PDHonline Course C493 (5 PDH)

FHWA Bridge Maintenance Manual—Main Concepts and Management

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2020

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I. INTRODUCTION

This reference manual was developed by Wilbur Smith Associates as part of a training course that is presented on behalf of the Federal Highway Administration. It is an update of the manuals and courses that were developed and presented by Wilbur Smith Associates in 1983 through 2000.

A. OBJECTIVES

EFFECTIVE MAINTENANCE AND REPAIR PROCEDURES

One objective of the training is to provide instructions for performing a wide range of useful and effective bridge maintenance and repair procedures. These procedures have been collected from transportation agencies nationwide and can be used in part or as concepts that can be adapted and expanded to provide solutions to specific bridge problems.

These procedures are not intended to override existing agency guidelines or policy, but are to be used as a source of information when the need arises. They are not intended as a substitute for consulting an engineer with the appropriate qualifications to determine the proper repair method. For example, a structural engineer should be consulted if the repair involves a structural member.

OVERVIEW OF GENERAL MANAGEMENT TECHNIQUES

The second objective of the training is to provide an overview of general management techniques useful to a bridge maintenance supervisor/technician, such as planning, scheduling, monitoring and reporting work. The objective is not only to acquaint the participant with techniques needed as a supervisor/technician, but also to include the needs of middle and upper management to provide an understanding of why reports and documentation are important.

IMPROVE TRAFFIC CONTROL, WORK SITE SAFETY AND AGENCY LIABILITY

The third objective is to improve work site safety for the bridge maintenance worker and the public, which will also reduce exposure of the agency to liability. Most maintenance workers are exposed to a large number of training and reinforcement programs related to work site safety and the use of traffic control devices. This course is not intended to duplicate that training. It focuses, instead, on the responsibility of the supervisor to ensure that the work site is in compliance with federal, state and local requirements related to the safety of the bridge crew and the public.

OVERVIEW OF BRIDGE MANAGEMENT SYSTEMS

The final objective is to improve participants' understanding of a Bridge Management System (BMS), its purpose, how it works, and how it can help the bridge maintenance worker do a better job. Most state DOTs are implementing, or have implemented, a BMS. Many incorporate the Pontis software developed under the sponsorship of the FHWA. Bridge maintenance crews are required to provide information such as maintenance activities, repair procedures, and costs for inclusion in the BMS database. This information can be used to refine costs and performance

standards, which are used to develop future estimates and schedules. In addition, the BMS can provide Bridge Maintenance Crews with information on maintenance needs and maintenance history to assist in scheduling work.

B. WHAT IS BRIDGE MAINTENANCE?

DEFINITION

The generally accepted definition of maintenance is work that is performed to keep a facility in its current condition. Some agencies also may include work that is performed to restore the facility to good condition; however, this may be called rehabilitation rather than maintenance work.

Transportation agencies may have a working definition of maintenance work performed by the agency that is based on who performs the work or how it is funded. These definitions have evolved for the following reasons:

- Traditionally, the federal government has not participated in the funding of maintenance activities.
- Private contractors have been successful in some states at getting legislation or agency policy adopted to restrict DOT maintenance crews from performing work that exceeds a certain cost.
- Some agency maintenance crews do not have the skills or equipment to perform complex work.

Since the target participant is a bridge maintenance supervisor/technician from a state transportation agency, this course will use a broad definition of bridge maintenance that includes the different activities performed by state bridge maintenance crews nationwide. It is understood that to some participants these activities may not be considered maintenance.

TRADITIONAL APPROACH

The traditional approach to bridge maintenance has been that bridges were built and then deferred until they became obsolete or the road was upgraded or relocated. Bridge maintenance was performed as a part of roadway maintenance with minimum attention and resources.

Large traffic volumes, heavier loads, and the use of deicing chemicals have accelerated bridge deterioration in recent years. Bridges are now deteriorating faster than they are being repaired or maintained. Agencies have recognized the fact that the tremendous investment in existing bridges has to be preserved. Bridges are critical links in our transportation system and states cannot afford to replace them at the rate at which they are deteriorating.

FUNDING / PRIORITY

Rarely does a state have all the funds that are needed by each department or agency within the government to provide the level of service that they consider necessary to do their job.

Therefore, agencies within the state are competing for funds. This competition extends down the line to units within the agency. The maintenance unit has not always received their fair share of the funds because the importance of maintenance has not always been understood.

Maintenance funding is often based on the amount that was allocated in previous years. When maintenance is neglected or budgets are cut and maintenance is deferred, the level of funding is carried forward. The results of proper maintenance are difficult to see and measure in the short term.

When bridge maintenance is grouped together with highway maintenance it may be competing with activities, such as mowing or paving, that have a greater immediate impact on the taxpayer or voter. Bridge maintenance is more expensive per mile and it is often not visible to the motorist.

THE IMPORTANCE OF PREVENTIVE MAINTENANCE

Studies discussed in Chapter IV have convincingly shown that appropriate bridge maintenance activities, performed at the proper time, are cost effective. Studies have also shown that it costs less to maintain bridges in a good condition than to maintain them in a poor condition. Therefore, preventive maintenance is cost effective and deferring maintenance results in increased costs over the life of the structure. Exhibit I.1 demonstrates the typical relationship between cost and timeliness regarding maintenance of transportation systems.

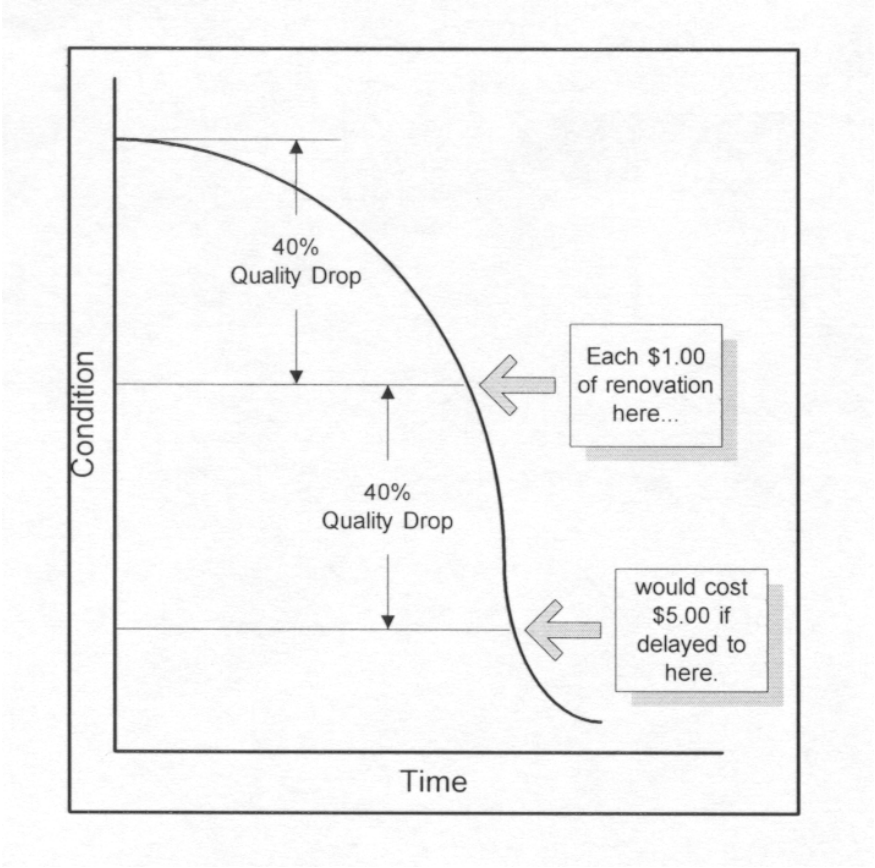

Exhibit I. 1 The cost of delaying maintenance

C. DOT ORGANIZATION

The location of the bridge maintenance group within the DOT organizational structure may also influence the priority and funding that bridge maintenance receives. The structure of the bridge maintenance group within state DOT organizations include the following possibilities:

- A separate department in the Central Office controlling all the bridge maintenance work statewide;

- A sub-unit within the Central Office, Design or Maintenance Department. If the state is decentralized the Central Office group may provide only technical advice or guidance to the district/regional units;

- Not represented (as a separate group or person) at the Central Office level but operating as a subunit of the bridge or maintenance units at the district or regional level; or

- All maintenance grouped together under roadway maintenance at all levels except that there may be a specialized bridge/building crew operating from the local area headquarters reporting to the area roadway maintenance superintendent.

The location of bridge maintenance within the organization influences the type of work performed and the amount of technical guidance or training provided to the crews. This may also affect the funding made available by the agency for bridge maintenance activities.

IV. BRIDGE MAINTENANCE CONCEPTS

Many bridges are functionally or structurally deficient. Maintenance cannot improve functionally deficient bridges. Although many structural deficiencies result from improper design and construction, improper maintenance is their number one cause.

Damage resulting from plugged scuppers and drains, leaky joints, rutted wearing surfaces and peeled paint accelerate deterioration and compound repair requirements. The damage ultimately imposes a severe limitation on the operational capabilities of structures, as shown in Exhibits IV.1, IV.2, and IV.3. With the cost of constructing and replacing bridges escalating every day, it is imperative that we make the most out of our existing bridges. Doing this is simple:

- First, properly maintain each bridge to extend its service life.
- Second, immediately repair any structural damage or deterioration of the bridge to prevent increased damage or deterioration.
- Third, upgrade the load capacity of structures to meet traffic requirements.

Categories of bridge maintenance and repair are discussed in the following section.

Exhibit IV. 1 Severely decayed timber beam

Exhibit IV. 2 Severe embankment erosion

Exhibit IV. 3 Severely Deteriorated Reinforced Concrete

A. LEVELS OF BRIDGE MAINTENANCE

Preventive maintenance, repair, rehabilitation and replacement are the successive levels of a comprehensive bridge maintenance program.

PREVENTIVE MAINTENANCE

Preventive Maintenance (PM) is the recurrent day-to-day, periodic, or scheduled work that is required to preserve or restore a bridge so that it can be effectively utilized as intended. It includes work to prevent damage to or deterioration of a bridge that otherwise would be more costly to restore. The concept of preventive maintenance involves repair of small or potential problems in a timely manner so that they will not develop into expensive bridge replacements. As such, PM is the most important function of bridge maintenance.

Preventive maintenance activities can be divided into two groups: those performed at specified intervals and those performed as needed.

SPECIFIED INTERVAL MAINTENANCE

This group includes the systematic servicing of bridges on a scheduled basis. The interval varies according to the type of work or activity. Tasks identified as interval maintenance can be incorporated into a maintenance schedule for that bridge. Examples are:

- Cleaning drainage facilities.
- Cleaning and resealing expansion joints.
- Cleaning expansion bearing assemblies.

