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The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration.

This report does not constitute a standard, specification or regulation.
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# Table of Contents

## Chapter 1: Introduction 1

1.1 Description of the Problem  
1.2 Research Objectives  
1.3 Scope of Work  

## Chapter 2: Research Methods 4

1.1 Identification of Preventive Maintenance Procedures  
1.2 Establishment of Project Team  
1.3 Literature Review and Resource Identification  
1.4 Development of Bridge Component / Distress Descriptions  
1.5 Compilation and Review of Photographs and Diagrams  
1.6 Field Visits to ODOT District / County Offices  
1.7 Preparation of Draft Bridge Maintenance Manual  
2.7.1 Organization of Manual  
2.7.2 Development of Website  
1.8 Beta Test Review of Bridge Maintenance Manual Website  

## Chapter 3: Deliverables and Recommendations 13

2.1 On-Line Access to the Ohio Bridge Maintenance Manual  
2.2 Recommendations  
3.2.1 Implementation and Training  
3.2.2 Future Development  

## References 17

## Appendix 19
Chapter 1: Introduction

1.1 Description of the Problem

According to the National Bridge Inventory [1], there are more than 27,900 bridge structures in Ohio. More than 7,260 (26%) of Ohio’s bridges were classified as being either structurally deficient or functionally obsolete in calendar year 2000. Although the overall percentage of deficient structures has shown a decreasing trend in recent years, maintaining the state’s infrastructure continues to be a major challenge for the Ohio Department of Transportation (ODOT) and the various municipal, county, and township transportation agencies.

While there is continual new construction of pavements and bridges on the secondary roadway system throughout the United States, most of the major Interstate routes were completed between the 1950s and the 1980s. As a result, there is a gradual trend toward less construction of new bridges, but an increased need to repair and maintain existing structures. This shift in focus has led to development of Asset Management concepts [2] to facilitate responsible decisions for preserving public investments in the nation’s infrastructure.

Preventive maintenance of bridge and culvert structures is an essential component of effective infrastructure management. The ODOT Office of Structural Engineering recognized the need to further develop reference materials and training resources in this area. As of 2000, there was no formal bridge maintenance manual for use in Ohio. Bridge maintenance programs were developed at the district or county level based on local experience, history, funding availability and workforce capability. As a result, the level of bridge maintenance effort varied considerably throughout the state. The gradual loss of experienced bridge inspectors and field personnel due to job changes or retirement from state and local transportation agencies represents an additional challenge, and underscores the importance of providing effective training and technical guidance to new employees.

Consequently, the need was recognized for development of a reference and training manual for preventive maintenance of bridges and culverts, specific to the structures and conditions found in
Ohio. It was decided that the Manual should be developed in the form of an internet website to provide easy access for a wide range of potential users. Presentation of the BMM in an electronic format would also allow for continual updates over time to reflect current practices and technologies.

1.2 Research Objectives

The objectives of this project were to:

1. Develop a web-based Bridge Maintenance Manual that can be used as a reference and training tool for ODOT district and county personnel.
2. Define and illustrate the common components of typical bridge structures found in Ohio.
3. Establish uniform guidelines for recognizing and identifying Preventive Maintenance needs during the bridge inspection process.
4. Provide information regarding Repair options for different types of distress/deterioration, including description of common causes, recommended repairs, initial cost, and expected life.
5. In addition to addressing bridge structures, describe Preventive Maintenance and Repair procedures for typical culvert types found in Ohio.

5.1 Scope of Work

This study addressed the most common types of bridge and culvert structures found in Ohio as described below.

Bridges (primarily constructed of steel-reinforced concrete):

1. Concrete deck supported by rolled steel beams or built-up plate girders
2. Concrete deck supported by pre-stressed concrete I-beams
3. Side-by-side pre-stressed concrete box beams (with asphalt overlay or concrete deck)
4. Cast-in-place concrete slab bridge
5. Concrete arch bridge
   • Filled spandrel arch
   • Open spandrel arch
• Through arch

Culverts:
  1. Corrugated metal / galvanized steel culvert
  2. Four-sided pre-cast concrete box
  3. Corrugated aluminum plate box culvert
  4. Three-sided pre-cast concrete box

