1.3 This practice does not address the sampling design criteria (that is, sampling plan that includes the number and location of samples) that are used for risk assessment and other purposes. To provide for valid conclusions, sufficient numbers of samples must be obtained as directed by a sampling plan.

2. E 1727-95: Standard Practice for Field Collection of Soil Samples for Lead Determination by Atomic Spectrometry Techniques
   1. Scope
   1.1 This practice covers the collection of soil samples using coring and scooping methods. Soil samples are collected in a manner that will permit subsequent digestion and determination of lead using laboratory analysis techniques such as Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Flame Atomic Absorption Spectrometry (FAAS), and Graphite Furnace Atomic Absorption Spectrometry (GFAAS).
   1.2 This practice is not suitable for collection of soil samples from areas that are paved.
   1.3 This practice does not address the sampling design criteria (that is, sampling plan that includes the number and location of samples) that are used for risk assessment and other purposes. To provide for valid conclusions, sufficient numbers of samples must be obtained as directed by a sampling plan.

3. E 1553-93: Standard Practice for Collection of Airborne Particulate Lead During Abatement and Construction Activities
   1. Scope
   1.1 This practice covers the collection of airborne particulate lead during abatement and construction activities. The practice is intended for use in protecting workers from exposures to high concentrations of airborne particulate lead. This practice is not intended for the measurement of ambient lead concentrations in air.
   1.2 This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

U.S. Environmental Protection Agency (EPA) Test Methods:

1. Method 3050, "Acid Digestion of Sediments, Sludges and Soils"
2. Method 1311, "Toxicity Characteristic Leaching Procedure"
3. Method 1312, "Multiple Extraction Procedure"
4. Proposed Method PB92-114172, "Proposed New Method for Analyzing Lead-Based Paints" from FHWA Report 94-100
5. SW 846, "Evaluating Solid Wastes, Physical and Chemical Methods" (This is a 3-volume set with many methods.)

NIOSH

1. Method 7082, "Sampling Airborne Particulate for Lead"

SSPC

1. SSPC-Guide 6: Guide for Containing Debris Generated During Paint Removal Operations
   1. Scope
   1.1 This guide describes methods of paint removal, containment systems and procedures for minimizing or preventing emissions from escaping the work area, and procedures for assessing the adequacy of the controls over emissions.

1.2 The containment systems are categorized in up to four classes per type of paint removal method, based on the extent to which emissions are controlled.

2. SSPC - Guide 7: Guide for the Disposal of Lead-Contaminated Surface Preparation Debris
1. Scope
1.1 This guide provides information regarding handling, testing, and disposal of solid debris generated during preparation of surfaces previously painted with lead-containing paint.
1.2 This guide is based on Federal regulations only. State or local regulations may be more restrictive and must be investigated. States or other local jurisdictions may have requirements which are stricter, such as requiring other analytical procedures or regulating other metals. Non-hazardous waste containing lead is also regulated in some states.
1.3 This guide does not cover removal of the coating from the structure or containment of the debris. These activities are described in SSPC-Guide 6.

3. Surface Preparation Specification No. 3, "Power Tool Cleaning"
2. Definition
2.1 Power tool cleaning is a method of preparing steel surfaces by the use of power assisted hand tools.
2.2 Power tool cleaning removes all loose mill scale, loose rust, loose paint, and other loose detrimental foreign matter. It is not intended that adherent mill scale, rust, and paint be removed by this process. Mill scale, rust, and paint are considered adherent if they cannot be removed by lifting with a dull putty knife.

4. Surface Preparation Specification No. 6, "Commercial Blast Cleaning"
2. Definition
2.1 A commercial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust coating, oxides, corrosion products, and other foreign matter, except for staining as noted in Section 2.2.
2.2 Random staining shall be limited to no more than 33 percent of each unit area of surface as defined in Section 2.6, and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating.

5. Surface Preparation Specification No. 10, "Near-White Blast Cleaning"
2. Definition
2.1 A near-white blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter, except for staining as noted in Section 2.2.

2.2 Random staining shall be limited to no more than 5 percent of each unit area of surface as defined in Section 2.6, and may consist of light shadows, slight streaks, or minor discolorations caused by stains of rust, stains of mill scale, or stains of previously applied coating.

6. Surface Preparation Specification No. 11, "Power Tool Cleaning to Bare Metal"
2. Definition
2.1 Metallic surfaces which are prepared according to this specification, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter. Slight residues of rust and paint may be left in the lower portion of pits if the original surface is pitted.
2.2 When painting is specified, the surface shall be roughened to a degree suitable for the specified paint system. The surface profile shall not be less than 1 mil (25 microns). NOTE: additional information on profile is contained in Sections A.5 and A.6 of the Appendix.

7. NACE/SSPC Joint Standard SSPC-SP 12/NACE No. 5, "Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating"
Section 1: General
1.1This standard provides requirements for the use of high- and ultrahigh-pressure water jetting to achieve various degrees of surface cleanliness. This standard is limited in scope to the use of water only without the addition of solid particles in the stream.

8. Technology Update on Overcoating
1. Scope
1.1 This technology update discusses the risks associated with the maintenance painting practice known as overcoating. Factors affecting overcoating risk, application, service and cost considerations are discussed.
1.2 This document is intended to serve as a resource for facility owners and others charged with developing and implementing maintenance painting programs.

9. Abrasive Specification No. AB-2, "Specification for Cleanliness of Recycled Ferrous Metallic Abrasives"
1. Scope
1.1 This specification covers the requirements for cleanliness of recycled ferrous metallic blast cleaning abrasives used for the removal of coatings, paints, scale, rust and other foreign matter from steel or other surfaces.
1.2 Requirements are given for lab and field testing of recycled ferrous metallic abrasives work mix.

1.3 Recycled ferrous metallic abrasives are intended for use in field or shop abrasive blast cleaning of steel or other surfaces.

10. Abrasive Specification SSPC-AB 3, "Newly Manufactured Or Re-Manufactured Steel Abrasives"

1. Scope

1.1 This specification covers the requirements for newly manufactured steel abrasive or re-manufactured steel abrasive for use in surface preparation by blast cleaning.

1.2 This specification does not cover recycled steel abrasive processed through field or shop abrasive blast cleaning units. Requirements for recycled steel abrasives are covered in SSPC-AB 2, Specification for Cleanliness of Recycled Ferrous Metallic Abrasives.

1.3 Steel abrasives covered by this specification are intended for the removal of rust, mill scale, paint or other surface coating system, or for general blast cleaning.

11. Qualification Procedure No. 1, "Standard Procedure For Evaluating Qualifications of Painting Contractors (Field Application to Complex Structures)"

1. Scope

1.1 This procedure describes establishment of a program to qualify industrial maintenance painting contractors.

1.2 The objective of this program is to determine if a painting contractor has the personnel, organization, qualifications, procedures, knowledge, and capability of produce surface preparation and coating application of the required quality for complex structures.

1.3 The program encompasses the field application of coatings in the industrial market.

12. Qualification Procedure No. 2, "Standard Procedure For Evaluating The Qualifications Of Painting Contractors To Remove Hazardous Paint"

1. Scope

1.1 This document establishes a standard procedure for evaluating the qualifications of painting contractors to remove hazardous paint (e.g., containing lead or other hazardous metals) from industrial structures.

1.2 The requirements of this standard procedure are intended to supplement the general requirements of SSPC-QP 1, "Standard Procedure for Evaluating the Qualifications of Painting Contractors (Field Application to Complex Structures)."

APPENDIX C

Overview of Regulations Affecting Lead Paint Removal

HOW LEAD IS DEFINED AND REGULATED

The effects of lead in its various forms, such as dust particles and as a contaminant in water and soil, can have a widespread impact. Regulations are needed to protect workers who are removing the paint, the environment (including air, water, and soil), and the public (persons in schools, businesses, and residences). Currently no regulation forbids the use of lead on industrial structures or requires its removal.

OVERVIEW OF WASTE REGULATIONS

Solid waste can be any construction debris. If it contains or is suspected to contain any hazardous component, it must be tested to identify and quantify the hazardous constituent. This can be a complicated procedure; however, lack of attention to detail can have serious short-term and long-term consequences.

Relevant Parts of RCRA

RCRA hazardous waste regulations are found in 40 CFR Parts 260-268 (*1*). Part 260 contains the definitions of terms and an overview of information applicable to Parts 261-268. Part 261 identifies solid wastes subject to regulation as hazardous wastes. Part 262 describes standards that waste generators are required to follow. Generators are one of three key players. The others are the transporter and the treatment, storage, and disposal facility (TSD).

Part 263 contains requirements for transporters of hazardous waste. Generators should be familiar with the requirements, such as transport containers and placarding.

Parts 264-267 contain the requirements for treaters, storers, and disposers of hazardous waste. Some of these requirements, such as site security and training, have been enforced for lead paint removal projects.

Part 268 contains the land disposal restrictions. It identifies hazardous wastes that are restricted from land disposal and prohibits dilution as a substitute for treatment. It also contains the wording of certifications that must accompany each shipment of waste that has been treated by the generator. According to RCRA's Land Ban (*2*), hazardous wastes must be treated to become nonhazardous before they can be buried.

Definition of Hazardous Waste

EPA classifies solid waste as hazardous if:

a. It is specifically included on lists published by EPA (listed)

b. It meets any of these four criteria (known as characteristics) for ignitability, corrosivity, reactivity, or toxicity.

c. It is not specifically excluded as a hazardous waste by EPA.

Toxicity

A waste is toxic if, using the Toxicity Characteristics Leaching Procedure (TCLP), the extract contains the substance at a concentration equal to or greater than that listed. This is the reason lead waste is of concern. It often shows the characteristic of toxicity.

Currently there are eight metals regulated by RCRA. Lead and chromium are those most commonly found in paints.

Metal	*ID#*	*Threshold (mg/l)**
Arsenic	D004	5.0
Barium	D005	100.0
Cadmium	D006	1.0
Chromium	D007	5.0
Lead	D008	5.0
Mercury	D009	0.2
Selenium	D010	5.0
Silver	D011	20.0

*Same as ppm

Testing for Lead in Waste (TCLP)

The test method for determining the leachable lead level is called the Toxicity Characteristic Leaching Procedure (TCLP), Method 1311. It is found in Appendix II of 40 CFR 261. The test requires 105 grams of waste. However, quality control procedures require additional samples; therefore 400 to 500 grams should be the minimum sample size (about 1 lb).

Total Lead is Not Equal to Leachable Lead

It is important to understand that total lead concentration in a sample is different from leachable lead concentration. A total lead determination measures all the lead in the sample, irrespective of its source or chemical form. Leachable lead concentration is the amount that dissolves into the extraction fluid in the TCLP test.

There is no consistent correlation between the total lead in a paint film or waste sample and the leachable lead. Factors such as the chemical form of the lead compounds and surface area of the lead-containing particles affect leachability.

Owner and Contractor Considered Co-generators of Waste

EPA defines a generator as "any person, by site location, whose acts or processes produce a hazardous waste."

There is no doubt that the owner of the structure is the person whose action first causes the waste to be generated. This "action" may consist of hiring someone to remove the lead.

The EPA has recently clarified that painting contractors are co-generators of lead waste, along with structure or building owners (*3*).

Under the RCRA definition, a painting contractor is considered a generator of hazardous waste because it is the contractor's process that first causes a hazardous waste to become subject to regulation.

Spills and Releases: Applicability of CERCLA

The main purpose of CERCLA (the Comprehensive Environmental Response Compensation and Liability Act) (*4*) commonly known as "Superfund," is to clean up existing waste sites. It provides the criteria and funds (hence "Superfund") to accomplish this. These are sites considered to be the most damaging to the environment and to which the Superfund monies were allocated. CERCLA also describes procedures to prevent spills and releases of hazardous substances.

Reporting of Spills

Under CERCLA, any lead-containing waste spill of 44 kg (10 lbs) or more in a 24-hr period must be reported to the National Response Center as hazardous waste.

In practice, lead waste spills during paint removal operations are rarely, if ever, reported to the National Response Center. Normally, the spills are immediately cleaned up. CERCLA was never intended to address these types of activities. However, under RCRA, spills of any lead-containing waste, whether hazardous or not, are not permitted.

Releases from Landfills

The part of CERCLA that may be of greater concern is its applicability to releases from landfills. After lead waste is stabilized and buried in a landfill, the generator's obligations under RCRA are satisfied. However, in a few instances the lead may become destabilized (resolubilized) after a period of time (perhaps years) in the landfill. This may be due to a breakdown or reversal of the chemical reaction used to stabilize the lead or some other influence. If the lead solubility increases, it may be leached by groundwater, resulting in a significant contamination of the environment. Under CERCLA, the generator of the waste is still liable for cleanup and damages caused by the waste.

State Regulations on Hazardous Waste

Under RCRA, states must be at least as restrictive as the federal rule, but can be more stringent. Thorough review of state waste regulations and statutes is beyond the scope of this synthesis. In general, most states follow the federal rule fairly closely. Some areas where state regulations may differ include:

- Definition of special waste—Some states may have different regulations for wastes that are not considered hazardous by EPA but require special treatment by the state. Special wastes are regulated by total lead or leachable lead depending on the state.
- Certain states, including Maryland and New Jersey, have slightly different definitions of listed waste from the Federal EPA list, based on certain industries and conditions in the state.
- Examples from Maryland are PCBs, phthalate ester waste, and certain chemical warfare agents (*5*).

Some states (e.g., Illinois) define certain nonhazardous waste (e.g., all lead-containing waste) as special waste. These wastes may require special treatment, handling or manifesting beyond what is required for nonhazardous waste by the Federal EPA. These rules may result in increased cost for disposal of the waste. It may influence a state's decision whether to use one of the methods discussed below for rendering a waste nonhazardous.