AS-NEEDED MAINTENANCE

These activities are performed when the need is foreseen for remedial work to prevent further deterioration or the development of defects. The need for this type of maintenance is often related to the environment or identified during inspections. Example activities include:

- Sealing concrete decks.
- Painting steel members.
- Snow and ice removal.

REPAIR & REHABILITATION

Bridge repair is actually an extension of a good maintenance program. It involves maintaining the bridge's current load capacity. Selection of the correct repair technique for a bridge of any type and material depends upon knowing the cause of a deficiency and not its symptoms. If the cause of a deficiency is understood, it is more likely that the correct repair method will be selected and that the repair will be successful. A general procedure to follow for designing and executing a repair involves the evaluation and determination of the causes for the deficiency and the methods, materials, and plans to be used in the execution of the repair.

EVALUATION

The first step is to evaluate the current condition of the structure. Items to include are:

- Review of design and construction documents.
- Review of past bridge inspection reports.
- Review of past maintenance records.
- Visual examination, nondestructive tests, and laboratory tests.

RELATE OBSERVATIONS TO CAUSES

Evaluation information must be related to what caused the damage. Since many deficiencies are caused by more than one thing, a basic understanding of the causes of deterioration is required.

SELECT METHODS AND MATERIALS

Once the underlying cause of the structural damage is determined, selection of appropriate repair materials and methods should be based on considerations such as:

- What temporary construction works are required? (e.g. dewatering, cofferdams, etc..)
- What are the operating constraints? (e.g. time, weather, traffic)
- What are the advantages of temporary versus permanent repairs?
- What materials are available?

PREPARE DESIGN PLANS AND SPECIFICATIONS

That is, make all of the drawings and write out all of the special requirements or instructions that are necessary to complete the job. For work done within your own organization, this may simply be hand drawn sketches and notes.

EXECUTE THE REPAIR

The success of the repair depends on the degree to which the repair is executed in conformance with the plans and specifications.

UPGRADING & STRENGTHENING

The upgrading of existing bridges is usually required where they are to carry heavier live loads than those for which they were designed to. Upgrading or strengthening may also be required because of inadequate design or as the result of localized deterioration.

REPLACEMENT

The replacement of bridge member components is based on the type of the existing member, equipment availability, and the training level of the repair crews.

B. COMMON PREVENTIVE MAINTENANCE (PM) TASKS

Some maintenance tasks are common to all bridges despite their individual designs and construction materials. These tasks are incorporated into standardized maintenance operating procedures and generally involve keeping the bridge clean and conducting work to prevent bridge deterioration. Some of these items are discussed below, and will be addressed individually in subsequent chapters.

OVERLAY

Overlays to bridge decks can be applied as part of a preventive maintenance program as well as part of the deck repair process. Types of overlays are discussed in Chapter X.

MAINTAIN DRAINAGE

DECK DRAINS

Drains and scuppers should be open and clear to ensure that the deck drains properly and that water does not pond. Ponding of water on the deck increases the dead load on the bridge and presents a hazard to drivers in the form hydroplaning. Proper drainage also prevents water from leaking through the deck or joints to deteriorate other superstructure components.

WEEP HOLES

Weep holes in abutments should be routinely flushed to ensure free passage of water. Weep holes in the undersides of voided slabs should be maintained pushing blockage back into the voids (similar to re-opening a tube of caulk).

ICE AND SNOW REMOVAL

The primary reason for the removal of snow and ice is to provide a safe bridge for motorists. Bridges are generally the first portions of the road network to ice over and require immediate attention in freezing weather. The primary means to combat the accumulation of snow and ice is plowing the snow from the traffic lane of the bridge, spreading abrasives (crushed rock, sand, cinders, etc.) to improve the wheel traction, and chemicals to lower the freezing point of the water on the deck. When deicing salts (calcium chloride or sodium chloride) are used as part of this process, it is imperative that the maintenance schedule includes cleaning the bridge in the spring to remove any lasting effects of the salts. Any abrasives used on the structure should be removed as soon as possible after the snow period is over to reduce wear on the deck.

TRAFFIC SAFETY FEATURES

It is important that traffic control items (clearances, load classifications, speed signs, centerlines, etc.) be maintained on a regular basis. It is especially important for moveable bridges that navigation lights, traffic control systems, and protective fender systems be monitored regularly. This is a safety issue; so it is important part of a complete maintenance program.

CLEANING, SEALING, PROTECTING AND LUBRICATING

A good pressure washer is a fundamental bridge maintenance tool. While cleaning bridges, crews should have the materials on hand to touch up, protect and lubricate freshly cleaned bridge parts. Paint, epoxy, wood preservative, mortar and general-purpose lubricants go hand-in-hand with cleaning activities. Some typical applications follow.

BEARINGS AND ROLLERS

All rockers, pins, and rollers are to be kept free of debris and corrosion, lubricated where necessary, and maintained in good working order. A "frozen" or locked bearing that becomes incapable of movement allows the stresses generated to become excessive and may even cause a major failure in some affected member.

BIRD CONTROL

Birds like to live on bridges. In particular, steel bridges with wide flanges or flat gusset plates are attractive to birds. Wash these areas and install bird screens routinely.

SPOT PAINTING STEEL MEMBERS

Once steel members begin to corrode, they will begin to lose strength. It is important that areas of spot rust be touched up routinely. The loose rust must always be removed before the touch up. Importantly, if the corrosion is due to exposure from a leaking drain or joint, maintenance or repair of the source defect must be coordinated with the spot painting.

CLEANING AND SEALING TIMBER MEMBERS

Pre-treated timber will deteriorate after about 5 years if it is not maintained. So, pressure wash and seal exposed timber elements on a routine basis. Commercial products such as Thompson's Wood Cleaner and Preservative are a good choice for this type of PM. The maintenance interval should be selected in accordance with the manufacturer's instructions.

CLEANING AND SEALING CONCRETE

Pressure wash decks and bridge seats routinely, at least once a year. Periodically apply an approved pourable concrete sealer after cleaning. Experienced bridge maintenance workers may recall applying linseed oil to concrete elements routinely. This practice has generally been eliminated for environmental reasons, but there are a number of products available today that will effectively seal concrete. Check with your Materials Engineer to see what is available in your state. Establish an interval for sealing concrete in accordance with the manufacturer's instructions.

CLEANING AND POINTING MASONRY UNITS

The mortar in masonry construction is a structural component, and the ability of a masonry unit to function as designed is dependent upon proper grouting and pointing. Many states include

requirements for pointing techniques and materials in their standard specifications. In any case, commercial grades Type N or Type S mortar are appropriate for bridge maintenance.

DEBRIS REMOVAL

SUPERSTRUCTURE

Any debris left on the superstructure due to traffic or high water should be removed for safety reasons and to prevent deterioration in areas were the debris would trap moisture onto the superstructure.

SUBSTRUCTURE

Debris or floating ice that drifts against the substructure can cause premature deterioration and place excessive lateral loads on the whole structure. The techniques available to remove drift are:

- Clear small debris with a pole or hook.
- Pull large pieces of debris clear with a crane.
- Clear large and small pieces of debris with a powerboat.
- Blast large jams to break them up.

MAINTAINING DECK JOINTS

Joints are designed to provide for rotation, translation, and transverse movements of the superstructure under live loading and thermal expansion. The system should also prevent water leakage onto the components below the bridge deck. Routine maintenance for various joint types is discussed below:

FINGER JOINTS

Interlocking steel fingers attached to a steel plate allow longitudinal deck movements.

- *Clogged joint and drain trough.* Frequently flush and clean the joint and drainage system to remove debris accumulation in the system. This will also help prevent corrosion and concrete deterioration.
- *Loose joints.* Remove loose or faulty bolts or rivets, reposition the expansion device, and rebolt. It may be necessary to countersink the bolts or rivets to avoid future problems.
- *Broken finger joints.* Weld replacement fingers onto the joint.
- *Fingers closed.* Trim the expansion fingers or remove the system, reposition, and reinstall.

ARMORED JOINTS

These consist of steel angles at concrete edges which are left open or filled with a mastic or other material to prevent intrusion of debris. If the joints are clogged, clean out the joint, repair any broken angles, and apply a liquid or preformed compression joint sealant for waterproofing and

to prevent debris intrusion.

SLIDING PLATE

A horizontally positioned steel plate is anchored to the deck and allowed to slide across an angle anchored to the opposite face of the opening.

- *Clogged expansion gap.* Remove any dirt, debris, or asphalt from the gap to ensure that sliding plate interacts properly with its angle seat.
- *Joint closed.* Trim the steel plate.

PREFORMED STRIP SEAL

A sealed, waterproof joint system that uses steel plates and angles molded into neoprene coverings to provide an anchorage and load transfer.

- *Faulty section.* Remove and replace.
- *Filled Fland.* Remove any dirt or debris.
- *Loose or broken bolts.* Remove broken bolts and replace with "J" bolts.

COMPRESSION SEAL

This is extruded neoprene with a cross-sectional design and elasticity to provide for retention of its original shape. Leakage is the most common failure associated with this joint sealant and requires replacement of the deficient seal over its entire length. If cold poured elastomeric sealants are approved for use, they make a desirable replacement for compression seals.

SCOUR PROTECTION

Removal of the soil from beneath the substructure undermines the load carrying capacity of the bridge. Preventive maintenance for scour includes:

- Place sandbags around the base of bents, piers, and abutments, particularly at the upstream end.
- Place riprap consisting of stones weighing at least 50 pounds or bags filled with stones or cement mortar.
- Divert drainage lines when scouring is due to local ground drainage, storm sewer outfall or drainage from the deck itself.

BANK RESTORATION

Bank restoration involves the area in and around the abutments and up to the waterline. Erosion is the biggest problem and a maintenance program should include filling in washouts and seeding or using riprap to help prevent erosion.

C. IMPORTANCE OF PREVENTIVE MAINTENANCE

One of the major reasons for performing preventive maintenance (PM) on a bridge is to preserve the investment that has been made in the acquisition of the bridge. The cost of replacement is usually considerably higher than the initial construction cost.

Similarly, when major repairs or rehabilitation become a necessity, the cost is high. The cost analysis completed for a particular bridge rehabilitation showed that normal preventive maintenance could have been performed on ten bridges for the same amount of money. This evidence supports the statement made by a bridge inspection engineer that the State of Illinois simply cannot afford NOT to perform preventive maintenance.

Several articles have been written that show the value of performing preventive maintenance on bridges. One such report describes New York's experience in bridge maintenance. The report describes how comparisons were made between the condition of bridges and the cost of repairs. The report shows the condition rating, number of structures, average repair cost per bridge for the rating, and, finally, the total repair cost, as shown in Exhibit IV .4. A plot of the average repair cost per structure and the rating is shown in Exhibit IV .5.

