FHWA Bridge Maintenance: *Overview*

Course No: S02-012
Credit: 2 PDH

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This course was adapted from the "Federal Highway Administration Bridge Inspector's Reference Manual", Publication No "FHWA- NHI-03-045", which is in the public domain.

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.

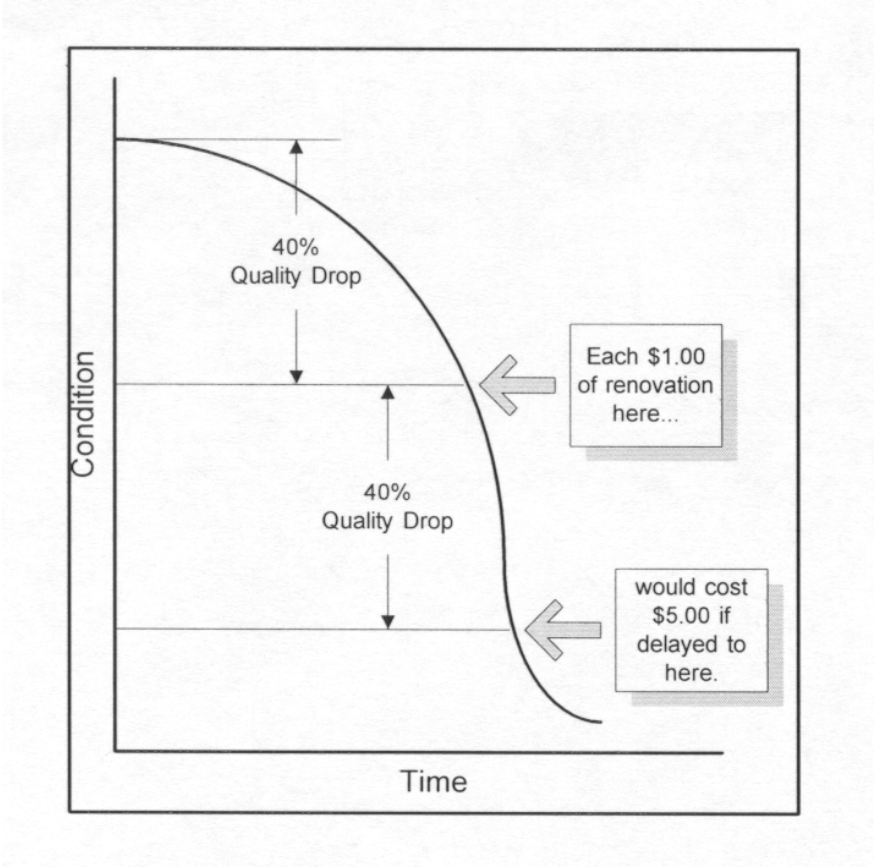

Exhibit I. 1 The cost of delaying maintenance

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

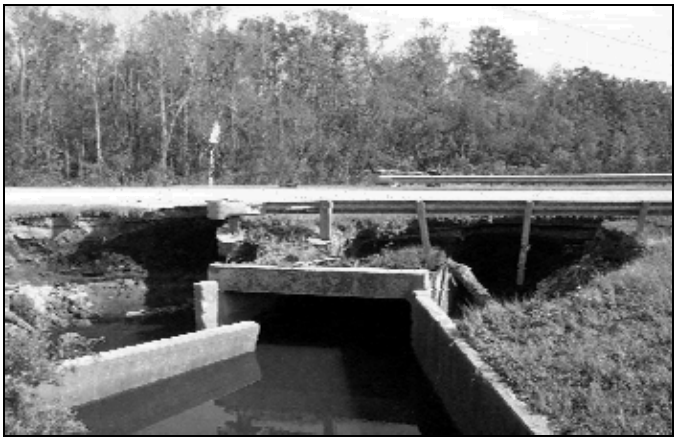

Exhibit IV. 2 Severe embankment erosion

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.

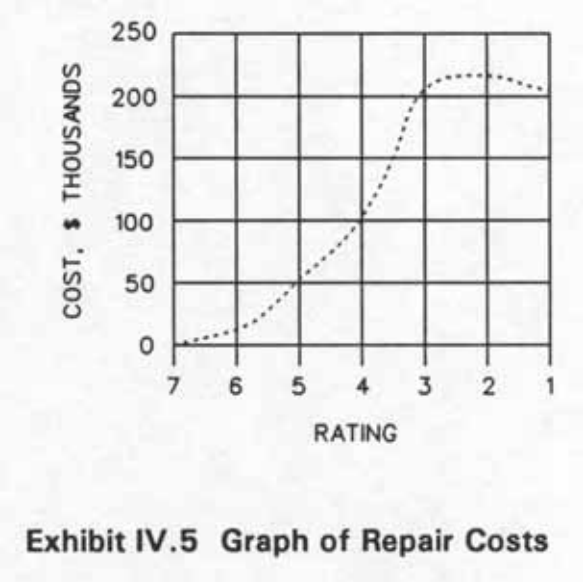

Exhibit IV.5 Graph of Repair Costs

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."

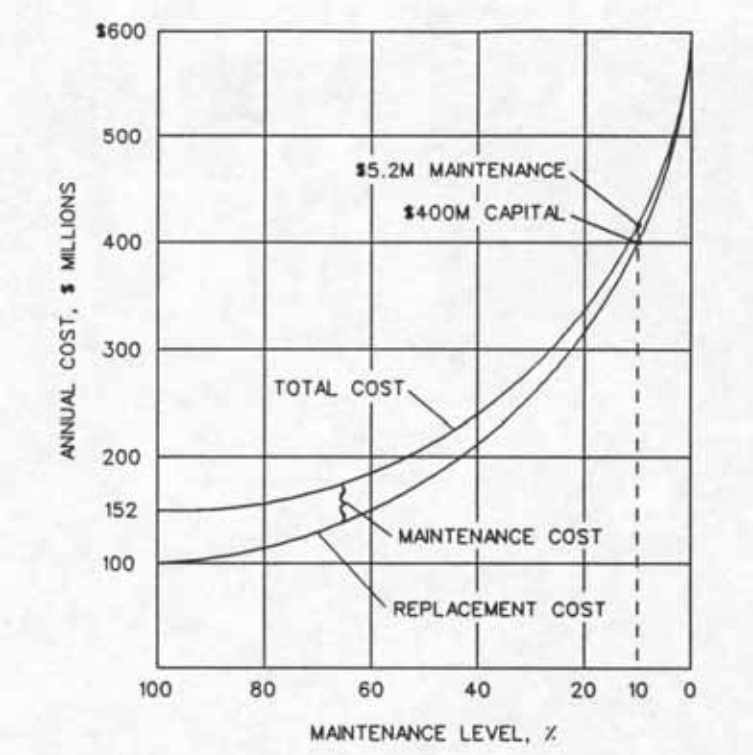

Exhibit IV.7 Total Costs vs. Maintenance Level