- Zinc as hazardous waste—Presently, two states, California (*6*) and Michigan, regulate zinc as a hazardous waste. EPA has stated that it has no plans to regulate zinc as a hazardous waste.
- Limits on total lead—California also has established a limit of 1,000 ppm of total lead content in waste (*7*). This is in addition to the limit on leachable lead. The California leaching procedure is different from the TCLP test.
- Enforcement—The fines imposed by states may vary (see chapter 3). Also, there is a large difference in the manner and efficiency of enforcing the waste regulations within states (e.g., district to district) as well as among different states.

AIR QUALITY REGULATIONS

The regulations governing the Clean Air Act are found in 40 CFR Subchapter C, "Air Programs," encompassing Parts 50-99 (*8*). 40 CFR Part 50 addresses those regulations that might be associated with industrial lead paint removal. Those are commonly referred to as the National Ambient Air Quality Standards (NAAQS). "Ambient air" refers to the air the public is exposed to. It is distinguished from the air that workers breathe, which is regulated by OSHA.

Monitoring of Pollutants Under NAAQS

Six air pollutants are regulated under the original Clean Air Act of 1970. Two of these, lead and particulates, can be generated during surface preparation.

Monitoring for Particulates

40 CFR 50.6, "National Primary and Secondary Ambient Air Quality Standards for Particulate Matter," addresses restrictions on the amount of particulate matter that can be emitted from a source within a 24-hr period (see Reference 9 of Chapter 7). The particulate matter in this case is defined as particles 10 micrometers or less in aerodynamic diameter. This size represents the respirable fractions of particulate, is equivalent to about 0.5 mil, and is termed "PM-10." The criteria for particulate matter (PM-10) is 150 $\mu g/m^3$ as a 24-hr average.

Monitoring for Lead

Another section in 40 CFR 50 that might be imposed on lead paint removal projects is 40 CFR 50.12, "National Primary and Secondary Ambient Air Quality Standards for Lead" (*9*).

Monitoring for lead is based on collecting total suspended particulate (TSP). That is, all airborne emissions from the source are collected and analyzed, rather than only the dust that is 10 µm or less in size. The NAAQS criterion for lead is 1.5 $\mu g/m^3$ as an arithmetic mean averaged over a calendar quarter (90 days).

Air Monitoring on Lead Paint Removal Projects

When are the National Ambient Air Quality Standards imposed on lead paint removal projects? They are not automatically invoked. In fact, the use of such monitoring is the exception, rather than the rule. As the regulations are currently written, they address continuous monitoring of entire cities or regions to determine the overall air quality, as compared with the monitoring of individual, short-term projects such as paint removal.

Monitors are typically located near high public risk receptors such as schools and hospitals, in addition to general area monitors placed downwind from the project. Factors that are taken into account when locating monitors include: wind direction, location of adjacent obstacles, and height of structure. In summary, monitoring for bridge paint removal is primarily geared toward determining whether public health is being impacted, rather than toward achieving strict compliance with the NAAQS.

Monitoring Visible Emissions

Assessing visible emissions provides a rapid means for determining changes or breeches in containment systems on industrial lead paint removal projects. Visible emissions give immediate feedback, as opposed to TSP or PM-10 monitoring, where laboratory results take a minimum of 24 hrs once the laboratory receives the samples. However, this method does not meet the requirements of the NAAQS for particulate matter.

Methods for Assessing Visible Emissions

40 CFR 60, Appendix A, "Standards of Performance for New Stationary Sources," provides two methods for assessing visible emissions:

- Method 22 provides a means for assessing the length of time that emissions occur, regardless of opacity. This method assesses total fugitive emissions escaping containment, including paint chips, abrasive blast cleaning grit, and lead dust.
- Method 9 uses an opacity scale. This method is not widely used or recommended on paint removal projects. Additional details on this method can be found in the *Industrial Lead Paint Removal Handbook,* Chapter 7 (*9*).

SSPC Visible Emissions Criteria for Method 22

The SSPC Guide 6 presents various levels of visible emissions that could be specified (*10*):

- Level 0 Emissions—No visible emission
- Level 1 Emissions—Random emissions of a cumulative duration of no more than 1 percent of the workday
- Level 2 Emissions—Random emissions of a cumulative duration of no more than 5 percent of the workday
- Level 3 Emissions—No more than 10 percent of the workday
- Level 4 Emissions—Emissions are unrestricted and may occur at any time.

Complying with Soil Quality Regulations

Lead contamination of soil is a concern because of potential contact by the public and workers. Due to the effect of leaded gasoline, lead-containing traffic, house, or industrial paint, and other sources, the average soil in the United States has a lead content of 16 ppm. Along street, road, or highway right-of-ways, levels typically are 100 ppm or greater. Under bridges, lead levels may reach 1,000-2,000 ppm or greater.

At the present time there are no federal regulations regarding acceptable levels of lead in soil, cleanup criteria, or required methods of sampling and measurement. However, contract obligations may require cleanup (i.e., owner specification requires no net addition of lead to soil.) High levels of lead in soil could pose a health hazard to children or affect groundwater.

EPA is expected to issue a rule on lead in soil under Title X (discussed below), but no specific timetable has been set. Interim guidance was issued in 1994 (*11*). The recommendations for clean-up activities are defined by whether or not children use that area. Some examples of these types of areas include:

- Residential backyards
- Daycare and school yards
- Playgrounds
- Public parks.

Pre- and Post-Job Testing

It is recommended that contractors take pre- and post-job soil samples. The pre-job sampling will establish background levels. The post-job sample will determine to what extent the contractor's work increased the soil lead level. The contractor cannot be held responsible for an increase if it can be documented that the soil lead was high prior to beginning the job. The lead level in soil is highly variable, so proper interpretation of the data is critical.

COMPLYING WITH WATER QUALITY REGULATIONS

The regulations associated with the Clean Water Act are found in 40 CFR Subchapter D, "Water Programs" (see Reference 9 of Chapter 7). The Clean Water Act and associated regulations provide controls over the discharge of a pollutant

- into bodies of water;
- onto the ground, which could potentially be carried into a water supply;
- or into storm sewers.

Lead is one of the hazardous substances included in the Clean Water Act.

Permits for Discharge of Lead-Containing Debris

The Clean Water Act covers permits for discharging (dumping) debris into ground or surface water. Although such permits exist, water quality regulators will typically not issue one for lead paint removal projects. Therefore, the debris must be contained and not allowed to enter storm sewers or bodies of water.

Discharge of Lead-Containing Water into Sanitary Sewer

It may be possible to dispose of laundry wastewater, cleaning (equipment) water, hygiene (hand wash) water, and water from wet removal methods, such as water blasting, into the sanitary sewer. Sanitary sewer standards vary by locale, and are generally in the range of 1-10 ppm total lead. It may be necessary to filter the water to meet local standards.

Containing Surface Debris in Water

When working over bodies of water, some regulators or specifiers may require the containment of surface debris. Fine particulate from blasting of bridges or other structures will float on water. Generally, this fine particulate eventually sinks, however, it can float several hundred feet before starting to do so. Booms may be used to capture the floating debris. Floating debris primarily consists of paint chips, dust, and abrasive fines, as abrasives usually will sink, and, since lead particulates are denser than water, some paint will also sink. The booms must be carefully monitored to prevent their damage from floating refuse, strong currents, or degradation resulting from weathering or overloading with debris. Booms are only effective for slow-moving water. In addition, booms are not very effective when there are rocks or other obstructions within 150 mm (6 inches) of the surface or where there is boat traffic that causes significant wave action, since water movement affects stability (booms may not be permitted in navigable waters).

TITLE X: LEAD EXPOSURE REDUCTION ACT

The Lead Exposure Reduction Act (1992), commonly known as Title X, is an Act of Congress which added a Section 4 to the Toxic Substances Control Act (TSCA). This act requires OSHA and EPA to develop rules to prevent lead contamination of workers and the environment (*12*). The Act specifically mentions bridges and other steel structures as part of the scope.

EPA has a major charge under Title X to develop training, certification, and environmental compliance standards. The training and certification requirements of Title X are in Sections 402 and 404 of the Act. They require EPA to develop general training guidelines, model training programs, and criteria for the individual states to use to certify courses and workers through state accreditation plans. It is up to the states to implement the various training and certification programs, which include:

- The state must assure that individuals performing lead paint removal and abatement (i.e., supervisors and workers) are qualified. This may entail required training and certification.
- The state must certify and license firms to do lead paint abatement work.

In August 1996, a final rule was published two and a half years beyond the deadline imposed by Congress (*13*). This rule applies only to target housing and public buildings frequented by young children. In May 1997, EPA initiated development of a new rule pertaining to industrial structures (*14, 15*). This rule is expected to be proposed in 1998 and finalized in 1999. However, several states have enacted standards for deleading of steel structures (e.g., New Jersey, Virginia, Maryland, and Missouri).

ANTICIPATED AND PROPOSED NEW REGULATIONS

Disposal of Residential Construction Debris

EPA is expected to propose a rule for disposing of residential construction debris in the spring of 1997. This would exempt debris such as doors and windows from being disposed under RCRA at a subtitle C (hazardous) landfill. Instead, EPA would define special "construction and demolition" landfills. The leaching is expected to be much slower at a construction demolition site than at a subtitle C landfill. This regulation is not expected to have a significant impact on debris generated from bridges, as it is not likely that EPA would also propose special such landfills for these industries.

The estimated cost for disposal at these sites is $6 to $50 per Mg (ton), which is on the order of one-tenth the cost of disposal at a subtitle C landfill.

Proposed Rule on Reducing Treatment Standard for Lead

In August 1995, EPA proposed lowering the treatment standards (i.e., making the standards more stringent) for lead from 5 mg/l to 0.37 mg/l, a greater than 90 percent reduction (*16*). This would not lower the level at which leachable lead is defined as a hazardous waste. It would remain at 5 mg/l. Thus, waste that initially leaches lead at less than 5 mg/l would not require further treatment and would be considered nonhazardous. However, waste that initially had a leachable lead content of 5 mg/l or greater would need to be treated until the leachable level was reduced to 0.37 mg/l or less.

This regulation could have the following impact if promulgated as proposed:

- The cost for treating lead-containing waste would be increased slightly. Waste streams with very high lead concentrations might require more costly treatments or multiple treatments to reduce them to the level of the lower concentration. From a survey of waste disposal firms, as part of this synthesis, the estimated increase in cost is 10 to 30 percent.
- There might be an added incentive to use materials that produce a nonhazardous waste initially. Such processes include proprietary calcium silicate additives and metallic recyclable abrasives (see chapter 3).

Proposed Rule on Limiting Use of Iron and Steel Additives

In March of 1995, EPA proposed banning the use of iron to stabilize lead waste from foundries (*17*). This rule was directed at foundries, which typically use iron filings to cause lead-contaminated sand to test as nonhazardous waste. However, depending on the exact language and interpretation of the rule, it could impact the use of recyclable steel grit, for example, by requiring contractors to handle the grit as a hazardous waste during the recycling process. This reinforces the need to ensure that the residues are disposed of as a hazardous waste.

To reduce potential risks to the environment and the public, SSPC has recommended that the EPA include language in its proposal to require that such waste be disposed of as hazardous waste (paint chips, debris, and abrasive fines).

SSPC has also proposed a modification to the TCLP test. It suggests that metallic iron be removed from lead-containing debris before running the test. This would prevent the "masking" of the test by the reaction between metallic iron and lead.

WORKER SAFETY AND HEALTH REGULATIONS

OSHA Lead Standards

The Lead in Construction Standard (29 CFR 1926.62) (*18*) applies to all work, including construction, alteration, repair, painting, and decorating, that is not covered by the General Industry Standard for Lead, 29 CFR 1910.1025 (*19*). The standard specifically states that it is applicable to: demolition or salvage of structures where lead-containing materials are present; removal or encapsulation of materials containing lead; new construction, alteration, or renovation of structures with lead-containing materials present; installation of products containing lead; cleanup of lead contamination; transportation, storage, or containment of lead or materials containing lead at the site; and maintenance operations associated with any of the above construction activities. Some of the basic requirements of this standard are described next.

Definitions

Competent person: A person who is capable of identifying hazards and has authorization to take corrective measures to eliminate them.

Action level: Employee exposure, without regard to the use of respirators, to an airborne concentration of lead of 30 micrograms per cubic meter (30 $\mu g/m^3$) of air as a time-weighted average over an 8-hour period. Exposure monitoring done at the start of the job establishing exposures in excess of 30 $\mu g/m^3$ will trigger certain provisions of the standard. Specifically, medical surveillance, training and information, and periodic exposure monitoring are required.

Permissible exposure limit (PEL): The PEL for lead in construction is defined as 50 $\mu g/m^3$ as a time-weighted average over an 8-hour period. It is the employer's responsibility to ensure that no employee is exposed to lead at concentrations greater than the PEL. If airborne exposures exceed the PEL, the employer must implement all aspects of the comprehensive health standard, including engineering controls, personal protective equipment, and personal hygiene facilities. These would be in addition to those requirements triggered when exposures exceed the action level.

Exposure Assessment

Employers are responsible for determining employee exposure levels to lead by personal air monitoring if there is a potential for worker exposures to lead to exceed the action level.

Initial determinations: For initial determinations, the employer must monitor at least a representative sample of the exposed employees who reasonably are expected to have the greatest airborne exposures to lead.

Presumed exposure: The standard includes special provisions for the protection of employees performing selected high-hazard tasks during the period of time that the initial monitoring of the exposures is undertaken. Until monitoring can be initially performed to document employee exposure levels, the employer shall treat the employee as if the employee were exposed above the PEL and shall implement employee protective measures (protection of employees during assessment of exposure). Historical data cannot be used in lieu of initial monitoring for those high-hazard tasks presumed to result in elevated exposures.