Rating	No. of Structures	Average Repairs Necessary per Structure ($)	Total Repairs Necessary ($)
1	60	217,490	13,049,000
2	170	217,490	36,973,000
3	296	211,496	62,603,000
4	931	109,445	101,893,000
5	1714	44,094	75,577,000
6	2192	13,446	29,474,000
7	972	3,238	3,147,000
Grand Total			322,716,000

Exhibit IV.4 Cost of Repairs Necessary in 1980

When comparing bridge conditions and maintenance costs, it was found that the repair cost increased rapidly as their condition worsened. The cost of maintaining a bridge at a condition of 5 was relatively modest in comparison to costs when it was allowed to deteriorate further. A second part of the study shows the relationship of the bridge condition to deterioration over time. Based on the then current rate of repair, it was estimated that a backlog of $39 million in repairs existed in 1980. This backlog was estimated to peak at $47 million by 1990.

A review was made of posted bridges versus rating. The conclusion was that the number of bridges requiring posting would jump dramatically by 1990 and by the year 2018, over half of the bridges in New York will need to be posted.

The American Public Works Association (APWA) conducted a survey to determine the preventive maintenance that was actually being performed based on costs and required man-hours. The results were shown using costs per square foot of bridge deck. The survey showed that an average of $7.53 per square meter ($0.70 per square foot) was expended while the amount estimated to adequately maintain the bridge deck was $25.83 per square meter ($2.40 per square foot). This value is for preventive maintenance only and does not include the cost of replacement or major repairs. While the survey is based on only 23 cities and counties, the results are fairly indicative of the money actually being spent for preventive maintenance. In addition to the need for more preventive maintenance the survey also noted a shortfall in the dollars necessary for restoration and rehabilitation work of the same magnitude of difference.

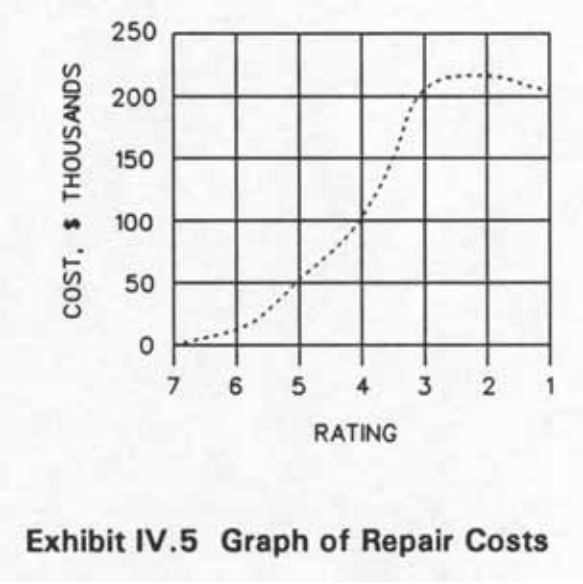

Exhibit IV.5 Graph of Repair Costs

Preventive maintenance is also essential to safety when one considers the possibility of catastrophic failure, such as the bearing failure that happened on the Connecticut Turnpike's Mianus River Bridge in 1983.

Agencies are beginning to address the cost effectiveness of preventive maintenance. The Pennsylvania Department of Transportation, however, has developed *Standards for Bridge Maintenance,* Publication 54, rehabilitation work and preventive maintenance. Cost effectiveness is addressed in this study. As bridge management systems are implemented it will be possible to measure the cost effectiveness of preventive maintenance and establish levels of preventive maintenance based on the bridge type and location.

AGENCY PM POLICY

Several DOT's have implemented procedures in their bridge inspection/maintenance programs to place more emphasis on PM. For example in Pennsylvania, PM crews precede the inspection unit to clean bridge seats, substructures and decks before most scheduled visits by inspectors. This prevents more serious problems and helps the inspectors to see problems more easily. Pennsylvania has added to the biannual bridge inspection over 76 maintenance items that, if needed, are, to be identified with a priority and quantity. This information is used to plan future maintenance work.

In New York State the performance of bridge maintenance units is measured based on the condition ratings of the bridges for which they are responsible. The objective of the maintenance crew, when they work on a bridge, is to get the condition rating above a certain level -say "6" or above. Rather than spending all the maintenance budget keeping bridges open that are in poor condition, agencies are recognizing that it is less expensive to concentrate on preventing them from getting in poor condition.

During 1988-1989, a consortium of civil engineering departments of New York City colleges and universities administered by the Center for Infrastructure Studies at Columbia University undertook the development of a preventive maintenance management system (PMMS) for New York City. The system concentrates on bridges in "good" to "very good" condition although it makes it clear that PM must also be performed on "fair" to "poor" bridges until a steady state is reached.

Maintenance Activity	Number of crews	Crew size	Total staff	Total cost
Debris removal	14.81	5	74	$2,941,853
Sweeping	5.11	1	5	299,690
Clean drain system	10.95	4	44	1,847,938
Clean pier/abut tops	5.19	5	26	1,595,406
Clean open gratings	0.17	5	1	37,223
Clean expansion joints	7.21	7	50	1,957,635
Wash salt splash zone	8.45	7	59	2,631,704
Painting of steel	24.66	11	271	19,438,300
Spot paint steel	21.36	5	107	8,737,013
Paint salt splash zone	7.27	11	80	5,667,292
Patch sidewalks	7.59	3	23	1,544,535
Crack sealing	4.89	5	24	1,603,081
Electrical maintenance	2.50	5	13	936,500
Oil mechanical parts	3.50	3	11	575,400
Replace wearing surfaces	0.20	30	6	1,614,980
Total personnel required	--	--	794	--
Total cost of program	--	--	--	51,428,550

Exhibit IV.6 Summary of Statistics for Preventive Maintenance Management Program

The objectives of the New York City PM plan are to:

(1) Keep the rating of bridge condition at a constant level; and
(2) Maximize the life of bridges before major rehabilitation or replacement,

Exhibit IV.6 summarizes the cost and workers required for the NYC PM program. Exhibit IV. 7 provides an example of the total annual cost of PM and replacement or rehabilitation. Note that as the level of maintenance decreases, the total cost increases dramatically. The consortium concluded, "the consequences of (NYC) not adopting some form of PMMS could be catastrophic."

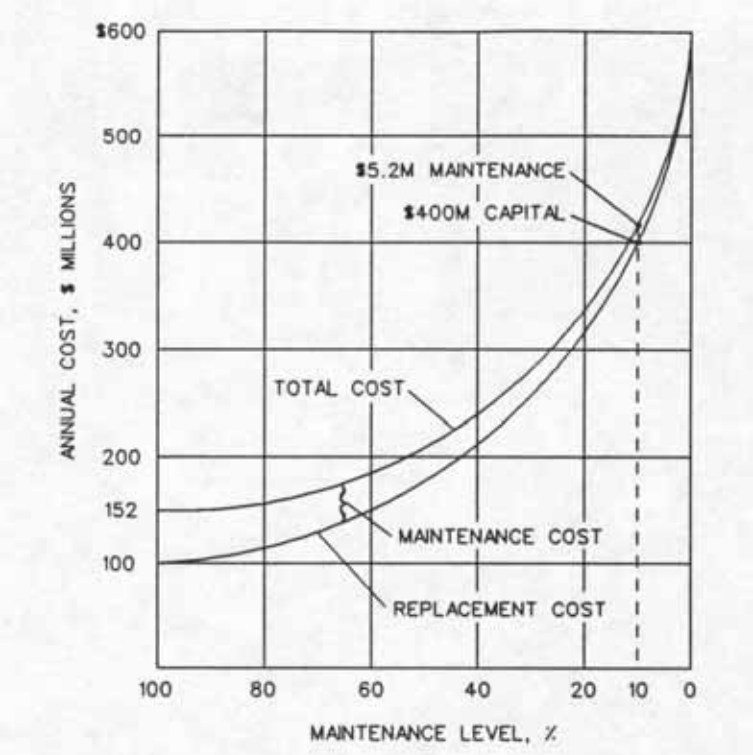

Exhibit IV.7 Total Costs vs. Maintenance Level

V. BRIDGE MAINTENANCE MANAGEMENT

The National Bridge Inventory (NBI) and the National Bridge Inspection Standards (NBIS) were created in the late 1960s and developed in the early 1970s. The standards require all structures over 20 feet long that carry public roads to be inspected at least every two years. Today, there are nearly 600,000 structures in the inventory. Nearly 100,000 of these were constructed over 70 years ago.

The NBI is a basic Bridge Management System (BMS). It is composed of data that are used by the FHWA to determine the extent of a state's eligibility for federal funding of its bridge programs.

In the 1980s, there was some concern that the NBI was incapable of efficiently prioritizing bridge needs in view of limited funds. In 1985, the FHWA initiated a two-phase demonstration project to refine the concept of BMS. The first phase was a review of existing state BMS practices, and a synthesis of these to establish the fundamental elements of a national BMS. Phase two developed a computer application that any state could use to manage its bridge inventory. This application is now called PONTIS, and it is licensed to over 40 states and localities in the U.S.

Over the last 10 years, the number of structurally deficient bridges has steadily declined from 34.6% in 1992 to 29% today. Since bridge management systems became a focus of national attention during this period, this reduction may be a testament to the effectiveness of good management practices.

But, we still have a long way to go. The FHWA's strategic plan states that by 2008 no more than 25% of the nation's bridges should be deficient. It is essential that structures not classified as deficient be included in a systematic maintenance program. This practice should preclude premature replacement or rehabilitation.

Many state highway maintenance managers have remarked that outside factors, such as political decisions, budget restrictions, or lack of personnel, have inhibited the implementation of a system to properly manage their bridges. Managers report much of their time and resources are spent reacting to emergency situations or patching bridges in poor condition to keep them operational. This is unfortunate, and in many cases unnecessary.

A. THE MANAGEMENT APPROACH TO BRIDGES

The practice of doing nothing until emergency work is required should be eliminated. Most states have, in varying degrees, adopted highway maintenance management programs. Several states are now successfully applying common management principles to bridge maintenance operations. Improved efficiency and effectiveness are the results.

ASSET MANAGEMENT vs. MAINTENANCE MANAGEMENT

ASSET MANAGEMENT

It is important to understand the differences between asset management and maintenance management. In the past, these terms have been used somewhat interchangeably, and this has led to confusion and disappointment regarding the utility of various management software programs.