This project did not address timber structures, steel grid decks, truss bridges, or special structures such as suspension or cable-stayed bridges.
Chapter 2: Research Methods

1.1 Identification of Preventive Maintenance Procedures

Preventive Maintenance procedures for bridge and culvert components were identified and cataloged based on the combined engineering and inspection experience of the project team members (see section 2.2 of this report), and by review of applicable reference standards (see section 2.3). As an example, the following preventive maintenance procedures were identified for steel beams:

1. Pressure wash the beams/girders once per year in the spring if possible, especially overpasses where salt spray from traffic passing below can collect on the steel (this is very difficult to do and perhaps not practical in some cases, but is very beneficial in the long run). Even if the entire bridge cannot be washed, at least wash areas under expansion joints (usually at abutments).

2. Touch up minor defects in the paint system such as scratches and small areas of corrosion with a good quality epoxy/urethane or acrylic paint (there are several water-based acrylic paints available for industrial applications).

3. On overpass-type bridges, watch for nicks or gouges in the bottom flange caused by overheight traffic passing below. These should be ground smooth with an angle grinder to minimize crack propagation. More serious damage caused by overheight load collisions such as bent beams should be repaired by heat straightening (see future Repair Section of this manual).

The following definition of the Preventive Maintenance concept was developed to serve as an introduction to the Bridge Maintenance Manual.

“Preventive maintenance can be defined as the act of keeping a structure in its as-built condition and/or protecting it from inevitable deterioration due to environment, traffic vibration and de-icing chemicals. In some cases, structures are built with flaws such as cracks in concrete which require action to prevent moisture and chlorides from infiltrating the microstructure and causing early deterioration. One fact remains, however; a structure starts to deteriorate the day its construction is completed, and it is the duty of the person in charge to slow the deterioration as much as practical using methods and materials that are considered best practices. It is the intent of this Manual to present best practices that have proven themselves to work in Ohio’s environment and with the type of construction and materials most commonly found in Ohio. This is not to say that other materials and methods do not have merit, and in fact an open mind should be kept for trying new materials as they are developed…”

The Appendix of this report includes the complete definition and introductory page (see p. 21).
Later in the project, after the Preventive Maintenance section of the BMM was completed, the Repair section was developed to describe for each type of distress the recommended repairs, initial cost, and expected treatment life.

3.1 Establishment of Project Team

In addition to the Ohio State University (OSU) researchers responsible for development of the Bridge Maintenance Manual, an expanded project team including ODOT and FHWA representatives was assembled early in the project. The purpose of this team was essentially to serve as an advisory board to provide additional expertise and guidance regarding the technical content of the BMM, with consideration given to the needs of ODOT bridge personnel and others who might ultimately make use of the Manual. It was also important to ensure that the BMM website being developed by OSU would be fully transferable to, and compatible with, ODOT’s computer server system at the end the project.

The expanded project team was comprised as follows:

Ohio State University:
- Principal Investigator
- Bridge Management Engineer
- Project Manager/Engineer
- Computer Specialist (website designer)
- Retired ODOT Bridge Inspection/Maintenance Engineer (consultant to OSU)

Ohio Department of Transportation:
- Administrator, Office of Structural Engineering
- Structural Engineer (computer specialist)
- Bridge Inspection/Maintenance Engineer
- County Manager (urban)
- County Manager (rural)

Federal Highway Administration:
- Project Liaison
- Bridge Engineer
The expanded team convened early in the project, and communicated subsequently by group e-mail.

3.2 Literature Review and Resource Identification

An abbreviated literature review was conducted to gather sources of information that could be used for development of the Ohio Bridge Maintenance Manual. A primary reference was the *Bridge Inspector’s Training Manual 90*, published by the Federal Highway Administration [3]. This manual was used as an aid in defining typical bridge components (see section 2.4 of this report), and as a source for several standard illustrative drawings that were added to the Manual. These included drawings of typical riveted and welded girders, and cross-section diagrams of typical pre-stressed concrete I-beams and box beams.

Standard ODOT proposal notes, supplemental specifications, and approved materials lists for various bridge treatment options were also reviewed to assist with developing the recommendations provided in the BMM. For example, the Manual makes reference to use of ODOT-approved concrete surface sealers and crack sealers, such as soluble reactive silicate [4], high molecular weight methacrylate [5], silane/siloxane [6], epoxy/urethane [6], and gravity-fed resin [7]. In December of 2002, hyperlinks to electronic versions of the applicable ODOT reference documents were added to the BMM website, to assist users in accessing the information.