Methods of Compliance

OSHA has specified that a hierarchy of controls are to be implemented when worker exposure to airborne concentration of lead exceeds the PEL. The employer is required to implement engineering and work practice controls, including administrative controls, to reduce and maintain employee exposure to lead at or below the PEL. The standard indicates that these steps shall be taken to the extent that such controls are feasible. OSHA states that after all feasible engineering and work practice controls have been instituted, if the employee exposure is still above the PEL, then respiratory protection is used as described in Paragraph (f) to ensure proper protection of the employee.

The employer is required to establish and implement a written compliance program prior to the commencement of any project where any employee may be occupationally exposed to lead above the PEL.

Respiratory Protection

Even with well-designed ventilation systems in a containment in which abrasive blast cleaning is occurring, workers will always be required to wear respiratory protective equipment. Beyond this, however, it is likely that workers will be required to wear respirators when using other lead removal techniques, such as power or hand tool cleaning and vacuum blasting, due to the very low levels of exposure required to trigger mandatory use (50 $\mu g/m^3$). It is also likely that most support personnel may be required to wear respirators in order to meet the PEL.

Protective Work Clothing and Equipment

Where an employee is exposed to lead above the PEL without regard to the use of respirators, the employer shall provide, at no cost to the employee (and assure that the employee uses), appropriate protective work clothing and equipment that prevents contamination of the employee and the employee's garments.

Housekeeping

The standard requires that all surfaces be maintained as free as practicable of accumulations of lead. It also requires that floors and other surfaces where lead accumulates be cleaned, when possible, by vacuum or other methods that minimize the likelihood of the lead becoming airborne.

Hygiene Facilities and Practices

Clean change areas must be provided for employees whose airborne exposure is above the PEL. Change areas are also required for employees performing the presumed exposure tasks while the exposure monitoring is underway (e.g., power tool cleaning, moving containment, etc.). Showers are required, where feasible, for use by employees whose airborne exposure to lead is above the PEL.

Medical Surveillance

The medical surveillance provisions comprise two parts: periodic biological (blood) monitoring and medical examinations.

Initial and periodic blood monitoring: Initial medical surveillance must be made available to employees who are exposed on any day to lead at or above the action level.

Frequency of testing: For each employee exposed at or above the action level for more than 30 days in any consecutive 12 months, blood lead and zinc protoporphyrin (ZPP) level testing shall be made available at least every 2 months for the first 6 months of exposure, and every 6 months thereafter.

Medical examinations: Medical examinations and consultations must be made available for employees exposed to lead at or above the action level for more than 30 days in any consecutive 12 months and has a blood lead level at or above 40 µg/dl, anyone showing signs or symptoms of lead intoxication or is concerned about their ability to procreate a healthy child.

Medical Removal Protection

Employees having been exposed to lead at or above the action level must be removed from work under the following conditions:

- A single blood test and a follow-up test conducted within 2 weeks of receiving the results of the first test are at or above 50 µg/dl. Note: The employee must be allowed to return to former job status when two consecutive blood tests indicate a blood lead level at or below 40 µg/dl. (During the medical removal period, blood tests are required at least monthly.)
- A final medical determination (a written medical opinion by the examining physician or the outcome of multiple physician review) results in a medical finding, determination, or opinion that the employee has a detected medical condition that increases the risk of material impairment to health due to exposure to lead.

On each occasion that the employee is removed from exposure to lead, the employer shall provide the employee up to 18 months of medical removal protection benefits or for the duration of the job or employment, whichever is less.

Employee Information and Training

At a minimum, the employer shall communicate information concerning lead hazards. The employer shall provide the training program as initial training prior to the time of job assignment. The employer shall also provide the training program at least annually for each employee subject to lead exposure at or above the action level on any day.

Training must consist of the following:

- Contents of OSHA standard
- Exposure-producing operations
- Respiratory protection plan
- Medical surveillance program
- Engineering and work practice controls
- Written compliance program
- Instructions on chelating agents.

An EPA-sponsored project discusses the typical and minimum recommended times required to present this training (*20*).

Recordkeeping

As with all other comprehensive OSHA standards, employers are responsible for establishing and maintaining accurate records of all monitoring and medical data. In general, exposure monitoring data must be maintained for 30 years. All medical surveillance records must be maintained for the duration of employment plus 30 years.

Observation of Monitoring

The final requirement of the construction industry standard on lead requires that employers provide affected employees or their designated representatives an opportunity to observe any monitoring of employee exposure to lead.

Compliance Directive for Lead

On December 13, 1993, OSHA issued its Lead in Construction Compliance Directive, CPL 2-2.58 (*22*). While the purpose of this directive is to provide uniform inspection and compliance guidance to OSHA Compliance Safety and Health Officers (CSHO), the directive also provides additional information and clarification of the standard. In particular, the directive provides information concerning the duties and responsibilities of competent persons. The Directive also covers inspections and citation policies, the computation of worker exposure to lead, guidelines on wipe samples, the relationship of blood lead levels to employer's actions, and a concise summary of the standard itself.

Special Emphasis Program on Lead

On March 11, 1996, Joseph A. Dear, Assistant Secretary of Labor, announced the implementation of OSHA Instruction CPL 2.105 (*22*). The purpose of this compliance directive is to target guidance for implementing an OSHA-wide Special Emphasis Program (SEP) for programmed health inspections of lead in construction operations. Many painting contractors have reported having these inspections during the 1996 construction season.

Key Points of OSHA's Special Emphasis Program on Lead

- Area or regional OSHA offices shall attempt to obtain blood lead data where possible. Employers with worker blood lead levels above 40 µg/dl shall be targeted for inspection.
- All compliance personnel shall be instructed to be on the lookout for construction activities where there is a potential for exposure to lead. Whenever a Compliance Safety and Health Officer (CSHO) observes or receives information, regardless of whether or not a violation is observed, the CSHO documents information concerning the work site and provides this information to the area office supervisor or area director. Based on the information provided, through informal complaints, referrals, reports from members of the general public, and so forth, all potential lead in construction work sites brought to the attention of the area office shall be inspected.
- Reports of imminent danger, fatality/catastrophe reports, formal/informal complaints, safety and health referrals from other federal, state, county, and city agencies, media reports, reports from physicians, hospitals, or medical clinics, and reports from the general public shall be investigated/inspected by the area office.
- Area OSHA offices are encouraged to develop a list of construction contractors under their jurisdiction likely to be involved in lead-related activities.
- Inspectors are instructed to address all aspects of any potential lead work or exposure including a review of all written documentation.
- If a contractor does not have an active site, OSHA may elect to review the contractor's records.
- CSHOs shall conduct personal monitoring and wipe samples as appropriate to document exposures.
- While evaluating exposures to lead, CSHOs will also need to be aware of and evaluate potential exposures to other metals including, but not limited to, arsenic, manganese, chromium, cadmium, copper, and magnesium.

OTHER HEALTH AND SAFETY REGULATIONS

Contractors performing lead paint removal on bridges are also subject to various other safety and health standards. These include:

- Fall protection (working on scaffolds and ladders)
- Hazard communication (working with hazardous chemicals, such as paint strippers, paint solvents, and abrasives)
- Fire hazards (solvents and other flammables).

Detailed descriptions of the hazards or standards is beyond the scope of this synthesis. Consult texts for further information (*9, 23*).

APPENDIX C REFERENCES

1. Resource Conservation and Recovery Act (RCRA), Public Law 94-580 (October 21, 1976).
2. "Land Ban Rule to Affect Disposal of Hazardous Waste from Blasting Operations," Regulation News, *Journal of Protective Coatings and Linings* (April 1990) p. 33.
3. Appleman, B., "A summary of EPA Rule on Certification and Training for Residential Deleading," *Compliance* 96/5 (1996) p. 1.
4. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Public Law 96-510 (1980).
5. Maryland Supplement to *C-3, Supervisor/Competent Person Training for Deleading of Industrial Structures*, SSPC, Pittsburgh, Pennsylvania (1996).
6. California State Senate Bill 1063, Chapter 437 (September 11, 1996).
7. California Administrative Code of Environmental Health, Title 22, Division 4.
8. Clean Air Act (CAA), Public Law 91-604 (December 31, 1970).
9. Trimber, K. A., *Industrial Lead Paint Removal Handbook, 2nd Edition,* KTA-Tator, Inc., Pittsburgh, Pennsylvania (1993).
10. "SSPC Guide 6, Guide for Containing Debris Generated During Paint Removal Operations," in *Systems and Specifications, Steel Structures Painting Manual, Volume 2,* SSPC, Pittsburgh, Pennsylvania (1995).
11. Appleman, B., "EPA Issues Guidance Document on Lead Contaminated Soil," *Pb, SSPC's Lead Paint Bulletin* (May 1994) p. 3.
12. *The Residential Lead-Based Paint Hazard Reduction Act of 1992* ("Title X"), Section 402 and 404 of the Toxic Substances Control Act, or TSCA (Public Law 15 U.S.C. 2682 and 2684).
13. 40 CFR Part 745, Lead; Requirements for Lead-Based Paint Activities in Target Housing and Child-Occupied Facilities; Final Rule, *Federal Register* (August 29, 1996) p. 45798.
14. "EPA Promises New Industrial Rule," *Journal of Protective Coatings & Linings,* Vol. 14, No. 6 (1997) p. 23.
15. "Industrial Lead Training Reg. Delayed," *Journal of Protective Coatings and Linings* (October 1996) p. 33.
16. "EPA Proposes Reduced Treatment Standards for Lead, Other Wastes," *Journal of Protective Coatings & Linings,* Vol. 12, No. 10 (1995) p. 23.
17. "EPA Proposes Ban on Iron Filings," *Journal of Protective Coatings & Linings,* Vol. 12, No. 7 (1995) pp. 25-27.
18. 29 CFR Part 1926.62, Lead Exposure in Construction, Interim Final Rule, *Federal Register,* Occupational Safety and Health Administration, Department of Labor (May 4, 1993).
19. 29 CFR Part 1910.1025, *Lead Standard for General Industry,* Occupational Safety and Health Administration, Department of Labor (1978).
20. Appleman, B. et al., *Training of Industrial Deleading Workers: Implementation, Assessment, and Recommendations,* SSPC Report 96-98, Pittsburgh, Pennsylvania (1996).
21. OSHA, Lead in Construction Compliance Directive, CPL 2-2.58 (December 1993).
22. OSHA, Instruction CPL 2.105 (March 1996).
23. Appleman, B., "Environmental Regulations Affecting Protective Coatings," Chapter 27.0 of "Good Painting Practice," Vol. 1 of *Steel Structures Painting Manual*, SSPC, Pittsburgh, Pennsylvania (1993).

APPENDIX D

Lead Exposures During Coating Removal or Other Operations

INTRODUCTION

Construction operations involving structures coated with lead-containing paint may create hazardous exposures for workers, people in the area, and the environment. These exposures can arise from removal of the paint or from structural modifications that disturb it. The lead contact may be in the form of paint dust, flakes, or vapors resulting from heating. Specific methods used in these general operations are described, along with the resultant exposures of air-borne lead and control methods for its reduction or containment.

BACKGROUND

The extent of lead exposure during construction or maintenance operations involving lead-containing paint is related to the nature of construction operations, the measures taken to reduce air-borne lead exposure, and the lead content in the paint being disturbed. In addition, the properties (e.g., hard and brittle or soft and flexible) and condition (e.g., tightly bonded or loose and peeling) of the existing coating and the method of removal will affect its rate of removal and consequently the total amount of contamination and the portion that is airborne.

OSHA requires controls be taken to protect workers from lead exposures that exceed the action level (30 $\mu g/m^3$) and to prevent elevated blood lead levels (*1*). The Preamble to the Lead in Construction Standard (*2*) provides a complete listing of expected lead exposure levels associated with different construction operations on structures coated with lead-containing paint. Data associated with a few operations of special interest are listed in Table D-1.

Obviously, it is difficult to compare air-borne lead measurements taken at different construction sites, because of wide variations in lead content and condition of the existing paints and method of measurement. For some activities, because of insufficient exposure data, OSHA did not establish a presumed level of exposure in the standard. More recently published exposure data (after the OSHA 1993 data) associated with different methods of coating removal will be cited in conjunction with descriptions of these methods.

TABLE D-1.
Typical and Maximum Lead Exposures (in $\mu g/m^3$) Associated with Selected Construction Operations

Construction Operation	*Typical*	*Maximum*
Open abrasive blasting	17,300	59,000
Contained blasting	25,700	59,000
Welding/cutting/burning	600	28,000
Hand scraping	45	167
Chemical stripping	11	476
Power tool use	735	20,600
Enclosure movement	500	2,100
Miscellaneous rehabilitation	45	41,000

EXPOSURE CONTROLS

OSHA recognizes several general methods of minimizing worker exposure to lead: engineering controls, work practice controls, and personal protective equipment such as respirators. Each of these general methods of exposure control will be discussed.

Engineering Controls

Engineering controls involve processes or equipment that eliminate or significantly reduce the amount of contamination. In lead paint removal, this might entail the use of wet instead of dry abrasive blasting to greatly reduce the amount of particulate dust.

Work Practice Controls

Work practice controls are work procedures instituted to minimize the time or level of exposure. Typical examples are:

- Good housekeeping
- Personal hygiene
- Scheduled inspection of process and control equipment
- Work procedures minimizing dust generation
- Monitoring of work practices by supervisors
- Management of workers' schedules/assignments.

Environmental Controls

Environmental controls are measures taken to prevent contamination from extending outside the contained work area to create air, water, or soil pollution. These include containment structures for work areas (e.g., tarpaulins) or support devices for tools (e.g., vacuum lines). This is also discussed in Appendix E "Overview of Containment Methods and Practices."