A BMS is an asset management system. A good BMS is an all-inclusive database of bridge features, traffic data, costs, safety data, and etc… that are included in an ongoing data collection effort. The BMS looks at network level trends and prioritizes bridge needs based on system wide constraints. A good BMS should be able to:

- Predict bridge deterioration, both with and without maintenance or repair activity,
- Develop alternatives to improve bridges,
- Estimate costs for improvement options,
- Determine network level maintenance strategies,
- Constrain a program plan for bridge needs to the available funds,
- Generate budget reports.

A Bridge Maintenance Management System (BMMS), on the other hand, is dedicated to project level needs. It should be used to plan, schedule, budget, and monitor individual maintenance projects. The differences between common BMS and BMMS applications are provided in the following paragraphs.

Pontis

Many states are implementing the BMS called Pontis. Pontis supports a series of bridge management activities involving information gathering, interpretation, prediction, cost accounting, decision making, budgeting and planning. The Pontis system consists of a set of interconnected models that address these functions systematically. The system is designed to help managers prepare and evaluate a capital program for bridges.

The system combines models that predict deterioration, provide costs, and compare feasible actions. As inspections and repairs are made, the system is updated and refined with additional cost, deterioration, and feasible action data. When more precise historical data is unavailable, it initially uses engineering judgement and NBIS data until predictive models can be generated using the agencies own data.

Commonly Recognized (Core) Elements

In 1993, a task force of the FHWA and six states (Minnesota, Oregon, Colorado, California, Virginia, and Washington) issued a list of common bridge elements called CoRe Elements. These elements are termed "Commonly Recognized" (CoRe) structural elements because of their nationwide recognition and use. The element descriptions are meant to provide a uniform basis for data collection for any bridge management system and to enable sharing of data among

States. All states are encouraged to use the CoRe element descriptions in setting up data collection procedures for bridge management systems. The Pontis system uses CoRe elements as the basis for data collection.

In general, all girders, trusses, arches, cables, floor beams, stringers, abutments, piers, pins and hangers, culverts, joints, bearings, railings, decks, and slabs are identified as CoRe elements. The element listing includes a description, a definition, condition state language, a unit of measurement, and feasible actions for each element. The element descriptions consider material composition and, where applicable, the presence of protective systems. The CoRe element definitions are supplemented in some cases with a "smart flag" to provide additional information about the condition of an element. There are a total of 98 CoRe elements and eight smart flags.

The FHWA has issued a translator program that can be used to convert CoRe element condition state ratings into the corresponding NBI condition ratings.

System Level Vs. Project Level Management Decisions

Pontis is a BMS designed to provide help in making management decisions for groups of bridges or "system level" decisions. It should help the manager to determine and support funding for maintenance needed to keep bridges in good condition. Bridge managers need a tool to prove to those that control funding that it costs less to maintain bridges in good condition than to defer maintenance and let bridges deteriorate.

Pontis was not designed to provide information for decisions needed to manage a specific bridge or "project level" decisions. For example Strategic Highway Research Program (SHRP) Project C104 developed a computer model to provide the most cost effective strategy to apply to a corrosion damaged concrete bridge. The manager can use the SHRP program to determine the best type of protection or repair for a certain bridge, given the bridge type and condition.

Some management systems provide project level support. Bridge maintenance activities, such as cleaning, patching, and joint sealing, have been identified and performance standards developed. The performance standard includes the resources (manpower, equipment, and materials) needed to perform a maintenance procedure on a specified unit of the activity. The units needed and urgency required must be identified for a bridge.

For example, the PennDOT Maintenance Management System (MORRIS) includes performance standards for each of the 76 maintenance activities identified. The system also contains manpower, equipment, and materials available to each bridge crew. PennDOT bridge inspectors identify maintenance needs for each bridge and give each need a priority. After the maintenance needs are input, the system develops bridge maintenance work orders for performing maintenance on specific bridges.

Since no two bridges are exactly alike, it is helpful to have the maintenance worker visit the bridge before the repair is planned to evaluate the requirements. Management systems should be considered as tools to assist managers. As the models and logic are refined, the results will more

accurately reflect a specific bridge. However, there will always be a need for engineering judgement.

The Role of Bridge Maintenance Workers in BMS

Bridge Maintenance workers play a very important role in the bridge management process. Since they are at the front line of delivering bridge maintenance services, they will provide information regarding the following:

- The effectiveness of BMS maintenance strategies.
- Labor production rates associated with BMS strategies.
- Actual costs associated with BMS repair alternatives.
- Accuracy of BMS models intended to predict the deterioration of bridge elements.

This information may be transmitted informally, via e-mail or other correspondence, or it may be incorporated into the BMS via interface with a formal Bridge Maintenance Management System.

BRIDGE MAINTENANCE MANAGEMENT SYSTEM

Exhibit V .1 shows the elements of an idealized Maintenance Management System (MMS).

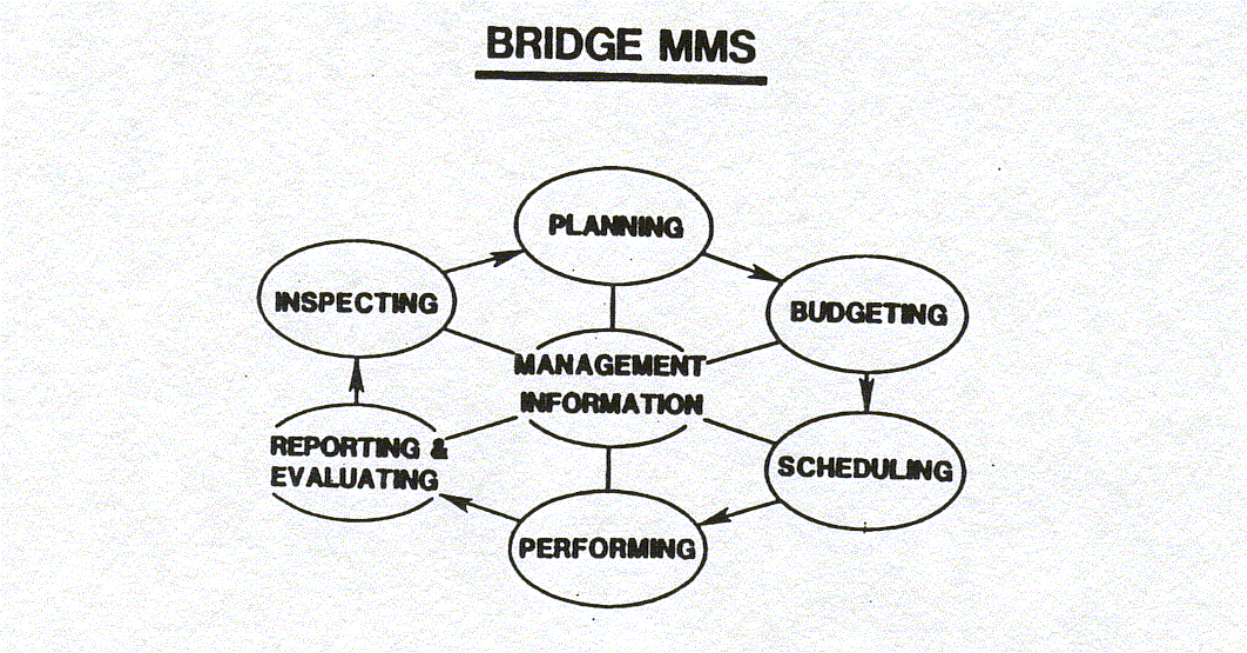

Exhibit V. 1 Elements of a Bridge Maintenance Management System (BMMS)

A Bridge Maintenance Management System (BMMS) should be dedicated to specific needs. It should accomplish the following: planning, budgeting, scheduling, performing, reporting, evaluating and inspecting. A brief description of these six activities follows.

Planning

Planning may be the most important function of a bridge maintenance supervisor. Improved planning techniques will pay off in many ways:

- Higher production rates on individual projects
- Limited “down time” in-between projects
- More efficient use of “down time” for training and yard PM
- Improvement of the condition of the bridge inventory
- Increased esprit de corps among bridge maintenance workers

Planning involves the selection of objectives and the determination of the policies, programs, and procedures to be used for achievement of the selected objectives. Of all the management functions, planning is the one function that has the most productive effect on utilization of available labor, equipment, and materials. On the other hand inadequate planning is often a basic cause for much of the criticism leveled at maintenance activities as being unresponsive, unproductive, or too costly.

Supervisors should consider the whole bridge system and the bridge maintenance needs over an extended period of time. Planning must also account for everything that can affect the bridge system. Begin planning by analyzing the bridge data base of the inventory, history, plans, and maintenance requirements in order to define priorities, needs and quantities. The bridge maintenance work plan is basic to the system. Once the work plan is developed and budgeted, it is the base from which specific work orders are developed and scheduled.

Budgeting

Budgeting is the process by which the funds and resources to implement the plans are obtained. Governmental agencies are accustomed to reviewing line item budgets that aggregate the budget requests into defined object classes such as "pay of personnel," "equipment purchases," etc. A performance-based budget that relates work to be accomplished with the required labor, equipment, and materials and their costs, is far superior because alternative budgets can be associated with needs.

Work estimating procedures that are fairly standard are used when developing a budget. The maintenance plans evolved in the planning process indicate the amount of work required. Utilizing the work estimates, costs are compiled and the budget is developed. The plan may need to be revised to match the budget received.

Scheduling

Scheduling is the process of laying out future work. A good scheduling process develops work schedules on at least three levels--organizational, supervisory, and foreman (or working) level. Scheduling is a tool to help achieve the project objectives without exceeding the budget. Scheduling accounts for all resources: labor, equipment, and material. Schedules must be more detailed at the working level than at higher administrative levels. The worker's schedules are the

final approved and budgeted work plans. The foreman's schedules are very specific as to location, date, time, and assigned crew members. The work schedule reflects seasonal requirements. Since emergency work is always a possibility for public works agencies, the scheduling process must also contain flexibility so emergency conditions can be met without undue strain on the organization.

Performing

Performing is the process that is concerned with the actual completion of the work in the field. The work should be done in a manner that conforms with prescribed quality and quantity standards. Material, equipment, and labor are used as indicated in performance standards, or as nearly as possible. Obviously, variations occur, but if these are consistently larger or smaller than the standards, either the standards are in error or procedures other than those prescribed are being followed.

The schedule is generally translated into performance through a work order system. Two types of work orders--one for in-house forces and the second for accomplishment by contract, may be used. The crews who will do the work should plan the work specified by the work order in detail. This may involve decisions as to the specific work methods and the provision of the resources as well as the actual performance of the work.

Reporting

Reporting represents the primary means of communication between those actually performing the work and those who must manage it. Work completions and the use of resources are reported as they occur. Work completions inform management that planned and scheduled maintenance goals have been met and provide data to account for funds. Obviously, standard reporting forms that are easy to complete with the correct information generate the best data. Completions must be entered in the inventory, database, and history record to provide an updated record.