As a reference and source for ideas regarding layout and development of the BMM website, a software program called HWYCON [8] was reviewed. The HWYCON program provides information about types of distress that affect concrete structures and pavements.

3.3 Development of Bridge Component / Distress Descriptions

Descriptions of typical bridge and culvert components were developed, based on the engineering and inspection experience of the project team and reference to standards such as the FHWA *Bridge Inspector’s Training Manual 90* [3]. For example, the components defined for a ‘typical’ multi-span concrete bridge structure included the following:

- Abutment
For each component, the typical types of distress or deterioration were defined, again from team members’ experience and existing references. For example, the following distress types were defined for reinforced concrete decks:

- Scaling
- Aggregate pop-outs
- Cracks
- Potholes
- Full-depth holes

For the various distress types identified, the typical causes, recommended repairs, initial cost, and expected life (where known) were defined for inclusion in the Manual.

5.1 Compilation and Review of Photographs and Diagrams

The project team had access to several hundred print and slide photographs of Ohio bridge and culvert conditions, from the ODOT Office of Structural Engineering archives and team members’ photo collections from their bridge inspection experiences. These photos were reviewed early in the project
to identify areas where additional images might be needed. Operating under the concept that “a picture is worth a thousand words,” efforts were made to incorporate the following images into the Manual for the benefit of those who will use it as a resource and training tool:

- Photos illustrating common types of bridge and culvert structures
- Photos illustrating common types of distress / deterioration
- Where available, photos showing application of recommended treatments

Throughout the project, team members periodically took field photos of existing structures or conditions to fill in gaps where images were missing from the BMM website. Additional photos of specific maintenance activities were requested of ODOT bridge personnel throughout the state.

### 3.1 Field Visits to ODOT District / County Offices

On-site visits were made to meet with ODOT personnel at seven district / county offices as listed below, to discuss development of the Bridge Maintenance Manual and elicit feedback.

- District 1 – Bridge / Guardrail Supervisor
- District 4 – Bridge Management personnel
- District 8 – District Bridge Engineer
- District 11 – Bridge Management personnel
- Hancock County Manager
- Ross County Manager
- Scioto County Manager

The individuals were asked to provide their input regarding the content and development of the BMM website. Requests were also made for any photos of local bridge or culvert conditions that might be suitable for inclusion in the Manual.

### 3.2 Preparation of Draft Bridge Maintenance Manual
The Appendix of this report includes a selection of sample pages from the December 2002 version of the BMM. Please note that the Manual will likely be further refined and updated when ODOT formally assumes custody of the site in January of 2003. The most current version of the BMM can be viewed through the internet website address (see section 3.1 of this report for details).

2.7.1 Organization of Manual

The technical content of the Bridge Maintenance Manual was organized into two sections: Preventive Maintenance and Repair. The Preventive Maintenance section is the most extensive, as it defines typical bridge and culvert types and describes their components, in addition to providing preventive maintenance recommendations.

The Repair section was originally designed as a series of spreadsheets, describing for each bridge/culvert type or component the typical types of distress and the associated repair recommendations, initial cost, and expected life. The spreadsheets were converted to split-screen menus when they were incorporated into the website format (see Appendix for example Repair page). To the extent possible, photographs were incorporated throughout the Manual to accompany the text and illustrate the components and distress types being discussed.
2.7.2 Development of Website

The Bridge Maintenance Manual website was developed using Microsoft FrontPage computer software. Features of the BMM site include drop-down menus, icon links, and hyperlinks to view enlarged versions of thumbnail photos. The ‘Contact Us’ icon provides an e-mail link for users to contact the ODOT Office of Structures. Users can also submit general comments through the ‘Guestbook’ icon. The ‘Support Forum’ is semi-interactive, allowing users to post responses to technical questions or comments posted by others.

An early version of the Preventive Maintenance section of the BMM was posted to the internet in January of 2001, and visitors to the site were invited to post review comments through the ‘Guestbook’ feature. Comments posted by users were reviewed and considered as development of the site proceeded.