Controls Using Respirators

When proper use of engineering, work practice, and environmental controls cannot reduce the lead exposure to the PEL, the Lead Standard requires employers to institute an appropriate respirator protection program. Available data indicate that the requirement for such programs is much greater in construction than most other industries.

ABRASIVE BLAST CLEANING

Cleaning with air-borne abrasives has historically been the preferred method of removal of existing coatings for repainting because it is cost effective and produces a clean, textured surface suitable for repainting. However, it produces dust that is hazardous to workers, other people in the area, and the environment. Thus, several alternatives to uncontrolled abrasive blasting have been developed:

- Open, dry abrasive blasting inside containment with disposable abrasives
- Open, dry abrasive blasting inside containment with recyclable abrasives
- Vacuum blasting
- Wet abrasive blasting.

It should be noted that although abrasive blasting produces more dust than other methods of coating removal (see Table D-1), its efficiency in complete coating removal and its high production rate greatly reduce the removal time and thus the worker exposure time for that project.

Open, Dry Abrasive Blasting

Exposure with Disposable Abrasive

Open (uncontrolled) dry abrasive (Figure D-1) blasting is the most dust-producing method of blast cleaning, creating air-borne lead levels as high as 59 000 μg/m^3. It could, however, be much lower, depending on the condition and type of paint, nozzle pressure, and air movement. The OSHA Standard indicates that, until otherwise determined by monitoring, air-borne levels greater than 2500 μg/m^3 should be anticipated.

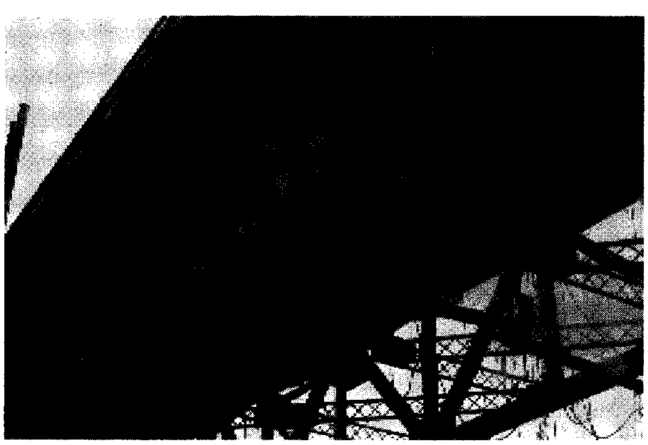


FIGURE D-1 Open abrasive blasting on bridge.

Measurement Issues

Concern has been expressed about the validity and suitability of the NIOSH method for determining the lead exposure in the worker's breathing zone. At high dust levels, such as produced during abrasive blasting, the cassettes become loaded very quickly (*3*), so if they are allowed to remain for 7 hours the dust levels recorded may not reflect the true level of exposure. The exact placement of the cassette is also a factor. Several experiments have been done in which the worker was fitted with two cassettes (on the left and right sides) (*3,4*). Significant differences were observed depending on the worker's particular manner of blasting. A related issue is the impact of the particle size, because the size affects the extent of penetration into the worker's lungs, the time for the particles to settle, and the extent to which they can be filtered.

Controls

Containment systems must be well designed, installed, and maintained for structural integrity, to prevent the dust and heavier debris from getting outside the work area, and for effective ventilation. The blasting operation creates a hazardous working environment for workers that requires respirators and other personal protective equipment and practices.

Open, Dry Abrasive Blasting with Recyclable Abrasives (In Containment)

Exposure

Although blasting with dry, recyclable abrasives such as steel grit or shot reduces the total amount of waste generated (spent abrasive plus existing paint, rust, etc.), it does not reduce the amount of lead dust in the air. Indeed, unless the lead in the spent abrasive is efficiently removed from the recycled abrasive in the cleaning process, some of it can recontaminate the air. It is noted, however, that recyclable abrasives often have fewer break-down (dusting) characteristics than other, expendable abrasives, which may improve visibility.

Controls

Controls used with open abrasive blasting with recyclable abrasive are similar to those for open, dry abrasive blasting without abrasive recycling. A tighter system is often designed to facilitate collecting abrasives for recycling.

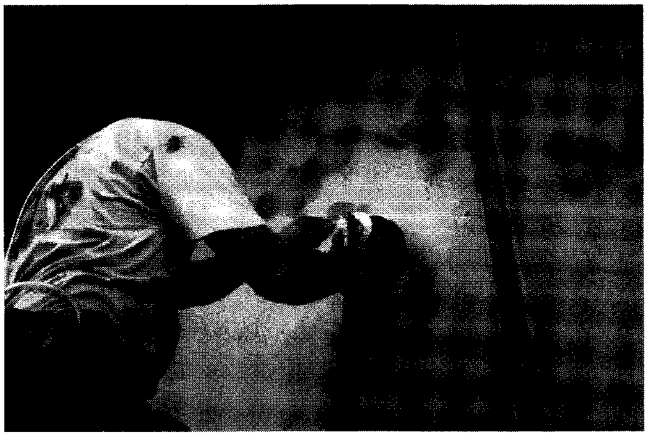


FIGURE D-2 Vacuum blasting.

FIGURE D-3 Wet abrasive blasting.

Vacuum Blasting

Exposure

Vacuum blasting equipment (Figure D-2) utilizes a shroud attached to a vacuum line to enclose the blast nozzle. This can be very effective in containing blasting dust and debris, especially on flat surfaces. Effective containment can be more difficult on irregular surfaces. This method is relatively slow and costly, although the abrasive is usually recycled.

Despite the great reduction of pollution, vacuum blasting may produce an air-borne lead content that exceeds the PEL. OSHA indicates a presumed exposure level of 50 to 500 μg/m^3, until monitoring indicates otherwise.

A recent NIOSH study (*5*) investigated vacuum blasting to remove lead-containing (14 percent to 20 percent lead) coating 6 inches from each side of iron work prior to torch cutting. Air monitoring indicated that lead levels in PBZ (personal breathing zones) for vacuum blasters ranged between 27 and 76 μg/m^3, with a median of 55. This is a reduction of more than 99 percent from the typical 17 300 μg/m^3 reported for open abrasive blasting (see Table D-1). Unfortunately, productivity was reduced by 90 percent compared to open abrasive blasting.

Controls

As might be expected, controls are usually much less stringent for vacuum blasting than for open abrasive blasting. Because there is always some debris not captured by the vacuum, ground covers are necessary.

Wet Abrasive Blasting

Exposure

In wet abrasive blasting, the water combined with the abrasive greatly reduces the dusting (Figure D-3). However, exposures can exceed the PEL. From limited data, OSHA has reported values of air-borne lead exposure as low as 2 μg/m^3 and as high as 660 μg/m^3, with an average of 170 μg/m^3.

A more recent bridge investigation (*6*) conducted by the Pennsylvania Department of Transportation selectively removed a marginally adherent finish coat from bridges. PBZ levels for lead of 1,684 μg/m^3 and 7,142 μg/m^3 were reported for wet abrasive blasters. Obviously, these levels vary greatly with the effectiveness of the water in containing the dust.

Controls

Despite the greatly reduced dusting, an enclosure, including a ground cover for collection of wet debris, is necessary. In some cases, controlled ventilation and filtration may be necessary. Wet debris is more difficult to remove from the surface and to handle. Also, the wet debris on the scaffolding and other walking surfaces is slippery and presents a fall hazard.

Water-Cleaning Methods

Water-cleaning methods for removal of coatings include the following systems:

- Water washing (below 35 MPa or 5,000 psi)
- Water cleaning (pressures between 35 MPa and 70 MPa or 5,000 psi and 10,000 psi)
- High pressure water-jetting (pressures between 70 MPa and 175 MPa or 10,000 psi and 25,000 psi)
- Ultra-high pressure water jetting (greater than 175 MPa or 25,000 psi).

Water washing is used mainly to remove dirt, grime, chalk, and water soluble contaminants. Loose paint may also be removed by water washing and water cleaning. It is widely used as a preliminary cleaning prior to mechanical cleaning of bridges (see chapter 4).

High pressure and ultra-high pressure water jetting are used to remove existing coatings and rust. Ultra-high pressure water jetting has combined advantages of a high coating removal rate and a low rate of generation of air-borne lead exposure. Injection of abrasive into the water stream may significantly accelerate the rate of coating removal, as well as impart a surface profile to metals that will enhance adhesion of coatings.

Exposure

Very little dust is produced by any water-cleaning method. In the Pennsylvania DOT investigation (*6*), monitoring of air-borne lead inside containment was conducted where paint was being removed by 280 MPa (40,000 psi) water jetting. Lead exposure levels here were below 10 μg/m^3. Although this is quite low, in rare cases, the PEL may be exceeded in the PBZ of water jetters.

Controls

Containment is required for collection of water and debris, but it does not have to be airtight except in very sensitive areas.

Alternative Blasting Methods

Because of the high levels of dust generated during abrasive blasting, several alternative approaches using novel blasting techniques have been developed. Much fewer field data have been obtained on the air-borne lead exposure levels developed during their use than with the more conventional methods described earlier, and OSHA has not published any exposure levels.

Sodium Bicarbonate Blasting

Sodium bicarbonate has been effectively used as an abrasive in blast cleaning. It can be propelled by high-pressure air or high-pressure (21 MPa or 3,000 psi) water. When propelled by air, a blast pot is used, as in conventional abrasive blasting. Often, water is introduced at the nozzle to reduce dusting and rinse the surface. When propelled by water, it is introduced into the blast stream at the nozzle. Sodium bicarbonate is a soft abrasive and will not remove tight rust or mill scale or roughen the surface.

Exposure: In the air-propelled mode, there is still significant dusting, and the air-borne lead exposure level must be assumed to be 2500 μg/m^3 until monitoring indicates otherwise. In the water-borne mode, there is much less dusting, but in some cases, the PEL may be exceeded.

Control: Containment requirements for the air-propelled mode are much like those of wet abrasive blasting. Those for the water-borne mode are much less; it is necessary, however, to use tarpaulins to collect the water and dispose of it properly.

Sponge Jetting

In sponge jetting, polyurethane sponge particles approximately 3 to 6 mm (1/8 to 1/4 inch) in diameter are propelled onto surfaces to be cleaned. In order to remove existing coatings, the sponge particles are formed around an abrasive such as staurolite, garnet, or steel grit. The sponge may be recycled five to ten times.

Exposure: Dusting from sponge jetting can be much lower than that of conventional abrasive blasting, because the sponge cells depress the dust and the paint chips come off in larger pieces. In the Pennsylvania DOT investigation (the level of lead in paint was about 15 percent by volume), PBZ lead levels of 2800 μg/m^3 and 2072 μg/m^3 were reported for sponge jetters (ref. D-6). Dampening the sponge will reduce dusting further, but the PEL may still be exceeded.

Control: Screens and tarps, together with ground covers, are necessary to isolate the work area and allow for collection of the abrasive and blasting debris. In some cases, ventilation and filtration of exhaust air may be required.

Other Alternative Abrasives

Several other alternative abrasives have been developed that to date have found limited use in paint removal. Relatively soft abrasives such as plastics and pelletized dry ice have been successfully used on soft metals such as aluminum on aircraft. Fine ice particles have also been investigated. In the Pennsylvania DOT investigation (*6*), PBZ lead values of 173 μg/m^3 and 25 μg/m^3 were obtained for ice blasters. Similar values were obtained when chemical stripping preceded the ice blasting. Ice blasting has a very low coating removal rate.

HAND AND POWER TOOL METHODS OF COATING REMOVAL

Mechanical removal of coatings is accomplished using hand or power tools. Both methods use similar tools (e.g., brushes, sanders, etc.), but power tools are generally preferred because they provide faster, less-costly removal. Hand tools only remove loose materials. Power tools can be used either to remove only loose materials or totally remove the coating and rust. However, both are relatively slow compared to abrasive blast cleaning.

Hand Tool Removal of Coatings

Exposure

Hand tools generate only a limited amount of dust. However, the Lead Standard indicates that, until worker exposures have been determined by monitoring, air-borne lead exposures up to 500 μg/m^3 should be anticipated.

Controls

Containment requirements may be satisfied using a ground cover and a few vertical tarps. Vacuum hoses may be secured to hand tools for use on structures such as towers where tarp containment is not feasible.

Power Tool Removal of Coatings

Exposure

Because power tools impart greater forces than hand tools, they generate more dust. The Lead Standard indicates that, until worker monitoring indicates otherwise, air-borne lead exposure levels of 2500 μg/m^3 should be anticipated. However, OSHA has documented levels as high as 20 000 μg/m^3. For shrouded power tools with dust collection systems (Figure D-4), the Lead Standard indicates that air-borne lead levels of up to 500 μg/m^3 should be anticipated.

In a later NIOSH investigation (*7*), effects of different methods of mechanical cleaning using unshrouded tools on air-borne lead exposure levels were investigated on two bridges (Figure D-5). Lead content by weight of the intact paint on both bridges was 30 percent, as compared to an average of 16 percent for deteriorated paint. The test results are summarized in Table D-2.

It can be seen from this table that *a*) much more air-borne lead resulted from power wire brushing than from pneumatic hammering or scraping and *b*) the PEL may be exceeded by each of these methods. It was hypothesized, however, that much of the air-borne lead to which the scraper and hammer operator were exposed resulted from power wire brushing in an adjacent area. Shrouding of the power tools would have greatly reduced the dusting.

Controls

OSHA recommends using shrouded power tools to reduce worker exposure at the point of dust and debris generation.

FIGURE D-5 Shrouded power tool cleaning.

Some agencies have established criteria for the air capacity (in cmm (CFM)) and extent of vacuum (in mm (in.)) of water (see chapter 4). Side screens or tarps and ground covers are usually adequate for containment. In rare cases, however, controlled ventilation and filtration may be necessary with shrouded tools.