Evaluating

Evaluating is the means by which the quantity and quality of work is measured and is the basis on which management can exercise control actions. Provisions should be made so that those most involved with the actual work, the foremen for example, regularly receive information so they can judge their own performance. Reports are provided to each administrative level appropriate to the needs of that level. Evaluations are based on comparisons between like crews or personnel performing like tasks with due account taken for extenuating factors such as individual work site specifics. Comparisons are also made against standards so the standards may be adjusted to make expectations reasonable and so that planning and budgeting efforts are more accurate. Evaluation is also the system element that serves to measure the effectiveness of all of the other elements and to provide the means by which not only bridge maintenance, but the personnel performing it, can be improved. A bridge maintenance management system can supply the manager with the means to more effectively and efficiently accomplish his maintenance program. At the same time the system will increase the control of operations and provide

credibility to the program since the manager will have information with which to respond to requests and justify budgets.

SYSTEM INTERFACES

In some states the BMMS is a part of the Maintenance Management System. In other states it is included in the BMS. Regardless of the system in which it is included, the BMMS cannot operate in a vacuum. It must interface with the other management systems in the Department. The need to interface with Bridge, Maintenance, and Construction Management as well as with Resource Systems is obvious. Pavement management systems manage the pavement rehabilitation and resurfacing projects. The bridge re-surfacing required may not be an integral part of the project unless an interface with the pavement management system ensures coordination. While a bridge is undergoing major repair or rehabilitation, other maintenance activities will be affected and coordination can improve performance and economy.

B. PLANNING AND SCHEDULING BRIDGE MAINTENANCE

The key to the successful execution of any bridge maintenance project is the proper planning and scheduling of the work. Increased needs combined with reduced funds (a problem that seems common) means that maximum advantage must be taken of every available hour and resource. This can only be done when a small part of these available hours are spent in planning and scheduling the work. The planning and scheduling must be done prior to beginning the project and continue during the execution of it.

If a BMMS is available, it may be used to aid in the planning and scheduling process. The accomplishing of the work can be broken into two major areas: job layout and work performance. The first involves the planning of how the job is to be accomplished. The second involves the coordination and efficiency of the work procedures.

LONG-RANGE PLANNING/SCHEDULING

The planning/scheduling of bridge maintenance work is performed on several levels. The worker may not be directly involved in the long range planning. Long range planning involves the following steps:

Needs are identified for all the bridges that are included in the planning area. The needs include procedures performed on a regular basis and procedures performed as needed. A ballpark cost estimate is developed and a budget is prepared.

After the budget is approved, a more detailed estimate is developed to determine the manpower and equipment requirements to accomplish the work and this is compared to the available manpower and equipment. Special needs for skills or equipment that may not be available are also evaluated.

Assuming there is insufficient manpower or equipment, or a lack of a special skill, decisions are made regarding whether to contract part of the work or add to the in-house resources.

Assignments are made for each crew, after the crew assignments are made, schedules can be developed and work orders can be generated. In most agencies the worker is responsible for, or involved in, developing the crew schedule. The scheduling process involves determining:

- The urgency of the work;
- When in the year the work can be performed;
- When necessary approvals or permits can be obtained; and
- When necessary support, equipment, and materials are available

Realistic scheduling improves efficiency. Workers should be challenged but if too little time is allotted to a job, short cuts and omissions will be encouraged or the schedule will not be taken seriously.

WORK ORDERS

Work orders, are prepared in advance to provide details of each job. The work order contains a description of the particular type of work to be performed, the exact location of the work, the names of all workers assigned to the project, and the list of equipment and materials available or needed to do the work. The work order may be prepared by the BMS based on performance standards and condition data from the inspection or prepared manually by someone in Maintenance after the assignment is made and the job layout is completed.

JOB LAYOUT

The worker (or a bridge maintenance engineer) usually performs the job layout after the job is assigned to the crew. This involves visiting the bridge to determine detailed work requirements. Factors that must be considered in preparation for each bridge maintenance project include:

- Traffic, employee safety and environmental considerations;
- How the work will be performed ;
- Job assignments for crew; and
- Equipment and material requirements.

It is vital that preplanning be done for every project to prevent delays. General guidelines for procedures that need to be followed in performing bridge maintenance projects are as follows:

Traffic Control

Any project that will place workers or equipment on or adjacent to the roadway requires traffic control procedures in conformance with standard uniform practices. This includes correct use and placement of signs and flaggers. Adequate traffic control is often the most important safety factor for the crew's protection and neglect in planning traffic control can place the agency in a vulnerable position to very costly liability judgments.

Environmental Considerations

Environmental factors are rapidly becoming the greatest source of delays in executing bridge maintenance work. Typical concerns are air, water, or soil pollution and disposal of toxic materials, such as salvage material containing lead-based paint or creosote.

Employee Safety

The high costs of employee injuries and OSHA penalties have demanded the attention of most transportation agencies. For example, agencies are requiring that fall protection or confined space plans be developed and submitted for approval prior to beginning work on a project that places the workers in risk of either. Other common hazards include exposure to toxic materials and embankment collapse during excavation.

Work Procedures

First, it is necessary to determine exactly what work must be performed. The worker should visit the site and make this determination. While at the site the worker should determine the exact location and total units of work. Storage of equipment and materials is also a consideration.

If performance standards are available, they can be compared to the work to be done to determine whether they are applicable or whether it is necessary to modify the standards for the job. If the information in the performance standards is applicable, it can be used to help determine the resource requirements of the job with modifications if necessary. If performance standards are not available, a written description of the work to be performed should be prepared. Usually, a simple outline listing the items of work to be done in the order in which they will be accomplished is sufficient.

Job Assignments for Personnel

Performance standards aid in determining the required number and either the classification of personnel or the skills that will be required. If performance standards are not available, required skills for each item of work in the outline of work previously prepared should be noted. The knowledge of the actual work that is to be done and the conditions at the work site should temper the requirements. Variations may be required due to traffic considerations, unusual complexity of the job, or weather factors. These should then be compared with the capabilities of the crew members and assignments made to appropriate individuals.

Individuals should be assigned specific tasks in accordance with their capabilities, the requirements of the job, and training opportunities, if possible and appropriate. Specific precautions or instructions should be given to the employees at the time of the assignment. If required skills are not available in the crew--a certified welder for example--arrangements should be made with superiors to obtain necessary assistance.

Equipment Requirements

The performance standards aid in determining the type and amount of equipment required to properly perform the work. Modifications may be necessary due to unusual work requirements that were determined when work procedures were established, personnel qualifications, or differences in the equipment available compared to those identified in the standards. If performance standards are not available, units of equipment required for items of work in the previously prepared outline should be noted. Back up units may be necessary, or alternative plans made so equipment failures will not delay completion, especially for critical tasks or when a reopening to traffic is mandatory.

Tools that might be required during the operation must also be considered and compared with the complement of equipment and tools readily available to the crews; if additional items are required, arrangements should be made to have them available and ready for use. Nothing can be more time consuming, inefficient, and destructive to morale than having a crew inactive while one member drives back to a staging area for a vital tool. As anyone in the public sector knows all too well, this can also be damaging to an organization's image in the eyes of the public. Every crew should carry a complement of standard tools.

Material Requirements

The amounts of material needed for the job can also be determined from the performance standards or estimated based on past experience. If any materials requiring a special order are needed, the necessary paperwork should be prepared. A reserve of the materials should also be taken to the job site in case the estimated amounts were understated. Other types of material that might be needed, such as wood for forming or aggregate for backfilling at approaches, should also be included. As is the case for the other resources needed to perform the work, an unnecessary delay caused by the lack of proper preparation is inexcusable.

Without proper planning, a crew can arrive at a work site totally unprepared to perform the work. The project may then be delayed due to a number of factors such as:

- EPA or OSHA delay;
- accident;
- lack of the particular skills required;
- lack of equipment or material; or
- Crew unsure how to do the job or the correct sequence of tasks.

SHORT -TERM SCHEDULING PROCEDURES

Once the job layout has been performed, the work can be programmed in the short-term schedule. Schedules are "roughed in" for several months and as time gets closer to do the work, the job layout is performed and scheduling becomes more precise.

When scheduling the work for the month, it is important that the maintenance activities be coordinated as much as possible. This includes such considerations as repairing concrete on

several bridges in the same area at the same time, cleaning and painting several adjacent bridges, or ordering material for several jobs at the same time.

Each week the schedule for the following week is developed. During this process the following steps should be taken:

- Check to see if any work scheduled for the present week will be carried over into the new work week because of emergencies, bad weather, or delays.

- Review the work scheduling to see which new activities are to receive the highest priority.

- Review the monthly schedule to see what projects are scheduled and if adjustments are indicated.

- Determine the employee days, equipment, and material required for the week

- If manpower is still available, alternative or fill-in projects should be identified.

- Complete the schedule by assigning men and equipment to the specific projects,

Obviously, inclement weather may disrupt the work schedule. It is important that other work is planned that can be performed in bad weather so that time will not be wasted. In most states, repairs are generally limited in the winter months to emergency patching, bridge cleaning, some joint sealing, and other emergency work. Since the winter work performed is minimal, the period is ideal for the training of employees and the repair of equipment. Many states use bridge crews during the winter months to precast concrete bridge elements such as slabs, curbs, and railings as well as other incidental items for the Department.

CRITICAL PATH METHOD

Critical path method (CPM) is one method of scheduling sub-tasks of a larger task or maintenance procedure. CPM is particularly useful in construction work but has many wide applications. It can be used for scheduling tasks within a work order or for the yearly activities of the entire maintenance unit.

The FHWA has developed a two-day course titles “Use of CPM for Estimating, Scheduling and Timely Completion.” This course is strongly recommended for all bridge maintenance supervisors.

C. PERFORMING THE WORK

More attention will be given in later sessions to step-by-step technical instructions for performing bridge maintenance procedures. The purpose of this session is to address the routine things that will help improve the efficiency of a bridge crew.

JOB EXECUTION

The daily routine for any job consists of:

- Housekeeping and PM of equipment and vehicles at the yard in the yard;
- Preparation for the job at the yard and moving to the job site;
- Performance of the work at the job site including occupying and leaving the site; and
- Cleanup after the job at the yard.