3.3 Beta Test Review of Bridge Maintenance Manual Website

A ‘Beta test’ review of the BMM website (with both the Preventive Maintenance and Repair sections in essentially complete form) was conducted by sending a group e-mail request to ODOT district and county personnel in November of 2002. The Beta test e-mail explained the origins and purposes of the Bridge Maintenance Manual, provided the website address for accessing the Manual, and requested responses to the following items:

1. Were you able to access the On-Line Bridge Maintenance Manual through the website address provided above? If not, please describe any difficulties.

2. Do you consider the layout of the website to be clear and easy to follow, or would you like to recommend any modifications to make the site easier to navigate?

3. In your county/district, are there any infrastructure-related meetings or training events that occur on a regular basis (monthly, quarterly, yearly), at which the Bridge Maintenance Manual website could be publicized in 2003? Please list or describe.
If you have time to conduct a more detailed review of the BMM website, please visit as many of the Preventive Maintenance and Repair pages as you would like to explore. Please consider the following questions as you prepare review comments:

4. Would you like to suggest any additions or changes to the descriptions of bridge elements and types of distress?

5. Would you like to suggest any additions or changes to Recommendations, or treatment Cost / Life estimates, provided in the BMM?

6. Did you notice any editorial corrections that need to be made to the text (terminology, spelling, punctuation, etc.)?

7. Do you have any photographs of bridge elements, distress conditions, or maintenance / repair activities that you would be willing to provide to help enhance the BMM website?

8. Would you like to suggest any specific or innovative ways in which the Bridge Maintenance Manual could ultimately be used as a resource and training tool for employees involved in bridge management, inspection and maintenance?

E-mail responses were received from 14 individuals, listed below by ODOT job classification and location within Ohio:

**ODOT district personnel:**

District 2 – Roadway Services Manager
District 3 – Bridge Crew
District 4 – Highway Management Administrator
District 7 – Bridge Inspection Engineer

**ODOT county personnel:**

Brown County Manager
Erie County Manager
Fairfield County Manager
Hancock County Manager
Lorain County Manager
Monroe County Manager
Paulding County Manager
Huron County – Transportation Administrator
Sandusky County – Transportation Administrator
Wood County – Transportation Administrator
In response to the first item, 13 of the 14 respondents indicated they were able to access the website without difficulty, and provided written feedback.

In response to item 2, all 13 respondents who were able to access the BMM website indicated that the layout of the site was clear and easy to follow. One respondent commented that the “pictures showing examples of items described are a great asset.”

In response to item 3, several respondents provided examples of infrastructure-related meetings held in their ODOT district/county office at which the BMM website could be publicized:

- District 4: monthly staff meetings with county managers, construction, production, and planning personnel.
- Brown County: yearly meeting to discuss problems identified by bridge inspectors.
- Huron County: culvert inspection training every few years.

None of the respondents indicated that they discovered any major omissions or inaccuracies within the website. One respondent suggested considering the possibility of combining the ‘Guestbook’ and ‘Support Forum’ into one feature, as postings from several previous visitors to the site indicated some confusion regarding the different uses intended for the two options.
Chapter 3: Deliverables and Recommendations

2.1 On-Line Access to the Ohio Bridge Maintenance Manual

At the time this report was prepared (December of 2002), the Ohio Bridge Maintenance Manual was available through the following internet website address:

http://www.dot.state.oh.us/preventivemaintenance/default.htm

It was planned that the Ohio Department of Transportation (ODOT) Office of Structural Engineering would formally assume custody of the BMM website by January of 2003. If the website address has changed from the one listed above, there should be an automatic URL redirect feature for the benefit of users who attempt to log on using the original address.

Alternately, the BMM website may be accessed through the ODOT Office of Structural Engineering home page: http://www.dot.state.oh.us/se/

This page contains a “Bridge Maintenance Manual” icon that links directly to the site.

Finally, regardless of current or future website addresses assigned to the Ohio BMM, visitors should be able to locate the website by use of common internet search engines (i.e., search by keywords such as “bridges”, “culverts”, “preventive maintenance”, etc.).