CHEMICAL STRIPPING

Chemical stripping of coatings involves applying chemicals to them, allowing time for interaction, and scraping or washing away the softened material (Figure D-6). Caustic chemicals are most effective on oil-based coatings, and solvent blends are most effective on lacquers and water-borne latex products. Coatings that cure by chemical reaction of components (e.g., epoxies) are more difficult to strip.

Chemical stripping frequently does not completely remove the coating in one application, so that an additional application or some other method may have to follow the original application for complete coating removal. However, chemical stripping, followed by abrasive blasting, has been shown (*8*) to cut the time of abrasive blasting in half.

FIGURE D-4 Unshrouded power tool cleaning.

TABLE D-2.
Air-Borne Lead Concentrations from Mechanical Removal of Coatings

Removal Method	*Bridge Number*	*Lead Concentration (μg/m^3)*
Power wire brush	1	2,500
	2	5,200
Pneumatic hammer	1	190
	2	220
Scraping	1	57
Hand scraping and	1	18
painting, operator 1	2	100
Hand scraping and	1	250
painting, operator 2	2	440

FIGURE D-6 Chemical stripping.

Exposure

Air-borne exposure of lead-containing dust during chemical stripping is minimal (typically less than 10 μg/m^3), although, in some instances, the action level (30 μg/m^3) has been excluded. Thus, OSHA does not expect the PEL to be exceeded. Hazards to workers are more associated with caustic chemicals and toxic solvents. However, initial monitoring for lead is still required.

A NIOSH investigation (*8*) was conducted on the effect of stripping of lead-containing paint from a bridge on air-borne lead exposures. An alkaline paste stripper was applied by spray, allowed to react with the coating overnight, and then removed along with the softened coating by scraping. The surfaces were then abrasive blasted to remove all remaining coating. In some instances, the stripped surfaces were rinsed with water before abrasive blasting. During application of the stripper, air-borne lead levels inside the containment averaged 3 μg/m^3. The exposure levels for the individuals performing the scraping were 18, 20, and 41 μg/m^3. The exposure level for the person performing the rinse was 18 μg/m^3.

Data from an FHWA research project (*9*) indicate that the PEL may be exceeded during chemical stripping. Levels of air-borne lead during subsequent abrasive blasting after stripping are shown in Table D-3. (It can be seen from this table that exposure levels were well below the PEL.)

Table D-3 shows that lead levels during abrasive blasting after stripping were about one-third of those typical of open abrasive blasting (see Table D-1). Water rinsing after stripping tended to lower levels further. The caustic stripping had deteriorated the residual paint so that it was more rapidly removed by the blasting. Although the combined time of stripping and blasting was essentially the same as the time required for blasting without stripping, stripping cuts in half the time of worker exposure to the high lead levels resulting from blasting.

TABLE D-3.
Air-Borne Lead Concentrations During Blasting After Chemical Stripping (μg/m^3)

Worker	*After water rinsing*		*Without water rinsing*	
Blaster I	550	3,400	5,800	5,000
Blaster II	6,500	3,300	5,000	—
Equipment operator	70	—	40	10

Controls

Dust-tight containment is not required if chemical stripping is not followed by abrasive blasting. The stripper debris and wash water, however, must be contained. Thus, ground covers must be in place to collect spill and splash. Vertical tarpaulins may be required on windy days. Wet-vacuum systems are available for rinsing and removal of stripping debris. For small areas, drop cloths, rubber gloves, and a collection bucket may be adequate.

HEATING PROCESSES

There are several construction processes involving heating for removing existing coatings or for modifying existing structures that may generate air-borne lead exposure levels.

Welding

Welding of metals produces temperatures as high as 1500°C (2,800 °F). Lead in coatings will begin to vaporize at 300°C (600 °F).

Exposure

OSHA estimates that lead exposure levels up to 30 000 μg/m^3 can be produced during welding operations. OSHA has issued a presumed exposure level in excess of 2500 μg/m^3 for these operations, or 50 times the PEL.

Controls

Conventional welding helmets are designed for protection from normal welding operations and do not meet the OSHA/NIOSH criteria for protection from lead. Only OSHA/NIOSH helmets approved for this use are effective for protection during welding operations where lead-containing paint is involved. Long welding rods will permit the worker to be further away from the source of fumes.

Torch Cutting (Burning)

Torch cutting temperatures are similar to those of welding and consequently also high enough to vaporize lead. Torch cutting is much more prevalent on lead-coated structures than welding and so constitutes a bigger problem in modifying and

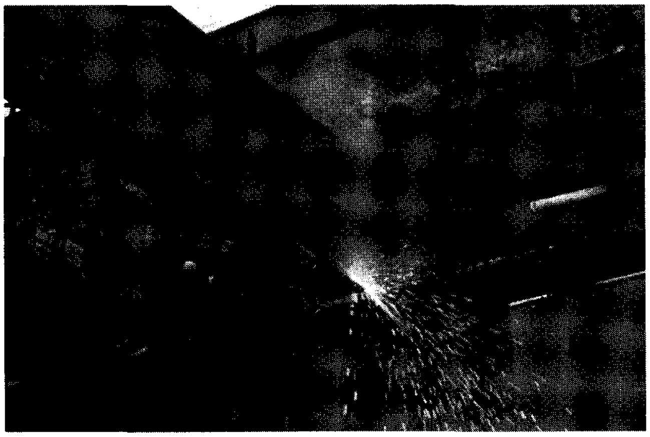


FIGURE D-7 Torch cutting on bridge.

demolishing structures coated with lead-containing paint (Figure D-7).

Exposure

OSHA estimates that lead exposure levels up to 30 000 μg/m^3 can be produced during torch cutting operations. OSHA has issued a presumed exposure level in excess of 2500 μg/m^3 for these operations, as with welding. It should be remembered that hazardous chemicals other than lead may also be vaporized during welding and burning operations, and these operations on painted surfaces may constitute a fire hazard (29 CFR 1926.354) (*10*).

Controls

Only OSHA/NIOSH helmets approved for this use are effective for protection during burning where lead-containing paint is involved. Long cutting torches will permit the worker to be further away from the source of fumes. Blowers can also reduce worker exposure by directing fumes away from the worker's breathing zone. Before beginning any welding or burning work on metal coated with lead-containing paint, at least 100 mm (4 in.) of the paint should be removed along the work area (29 CFR 1926.354). (OSHA Standard 29 CFR 1926.354 treats the welding and cutting of surfaces covered by toxic coatings, not just lead coatings.) This can be accomplished using vacuum-shrouded power tools, vacuum blasting, or chemical stripping.

MECHANICAL DISTURBANCE OF COATINGS

There are many construction operations that result in the mechanical disturbance of lead-containing paint to generate airborne dust. Some of the more common ones are listed below:

- Moving/dismantling containments and their components
- Recycling abrasives
- Maintaining dust collectors and replacing filters
- Handling waste debris
- General clean-up
- Removal of bolts, rivets, or other fasteners
- Maintenance of valves, piping, and electrical equipment.

Exposure

Air-borne lead exposure levels from the above operations have greatly differing ranges. Clean-up activities involving expendable abrasives can produce levels as high as 500 μg/m^3. The exposure can be minimized by use of pneumatical or mechanical transfer methods. OSHA has also identified moving of blast enclosures as a significant source requiring controls. It can create 13 to 2100 μg/m^3 levels, while bolt-busting operations can produce 1 to 189 μg/m^3 levels (Figure D-8).

Controls

Containments and their components should be cleaned using HEPA vacuuming equipment or wet wiping before moving or dismantling (Figure D-9). Dry sweeping and shoveling of debris are not permitted. Good housekeeping techniques should be practiced during all operations, particularly those involving waste debris. Ground covers should be used extensively to avoid contact of debris and its handling and storage equipment and containers with the ground.

OTHER REMOVAL METHODS

Several innovative approaches have been proposed and evaluated for removing lead paint from bridges:

- Laser Paint Removal

  This method has been investigated by the U.S. Army Corps of Engineers. Lasers are capable of vaporizing paints, which are then collected by vacuum. The units are cumbersome

FIGURE D-8 Removing rivets on bridge.

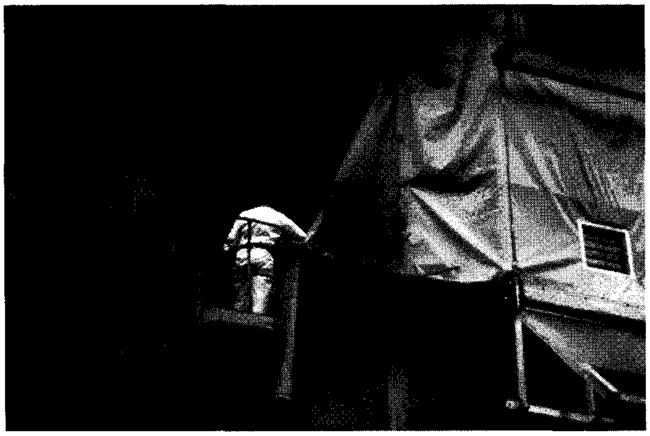


FIGURE D-9 Moving containment.

and expensive and are not yet considered practical for exterior structures such as bridges.

- Paint Vitrification

This method, also pioneered by the U.S. Army Corps of Engineers, sprays a molten glass onto the lead paint. The glass-paint composite hardens (vitrifies) into a brittle composite that can be readily removed. A portion of the work was done in collaboration with New York State DOT. This method has also not been applied commercially.

- Dry Ice

Solid carbon dioxide has been commercialized for several years for removing coating from aluminum and other softer substrates. The equipment is relatively expensive and the production rate slow compared to traditional removal methods. It has not been used to any significant extent for lead paint removal.

- Ice Blasting

Like CO_2, the process uses small pellets (in this case, of frozen water) to remove the paint. The advantage of this is that only a small amount of water has to be disposed of. The process is still being evaluated. Ice blasting can be combined with chemical stripping for removing the stripper.

- Robotics

Because of the hazard to the worker in containment, any process which can remove the worker can have some advantage. Several groups have developed robotic units. Evaluation on bridges or bridge companies have been reported by Ontario Ministry of Transportation and by North Carolina DOT. This method, though relative costly, may benefit from advances in robotics and computerized components (*11*).

APPENDIX D REFERENCES

1. 29 CFR Part 1926.62, Lead Exposure in Construction, Interim Final Rule, *Federal Register*, Occupational Safety and Health Administration, Department of Labor (May 4, 1993).
2. 29 CFR 1926.62, Preamble to Lead Exposure in Construction, Interim Final Rule, *Federal Register,* Occupational Safety and Health Administration, Department of Labor, (May 4, 1993) pp. 26590-26627.
3. Tinklenberg, G.L., and D.M. Doezema, "Health Concerns for Workers Using Zinc-Rich Coatings," in *Lead and Other Safety, Health, and Environmental Issues: Piecing Together the Critical Issues*, Proceedings of the SSPC 1997 Compliance in Industrial Painting Conference, SSPC Report 97-03, Stamford, Connecticut (March 1997) p. 69-83.
4. Dawson, J.L., M. Brown, and R.A . Kogler, "Containment Efficiency: Environment and Worker Exposure," in *Lead and Other Safety, Health, and Environmental Issues: Piecing Together the Critical Issues*, SSPC Report 97-03, Proceedings of the SSPC 1997 Compliance in Industrial Painting Conference, Stamford, Connecticut (March 1997) p. 34-38.
5. Mickelsen, R.L. and O.E. Johnson, "Lead Exposure During Removal of Lead-Based Paint Using Vacuum Blasting," *Journal of Protective Coatings and Linings* (February 1995) pp. 78-84.
6. Smith, L.M., *Analysis of Pollution Controls for Bridge Painting*, Final Report, Pennsylvania Department of Transportation Research Project 86-23 (July 1991).
7. Mickelsen, R.L. et al., *Control technology for Removing Lead-Based Paint from Steel Structures: Power Tool Cleaning,* NIOSH Report ECTB183-16A (November 1995).
8. Mickelsen, R.L., *Control Technology for Removing Lead-Based Paint from Steel Structures: Chemical Stripping at Columbus, Ohio Bridge,* NIOSH, Report ECTB183-17a (March 1995).
9. Smith, L.M., and G.L. Tinklenberg, *Lead-Containing Paint Removal, Containment, and Disposal*, FHWA-RD-94-100, Federal Highway Administration, McLean, Va. (February 1995).
10. 29 CFR 1926.354 "Welding, cutting, and heating in way of preservative coatings."
11. Moon, S., and L.E. Bernold, "A Computer-Integrated Control System for Robotic Bridge Paint Removal," *Journal of Protective Coatings & Linings* (February 1996) pp. 23-32.

APPENDIX E

Overview of Containment Methods and Practices

INTRODUCTION

The Need for Containment and Ventilation

Containment is required to prevent debris from contaminating adjacent property and exposing the public to lead, dust, or debris. The most important regulation is the Resource Conservation and Recovery Act (RCRA), which prohibits deposition of "any" hazardous material into the environment (e.g., soil, air, water).

CLASSIFYING AND DESCRIBING CONTAINMENT AND VENTILATION

SSPC Guide

The major industry guidance document for containment and ventilation of hazardous waste projects is SSPC Guide 6, "*Guide for Containing Debris Generated During Paint Removal Operation*" (*1*). A portion of the scope is as follows:

> This guide describes methods of paint removal, containment systems, and procedures for minimizing or preventing emissions from escaping the work area, and procedures for assessing the adequacy of controls over emissions. The containment systems are categorized in up to four classes per type of paint removal method, based on the extent to which emissions are controlled.