The daily routine can contribute to coordination and efficiency of the performance of the work at the job site if properly and carefully done. Each segment has a number of subtasks that are identified below:

HOUSEKEEPING

The maintenance yard is the base of all operations. The yard must be maintained in at least good condition in order to facilitate field operations, and to maintain a high level or worker morale. Most states have a Safety Engineer or equivalent person that help yard supervisors comply with OSHA requirements, and an Environmental Engineer or equivalent that helps with EPA compliance. Bridge maintenance supervisors should strive to develop a close working relationship with these people, and work with them to develop a Standard Operating Procedure (SOP) for yard maintenance activities. Some of the items and activities that should be covered in the SOP include:

- Periodic updating of material safety data sheets (MSDS)
- Periodic check of parked vehicles for fluid leaks
- Check yard signs for compliance and legibility. (E.G. are “No Smoking” signs posted at the proscribed distances from combustible materials, and are they legible?)
- Return all flammable/combustible materials to the designated storage areas
- Periodically check flammable/combustible material storage areas for compliance, and to ensure reactive materials are separated. Clean these areas daily.
- Properly secure all compressed gas cylinders, and ensure storage is in compliance with regulations.
- Check and service fire extinguishers
- Check and clean all hazardous waste storage areas. Periodically inspect these areas for compliance.
- Clean and disinfect all common areas (shower, toilet, shop floor, etc…) daily.

PM EQUIPMENT AND VEHICLES

Equipment and vehicles must be maintained in good working order. It is unacceptable to report to a work site with inoperable equipment. All equipment and vehicles should be checked and serviced prior to mobilization. Checks and services should be performed in accordance with the manufacturer's schedule and guidelines.

YARD PREPARATION

Prior to leaving for the job site, the crew is first assembled to determine if, due to absences or for any other reason, any changes must be made in job assignments. Following the assignments, the crew members should be informed of the tasks each is to perform, including those related to safety. This allows each crew member to know what his assignment is and who is to support him, or who he is to support. The crew then gathers the required equipment and material needed. Once the necessary resources (labor, equipment, and material) are assembled, the crew is informed of the staging location and proceeds to the work site.

If one job is to take a number of days, this process is obviously much simpler after the first day. Depending upon local rules, regulations, and agreements, it may even be possible and economical as well, for the crew or some members of it to report directly to the work site. In any event, time getting ready is not wasted.

AT THE SITE

When the crew arrives at the work site, the crew leader should review the safety procedures to be followed on the job and ensure that safety-related assignments are fully understood. Once proper traffic control has been established, the crew can proceed with the work. Traffic control items should be checked periodically and the site should be kept as clean and uncluttered as possible while the work is underway.

The practice of leaving tools and materials lying around the work site is hazardous, unprofessional, and an eyesore. When the job is complete, the tools and excess material should be properly stowed prior to leaving the site. Once the site is clean and again suitable for traffic, the traffic control devices can be removed. Correct opening-to-traffic procedure requires that the removal of signs and devices start at the work site and proceed back from the work site in the opposite direction of traffic.

YARD CLEANUP

There are tasks that must be performed after the crew returns to the yard. The tasks include storing the tools and materials in their proper locations, preparing equipment for the next day, and reporting the work accomplished. In order to save time the next work day, all equipment should be serviced, including adding gas and oil. Problems encountered with the equipment during the day should be reported. The final tasks for the crew lead and perhaps the most important, are reporting the work accomplished during the day and ensuring that work for the

following day is planned and resources for performing it are available. Work reporting information is presented in a subsequent session.

MANPOWER

To ensure that the job can be performed properly, the crews should be made up of personnel who have been trained to perform the specialties that are required. This includes such specialists as:

- Carpenters for form building and wood working,
- Welders for steel work,
- Laborers for concrete and masonry work, and
- Operators for special equipment.

These specialists are able to perform a majority of the tasks. The remainder of the crew should be made up of general laborers who can assist the specialists and perform other required tools. In addition, the crew should have the necessary equipment and stockpiled material to ensure that the scheduled work can be performed.

EQUIPMENT

Each bridge crew should have as full a complement of tools and equipment as possible so that there is no lost time attempting to obtain items from other sources. The scheduling process will often reveal a continuing lack of necessary items that can cause delays to bridge maintenance projects that are far more expensive than the acquisition cost of proper equipment and tools.

Some suggested items include:

- Flat-bed truck with winch and A-frame, or some other type of lifting equipment
- Pick-up trucks, as needed
- Pole trailer or unit for lengthy materials.
- A variety of air-powered tools.
- Air compressor.
- Small concrete mixer or mortar mixer
- Oxygen and acetylene welding and cutting equipment
- Heavy duty jacks--180 kN to 450 kN (20-ton to 50-ton) hydraulic.
- Portable arc welder with electric service outlets
- Heavy-duty electric drill fitted with an electromagnet.
- Small, portable high pressure water pump.
- Sandblasting equipment
- Hand tools: steel, carpentry, concrete, and mechanical.
- Staging (scaffolding).
- Spray paint outfit.
- Tow cable and chains
- Radio equipment.
- Chain saw

- Heavy duty chain hoist
- Digital camera to instantly record activities
- Miscellaneous survey equipment (tape, level-rod, etc.)

MATERIALS

Each bridge crew should have a small supply of materials, especially for emergency repairs. Many materials can be accumulated from salvaged materials or material left over from new bridges:

- Timbers for blocking and cribbing (usually salvaged material).
- Assorted bridge planks.
- Steel decking
- Assorted I-beams, angles, channels and plates.
- Reinforcement bars.
- Sheet piles.
- Timber and steel piling
- Cement, mortar, mason sand, and aggregates .Epoxy
- One gallon Pentachlorophenol (Penta) and brushes.
- Paint, primer and finish, paint brushes
- Nails, spikes, bolts, nuts, washers, drift pins, lag screws

D. REPORTING BRIDGE MAINTENANCE ACCOMPLISHMENTS

A question that many new workers ask is "Why do we have to fill out reports to tell others what we did?" Basically the answer is, "Because we learn and base future decisions on the information collected from each job." In general, information provided by workers allows managers to maintain:

- A historical record of maintenance and repair;
- A record of regular periodic and special expenditures as a basis for developing future budgets;
- A current record to establish cost/performance relationships;
- A source of information to facilitate identifying trends, and the need for additional cost or work item controls;
- A source of information for public relations, accomplishment reports, and defense of tort liability claims; and
- A record of costs versus budget.

REPORT REQUIREMENTS

Each state has specific reporting requirements but, in general, the information fulfills the manager's needs. The following is a brief description of each of these five information requirements:

WHO

This indicates who performed the work, by specifying the crew or the individual in charge of the work. This permits the work to be charged to the proper department and permits future verifications and follow-up in case of discrepancies or claims. The actual coding of the "who" identifier will vary with the state requirements.

WHAT

This reports the activity number that has been assigned to the specific type of work performed. The amount of work performed should also be recorded. The performance standards for each of the activities indicate how the amount of work is to be measured. The report of what and how much is used in evaluating crew performance, the suitability of standards, project progress, and is also used for budget comparison.

WHEN

This reports the date, or dates, on which the work was performed. This information is helpful in determining when work should be scheduled in future years and is required for scheduling periodic maintenance, particularly preventive maintenance.

WHERE

This reports the location of the bridge by reference to a route, milepost, or both, and the bridge number. This information correlates the work to the repair history of the bridge. In addition, the information allows sorting by road types and locations.

HOW

This reports the resources that were used as well as how the job was performed. The hours of labor, types of equipment, and the type and amount of materials used are included. This permits computing the cost of performing the work and provides utilization data. The information also permits the determination of monthly resource needs for use in future scheduling.

REPORTING PROCEDURES

The actual reporting of the work performed has many variations. Most states already collect the major portion of the information required. Some states use separate forms for bridge work, while others include bridge work in the highway maintenance management system or the payroll section. Personnel at the field level are able to furnish the most reliable information. Generally

the individual in charge of a crew has the best knowledge of what has transpired. Many reporting errors are caused by permitting several, or all, of the crew members to report the same information on different forms. The most complete and accurate reporting is obtained when the crew leader prepares, or at least reviews, the reports.

Ideally, the information requirements of each system can be minimized while the accuracy of the information is increased. This can be accomplished by requiring that each system collect only the information that it needs to function efficiently. Thus, if the payroll system collects information on hours worked by each employee, the equipment system collects information on vehicle usage; and the material system collects information on material usage; these sources can furnish the basis for bridge work reports.

Many systems use one form to collect all data. This creates a very complex reporting form that leads to inaccurate reporting. Consequently, the management information that the system produces is of questionable value. When simple forms are used, the data collected is generally more accurate and reflects the work that has been performed more realistically.

The use of digital cameras and electronic or Internet based reports is increasing in popularity and will likely become the state of practice in the near future. The tools allow for quick reporting and report distribution to remote locations.

E. USE OF CONTRACT MAINTENANCE

All state DOT's contract for some portion of their maintenance work. A bridge maintenance program requires the purchasing and procurement of a wide variety of materials, supplies, equipment, and services. Routine purchasing and procurement is usually handled with procedures established at the department level. Contracting, the subject of this session, represents a specialized area of procurement that will probably become more common for bridge maintenance work.

NCHRP Report No.344 lists the following reasons for maintenance contracting by agencies:

"Fifty-one of the fifty three agencies who responded to the question on the factors considered in deciding to contract for maintenance cited limitations on in-house staffs as one of the reasons. Other factors listed and the number responding were: the need for specialized equipment (50), *the need for specialized personnel* (44), *to cover peak work loads* (42), *to obtain services at lower cost* (38), *executive policy* (37), *emergency work* (35), *to improve responsiveness* (31), *legal restrictions on the amount of work performed by agency forces* (16), *legal restrictions on contracting* (16), *and employee contract restrictions* (11). "

Contracting is a formalized process governed by state law and departmental policies and regulations. It is common for contracts of different types and for different amounts of money to have different restrictions placed on their use. Before a bridge maintenance organization enters into any contract or agreement with any entity in the private sector, appropriate higher authorities and/or legal counsel should be consulted to ensure that both the contract and the procedures associated with it are within applicable laws and regulations or directives. This practice is

absolutely vital when an application for federal reimbursement for any portion of the work may be made or if the maintenance work can be construed to be rehabilitation.

The requirement that a public agency must use a competitive process of some type in the awarding of contracts is essentially universal. Competition takes different forms depending on the type of contract and the service to be provided, but it should always be a factor .

LUMP SUM CONTRACTS

This type of contract is only suitable if the amount and scope of work can be defined precisely as might be the case in the complete replacement of specific elements of a structure. Even in this instance, there must be reasonable assurance that unexpected conditions such as deterioration of adjoining elements will not cause delays, increase material requirements, and other problems. Unanticipated difficulties can also arise when some portion of the work is not defined in sufficient detail thereby causing a situation where the agency and the contractor cannot agree on the intended interpretation of the plans and specifications. If the contract is written in a way that allows some flexibility in the amount of work required for a single price, the contractor will have to assume the worst case to protect himself and the contract cost will tend to be high. As a result of these considerations, it is recommended that lump sum contracts for bridge maintenance be used only for projects on which all features can be easily and conveniently described in the plans and specifications.