2.2 Recommendations

2.2.1 Implementation and Training

The ODOT Office of Structural Engineering may decide to further update or refine the Bridge Maintenance Manual website, after formally assuming custody of the site by January of 2003. At such time that ODOT has formally reviewed and approved the content of the website, several options for
implementing the Bridge Maintenance Manual could be considered. These options can be categorized in three groups: (1) widely publicizing the BMM website to potential users, (2) incorporating the BMM website into existing training activities, and (3) development of additional training activities.

1. Possibilities for widely publicizing the BMM website.

A. Establish links from existing websites
   - An icon link to the BMM site has already been added to the web page for the ODOT Office of Structural Engineering
   - FHWA Ohio Division website
   - Ohio Local Technical Assistance Program (LTAP) website

B. Publicize by direct e-mail
   - Use of ODOT district/county group e-mail listings (similar to Beta test conducted by e-mail in this project)

C. Publicize in publications
   - Transcript newsletter, published by ODOT
   - Moving Forward newsletter, published by ODOT’s Office of Research and Development
   - The Ohio LTAP Quarterly newsletter

D. Publicize at technical/transportation events
   - ODOT Conferences: Research and Development, Highway Operations, etc.
   - Ohio Transportation Engineering Conference (OTEC)
   - Local government conferences: County Engineers Association of Ohio (CEAO), Ohio Municipal League (OML), Ohio Township Association (OTA)
2. Possibilities for incorporating the BMM website into existing training activities.

- ODOT Annual Bridge Engineer Meeting (February/March)
- ODOT district/county training events
- Ohio LTAP workshops, such as Bridge Preventive Maintenance

3. Possibilities for additional training activities.

- The BMM website could be further developed to allow for interactive self-training. For example, a module could be developed in which users are prompted to view a photograph showing a bridge or culvert distress condition, then asked to input responses to questions regarding identification of the type of distress, likely causes, and feasible alternatives for preventive maintenance/repair. The program could then provide confirmation of correct or incorrect responses, along with additional commentary to assist the user in learning the material. This approach to computer self-training was explored by development of compact disk interactive (CD-I) technology in the early 1990s, and the similar development and more widespread use of interactive CD-ROM technology.

- On-site, face-to-face training classes could be developed based on the Ohio Bridge Maintenance Manual. Instructors could visit district and county offices throughout the state to provide training on use and implementation of the Manual to bridge inspection and maintenance personnel.

3.2.1 Future Development

The on-line Ohio Bridge Maintenance Manual as developed in this project is suitable for use as a reference and training tool, following formal approval by the ODOT Office of Structural Engineering. Nonetheless, the Manual could eventually be further developed to assist users in making decisions regarding selection of appropriate preventive maintenance or repair options. One approach that could be considered is development of decision trees or matrices [9], which would provide guidance on
selection of treatment options based on factors such as bridge component condition, serviceability, and cost considerations. It is recommended that any incorporation of decision-making guidelines to the Bridge Maintenance Manual should be conducted with due consideration given to current concepts of Asset Management as delineated by the Federal Highway Administration [2].

Because the BMM was developed using an electronic website format, the Manual can be maintained as a ‘living document’ that can be continually updated over time to reflect current practices and technologies for preventive maintenance and repair of bridge and culvert structures in Ohio.
References


[8] HWYCON software program, developed by the Cementitious Materials Modelling Laboratory (CMML) under sponsorship from the Strategic Highway Research Program (SHRP), circa 1996.

Appendix:

Sample Pages from
Ohio Bridge Maintenance Manual Website
December 2002 Version*

Contents:
Home Page  Introductory page of BMM website, with icon links (on left) for Preventive Maintenance pages and and drop-down menu (center) for Repair pages.
‘Definitions’  Definition page for Preventive Maintenance.
‘Decks’  Sample Preventive Maintenance and Repair pages for reinforced concrete decks.
‘Steel Beams’  Sample Preventive Maintenance and Repair pages for steel beams.
‘Culverts’  Sample Preventive Maintenance pages for four types of culverts.
‘Glossary’  Sample page from glossary of bridge terms.

* NOTE:  The Ohio Bridge Maintenance Manual is considered to be a ‘living document’ that may be continually updated by the Ohio Department of Transportation.  To view the complete Manual in its most current form, please visit the Ohio BMM website at:

http://www.dot.state.oh.us/preventivemaintenance/default.htm