A general description and outline of the guide are as follows:

> *General*
>
> During surface preparation, airborne particulate and debris from the removal of paint (particularly paints containing lead, cadmium, and chromate pigments) can contaminate the air, soil, and water surrounding work sites. The potential environmental hazards are reduced by minimizing or eliminating the airborne particulate, and by containing and collecting the debris. Controlling airborne particulates and other emissions may be necessary to comply with Federal, state, and local regulations.
>
> *Outline of Guide*
>
> Procedures included in this Guide:
> - Selecting Methods of Surface Preparation and Debris Collection (Section 4.1)
> - Specifying Containment Systems (Section 4.2)
> - Selecting Methods for Assessing the Quantity of Emissions (Section 4.3)
> - Implementing Containment Project (Section 4.4)

The Guide also includes descriptions and commentaries on:

- Methods of Coating Removal (Section 5.1)
- Methods of Collecting Debris (Section 5.2)
- Containment Enclosure components (Section 5.3)
- Ventilation System Components (Section 5.4)
- Methods for Assessing Quantity of Emissions (Section 5.5)
- Methods of Assessing Efficiency of Debris Collection and Bulk Abrasive Recovery (Section 5.6).

Two key terms are defined in Guide 6:

Containment System: A containment system includes the cover panels, screens, tarps, scaffolds, supports, and shrouds used to enclose an entire work area or a paint removal tool. The purpose is to minimize or prevent the debris generated during surface preparation from entering into the environment, and to facilitate the controlled collection of the debris for disposal. Containment systems may also employ the use of ground covers or water booms.

Ventilation System: Ventilation systems include both natural ventilation and mechanical ventilation (fans, hoods, and duct work), to provide air movement across the work area, and dust collectors to clean the discharged air.

The containment ventilation system consists of components of the enclosure and components of the ventilation system.

Components of Containment Enclosures

Guide 6 defines four major components of the containment enclosures including: containment materials; containment support structure; joints; and entryways.

Containment materials are the walls, floors, and ceiling of the enclosure. A number of materials have been used, including screens, tarpaulins, aluminum, plastic, plywood, etc. Containment materials are characterized by physical properties (e.g., rigid or flexible); permeability or penetrability by air, moisture, or chemicals; and durability (e.g., resistance to mechanical wear, ultraviolet radiation). Other factors are burst strength, light transmission, and weight.

The alternative materials and their properties are described in more detail (*2,3*). A variety of containment materials were evaluated in an FHWA study including screens, reenforced vinyl, reenforced rubber, reenforced polyethylene and coated and uncoated woven polyethylene (*4*). These materials were evaluated under simulated field conditions for durability and permeability to lead. Conclusions are presented in the sections below.

Support structures are intended to provide a frame for the containment walls, ceilings, and sometimes floors. The frame also supports the weight of the structure itself, the equipment, the workers, and all aspects of the abrasive operation that will be conducted inside the enclosure. Supports are classified as rigid, flexible, or minimal. The following descriptions are from a 1995 publication (*5*).

- *Rigid support structures* consist of scaffolding and framing to which the containment materials are affixed to minimize movement of the containment cocoon.
- *Flexible support structures* comprise cables, chains, or similar systems to which the containment materials are affixed. Flexible support structures allow some movement of the containment.
- *Minimal support structures* little or no additional support to the containment materials other than the cables or chains used to affix the materials to the structure being prepared and perhaps the floor or ground.

Containment Enclosure Joints

The joints between containment materials, and between the materials and the structure being prepared, are either fully or partially sealed. The sealing of the joints has an impact on the degree of emissions control provided by the containment system.

- *Fully sealed joints* require that all mating surfaces between containment materials and between the containment cocoon and the structure are completely sealed. Materials for sealing include tape, caulk, Velcro, or any other material capable of forming a continuous, impermeable, and impenetrable seal.
- *Partially sealed joints* are those in which materials are mated to one another and to the structure being prepared to assure the structural soundness of the joint, but without consideration for creating a continuous, impermeable seal. This method of sealing can provide suitable control when using removal methods that produce lower levels of emission, such as hand tool cleaning or vacuum-shrouded power tool cleaning.

Containment Entryways

Access to and from the containment requires elaborate controls to assure that emissions do not escape during worker use, or during windy periods that could cause the entryway to open.

- *Airlock entryways* involve a minimum of one stage that is fully sealed to the containment. One door connects the airlock to the containment; a separate door connects the airlock to the outside. Both doors of the airlock must not be opened at the same time; otherwise, emissions may escape.
- *Resealable door entryways* involve the use of entry doors capable of being repeatedly opened and resealed. Sealing materials include zippers, Velcro, and similar fasteners.
- *Overlapping door tarpaulin entryways* employ two or three tarps. This system may have a tendency to open under windy conditions or could disrupt designed airflow patterns when a negative pressure ventilation system is used.

Ventilation System Components

Designing ventilation for a containment enclosure requires a basic understanding of ventilation principles. The recognized industry source is the Industrial Ventilation Manual (*6*). Two critical aspects of ventilation are air flow and air pressure (*2*).

- Air flow is the movement of air from the intake portion of the enclosure through the various sections of the enclosure to the outside (ambient environment). Air flow is necessary to transport the dust from the place of generation (i. e., near the blasting or other operation) so it can be removed from the work vicinity, filtered, and vented to the outside. In designing air flow it is necessary to consider the velocity of the air flow (measured in ft./min across a given area) and the direction of air flow. Containments are often irregular in shape with obstructions such as beams, supports, and equipment. Also the action of the paint removal (e.g., blasting) creates significant turbulence and nonlinear flow of air inside containment.
- Air pressure differential is of concern in a ventilated containment. Air flows from spaces of high pressure to low pressure. The goal is to create a (low) negative pressure inside the containment, compared to the pressure outside the containment. This prevents the air inside containment from escaping the containment (except for designated exit points) and contaminating the ambient (outside) environment.

To develop a ventilated containment, which provides appropriate air flow and establishes negative pressure throughout the containment, is a challenge. It entails consideration of the means by which outside air will enter the containment, means for generating air flow (e.g., fans), the means by which air will be exhausted from the containment (e.g., ducts), and the means by which air will be cleaned before exiting (e.g., filters, dust collectors). Guide 6 describes the following ventilation system components:

- Air supply (intake) points
- Input air flow
- Air pressure inside the containment
- Air movement inside containment
- Exhaust air flow
- Dust collection.

Additional information is given in previously cited references (*2,3*). Figure E-1 shows a dust collector.

Ventilation System Design

Ventilation Guideline

The following guidelines on ventilation designs are derived from *Project Design: Industrial Lead Paint Removal Handbook* (*5*).

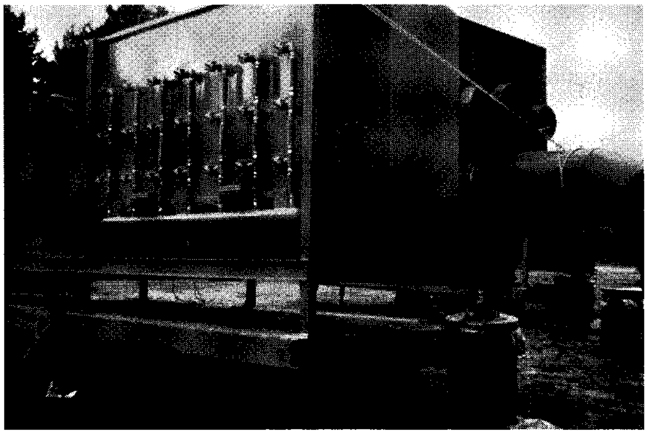


FIGURE E-1 Dust collector.

FIGURE E-3 Measuring air velocity in ducts.

- Ventilation design alternatives include designed mechanical systems or natural ventilation. When a mechanical system is specified, a negative pressure condition should be required, together with filtration of the exhaust air. When natural ventilation is specified, the negative pressure condition is not achieved, nor is filtration of exhaust air applicable.
- Mechanical ventilation of a containment enclosure should be designed to assure that adequate air movement is achieved to reduce worker exposure to lead or other toxic metals to a level as low as feasible, and to enhance visibility. The system should be designed for a relatively uniform air flow through the containment in either a cross-draft or down-draft mode.
- The exhaust system must be designed with properly distributed exhaust ports or plenums, adequately sized exhaust ductwork for proper transport velocity, properly selected air filtration media, adequately sized discharge fan(s) to provide the necessary air velocity within containment and to overcome system static pressure, and properly sized and distributed make-up air points (Figure E-2).

SSPC Guide 6 suggests target rates of air movement through the containment as shown below during abrasive blast cleaning operations (Figure E-3).

FIGURE E-2 Flexible ducts for ventilating containment.

- 30 m/min (100 ft/min) cross-draft
- 18 m/min (60 ft/min) down-draft
- This guide cautions that these target velocities may or may not be suitable for proper worker protection.

Negative pressure achieved with mechanical ventilation can be confirmed through instrument monitoring or visual observations. When instrument monitoring is employed, a minimum of 7.5 mm (0.03 in.) water column relative to ambient condition is suggested.

- Exhaust Air Filtration: When mechanical ventilation systems are used, filtration of the exhaust air should be specified; otherwise, airborne particulate from within the containment will be exhausted directly into the ambient air.

Filtration systems typically employ wet or dry dust collectors or bag houses. Filtration of 2.0 micrometers (99.9 percent efficiency) is typically suitable to control release to the ambient air, although filtration to 0.5 microns is becoming common, particularly when workers are continually in the immediate vicinity of the exhaust. For removal methods that produce low emissions, dust socks on the exhaust fan may be sufficient.

- Natural Ventilation System: Natural ventilation does not use mechanical equipment for moving dust and debris through the work area. This method relies on natural air flow patterns, if any, through the containment.

Limitation on Dilution Ventilation

Dilution ventilation refers to the use of air flow to reduce the lead exposure level of blasters or other workers inside containment. Numerous evaluations have demonstrated that dilution ventilation is not adequate to reduce the lead exposure levels to below the PEL. Lead dust levels during blasting often reach 10 000 to 50 000 $\mu g/m^3$. Dilution ventilation can reduce these levels by up to a factor of two to four as an engineering control. Even at air velocities of 91 m/min (300 ft/min), the air flow could not compensate for the large amount of dust being generated by typical abrasive blasting operation (*4*).

However, a reduction of 50 to 75 percent may be significant. As the exposure exceeds 50 000 $\mu g/m^3$, even the most protective air fed helmets (with an assigned protection factor of 1,000) would be inadequate to prevent the worker from being exposed to levels above the PEL.

Other Benefits of Ventilation

An important benefit of air flow is to produce negative pressure more uniformly throughout the containment. As noted, SSPC Guide 6 recommends a pressure differential of 0.75 mm (0.03 in) of water.

Another objective of ventilation is to allow improved worker visibility, safety, and productivity. This is the basis of the recommendation of the SSPC Guide 6 of 30 m/min (100 ft/min) for cross-draft ventilation (parallel to the ground) and 18 m/min (60 ft/min) for down-draft. Note: the down-draft number is lower because the movement of dust and debris is assisted by gravity. These numbers are derived from an ANSI standard (*7*).

Efficient ventilation has been shown to reduce the level of lead dust from blasting by more than 50 percent within a matter of minutes (*8*). This allows the worker to exit the containment without causing major contamination of the airlock entryway or the exterior of the containment.

Evaluating Ventilation and Containment

In a Federal Highway Administration research project (*4*), tests were performed on a simulated bridge to characterize several containment designs for a typical two-span grade separation (overpass). Designs examined included a suspended platform with a plywood floor and a bridge-to-grade containment using reenforced woven polypropylene. Several methods of air input were evaluated, including an open hole, a plywood baffle, and high- and low-speed fans. The containment was constructed using air flow parallel to the beams and perpendicular to the beams. Air velocity, negative pressure, production rate, and worker exposure to lead were measured for blasting operations inside the containment (Figure E-4). The conclusions of these and related experiments are as follows:

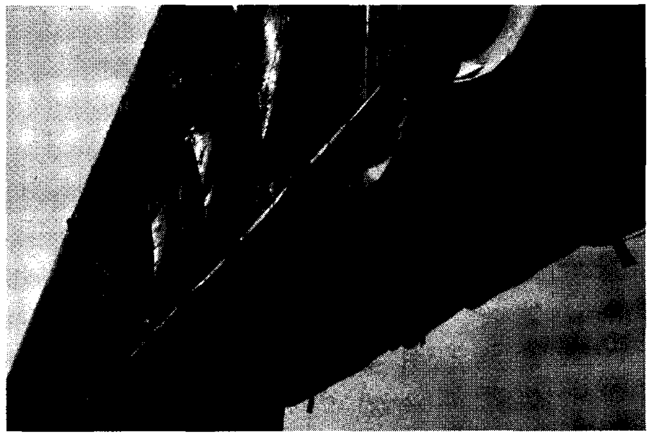


FIGURE E-4 Containment under negative pressure.

- Only air-impermeable materials should be allowed for constructing containments when abrasive blasting is performed. Uncoated woven materials do not appear to be impermeable to lead. Coated, woven materials, while initially impermeable to lead, deteriorated with time. Durability requirements for the containment material should be specified. A minimum of 1.5 m (5 ft) between the containment and the steel should be required when flexible materials are used to construct containment to avoid perforating the material.
- Properly designed and sized air inputs are essential for air flow through containment. High-speed, low-volume fans were found to be most effective. A baffle was also found to be effective for air movement, but an improper design would allow dust to escape into the environment when the blast nozzle is near or pointed toward the baffle. Louvers or filters would reduce the amount of dust that escapes.
- Fully sealed joints do not allow dust to escape into the environment.
- Negative pressure of 0.75 mm (0.03 in) water column inside containment was effective at keeping dust from escaping.
- Many factors contribute to worker exposure to lead, including the high-speed air exiting the blast. No difference in worker exposure was found by increasing the ventilation air flow above the current velocity of 30 m/min (100 ft/min) in a cross-draft direction recommended for visibility purposes.
- Adequate air flow is needed to clear containment of dust when blasting ceases. Adequate air flow includes velocity and distribution. Velocity is best determined by measuring the air volume drawn through the exhaust ducts and dividing by the cross-sectional area of the containment. Air distribution can best be determined with smoke bombs. Measuring air velocity inside containment with an anemometer was found to be inaccurate. Properly designed and functioning input and exhaust plenums can provide uniform air flow through containment.