In some cases a modification of this type of contract that allows some variation in the quantity of work may be useful and convenient. This modification requires that a specific lump sum for an element of work be bid but that a variable number of elements be provided. A typical example would be the complete replacement of piles in a wooden trestle bridge with a minimum number and maximum number specified and the exact number to be determined during the progress of the work. Obviously the minimum and maximum amount of work must be specified in all such contracts for the protection of both parties to the contract. The price in contracts of this kind would be a single lump sum price for each unit of work for all labor, equipment, and materials with the element, such as a pile, complete and in place. A lump sum price may also be used for some items in a unit price contract as discussed in that section .

UNIT PRICE CONTRACTS

If the amount and scope of work can be defined within reasonable limits, ten percent or so, the unit price contract is usually the best choice for bridge contracts as well as bridge and highway construction contracts. This type of contract is by far the most commonly used for construction projects in highway agencies. In this type of contract the contractor receives payment for the actual amount of work that he does and the contracting agency retains a reasonable degree of control. It is often convenient to have some well defined items within a unit price contract paid for as a lump sum. A brand new concrete deck, for example, could be paid for as a lump sum item since its width, length and thickness determines the amount of materials needed to complete it and are not subject to change.

For bridge maintenance projects special modifications can be made to unit price type contracts to increase their flexibility while still staying within the definition of such contracts. This is done to make the contracts more convenient to administer and to eliminate sources of controversy between agency personnel and the contractor. Such a modification specially tailored to a maintenance project, for example, might occur when a deck requires repair rather than replacement. The contract could specify that the removal of deteriorated concrete and its replacement would be paid for under one of three items. The first item could be removal and replacement with no reinforcing exposed. The second item could be removal and replacement with the top layer of reinforcing completely exposed and cleaned. The third item could be removal and replacement for the full depth of the slab. Each item would be paid for on a square foot basis for all work and materials required. It would, of course, be necessary to make a complete survey of the condition of the deck while the contract documents were being prepared so the quantity of work required could be estimated within reasonable limits.

It is recommended that unit price contracts be selected for use instead of other types of contracts whenever it is reasonable to do so. A limited number of labor and equipment hours can, and probably should, be included as bid items to account for unexpected conditions. This permits some flexibility within the contract although an excessive use of these bid items should be avoided since it is likely to be costly and it has some of the undesirable characteristics of a cost reimbursement type contract.

COST REIMBURSEMENT CONTRACTS

If it is impossible to define the amount and scope of work, it may be necessary to resort to a cost reimbursement contract. In contracts of this type the contractor is reimbursed for his labor, equipment, and material costs at a predetermined rate. Cost reimbursement contracts require a great deal of inspection and record keeping on the part of the agency to verify the contractor's charges. Some cost reimbursement contracts require the contractor to keep records in a specified manner to assist in documentation and verification. If federal participation is to be requested under circumstances previously described, preliminary discussions must be held to ensure that a cost reimbursement contract will be approved for the work contemplated. If the contracting procedure is approved, a detailed review should then be conducted to ensure that all documentation requirements would be satisfied. A common difficulty in obtaining reimbursement for work performed in this manner, as well as by force account, is the lack of a complete audit trail for all work because of defects in the record keeping system.

Another key problem with many cost reimbursement construction contracts is that there may be a perceived, if not actual, loss of competition. The contractor working at a slower rate, or using more material, on those work items that provide him the greatest return causes this. This means that the agency representatives must not only be fully aware of the quality of work provided, but the amount of work done per unit of time as well. Even if the inspector is not fully satisfied, it is difficult to document poor performance unless it is well below standard. Another contractor who competed unsuccessfully for the work can obviously take the position that competition was unfair or nonexistent because the quality and quantity of work he would have provided per dollar expended would have been superior. Rigorous and detailed inspection based on good specifications is the only way charges of this kind can be refuted.

On occasion a special version of a cost reimbursement contract can be used as a valuable adjunct to a force account project. If special skills or equipment are required, an abbreviated version of a cost reimbursement contract can be used to obtain them. The same care should be used in this contracting process as would be used for a complete project, particularly if federal participation is to be requested, since detailed documentation could very well be required.

One state, and perhaps others, uses a very interesting variation of the cost reimbursement type of contract. The contacts are awarded for a period of up to 18 months to perform a wide variety of bridge maintenance activities in a highway district including but not limited to the following:

- Remove and replace concrete curb
- Remove and replace concrete deck or portions thereof
- Repair concrete or block slope protection
- Repair of damaged reinforcing or structural steel.
- Repair of miscellaneous painted areas.
- Remove, repair, and replace damaged railing or balustrade.
- Remove or replace bridge sidewalks.
- Repair scupper and drain systems.
- Repair piers, caps, and abutments

Contracts are awarded to the lowest responsible bidder on the basis of specified quantities of labor, equipment, and traffic control and management items. Fifteen categories of labor are bid including foremen, laborers, welders, concrete finishers, painters, and various equipment operators. Equipment items include several types and sizes of trucks, front-end loaders, cranes, and concrete mixers. Traffic control items include cones, flashing arrow boards, signs, barricades, and steel plates.

The crew size furnished by the contractor for projects is determined by the size of the project but normally ranges from five to eight. Except in emergencies, a seven day notice of specific work is provided to the contractor including recommended equipment and labor requirements.

If equipment not included in the contract is required, the rate paid is taken from rental guides such as the *Rental Rate Blue Book for Construction*. In the case of specialized equipment specified by the state, the contractor is reimbursed at the third-party rental rate plus a percentage (five percent is customary). The contractor is reimbursed for material costs plus ten percent so material costs are not a factor in the bidding process.

Cost reimbursement contracts covering extended periods of time as described above can alleviate the problems caused by reduced staffing and increased workloads. It is also easy to conceive of circumstances where such an arrangement can offer the most cost-effective means of conducting bridge maintenance activities on a permanent basis. There are, however, some precautions that should be carefully observed during the bidding and implementing of the contract. These include the following:

- Items and quantities of items used in the bidding process should be selected with a great deal of care. Unbalancing of bids can result if items are shown that are never used or if unrealistic quantities are indicated.

- Every effort should be made to encourage competition between contractors. If a single contractor becomes too entrenched in a district, prices can become unreasonably high.

- The state's representative should be particularly well trained and experienced The representative should have "hands on" experience in bridge maintenance but should also be well-grounded in contract management.

It is recommended that cost reimbursement contracts be used only when a complete and thorough evaluation indicates they are the most cost-effective means of performing the work. Perceived savings resulting from reduced efforts in preliminary investigation and planning or a reduction in overhead and fringe benefit costs of employees by the use of this type of contract can be offset by increased inspection and construction costs.

NEGOTIATED CONTRACTS

In some instances it may be necessary to resort to a negotiated contract. The competitive aspect in this type of contract is the receipt of the best value for the price paid. The most common use of a negotiated contract in highway agencies is to obtain professional engineering services. Every highway agency has well established procedures within applicable laws and regulations to obtain professional services. If such services are necessary in connection with bridge maintenance activities the standard established procedures used in the department should be used.

On occasion when a particularly unusual requirement arises, it may be necessary to obtain services other than engineering through negotiation. If there is only one feasible source of such service the process is straightforward and simple with the highway agency responsible for obtaining the most favorable price under the circumstances. In some instances, however, there can be two or more suppliers who furnish similar services using procedures so different that other types of contracts are not feasible. In these cases total cost factors including expected life must be considered. Justification for negotiating with a contractor under circumstances when the initial cost is higher but the difference between his work and another's work is more than offset by Quality or value received must be based on solid well-documented records of performance and not just opinions.

COST COMPARISON -CONTRACTING VS. IN-HOUSE

COST OF CONTRACTING

When determining whether or not to contract, or when estimating the total cost of a project to be done by contract, the incidental costs of contracting should not be neglected when developing estimates. These can be appreciable, and they can also vary with the type of contract. Costs incidental to contracting include the following:

- Administrative costs of preparing requests for a proposal or bid documents and plans;
- Costs of selecting the contractor or vendor *I* particularly for negotiated contracts;
- Administering the contract while the work is being done;
- Inspecting the work;
- Field record keeping;
- Consultations with the contractor; and
- Verifying charges, approving final results, and approving invoices for payment,

IN-HOUSE COST

There is a tendency when comparing contract to in-house cost to compare the salaries of the agency employees with those of contractors and ignoring the hidden cost to the agency of having the employees on the payroll. Other costs of performing work in-house include:

- Overhead costs such as employee benefits, work space, administrative support (payroll etc.), and tools;
- Cost of keeping employees on the payroll during bad weather, during winter months, or when the workload is light;
- Cost of purchasing equipment and keeping it operational; and
- Liability costs associated with the maintenance operation such as injury to employees or the traveling public.

F. QC/QA OF BRIDGE MAINTENANCE OPERATIONS

Quality Control/Quality Assurance (QC/QA) is an important part of supervision. QC is normally performed within the group, or maintenance crew. QA is performed from outside the group. QC is the responsibility of the bridge maintenance worker. QC includes maintaining quality work, on schedule and within budget. It also includes performing the work safely.

QC AT THE WORK SITE

There are two general classifications of items to be reviewed at the work site. The first is how well the work is being performed in terms of quality of results and the amount of work being done or productivity. The second is how the work is being performed in terms of safety to the workers and the public.

While the quality review would often be considered to be the most significant and difficult to review it is often far easier than the safety review. Even if performance standards have not been developed, standard practices, formal or informal, are usually available. Safe practices and total crew motivation to perform the work safely, however, are almost always different matters since small errors of omission or commission can produce unfortunate or even tragic results. The general attitude of a crew toward satisfactory or unsatisfactory work practices can be revealed in a number of ways that would only be noticed by someone looking specifically for such indications. In addition, it is often tempting to overlook departures from the best practices because of expediency or a lack of willingness to caution or reprimand a foreman who attains high performance and productivity through the use of short cuts or questionable practices that carry relatively high risks of causing personal injuries.

TECHNICAL SITE REVIEW

If performance standards have been developed for the work, the reviewer should use them as a guide. State construction standards are also good resources for basic repair methods and procedures. Obviously the worker should be thoroughly familiar with them before visiting the site to take full advantage of the available time.

In some cases bridge maintenance crews are called upon to perform work for which plans, sketches, or engineering drawings have been prepared. In these instances workers should be thoroughly familiar with the pertinent documents before visiting the site. The best practice is for workers to be consulted during the preparation of such documents so he or she is familiar with the project at its inception. In this way the capabilities of the crews to be assigned to the work are properly accounted for and arrangements can be made well in advance to obtain the services of individuals with special skills such as certified welders, specialized equipment, or special materials. As pointed out in other sessions, advance planning of this type can greatly increase efficiency and reduce costs.

In agencies where performance standards have not been developed or plans are not needed for a bridge maintenance project, the work is done by standard practice with or without written instructions. In cases of this type the worker must use his experience and knowledge of satisfactory practices to evaluate the progress of work at the site. In smaller agencies with a stable work force and relatively light workloads, this process can be satisfactory for as long as those conditions prevail. Unfortunately, however, as more bridge maintenance work is required and if turnover of employees is frequent the lack of written standards can become a significant problem.

Even if standards or plans are available there are a number of specific quality control related items that would not usually be shown on such documents and that should be reviewed by the worker. These are described in considerable detail in several sessions. The questions in Exhibit V.2 summarize the most significant issues and they can serve as a convenient mental check-off list for use by supervisors and workers.

TRAFFIC CONTROL SITE REVIEW

Almost all bridge maintenance activities interfere to some extent with normal traffic flow. To properly protect both the work force and the public, proper traffic controls must be used. This is discussed in detail in Section VIII but the questions in Exhibit V.3 summarize key points that should be reviewed when a worker visits a site.

EXHIBIT V.2 TECHNICAL SITE REVIEW CHECKLIST

Concrete Related Items

- When concrete is mixed on site:
  __ Are bags of cement stored so they will remain dry?
  __ Is the class of cement used appropriate?
  __ If admixtures are used, are they added properly and in correct proportions?
  __ Are piles of fine and coarse aggregate properly separated and are they of good quality?
  __ Is there proper control of the quantity of water used ?
  __ Are correct proportions of materials used and are measurements carefully made?
  __ Is the concrete being mixed for the correct length of time ?

- When concrete is delivered in ready-mix trucks:
  __ Is there sufficient control on amount of water used?
  __ Are precautions taken to ensure that concrete is not over-mixed or retempered if travel time is excessive?
  __ Is the supplier approved by the state?
  __ Is the mix that is supplied suitable for the specific application?

__ Are forms properly constructed true to described dimensions and cleared of debris?

__ Are forms properly braced to resist the loads caused by plastic concrete?

__ Are reinforcing bars properly placed to provide and maintain correct cover?

__ Are reinforcing bars tied at every intersection and free from oil spillage?

__ Are forms wetted or is form-release material used before placing concrete?

__ When placing concrete, are steps taken to prevent a vertical drop of more than 1.5 meters (five feet)?

__ Are vibrators used correctly?

__ Is the curing process begun soon enough to prevent too rapid drying of the surface particularly on hot windy days?

__ When removing deteriorated concrete, are small jackhammers or chipping hammers used when appropriate ?

__ When concrete is to be patched, is sufficient deteriorated concrete removed to a sound substrate before surfaces properly prepared for the patching material that is to be used ?

__ Are any means such as dowels required to connect new concrete to old concrete?

__ When deteriorated concrete is removed prior to patching, is the removal done so feather edges will be avoided?

__ If proprietary materials are used for patching, are the manufacturers' directions followed exactly in every respect?

Structural Steel Related Items

__ Are only certified welders allowed to weld, and are proper welding procedures including storage of electrodes being used?

__ If welding is used, is there strict adherence to weld sizes called for by plans or standard practice?

__ If members are bolted, are high strength bolts used when required?

__ If high strength bolts are used, are they tightened to the correct tension?

__ When preparing surfaces for patching, is rust properly removed?

__ When steel is cleaned and ready for painting, is the prime coat promptly applied ?

__ When steel is being readied for painting, are all areas, including those that are relatively inaccessible, properly prepared?

Timber Related Items

__ Is treated wood used where appropriate?

__ When wood damaged by insects, is removed is sufficient care taken to remove all damaged portions?

__ Are appropriate fasteners used?

__ If treated wood is used are proper precautions taken in handling it?

__ Are timber members prevented from coming into direct contact with the ground?

EXHIBIT V.3 TRAFFIC CONTROL SITE REVIEW

__ Are advance signs placed at locations in conformance with standard practice?

__ Are the proper signs used and are signs clean and legible?

__ Have proper arrangements been made to control traffic at night and is the site reviewed periodically at night?

__ Are flaggers appropriately dressed and attentive?

__ Are cones, barricades, or barriers properly located in conformance with standard practice?

__ Are flashing arrow boards used if appropriate for the location?

__ Are motorists unnecessarily delayed?

__ When the travel width has been seriously restricted, has the permit issuing authority been notified to restrict the movement of overwidth loads through the area?

__ Have special precautions been taken if visibility is seriously restricted by unfavorable alignment or grade?

TOOLS AND EQUIPMENT USE SITE REVIEW

All highway maintenance related work is dangerous because of its proximity to traffic and the nature of the activities requiring the use of a wide variety of tools and heavy equipment. This is particularly true for bridge maintenance work since the area where the work is performed is likely to be restricted and a great deal of the work must be done manually. As a result every precaution should be taken to reduce unnecessary risks. The questions in Exhibit V.4 summarize key points in regard to the use of tools and equipment that should be reviewed by supervisors when visiting work sites.

RIGGING AND CLIMBING SITE REVIEW

The dangers inherent in bridge maintenance activities that were previously described are often made even more severe by the necessity of performing work at a considerable height from the ground or surface of the water. This not only requires that personnel be protected when working at such heights but that tools, equipment, and material are safely and efficiently transported to the work level. When visiting sites involving activities that require the use of cranes, staging, ladders, manlifts and other devices used in working at locations above the ground, the worker should be particularly alert to practices and procedures that create unnecessary hazards. The following questions in Exhibit V.5 summarize significant issues in regard to climbing and rigging practices and they can be used as a convenient mental check off list.

BUDGET MONITORING

A major control task is monitoring the budget expenditures and accomplishments. Two major elements of this task are controlling the funds to keep spending within the budget limits and re-budgeting of work. The first requires continuously current information on actual expenses. Changes or reallocations that need to be made can then be based on accurate information.

A method of controlling the budget is redirecting resources. This determination applies primarily to labor and equipment use where scheduling has the most impact. Adjustments may include:

- Change work scheduling;
- Add or reduce labor;
- Add or reduce the equipment fleet; and
- Reduce peak demand for labor and equipment.

EXHIBIT V.4 TOOL AND EQUIPMENT USE SITE REVIEW

__ Does the general appearance of the work site demonstrate that tools are used and then replaced or are tools scattered around the area?

__ Are oxygen and acetylene cylinders stored properly in an upright position?

__ Are safety glasses, masks, and hearing protection used when appropriate? For example, safety glasses should be used when chipping concrete or paint; masks should be used when sand blasting or spray painting, and ear protection should be worn when using a jackhammer.

__ Are proper tools of the correct size available and being used?

__ Does it appear that tools are being used correctly for the purpose for which they were designed and made?

__ Are tools being maintained properly with secure handles and sharp edges?

__ Are trenches over the proscribed maximum depth shored or cut back to the natural angle of repose of the material?

__ Are air hoses and electric lines protected if they are in a vulnerable location?

__ Are electric tools properly grounded?

__ Are safety shoes and protective helmets being worn?

__ Are life jackets being worn if appropriate?

__ Is proper equipment of the correct size available on site?

__ Has the equipment received scheduled preventive maintenance?

__ Are only qualified operators operating equipment?

__ Is there excessive equipment at the site?

__ Have reports of defective equipment been made promptly and has the response by equipment personnel been satisfactory?

__When not in use is equipment parked as far from the traveled way as is reasonably possible?

EXHIBIT V .5 RIGGING AND CLIMBING SITE REVIEW

__ Is every person in the crew made fully aware of his or her responsibilities and assignment before the work starts?

__ Is all manila rope on the site fresh and in good condition with the inside bright and clean?

__ Is all manila rope coiled loosely, hung above the floor, and under cover when not in use?

__ Are thimbles used when attaching manila rope to a ring, hook, or a pulley block?

__ Are all wire ropes properly lubricated?

__ Have thimbles been used to form all loops in wire ropes?

__ Is all wire rope on site in good condition without excessive numbers of broken wires?

__ Are personnel and loads always transported to work area separately?

__ Is all scaffolding, either tubular or wood, properly constructed and erected?

__ Are work platforms long enough to safely hold the men and materials to do the job?

__ Are platforms equipped with toe boards, guiderails, and mid rails?

__ Are all ladders tied fast at the top?

__ Are all wooden ladders unpainted?

__ Do all swinging scaffolding have a lifeline for each man and are they used properly?

__ Are boatswain's chairs, safety harnesses, or safety nets used when personnel are working at heights in excess of those proscribed?

__ When working from bucket trucks are personnel using the safety belts provided with such equipment?

__ When a crane is being used is it correctly located with regard to operator visibility and utility lines and has the responsibility for directing its operation and giving hand signals been properly assigned to only one person?

__ Are slings properly formed to safely carry the loads for which they are to be used?

SCHEDULE MONITORING

Methods of developing and monitoring work schedules for a bridge maintenance crew was discussed in the previous section. Since bridge maintenance activities tend to get interrupted by emergency repairs and bad weather they tend to be ignored. An important part of quality assurance is to make sure that the schedule is updated to properly account for interruptions. The schedule must be realistic and it must be current. Completing assignments on schedule has a direct impact on performance for the following reasons:

- Efficiency can be measured by success in meeting schedules.
- Support and equipment has to be scheduled ahead for the next assignment and adjustments influence other activities, therefore, they should be minimized.
- Interruptions tend to be the same over a year's time so that so they cancel out when comparing performance between years or between crews.

METHODS OF QUALITY ASSURANCE

QA is performed from outside the maintenance crew. Some agencies have formal QA programs that are developed to measure their crews' performance. The QA evaluation may be generated by the BMMS. The QA should follow up on repairs to evaluate the extent to which the goals of the maintenance program in general, and objectives of the specific project in particular, have been met. Components of the evaluation could include:

- Comparison of actual labor production rates to planned rates;
- Comparison of actual costs to budgeted costs;
- Evaluation of the appropriate use of equipment and materials;
- Comparison of actual repairs to those shown in plans and/or specifications;
- Comparison of actual field procedures to SOP ;
- Comparison of NBI or CoRe element condition ratings before and after repairs; and
- Accidents or injuries related to crew assignments.

If there is no formal program, QA is probably taking place on an informal basis. The disadvantage of informal QA is that it is often subjective and it is rarely quantified. Therefore, it may be applied based on the experience of the person making the evaluation. The items that are checked are often based on recent problems. For example, if an accident occurred because of improper placement of traffic signs, the emphasis may be placement of signs. A carefully developed QA program that everyone understands, that is considered fair, that provides objective evaluations and that provides quantitative results will have the best results.