EXAMPLES OF COMMON CONTAINMENT VENTILATION DESIGNS

General Approaches to Containment of Full Removal by Abrasive Blasting and Other Methods

Gozion (*9*) has identified several types of containment design used for full removal of coatings from bridges being abrasive blast cleaned. These include suspended tarpaulin (Figure E-5), bridge-to-grade, suspended platform outrigger and cable, enclosed staging, and micro-containment.

Suspended tarpaulin containment, which is made up of tarpaulins draped from taut horizontal cables spanning piers, may be the most economical system available. This design is best for projects with a low volume of abrasive blasting and paint debris. Work is performed from scaffolds supported by separate cable systems. Waste debris from the containment may be

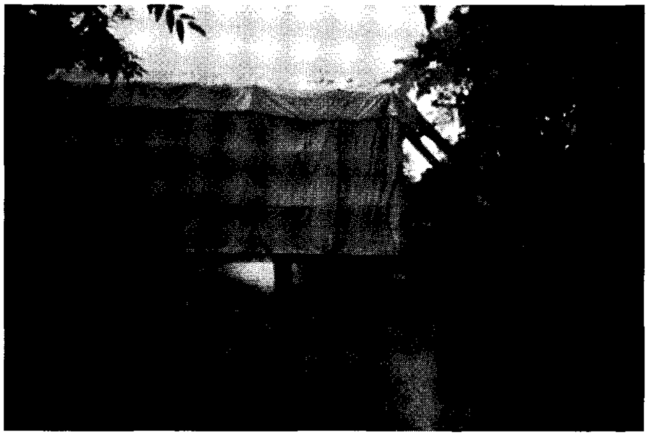


FIGURE E-5 Suspended tarpaulin containment.

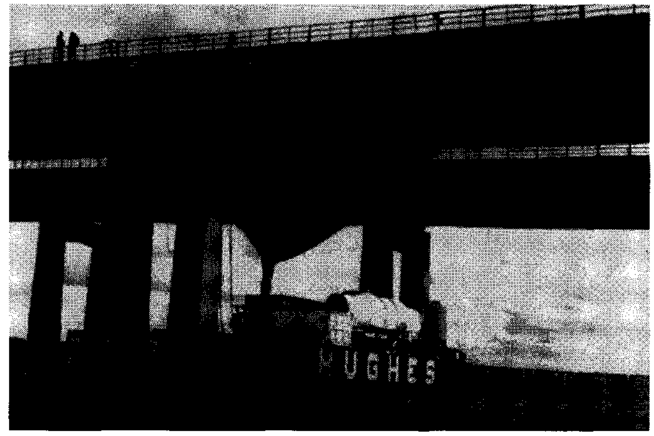


FIGURE E-7 Containment funneling to barge.

removed manually with periodic vacuuming from the suspended scaffolding or automatically by incorporating funnel-like tarpaulin hoppers into the draped containment tarpaulins.

Bridge-to-grade containment is composed of tarpaulins draped vertically from the bridge structure or from taut horizontal cables spanning the piers; it is economical and effective. It is primarily used on bridges that are relatively close to grade. Work may be performed from grade, using a lift truck or scaffolding, or from scaffolds supported by a separate cable system. The floor of the containment (i.e., roadway or natural terrain) is covered with tarpaulins to contain the waste debris and accommodate collection and cleanup.

Suspended platform containment is a rigid, lightweight structural assembly covered by a plywood or grated work deck (Figure E-6). The platform assembly is suspended beneath the structure, supported by stationary or trolley beam clamps. Suspended platform containments are primarily used on large, elevated structures. The suspended platform assembly provides a solid, stable work deck. A mechanical or pneumatic waste collection system can be added to reduce the labor required for vacuuming and cleanup. A gravity system of flexible hoses may also be used to discharge the waste debris to containers on a barge on grade beneath the structure (Figure E-7).

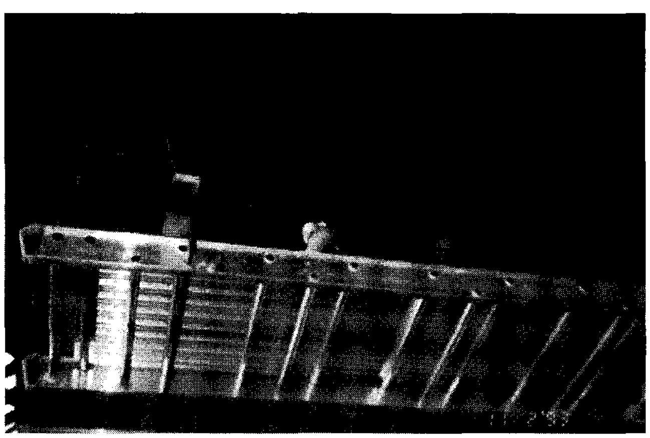


FIGURE E-6 Suspended platform containment.

Outrigger and Cable containment is regularly used on through-truss and deck-truss bridges. It consists of a tarpaulin enclosure affixed to a flexible cable support system and is supported by outriggers bolted along the length and width of the structure. This type of containment may be installed as an independent system or used with the suspended platform assembly described below if work is to be performed on both the below-deck steel and the superstructure. Work may be performed from grade, using manlifts or scaffolding, or from scaffolds supported by a separate cable system.

Enclosed Staging containment, like the outrigger and cable system, is used on through-truss and deck-truss bridges. It includes a tarpaulin enclosure supported by tubular staging on the bridge structure or on grade. It may also be installed as an independent system or used with a suspended platform assembly. Depending on the configuration of the superstructure, either cross-draft or down-draft ventilation may be used. A large main containment with divider walls is often used to minimize labor requirements and maintain minimum recommended air flow velocities.

Micro-Containment is a small cross-sectional area in the direction of air flow. The entire system can be 1.2 m (4 ft) wide by 2.4 m (8 ft) high by 3.6 m (12 ft) long. This containment is ideal for intermittent blasting on isolated areas. Waste debris generated within the enclosure may be removed manually with periodic vacuuming or automatically with flexible discharge hoses to collection hoppers on grade.

General Approaches to Containment for Partial Removal

The amount of dust and debris produced during an overcoating project is normally much less than for total removal. It depends on the type of removal methods (e.g., hand tool cleaning generates the least dust and spot or brush blast cleaning the most). There remains a need to contain the debris in accordance with RCRA, which defines any lead-containing debris (hazardous or nonhazardous) deposited in the environment as "illegal disposal." Vacuum shrouds around the tool (e.g., needle gun, rotary peening tool, or vacuum blasting) can significantly reduce the dust, but none is 100 percent effective. The vacuums are less effective around connections, edges, and corners. The operator must often use a variety of heads or tools, which can slow productivity, therefore inspection and monitoring are important. Where vacuum tools are not used or are not rigorously enforced, conventional containments are strongly recommended. At the least, impermeable ground covers should be placed under the bridge at least 3 m (10 ft) out (more if working at elevations of 6 m [20 ft] or higher). Side containment is also normally required. These can be suspended from the hand rails or outriggers in a manner similar to that for full containment. The containment tarps or screens are designed to catch the solid particles and keep the dust from dispersing outside the work area.

FIGURE E-8 Ground cover for containing power tool debris.

Containment for Power Tools

For containing hand and power tool removal operation, SSPC Guide 6 defines three levels of emission controls. The most stringent (Class 1P) is the situation where no dust emissions are permitted (e.g., adjacent to houses or schools) and where vacuum shrouds are not used. As a result, the containment must catch all of the debris. Containment Class 1P is almost as stringent as the requirement for blast cleaning (Class 1A) except for the following:

- Air penetrable materials are permitted
- Resealable seams are permitted without airlocks
- Visual verification rather than instrument verification of negative pressure is permitted.

Note: This still requires air intakes for air supplies, and filters on the exhaust side to prevent inadvertent emission. In addition, fully sealed joints (e.g., tape or stitches) are required.

Level 2P eliminates the need for air emission controls and allows open seams. This is the level of containment required by New York City DOT, which in late 1996 prohibited the use of abrasive blasting on all city owned bridges (*10*). This was caused by concern from community residents about lead contamination of residential and recreation areas (*10*). The DOT has developed very stringent guidelines for controlling emissions when using power tools (*11*).

When using vacuum shrouded tools, Guide 6 permits the use of ground covers or free hanging tarps as equivalent to Class 1P (Figure E-8). This assumes that the tools are used properly.

Containment for Water Method Removal

Most highway agencies require that the water used for spot cleaning or general surface rinsing or washing be contained and collected. Guide 6 defines three levels of emission controls for these methods. Again, the most efficient control is when the water is captured by a vacuum attached to the spray nozzle. Various containments have been designed to capture water and direct it to ground covers or water attachment areas. However, there is little guidance on how to collect the water. This is an area where new advances in equipment and engineering are needed to improve the efficiency and productivity of the collection of water.

Containment of the water used for pressure washing is an important concern. The water may contain suspended lead particles and may itself need to be tested for leachable lead per TCLP prior to discharge. If small quantities of water are used, it may be acceptable to pond it until the testing can be conducted. Many decontamination trailers have water filtration systems for the shower and wash water. This system may also be suitable for the water used for surface cleaning, once it is collected.

For work done over water, a containment water boom may be required if the waterway or the community is sensitive to the threat of contamination. It is more difficult to collect debris without employing a barge. For these reasons, when working over water it might be preferable to require stringent vacuum shrouds (e.g., with power tools) to minimize the debris that is released. Also, if extensive rigging over the water is required, it may be more appropriate to undertake full removal in the first place.

A recent article describes the use of some of the latest techniques and the concerns of the industry about collecting and disposal of water and debris from water washing and related activities (*12*).

DETERMINING THE EFFECTIVENESS OF CONTAINMENT

Containment systems are designed by contractors who may employ design professionals. A major responsibility of the transportation agency is to determine whether the containment is effective in controlling emissions.

Guide 6 describes several methods for assessing the effectiveness of containment by measuring air emissions (e.g., by visual and instrumental methods), measuring soil containment, measuring water and sediment contamination, and measuring efficiency of waste collection.

Methods of Air Contamination Assessment

Assessment of air contamination is one of the major concerns of highway agencies. The following methods are available: visible emission (Method A of Guide 6), ambient air monitoring for PM-10 (Method B), occupational monitoring of area emissions for lead (Method C), and EPA ambient air monitoring for toxic metals (Method D).

Visible Emissions (Method A)

Observations of visible emissions from the work area provide immediate feedback on the performance of the containment system. Typically, particles under 20 to 30 micrometers in diameter cannot be readily observed. Two methods can be used:

General Surveillance Visible emissions are permitted at given frequencies or durations provided they do not extend beyond an established boundary line (e.g., property line). Possible frequencies include:

— Level 0 Emissions: No visible emission. (This level is typically not achievable during abrasive blasting.)

— Level 1 Emissions: Random emissions of a cumulative duration of no more than 1 percent of the work day (5 minutes in an 8-hour work day).

— Level 2 Emissions: Random emissions of a cumulative duration of no more than 5 percent of the work day (24 minutes in an 8-hour work day).

— Level 3 Emissions: Random emissions of a cumulative duration of no more than 10 percent of the work day (48 minutes in an 8-hour work day).

— Level 4 Emissions: Emissions are unrestricted and may occur at any time. Note: The workday activities for timing emissions encompass surface preparation and clean-up only.

Opacity Scale Opacity measurements are made by trained, certified observers. A scale from 0 percent to 100 percent, in 5 percent increments, is used. Measurements are typically made at 15-second intervals for given periods of time (e.g., 30 minutes). The acceptance criteria might restrict the opacity to no more than 20 percent for any 3-minute period in 60 minutes. Medford described the results of visible emission monitoring for two bridges in North Carolina that were blast cleaned under full containment with negative pressure (*13*). A DOT inspector was present during all work activities. The criterion was to stop blasting if visible release exceeded 36 seconds (1 percent of an hour). This proved difficult to achieve. The reported emission times ranged from 6.4 percent to 11.4 percent on one bridge and 1.8 percent to 10 percent on the second bridge.

Ambient Air Monitoring for PM-10 (Method B)

High-volume air samplers equipped with PM-10 heads are used to assess the total amount of particulate matter 10 microns (0.39 mils) or less in size that escape the contained work area in accordance with 40 CFR, Part 50, Appendix J (*14*). The number of monitors to be used is based on wind direction and proximity to homes, playgrounds, businesses, bodies of water, etc. The National Ambient Air Quality Standard for PM-10 according to 40 CFR Part 50 is 150 $\mu g/m^3$ over a 24-hour period. Using an adjusted level of 450 $\mu g/m^3$ over an 8-hour period may provide a rational method for applying the EPA criteria, provided no emissions occur from the worksite during the remaining 16 hours.

Occupational Monitoring of Area Emissions for Lead (Method C)

Personal monitors can be used to determine the level of lead being emitted near equipment such as dust collectors and abrasive recycling equipment. The lead particles captured on a cassette would be analyzed for lead in accordance with NIOSH Method 7082 (see Appendix B). Action level lead limits are 30 $\mu g/m^3$ per 29 CFR 1926.62.

EPA Ambient Air Monitoring for Toxic Metals (e.g., TSP lead) (Method D)

When removing paints containing toxic metals, air quality measurements for the toxic metals can be made by instrument monitoring in accordance with EPA criteria. The selection of monitoring locations should be based on factors including wind direction, surface or terrain irregularities, and proximity to homes, playgrounds, businesses, bodies of water, etc. Depending on the variability of the results, full-time background monitoring throughout the project may be necessary.

High-volume air samplers equipped for the collection of total suspended particulate (TSP) are used (Figure E-9). When removing paints containing lead, the filters are analyzed for lead in accordance with the EPA 40 CFR Part 50, Appendix, G (*14*). The National Ambient Air Quality Standard for Lead according to 40 CFR Part 50 is 1.5 $\mu g/m^3$ as a 90-day average.

Note: Because paint removal operations are not normally conducted continuously over a 90-day period, it may be appropriate to establish a daily criteria for monitoring. Note that the suggested modification of the procedure shown below may not be acceptable to state or local environment officials. The appropriate officials should be contacted prior to its implementation.

$$DA = (90 \div PD) \times 1.5\ \mu g/m^3$$

DA = Daily allowance ($\mu g/m^3$)

PD = Number of preparation days anticipated in a 90-day period.

Methods For Measuring Soil, Water and Sediment Contamination

Sources of Soil Contamination

Soil contamination can arise from deposits of particulates emitted during the blast cleaning process, or from spills during

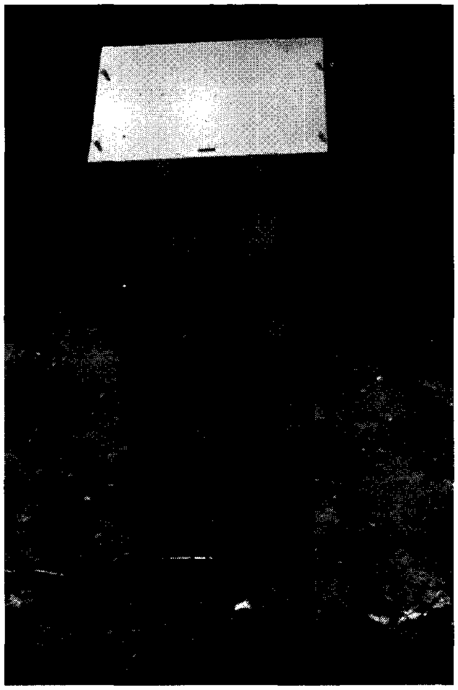


FIGURE E-9 Monitor for total suspended particles of lead.

the collection and transport process. They can also arise from previous activities on the site, including previous lead removal or application or lead from gasoline. SSPC Guide 6 also describes the procedure for soil collection and analysis.

Soil Analysis for Toxic Metals (Method E)

A prejob and postjob soil analysis for toxic metals such as lead is useful for determining if adequate ground protection was employed.

Prior to project set-up, select test sites beneath the structure as applicable away from the structure in each of four directions (e.g., at least one or two from 3 to 30 m (10 to 100 ft)). Long structures such as bridges may require additional sampling locations. Document the specific location of each site. At each test site, center and align a 0.3 m by 0.3 m (1 ft by 1 ft) template parallel or tangential to the structure. Remove a sample of soil 1.9 cm (3/4 in.) in diameter and 1.3 cm (1/2 in.) in depth at the center of the square and at each of four corners. Combine the five soil plugs in a single bag to represent the sample at the given location. At project completion, return to the same locations and remove a similar sample. Analyze the prejob and postjob soil samples for the appropriate toxic metals in accordance with EPA Method 3050 (see Appendix B). In some instances an alternate procedure may be used.

Measuring Water and Sediment Analysis for Toxic Metals (Method F)

When work is done over or near water, there is potential for contaminating the water and/or the sediment with lead. Guide 6 presents the following analysis method:

Water and Sediment Analysis for Toxic Metals (Method F)

Prejob and postjob assessment of toxic metals (e.g., lead) in sediment can be useful in determining if proper protection of a water body has been achieved. Prejob sampling should be accomplished in discrete locations around and beneath the project site to a sediment depth of no more than 1.6 cm (6 in). Samples should be removed at the same locations on project completion. Sampling of water may or may not provide valuable information due to the transient nature of toxic metals in fast-moving water bodies (sediment analysis may be a more reliable indicator). However, for sedentary bodies of water or if drinking water intake is located nearby, prejob and postjob water sampling and analysis may be beneficial.

Assessing the Efficiency of Containment from Amount of Waste Recovered

It is also possible to determine the efficiency of the containment by determining the percentage of the waste that has been collected. One approach is to measure the amount of abrasive used for the paint and rust removal and measure the amount of abrasive collected. This is described in Guide 6 of the "Weigh In/Weigh Out Method."

Method of Assessing Efficiency of Debris Collection and Bulk Abrasive Recovery

(*Weigh In/Weigh Out Method*): This method is suitable for estimating the efficiency of debris collection and bulk abrasive recovery. It is not suitable for estimating air emissions.

Determine the dry weight of abrasive (W_a) used in blast cleaning an entire structure or portions of a structure and the weight of paint debris (W_p) for the same area. Determine the dry weight of abrasive and paint debris removed from blast cleaning the entire structure or portions of structure (W_d). Compute the recovery efficiency (RE) as follows:

$$RE = \frac{W_d}{W_p + W_a} \times 100$$

Case Histories of Abrasive Recovery Method

This approach was applied to measure the effectiveness of containment on two bridges in North Carolina (*13*). As shown in the table below, the recovery rates were both greater than 90 percent.

Abrasive Recovery Rates From NC DOT Bridges

Site	Debris Collected Mg[1] (tons)	Estimated Paint and Millscale[2] Mg (tons)	Abrasive Used Mg (tons)	Percent Recovery[3]
Smoky Park	109.4 (120.6)	6.8 (7.5)	106.7 (117.6)	96.4
Mountain Island	91 (100.5)	3.8 (4.2)	96.9 (106.8)	90.5

[1] Megagrams
[2] Based on 366 g/sq. m (1.2 oz/sq. ft.)
[3] Calculations based on dry weight

Conroy compared the amount of lead generated by two methods (*15*). The first method entailed estimating the amount of lead on the structure from the surface area, average paint thickness, and percent lead in the paint. This gave a mass of lead per square meter of surface area from which the total amount could be derived from an estimate of the surface area.

For the second method, the total volume of abrasive and the concentration of lead were determined. Based on this, the amount of lead collected could be computed. This method shows collection efficiencies of 55 percent to 95 percent. Also, the lead emission factors were determined to range from 7000 to 35 000 mg of lead/m^2 of surface area.

PROJECT DESIGN METHOD FOR RISK ANALYSIS

Project Design (*5*) provides a methodology to determine the type of containment required (as defined in Guide 6) based on two factors: the emission potential of the removal method and the site-specific risk indicators.

Determining Risk Indicators

The procedure first identifies three risk indicators (the risk to adjacent workers, the risk to the public and the risk to the environment). Each of these several levels of risks are defined based on criteria given in the text.

The risk to the adjacent worker is classified as nil, low, or high. The risk to the public is classified as nil, low, moderate, or high. The risk to the environment is classified as low or high.

The three risk indicators are then combined into a matrix to establish the level of emission control required for the project. The emission control required is at one of two levels:

- Level A (requires a very high level of emission control)

or

- Level B (requires a high level of emission control).

Determining Emission Potential of Removal Methods

Removal methods are categorized into the following four emission potentials:

- Emissions Category 1 (very high emissions potential). The methods in this category include open abrasive blast cleaning with expendable or recyclable abrasives.
- Emissions Category 2 (high emissions potential). The methods in this category include all systems that employ water, such as high or ultra-high pressure water jetting (with or without abrasives), wet abrasive blast cleaning, and sodium bicarbonate blast cleaning.
- Emissions Category 3 (moderate emissions potential). The methods in this category include sponge jetting, chemical stripping, vacuum blasting, portable centrifugal wheel blast cleaning, and power tool cleaning without vacuum attachments.
- Emissions Category 4 (low emissions potential). The methods in this category include power tool cleaning with vacuum attachments and hand tool cleaning.

Combining Level of Emission Control Needed and Emission Potential of Removal Methods

The design of the containment for the specific method of paint removal is determined by three factors: the type and nature of the emissions that are generated by the removal method, emissions potential, and the required level of emission control (Level A or Level B as established through prior analysis).

For example, consider the structure that requires a very high level of emission control in combination with a removal method having moderate emission potential (e.g. power tools without shrouds or chemical stripping), the allowable containment classes (e.g., derived from the accompanying tables in the text (*5*)) are 2P and 3C. (Note: These tables are based on SSPC Guide 6).

Selecting Emission Monitoring Procedure

The next step in this multiphase product design is to guide the owner into selecting project-specific emission monitoring requirements. The need for monitoring is based on the potential risks to the three areas previously identified (risk to adjacent workers, risk to the public, and risk to the environment.)

Five types of monitoring are considered: instrumental monitoring (TSP or PM-10), visible monitoring, soil monitoring, water sediment monitoring, and establishing regulated areas. These correspond relatively closely to the methods identified in the SSPC Guide 6.

Monitoring Methods and Extent of Monitoring

For each category of the monitoring methods the scheme identifies two to three levels or approaches. They are as follows:

Method 1: TSP Lead/PM-10
Full = Full time monitoring
Start = Start-up monitoring only
N/A = No TSP Lead or PM-10 monitoring required.

Note: The use of both TSP and PM-10 monitoring may not be required on all projects. The use of TSP alone may be adequately protective.

Method 2: Visual

Level 0 = SSPC Level 0 (No visible emissions)

Level 1 = SSPC Level 1 (Visible emissions 1 percent of work day)

Level 2 = SSPC Level 2 (Visible emissions 5 percent of work day).

Method 3: Soils

Lab = Laboratory testing and analysis, together with a visual assessment

Vis = No laboratory testing required, visual assessment only.

Method 4: Water/Sediment

Lab = Laboratory testing and analysis, together with a visual assessment

Vis = No laboratory testing required, visual assessment only.

Method 5: Regulated Area

Weekly = Weekly verification monitoring

Monthly= Monthly verification monitoring

Start = Start-up monitoring only.

Using Matrix and Determining Extent of Monitoring

A matrix is then constructed that identifies the type of monitoring recommended based on the category and the three risks.

For example, consider a category 2 removal method. This is a method with high emission potential, such as water jetting. Also assume the following: the risk to adjacent workers is low, public health risk is low, and environmental impact is high. Based on the tables in the text, the following risk monitoring schemes are selected:

- TSP/PM-10: start-up monitoring only.
- Visual Monitoring (Level 1): visible emissions 1 percent of work day.
- Soils Analysis: lab testing and analysis plus visual assessment.
- Water/Sediment Analysis: lab testing and analysis plus visual assessment.
- Regulated Area: monitor monthly.

See discussion in chapter 7 on other features of the procedures in *Project Design* (5).

APPENDIX E REFERENCES

1. "SSPC Guide 6, Guide for Containing Debris Generated during Paint Removal Operations" in *Systems and Specifications, Steel Structures Painting Manual, Volume 2*, SSPC, Pittsburgh, Pennsylvania (1995).
2. *C-3, Supervisor/Competent Person Training for Deleading of Industrial Structures*, Unit 3, SSPC Report 93-02, SSPC, Pittsburgh, Pennsylvania (1997).
3. Trimber, K.A., *Industrial Lead Paint Removal Handbook, 2nd Edition*, KTA-Tator, Inc., Pittsburgh, Pennsylvania (1993).
4. Smith, L.M, and G.L. Tinklenberg, *Lead-Containing Paint Removal, Containment, and Disposal*, FHWA-RD-94-100, Federal Highway Administration, McLean, Virginia (February 1995).
5. Trimber, K.A. and Adley, D.P., *Project Design: Industrial Lead Paint Removal Handbook, Volume II,* SSPC Report 94-18, Technology Publishing Company, Pittsburgh, Pennsylvania (1994).
6. *Industrial Ventilation: A Manual of Recommended Practice,* 21st edition, American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio (1995).
7. "For Exhaust Systems — Abrasive Blasting Operations — Ventilation and Safe Practices," ANSI/ASC Z9.4, American National Standards Institute, New York.
8. Froehlich, P.A., and R.L. Mickelsen, "Control Technology for Removing Lead-Based Paint from Steel Structures: Abrasive Blasting Using Staurolite XL in Containment," ECTB 183-13a, NIOSH (July 1993).
9. Gozion, M., "Design and Cost Estimating for SSPC Class 1 Containment Systems," *Journal of Protective Coatings and Linings* (November 1994) pp. 59-68.
10. Pasher, I., "A Case Study in Community Participation: Greenpoint-Williamsburg and Williamsburg Bridge," Lead and Other Safety, Health and Environmental Issues: Piecing Together the Critical Issues, *Proceedings* of the SSPC 1997 Compliance in Industrial Painting Conference, SSPC Report 97-03 Stamford, Connecticut (March 3-4, 1997) p. 34-38.
11. New York City DOT, Bureau of Bridges, Protocol on Lead Paint Removal from Bridges, Final Revision 10/27/94.
12. Schuster, J., "Wastewater Regulations," *Painting and Wallcovering Contractor*, (March/April 1996).
13. Medford, W., "Removing Lead Paint from North Carolina Bridges," *Journal of Protective Coatings and Linings* (February 1993) pp. 64-72.
14. 40 CFR 50, National Primary and Secondary Ambient Air Quality Standards (NAAQS), Appendix G, "Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air" and Appendix J, "Reference Material for the Determination of Particulate Matter of PM-10 in the Atmosphere."
15. Conroy, A, "Lead, Chromium and Cadmium Emission Factors by Bridge Painters," *AIHA Journal* (March 1995) pp. 266-271.

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, a private, nonprofit institution that provides independent advice on scientific and technical issues under a congressional charter. The Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering.

The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encouraging education and research, and recognizes the superior achievements of engineers. Dr. William A.Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences, by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED