U.S. Department
of Transportation
**Federal Highway
Administration**

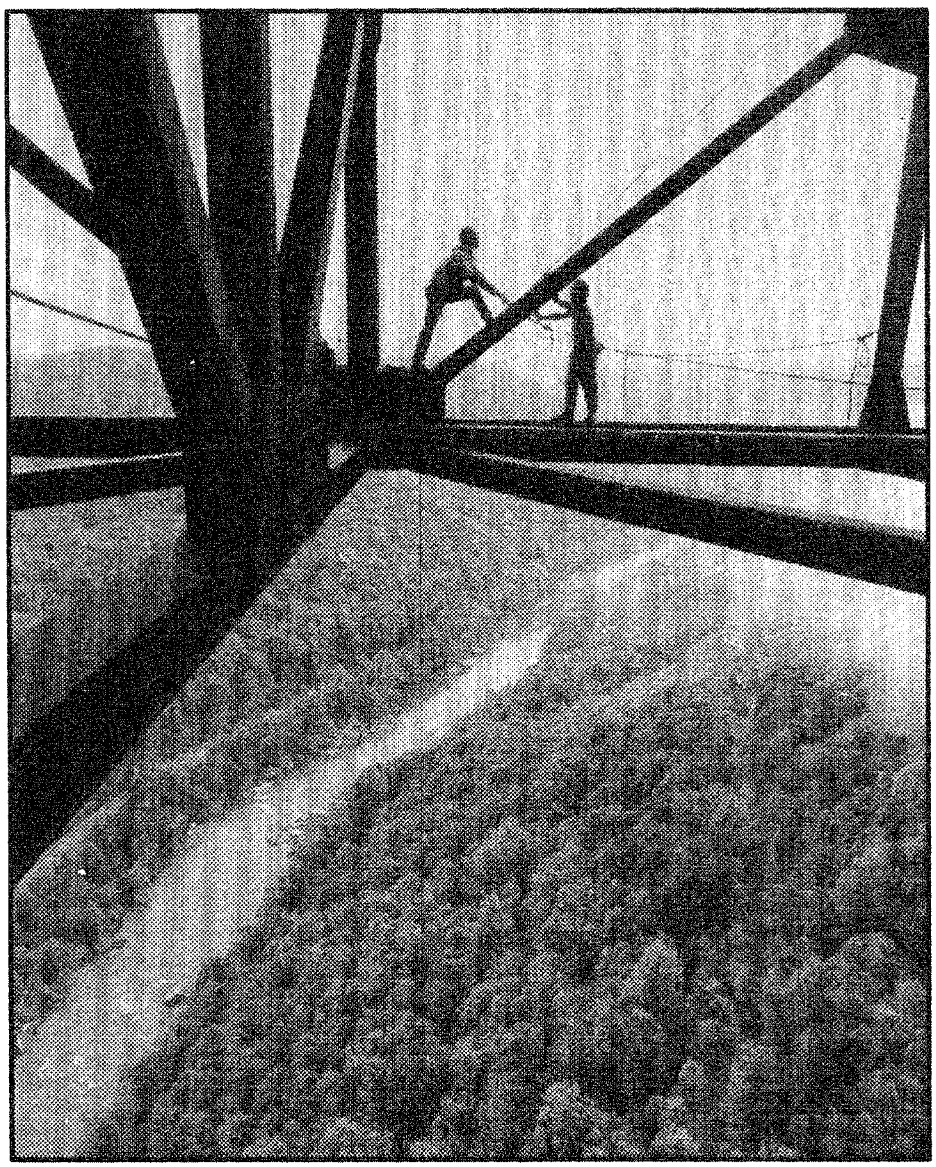
Publication No. FHWA HI-94-031
Revised May 1994

NHI Course No. 13055

Safety Inspection of In-Service Bridges

Participant Notebook

Volume 1



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APPENDIX

COURSE OUTLINE

COURSE OUTLINE

TOPIC		DURATION
	SESSION 1: INTRODUCTION	90 minutes
	SESSION 2: BRIDGE INSPECTION PROGRAMS	
2-1	History of the National Bridge Inspection Program	30 minutes
2-2	Responsibilities of the Bridge Inspector	30 minutes
2-3	Condition Coding Exercise	60 minutes
2-4	Basic Metrication	30 minutes
	SESSION 3: BASIC CONCEPTS	
3-1	Bridge Mechanics*	90 minutes
3-2	Bridge Materials*	3.5 hours
3-3	Bridge Components and Elements	60 minutes
Q-1	Quiz No. 1 (Topics 3-1 and 3-2)	----
Q-1	Quiz No. 1 Review	30 minutes
	SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION	
4-1	Duties of the Bridge Inspector	15 minutes
4-2	Safety Practices	60 minutes
4-3	Traffic Control	45 minutes
4-4	Inspection Procedures	45 minutes
4-5	Inspection Equipment*	45 minutes
4-6	Methods of Access*	30 minutes
Q-2	Quiz No. 2 (Topics 4-1 through 4-6)	----
Q-2	Quiz No. 2 Review	30 minutes
	SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM	
5-1	Structure Inventory, Condition, and Appraisal	90 minutes
5-2	Record Keeping & Documentation	60 minutes
5-3	The Inspection Report	30 minutes
5-4	Review Agency Inventory Items	90 minutes
5-5	The Pontis Bridge Management System (Optional)*	2.5 hours
Q-3	Quiz No. 3 (Topics 5-1 through 5-4)	----
Q-3A	Quiz No. 3A (Topic 5-5, Pontis)	----
Q-3 & Q-3A	Quiz No. 3 and 3A Review	30 minutes
	SESSION 6: INSPECTION AND EVALUATION OF BRIDGE DECKS	
6-1	Decks	90 minutes
6-2	Joints, Drainage, and Safety Features	60 minutes

* Including Videotape

6-3	Approach Roadways	30 minutes
6-4	Rating Exercises	60 minutes
Q-4	Quiz No. 4 (Topics 6-1 through 6-4)	----
Q-4	Quiz No. 4 Review	20 minutes
	SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES	
7-1	Introduction	30 minutes
7-2	Solid Sawn Beams	30 minutes
7-3	Glulam Beams	30 minutes
7-4	Trusses and Covered Bridges	30 minutes
7-5	Protective Systems for Timber Bridges	30 minutes
	SESSION 8: INSPECTION AND EVALUATION OF COMMON CONCRETE SUPERSTRUCTURES	
8-1	Introduction	30 minutes
8-2	Cast-In-Place Slabs	30 minutes
8-3	Tee Beams	60 minutes
8-4	Girders	30 minutes
8-5	Channel Beams	30 minutes
8-6	Arches*	60 minutes
8-7	Rigid Frames	30 minutes
8-8	Prestressed Slabs	30 minutes
8-9	Prestressed I-Beams	60 minutes
8-10	Prestressed Box Beams	45 minutes
8-11	Box Girders	30 minutes
8-12	Segmental Box Girders (Optional)*	90 minutes
8-13	Protective Systems for Concrete Bridges	30 minutes
Q-5	Quiz No. 5 (Sessions 7 and 8)	----
Q-5	Quiz No. 5 Review	15 minutes
	SESSION 9: INSPECTION AND EVALUATION OF COMMON STEEL SUPERSTRUCTURES	
9-1	Introduction*	45 minutes
9-2	Rolled Multi-beams	45 minutes
9-3	Fabricated Multi-girders	45 minutes
9-4	Two Girders	45 minutes
9-5	Pins and Hangers (Optional)*	60 minutes
9-6	Through Girders	30 minutes
9-7	Box Girders	30 minutes
9-8	Trusses	2 hours

* Including Videotape

* Including Videotape

* Including Videotape

INTRODUCTION

SESSION 1: **INTRODUCTION**

LESSON PLAN

SESSION DURATION	90 minutes
PARTICIPANT MATERIALS	Pencil
GOAL	Understanding of the need for bridge safety inspection training
OBJECTIVE	Be able to state the objective of the course and the purpose for being a participant.

PRE-REGISTRATION ACTIVITIES CHECKLIST

* Check the operation of:

  - Lights
  - Slide Projector
  - Microphone (optional)
  - Slide Projector Remote Control
  - Pointer
  - HVAC controls
  - Doors

* Check the placement of the:

  - Slide Screen
  - Slide Projector Stand
  - Podium
  - Extension Cords

PRE-REGISTRATION EQUIPMENT AND SUPPLIES CHECKLIST

- Slides
- Slide Carousels
- Slide Projector (with extra light bulb)
- Slide Projector Cart
- Slide Projector Remote Control
- Extension Cords, 25 foot minimum - electrical and remote control
- Slide Screen
- Videotape player and colors monitor(s)
- Flipchart and Color Markers
- Podium, with clip-on light
- Supply of Participant's Notebook
- Supply of BITM 90
- Supply of handout material (if provided)
- Overhead transparencies of Host Agency Inspection Forms
- Pointer
- Duct Tape
- Box of Miscellaneous office supplies
- 25' (8 m) video cable and splitter (if 2 monitors are used)

- Videotapes:

  - A Scar Remains: 25 Years After The Silver Bridge Disaster
  - Load Posted Bridges
  - Deterioration of Timber Bridges
  - Deterioration of Concrete Bridges
  - Corrosion of Steel
  - Bridge Inspection Equipment
  - 911 Florida (Inspection Access)
  - Jacks Run Bridge (Concrete Arch Demolition)
  - Fatigue in Metal
  - Pins and Hangers
  - Bridges Unbroken - Timber Pile Inspection
  - Bridge Scour
  - Underwater Inspection

- Inspection Equipment:

  - Boots
  - Hard Hats
  - Safety Vests
  - Clip Boards
  - 6' (2 m) Folding Rule

I. REGISTRATION

II. OPENING REMARKS AND INTRODUCTION

III. PURPOSE AND OBJECTIVES

A. Overview of Training Program

1. The one-week course, "Engineering Concepts for Bridge Inspectors," is targeted for new inspectors with little or no practical bridge safety inspection experience and little or no background in bridges and bridge terminology. It provides coverage of basic engineering concepts as well as inspection procedures and information on bridge types, bridge components, and bridge materials.

2. The two-week course, "Safety Inspection of In-Service Bridges," is intended for Federal, State and local engineers, inspectors and technicians who will be or currently are assigned to bridge inspection duties. The participants should be experienced technicians, inspectors or engineers who have a background in bridge engineering and who may already be performing or managing bridge inspections. There are no prerequisites to this course. However, a background in bridge engineering or completion of "Engineering Concepts for Bridge Inspectors" and successful completion of the exam from that course is strongly recommended. Emphasis is on inspection applications and procedures; i.e. knowing where, how and what to look for to find bridge deficiencies. Nationwide uniform coding and rating of bridge components is another objective of the course.

INSTRUCTOR REFERENCE MATERIAL CHECKLIST

1. FHWA. *Comprehensive Bridge Safety Inspection Training Program Part I - Engineering Concepts for Bridge Inspectors, Instructor's Guide.* Washington, D.C.: United States Department of Transportation, 1991.

2. FHWA. *Comprehensive Bridge Safety Inspection Training Program Part II - Safety Inspection of In-Service Bridges, Instructor's Guide.* Washington D.C.: United States Department of Transportation, 1991.

3. FHWA. *Bridge Inspector's Training, Manual 90.* Washington, D.C.: United States Department of Transportation, 1991.

4. FHWA. *Bridge Inspector's Training, Manual 70.* Washington, D.C.: United States Department of Transportation, 1979.

5. FHWA. *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* Washington, D.C.: United States Department of Transportation, 1988.

6. FHWA. *Bridge Inspector's Manual for Movable Bridges.* Washington, D.C.: United States Department of Transportation, 1977.

7. FHWA. *Culvert Inspection Manual.* Washington, D.C.: United States Department of Transportation, 1986.

8. FHWA. *Inspection of Fracture Critical Bridge Members.* Washington, D.C.: United States Department of Transportation, 1986.

9. FHWA. *Underwater Inspection of Bridges.* Washington, D.C.: United States Department of Transportation, 1989.

10. FHWA. *Advanced Bridge Inspection Methods: Application and Guidelines.* Washington, D.C.: United States Department of Transportation, 1989.

11. FHWA. *Guidelines for Developing Inspection Manuals for Segmental Concrete Bridges.* Washington, D.C.: United States Department of Transportation, 1989.

12. U.S. Forest Service. *Timber Bridges - Design, Construction, Inspection, and Maintenance.* Washington, D.C.: United States Department of Agriculture, 1990.

13. Yen, B. T., et. al. *Manual for Inspecting Bridges for Fatigue Damage Conditions.* Harrisburg, Pennsylvania: Commonwealth of Pennsylvania Department of Transportation, 1990.

14. FHWA. *Fatigue Cracking of Steel Bridge Structures.* Volumes I - III. Washington D.C.: United States Department of Transportation, 1990.

15. AASHTO. *Manual for Maintenance Inspection of Bridges.* Washington D.C.: Association of State Highway and Transportation Officials, 1983.

16. Derucher, K. N. and G. R. Korfiatis. *Materials for Civil and Highway Engineers.* 2nd Ed. Englewood Cliffs, New Jersey: Prentice Hall, 1988.

The training course will, as a minimum, cover the following topics:

Bridge Inspection Programs
Review of Basic Concepts
Safety
Inspection Documentation
Inspection and Evaluation of:

- Bridge Decks
- Common Timber, Steel and Concrete Superstructures
- Fracture Critical Bridge Members
- Bridge Bearings
- Substructures
- Waterways
- Underwater Inspections
- Culverts

3. The National Bridge Inspection Standards have established qualifications for bridge inspectors. An inspector can qualify as an inspection team leader after having at least five years of experience in bridge inspection assignments in a responsible capacity and having completed a comprehensive training course based on the *Bridge Inspector's Training Manual 90*. The one and two week courses combine to form the basis of the comprehensive training program. The level of experience (five years minimum) discussed above is a valid substitute for the one week training course.

B. Upon completion of the two-week course, "Safety Inspection of In-Service Bridges," the participants should be able to:

1. Evaluate a variety of bridges and determine the critical areas for inspection including fracture prone details, common points of deterioration and distress, and fracture critical members.

2. Review as-built plans and previous inspection reports; based on this review, plan and conduct an effective safety inspection for all of the common types of bridges including bridges with fracture critical members and culverts.

3. Recognize the various deficiencies that can exist on a bridge and discuss the cause of the deficiencies.

4. Understand the need to inspect the underwater portions of bridge structures; describe the type of deficiencies to look for, such as scour; determine when an inspection is necessary; and describe the procedures and types of equipment available and the advantages and limitations of each.

5. Understand the consequences of lack of inspections or inadequate inspection and discuss the responsibilities of an inspector.

6. Evaluate the general and specific condition of a bridge and its components by using a variety of inspection procedures and equipment.

7. Evaluate the severity of material deterioration and member distress and assign ratings according to coding guidance as developed by the Federal Highway Administration (FHWA) and/or the highway agency. Determine when it is necessary to close the bridge (or recommend closure to appropriate authority) because of imminent danger.

8. Discuss the equipment requirements for a complete inspection and demonstrate proficiency in the use of same.

9. Recognize when further inspection (e.g. NDT) is required beyond the usual visual and hand tool inspection and decide what type of inspection should be conducted.

10. Successfully complete an exhaustive examination based on the contents of the course. A two hour written examination will be given on the last day of the training course. The examination will be open book.

11. Satisfy the requirements for training described in the National Bridge Inspection Standards (NBIS) for individuals in charge of the organizational unit that have been delegated bridge inspection responsibilities and for individuals in charge of a bridge inspection team.

C. Table of Contents/Schedule

Take a few minutes to review the organization of the various handouts; *BITM 90* and *Participant's Notebooks*. Review the course schedule, indicating which optional topics have been selected.

D. Ground Rules

1. Feel free to ask questions at any time. Don't worry about interrupting.

2. Please do not talk while others are speaking.

3. Please do not smoke in the classroom.

4. You are free to leave the room at any time.

5. There are break periods scheduled for each morning and afternoon.

6. Attendance will be taken daily. The attendance sheets will be given to the host agency at the conclusion of the course.

7. Review daily schedule times:

Start	8:00 a.m.
Lunch	12:00 p.m. - 1:00 p.m.
Finish	4:30 p.m. - 5:00 p.m.

PARTICIPANT BACKGROUND QUESTIONNAIRE

Date: ______________________

Name: ____

(Please Print)

Employer: ____

Title/Job Description: ____

____

Education: ____

License/Certification: ____

Years Experience: Total: ________ Bridge Safety Inspection: __________

Bridge Constr. Inspection: __________

Underwater Inspection: __________

What would you like to get from this course?

____

____

____

____

____

____

BRIDGE INSPECTION PROGRAMS

SESSION 2: BRIDGE INSPECTION PROGRAMS

TOPIC 1: HISTORY OF THE NATIONAL BRIDGE INSPECTION PROGRAM

LESSON PLAN

TOPIC DURATION 30 minutes

PARTICIPANT MATERIALS Participant Notebook, BITM 90 - Chapter 2

GOAL An appreciation of the historical and evolutionary aspects of today's inspection programs.

OBJECTIVE Be able to state the objective of the NBIS

REFERENCES

1. FHWA. *Bridge Inspector's Training Manual 90.* Washington, D.C.: United States Department of Transportation, 1991.

2. FHWA. *Bridge Inspector's Training Manual 70.* Washington, D.C.: United States Department of Transportation, 1979.

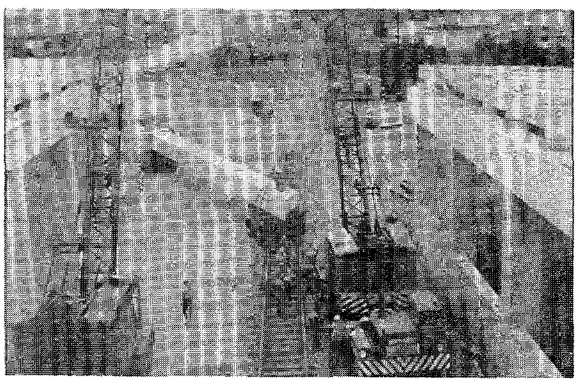
3. AASHTO. *Standard Specifications for Highway Bridges, 14th Edition.* Washington, D.C.: Association of State Highway and Transportation Officials, 1989.

4. FHWA. *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* Washington, D.C.: United States Department of Transportation, 1988.

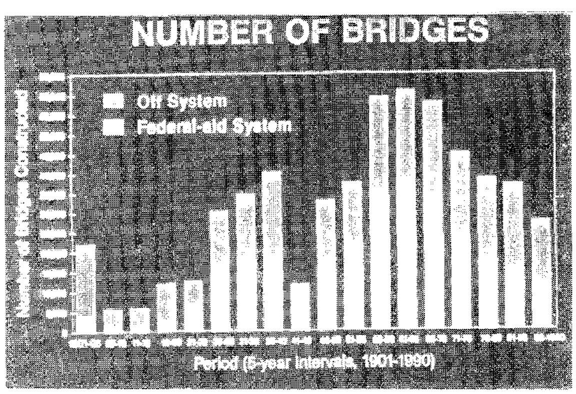
5. NBIS. *Code of Federal Regulations.* 23 Highways Part 650, Subpart C - National Bridge Inspection Standards, 1988.

NBIS

Slide No. 2-1-1
Narrative Slide
National Bridge Inspection Standards



Slide No. 2-1-2
Example Slide
Bridge construction during the 1950's and early 1960's



Slide No. 2-1-3
Schematic Slide
Number of bridges constructed 1901-1990

I. INTRODUCTION

There are four letters that define the scope of bridge inspections in this country. They are NBIS-standing for the National Bridge Inspection Standards. These standards define our bridge inspection efforts. To better understand the National Bridge Inspection Program, it is helpful if we take a look back at the development of the program.

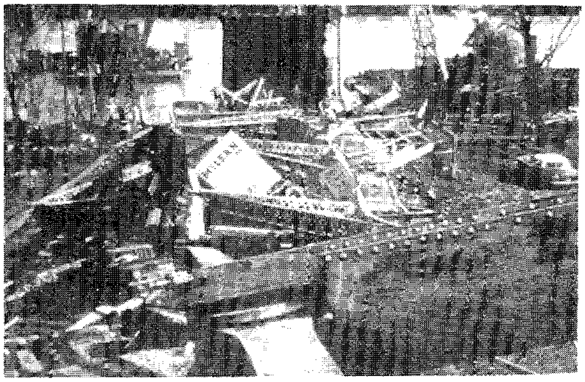
II. BACKGROUND

See Slide 2-1-2

During the bridge construction boom of the 1950's and early 1960's, not much emphasis was placed on inspection and maintenance of bridges.

See Slide 2-1-3

This slide shows the number of bridges built between 1900 and 1990. As you can see the greatest number of bridges built was in the 1960's. Those are now approaching 30 years of age. This means that we are now beginning to experience an increasing number of problems with this large group of bridges. Many other bridges such as the older bridges built in the 1920's and 1930's are also experiencing significant problems. Obviously, our need for timely and thorough inspections has also increased. The need for, and the job of, bridge inspection has never been more important than it is today.



Slide No. 2-1-4

Example Slide

Wreckage of the Silver Bridge

Federal Aid Highway Act of 1968

Slide No. 2-1-5

Narrative Slide

See Slide 2-1-4

We were all jolted into a new realization of the need for better bridge inspection when the Silver Bridge, spanning 2,235 feet (681.2 m), at Point Pleasant, West Virginia, suddenly collapsed into the Ohio River.

On that cold December day in 1967, 46 people were killed.

The tragic collapse aroused national interest in the inspection and maintenance of bridges. The U. S. Congress was prompted to add a section to the "Federal Aid Highway Act of 1968" which directed the Secretary of Transportation to establish a national bridge inspection standard. The Secretary also had to develop a program to train bridge inspectors.

1971 NBIS

Slide No. 2-1-6

Narrative Slide

- Standards
- Procedures
- Frequency
- Qualifications
- Reports
- Inventory

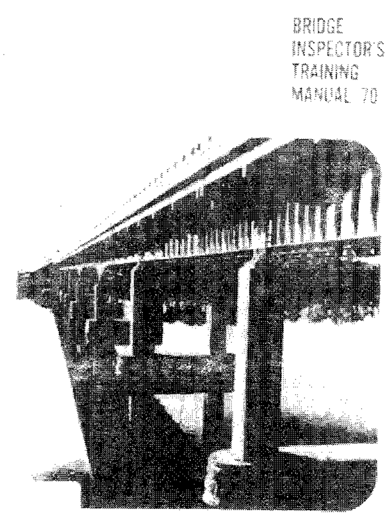
Slide No. 2-1-7

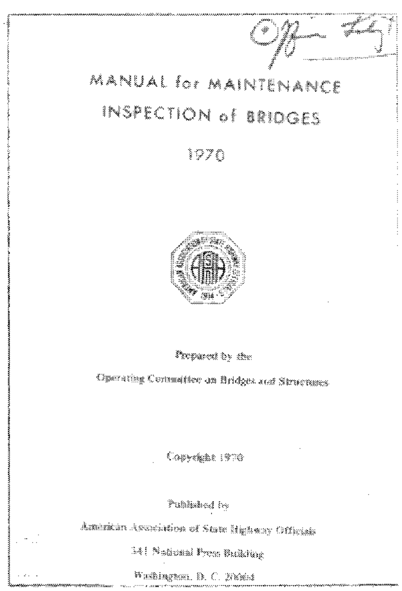
Narrative Slide

Slide No. 2-1-8

Example Slide

Cover of the FHWA's *Bridge Inspector's Training Manual 70*





Slide No. 2-1-9

Example Slide

Cover of the AASHO *Manual for Maintenance Inspection of Bridges*

III. THE 1970's

Thus, in 1971, the National Bridge Inspection Standards (NBIS) came into being. The NBIS established national policy regarding:

- When and how the standards were to be applied
- Inspection procedures
- Frequency of inspections
- Qualifications of inspection personnel
- Inspection reports
- Development of a national bridge inventory

A. MANUALS

Three manuals were developed. These manuals were vital to the early success of NBIS.

See Slide 2-1-8

1. The first manual was the FHWA's *Bridge Inspector's Training Manual 70 (Manual 70).* This manual set the standard for inspector training.

See Slide 2-1-9

2. The second manual was the AASHO *Manual for Maintenance Inspection of Bridges, 1970.* Often referred to as the *AASHTO Manual.*

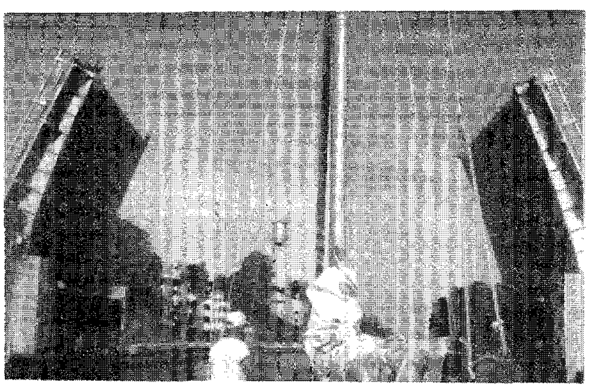
Slide No. 2-1-10
Example Slide
Original cover of the FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*

Manual 70 Coding Guide

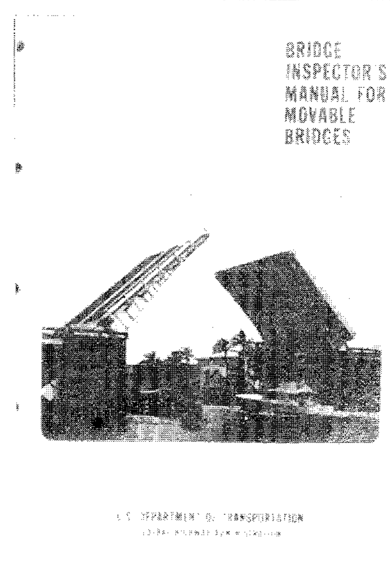
NBIS

Maintenance Manual

Slide No. 2-1-11
Narrative Slide



Slide No. 2-1-12
Example Slide
Movable Bridge



Slide No. 2-1-13
Example Slide
Cover of the *Bridge Inspector's Manual for Movable Bridges*

See Slide 2-1-10

3. The third manual was the FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (the *Coding Guide*).

B. CONCERNS

With the publication of *Manual 70*, the implementation of national standards and guidelines, support from AASHTO, and the availability of the new FHWA bridge inspector's training course for use in individual states, improved inventory and appraisal of the nation's bridges seemed inevitable. The 1970's looked promising.

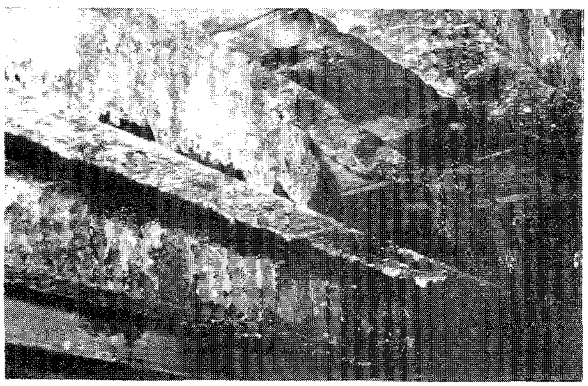
See Slide 2-1-12

See Slide 2-1-13

In 1977, maintenance and inspection problems associated with movable bridges were also addressed when the *Bridge Inspector's Manual for Movable Bridges* was published. This was the first supplement to *Manual 70*.

Bridge Needs Exceed Funding

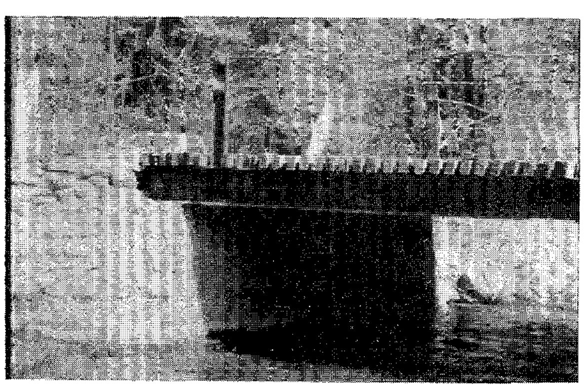
Slide No. 2-1-14
Narrative Slide



Slide No. 2-1-15
Example Slide
Advanced deterioration of a steel multibeam bridge

Non-Federal Aid Highway Bridges Exempt

Slide No. 2-1-16
Narrative Slide



Slide No. 2-1-17
Example Slide
Small, local, "off-system" bridge

However, the future was not to be trouble-free. Two predominant concerns were identified during this period.

See Slide 2-1-15

1. One was that bridge repair and replacement needs far exceeded available funding. The extent of deterioration identified and the costs to correct it were way beyond the program funding levels available.

See Slide 2-1-17

2. The other was that NBIS activity was limited to only Federal Aid Highway bridges. This meant that Non-Federal Aid bridges were exempt from the requirements of NBIS, and inspection and inventory were not mandatory. Thus, there was little incentive for inspection and inventory of non-Federal Aid Highway bridges. The non-FA bridges are often referred to as "off-system" bridges.

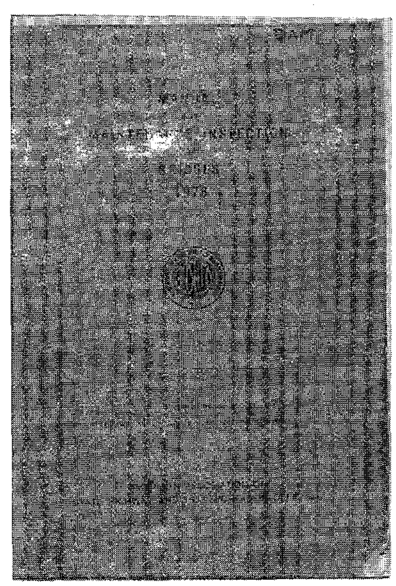
Surface Transportation Assistance Act of 1978

Slide No. 2-1-18
Narrative Slide

- Increased funding
- NBIS compliance

Slide No. 2-1-19
Narrative Slide

Slide No. 2-1-20
Example Slide
Inspection of an "off-system" bridge



Slide No. 2-1-21
Example Slide
Cover of the 1978 edition of the
AASHTO *Manual*

C. REVISIONS

These two concerns led to the passage of the "Surface Transportation Assistance Act of 1978." This act established a formal funding mechanism for providing Federal funds specifically for bridge replacement.

This legislation provided badly needed funding and required all bridge structures located on public roads and over 20 feet (6.1 m) in length to be inspected and inventoried in accordance with NBIS by December 31, 1980.

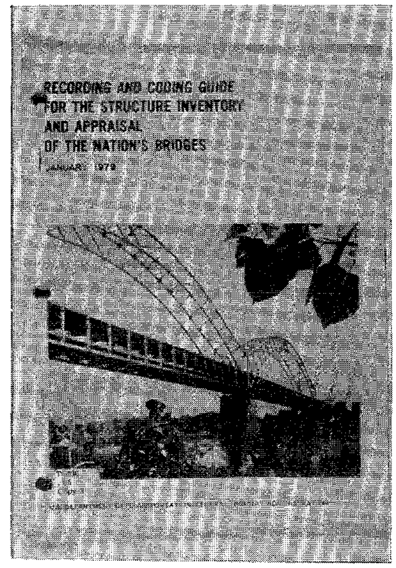
See Slide 2-1-20

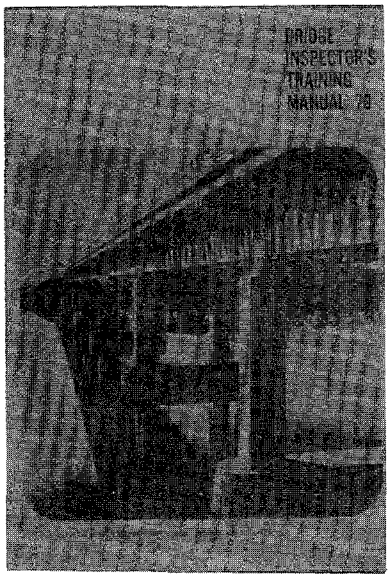
But there was a "string" attached. Any bridge not inspected and inventoried in compliance with NBIS would be ineligible for funding from the special replacement program. The bridge inspection effort, obviously, was expanding.

See Slide 2-1-21

In 1978, AASHTO revised their *Manual for Maintenance Inspection of Bridges*.

Slide No. 2-1-22
Example Slide
Cover from 1979 *Coding Guide*





Slide No. 2-1-23
Example Slide
Cover from 1979 *Manual 70*

The 1980's

Slide No. 2-1-24
Title Slide

See Slide 2-1-22

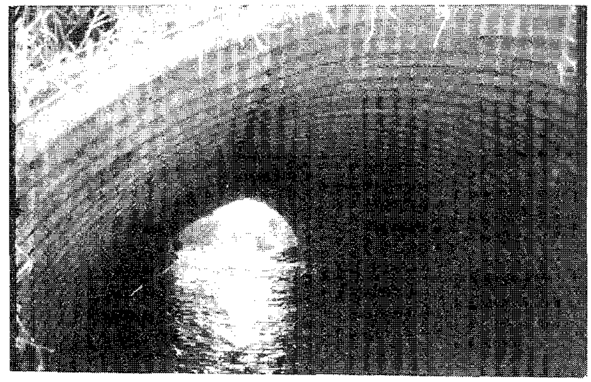
See Slide 2-1-23

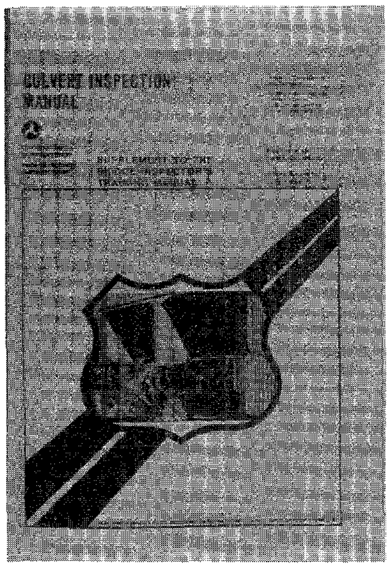
Then, in 1979, both NBIS and the FHWA *Coding Guide* were revised. These publications, along with a corrected reprint of *Manual 70* provided state agencies with definite guidelines for compliance with NBIS.

IV. THE 1980's

In the 1980's, the National Bridge Inspection Program matured considerably and was well positioned for the 1990's. However, as progress was being made, several tragic bridge failures once again forced us to examine more closely some problem areas we had not yet recognized.

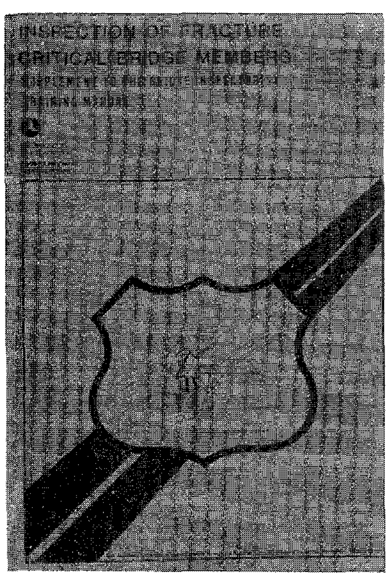
Slide No. 2-1-25
Example Slide
Corrugated plate pipe culvert





Slide No. 2-1-26
Example Slide
Cover to *Culvert Inspection Manual*

Slide No. 2-1-27
Example Slide
Mianus River Bridge collapse



Slide No. 2-1-28
Example Slide
Cover to *Inspection of Fracture Critical Bridge Members*

A. CULVERTS

See Slide 2-1-25

One such problem area was that of culverts, after several failures occurred. The 1979 NBIS revisions thus included more emphasis on culvert inspection.

See Slide 2-1-26

Later, in July 1986, the *Culvert Inspection Manual*, was published as the second supplement to *Manual 70.*

The FHWA now has a short course available on culvert inspections.

See Slide 2-1-27

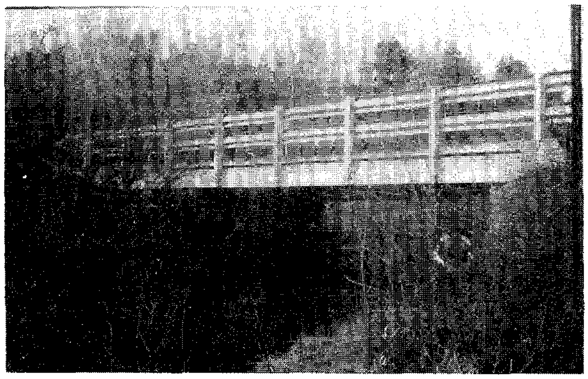
B. FRACTURE CRITICAL

Another problem area which has surfaced is that of the fatigue and fracture of steel bridges. This concern was intensified by the tragic collapse of the Mianus River Bridge in Connecticut in June 1983.

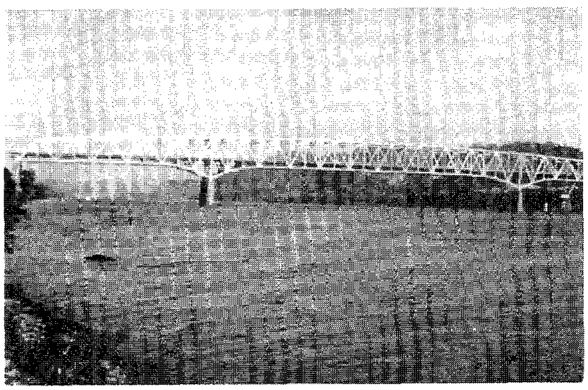
See Slide 2-1-28

The third supplement to *Manual 70*, which was entitled the *Inspection of Fracture Critical Bridges*, was already under development when this bridge collapsed. It was subsequently published in September 1986.

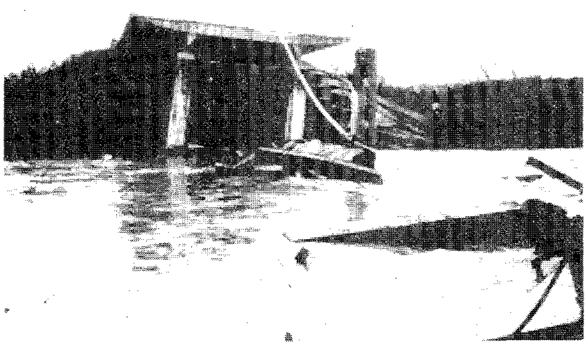
The FHWA also has a short course on the inspection of fracture critical bridge members.



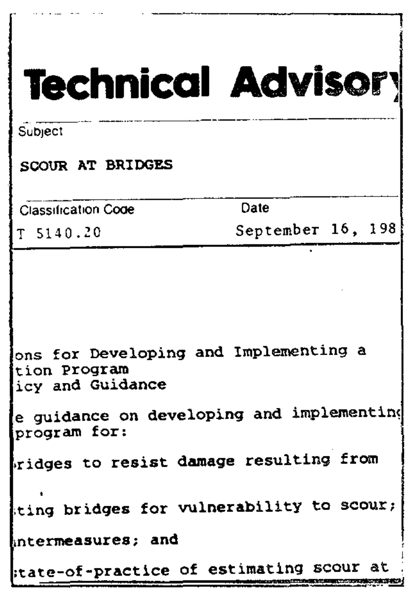
Slide No. 2-1-29
Example Slide
Small local bridge over stream



Slide No. 2-1-30
Example Slide
Major river crossing



Slide No. 2-1-31
Example Slide
Schoharie Creek Bridge collapse



Technical Advisor

Subject
SCOUR AT BRIDGES

Classification Code: T 5140.20
Date: September 16, 198

ons for Developing and Implementing a
tion Program
icy and Guidance

e guidance on developing and implementin
program for:

ridges to resist damage resulting from

ting bridges for vulnerability to scour;

ntermeasures; and

tate-of-practice of estimating scour at

Slide No. 2-1-32
Example Slide
Cover to technical advisory "Scour at Bridges"

See Slide 2-1-29

C. UNDERWATER INSPECTION

See Slide 2-1-30

Of the nearly 577,000 bridges in the national inventory, over 86% cross waterways.

See Slide 2-1-31

With the April 1987 collapse of the Schoharie Creek Bridge on the New York State Thruway, national attention turned to underwater inspection and scour.

See Slide 2-1-32

The FHWA again responded, with a technical advisory entitled "Scour at Bridges," which was issued in September 1988.

This advisory provided guidance for developing and implementing a scour evaluation program for:

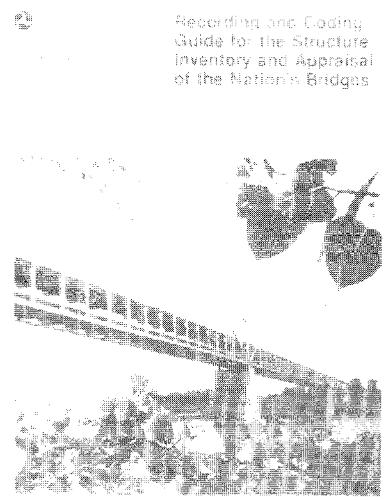
- designing new bridges to resist damage resulting from scour
- evaluating existing bridges for vulnerability to scour
- using scour countermeasures
- improving the state-of-practice of estimating scour at bridges

The FHWA has developed a short course on stream stability at highway bridges, and they also have an "Underwater Inspection Manual" which accompanies a short course.

1988 Revisions to NBIS

- Fracture critical inspections
- Underwater inspections
- Variable frequency
- NICET certification

Slide No. 2-1-33
Narrative Slide



Slide No. 2-1-34
Example Slide
Cover to 1988 *Coding Guide*

Objective:

Nationwide Uniformity

Slide No. 2-1-35
Narrative Slide

D. NBIS REVISED

In October 1988, NBIS were revised to require the states to identify those bridges with fracture critical details, and then to establish special inspection procedures for those structures. Similar requirements were made for bridges requiring underwater inspections. The NBIS revisions also allowed for adjustments in the frequency of inspections and the acceptance of National Institute for Certification in Engineering Technologies (NICET) Level III and IV certification for inspector qualifications. This certification program is administered by NICET.

See Slide 2-1-34

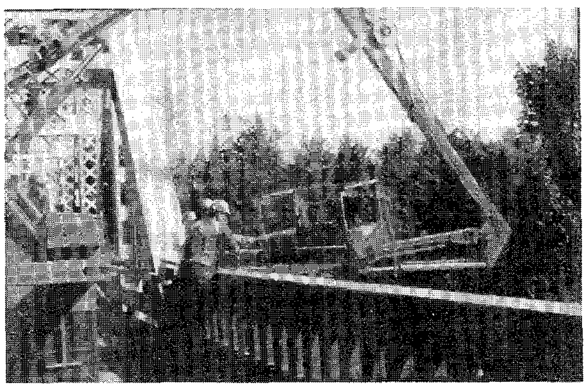
E. CODING GUIDE REVISED

In December 1988, the FHWA issued a revision to the *Coding Guide*. This time the revision was extensive, and it will significantly shape the National Bridge Inspection Program for the next decade.

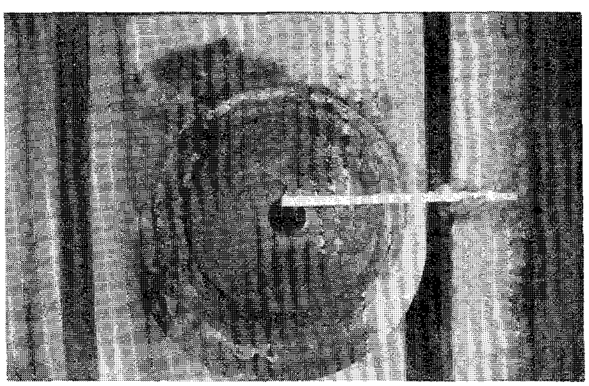
The *Coding Guide* now provides inspectors with new direction in performing uniform and accurate bridge inspections. Some items were deleted, some were added, and rating guidance for many was clarified. The issuance of this guide has already prompted the revision of many State bridge inspection manuals.

The 1990's

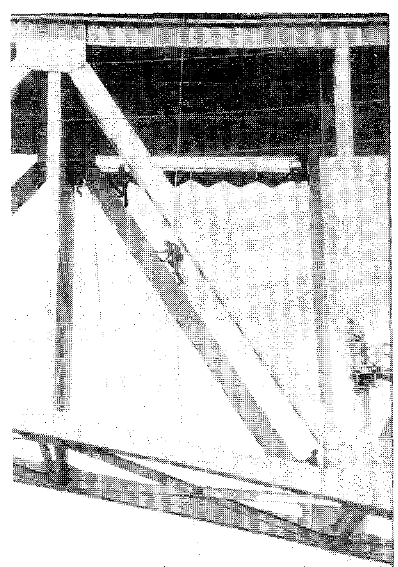
Slide No. 2-1-36
Title Slide



Slide No. 2-1-37
Example Slide
Inspection using an inspection access vehicle



Slide No. 2-1-38
Example Slide
Large pin and hanger assembly



Slide No. 2-1-39
Example Slide
Inspectors climbing and using special rigging equipment

V. THE 1990's

See Slide 2-1-37

As discussed, in the past 20 years, bridge inspection programs have gradually intensified.

There has been an increasing recognition of the importance of your work as bridge inspectors. Yours are the eyes, the ears, the hands . . . and the minds that all of us, as motorists, must depend upon to assure that every bridge we cross is safe to use.

See Slide 2-1-38

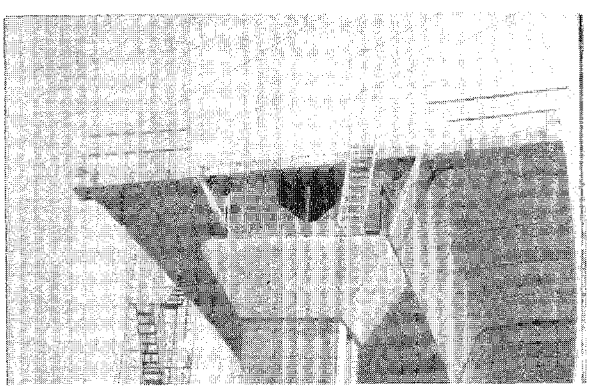
Much has been learned and implemented in the field of bridge inspection.

See Slide 2-1-39

Programs are more organized, better managed and much broader in scope.

Slide No. 2-1-40
Example Slide
Pin inspection using ultrasonic techniques

Slide No. 2-1-41
Example Slide
Diver entering water for underwater inspection



Slide No. 2-1-42
Example Slide
Segmental concrete bridge

Slide No. 2-1-43
Example Slide
Inspection of a local bridge

See Slide 2-1-40

The technology to inspect and evaluate bridge members and bridge materials is significantly better.

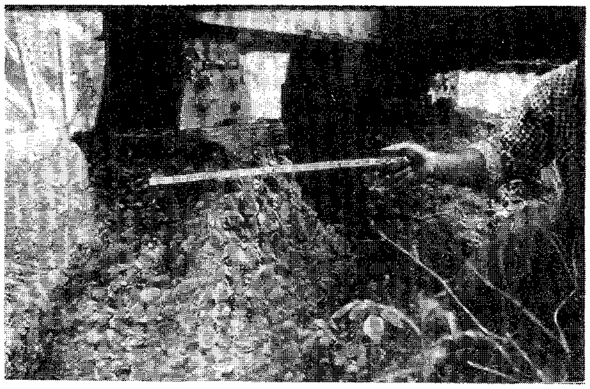
See Slide 2-1-41

See Slide 2-1-42

Emphasis areas in bridge inspection programs continue to change and expand as new problems become apparent, and as newer bridge types become more common.

See Slide 2-1-43

Guidelines for inspection ratings have been refined to increase uniformity and consistency of inspections. An October 1993 revision to the NBIS also permits bridge owners to request approval from the FHWA of extended inspection cycles of up to 4 years for bridges in good condition. We can anticipate even more sophistication and much better precision in the rating and evaluation of bridge conditions as we enter the era of full-fledged bridge management systems. These systems will be required of all states in the future.



Slide No. 2-1-44
Example Slide
Deterioration of a concrete pedestal

Inspector's Ability

Slide No. 2-1-45
Title Slide

Slide No. 2-1-46
Example Slide
Inspector's measuring bridge width

- Training
- Experience

Slide No. 2-1-47
Narrative Slide

See Slide 2-1-44

Data from bridge inspections are now critical input into a variety of analyses and decisions by state highway agencies and the Federal Highway Administration.

A. INSPECTOR'S ABILITY

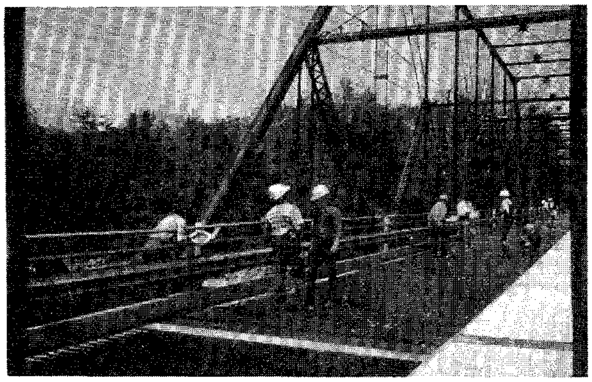
Throughout these expansions and improvements in bridge inspection programs and capabilities, one factor remains constant: the overriding importance of the inspector's ability to effectively inspect bridge components and to make sound evaluations.

See Slide 2-1-46

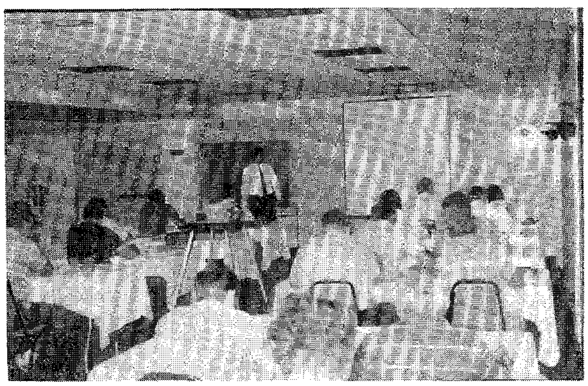
The validity of any analysis or decision which is based on inspection data is totally dependent on the quality, accuracy, and consistency of that data.

B. TRAINING

Across the nation, the duties, responsibilities, and qualifications of bridge inspectors vary widely. The key to a knowledgeable and effective inspector is good training plus good experience in making actual bridge inspections.



Slide No. 2-1-48
Example Slide
Bridge Inspection Training with field trip exercise



Slide No. 2-1-49
Example Slide
Bridge Inspection Training in classroom

BITM 90

- Revise
- Update

Slide No. 2-1-50
Narrative Slide

See Slide 2-1-48

This is true even of professional engineers and is certainly true for inspectors who have little or no background in engineering.

See Slide 2-1-49

Training of bridge inspectors has been an active process within many State highway agencies for many years.

C. BITM 90

This document, the *Bridge Inspector's Training Manual (BITM) 90*, is a comprehensive manual on programs, procedures and techniques for inspecting and evaluating a variety of in-service highway bridges. It is intended to replace the BITM 70, which was first published in 1970 to assist in training highway personnel for the new discipline of bridge safety inspection. BITM 70 has been in use for 20 years and has been the basis for several training programs varying in length from a few days to two weeks. Comprehensive supplements to BITM 70 have been developed to cover inspection of fracture critical bridge members, movable bridges and culverts.

BITM 90 is a revision and upgrading of the previous manual. Improved bridge inspection techniques are presented and state of the art inspection equipment is included. New or expanded coverage is provided on culverts, fracture critical members, cable stayed bridges, prestressed segmental bridges and underwater inspection. Previous supplemental manuals on culvert inspection, fracture critical inspection, movable bridge inspection and non-destructive testing are excerpted and referenced. These previous special manuals are still valid supplements to BITM 90.

A 3 week comprehensive training program on bridge inspection, based on the BITM 90, has been developed. The program consists of a one-week course, "Elementary Concepts for Bridge Inspectors" and a two-week course "Safety Inspection of In-Service Bridges." Together, these two courses meet the definition of a comprehensive training program in bridge inspection as defined in the National Bridge Inspection Standards. The one-week course is optional for technicians, inspectors or engineers who have an adequate background in bridge engineering concepts.

One Week Course
"Engineering Concepts
For
Bridge Inspectors"

Slide No. 2-1-51
Title Slide

Two Week Course
"Safety Inspection
of
In-Service Bridges"

Slide No. 2-1-52
Title Slide

Summary

- Background
- The 1970's
- The 1980's
- The 1990's

Slide No. 2-1-53
Title Slide

D. "ENGINEERING CONCEPTS FOR BRIDGE INSPECTORS"

This course is designed to provide knowledge of basic concepts in bridge engineering for use by bridge inspectors. The training is intended to prepare technicians and other personnel with little or no background in bridge engineering for a more intensive training course in bridge inspection such as the NHI 2-week course "Safety Inspection of In-Service Bridges." The combination of these two courses meets the requirements of the National Bridge Inspection Standards (NBIS) for a comprehensive training program in bridge inspection based on the *Bridge Inspector's Training Manual 90.*

E. SAFETY INSPECTION OF IN-SERVICE BRIDGES

This course is based on the *Bridge Inspector's Training Manual 90* and will provide comprehensive, intensive training on the safety inspection of a variety of in-service highway bridges. The combination of NHI course "Engineering Concepts for Bridge Inspectors" and this course meets the requirements of the National Bridge Inspection Standards (NBIS) for a comprehensive training program in bridge inspection based on the manual.

VI. SUMMARY

A. BACKGROUND

B. THE 1970'S

C. THE 1980'S

D. THE 1990'S

SESSION 2: BRIDGE INSPECTION PROGRAMS

TOPIC 2: RESPONSIBILITIES OF THE BRIDGE INSPECTOR

LESSON PLAN

TOPIC DURATION	30 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 5
GOAL	Awareness and an understanding of the importance of bridge inspection and what is meant by a proper bridge inspection.
OBJECTIVE	To be able to list the responsibilities of the bridge inspector, and the organization requirements necessary to perform inspections successfully and efficiently. Explain the importance of the inspector's job in relation to public safety.
PARTICIPATION	Participants will be asked to describe their own responsibilities at the beginning of the lecture.
PARTICIPATION	Participants will be asked to describe their own responsibilities at the beginning of the lecture

Responsibilities

Slide No. 2-2-1

Narrative Slide

Maintain Public Safety and Confidence

- Public Attitude
- Engineer's Role
- Inspector's Role

Slide No. 2-2-2

Narrative Slide

I. RESPONSIBILITIES OF THE BRIDGE INSPECTOR

A. MAINTAIN PUBLIC SAFETY AND CONFIDENCE

1. **The Public Attitude** - People travel our highways and over thousands of bridges without hesitation or any thought that the bridge may not be safe. Most of them are safe and will be for years to come.

   However, when a bridge fails, the public immediately asks the question, "Who was responsible? Who inspected the bridge? Why didn't they do this or that?"

2. **The Engineer's Role** - What can the engineer do to ensure bridge safety?

   Conservative Designs - Engineers provide "extra" material in members to compensate for a lack of precise calculations, variations in the quality of material, erection loading conditions, and uncertain maintenance. This conservativism is particularly evident in older bridges, especially those designed prior to the use of computers for design calculations. The bridge design engineer must be as confident as possible that the bridge will never fail under natural or man-made loads. Conservatism can also be exercised in the load rating process and in load posting practices.

   Safety Factors - Modern designs incorporate safety factors which compensate for material flaws, construction deficiencies, and overloads.

3. **The Inspector's Role** - What can the bridge inspector do to ensure bridge safety?

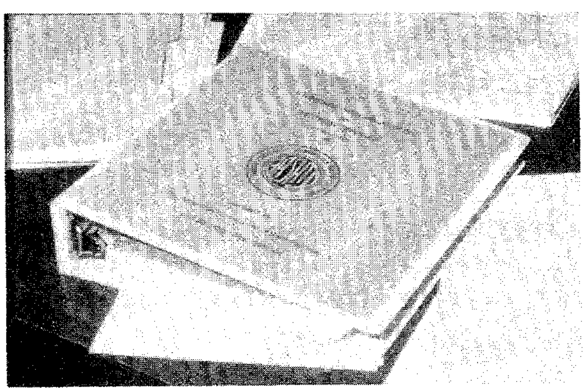
   Continual Surveillance - Due to the destructive forces of nature, ever-increasing public use, and heavier loads, bridge structures eventually become defective or deficient. Inspectors must find and report those conditions.

   Condition Report - When the inspector finds deficiencies in a bridge, an accurate report must be written to identify the deficiencies and address recommendations for maintenance or repair activities.

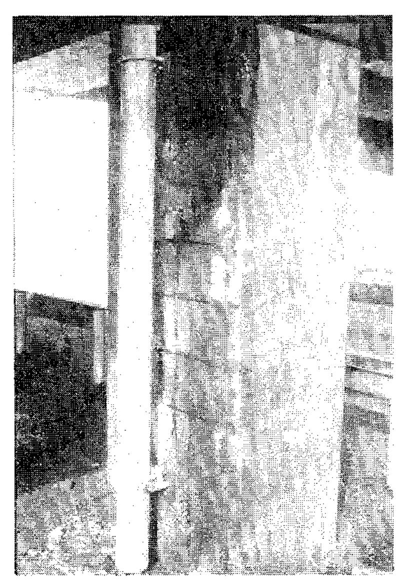
Responsibilities

- Public Safety
- Public Investment

Slide No. 2-2-3
Narrative Slide



Slide No. 2-2-4
Example Slide
AASHTO Specifications



Slide No. 2-2-5
Example Slide
Extensive spalling caused by defective drainage system

B. PROTECT PUBLIC INVESTMENT

1. Bridge Replacement Costs

The funding available to rehabilitate and replace deficient bridges is not adequate to meet the needs.

In 1980, 100,000 structurally deficient or functionally obsolete bridges needed to be replaced. Twenty-five billion dollars was needed to replace those bridges.

In 1989, 250,000 structurally deficient or functionally obsolete bridges needed to be replaced. Fifty-two billion dollars was needed to replace those bridges.

See Slide 2-2-4

2. **The Engineer's Role** - Engineers are continually upgrading design detail standards to promote longevity of modern bridges.

3. **The Inspector's Role** - We are faced with the situation that there will not be adequate funds in the future to replace all deficient bridges. We must attempt to make every bridge as safe as possible and to protect the investment that has been made in the bridge.

"A stitch in time saves nine" means that simple measures made early enough may eliminate the need for more extreme measures later. Although it is old, this saying can apply to bridges. We must continually be on guard for minor problems that can become costly repairs.

- **Preventative Maintenance**

See Slide 2-2-5

The inspector must be on guard for minor problems which can be corrected before they lead to costly major repairs.

The inspector must also be able to recognize bridge components which need repair in order to maintain bridge safety and avoid the need for costly replacement.

Responsibilities

- Public Safety
- Public Investment
- Inspection Program Support

Slide No. 2-2-6

Narrative Slide

Bridge Inspection Program Support

- NBIS
- Surface Transportation Act of 1978
- Inspections use Tax $

Slide No. 2-2-7

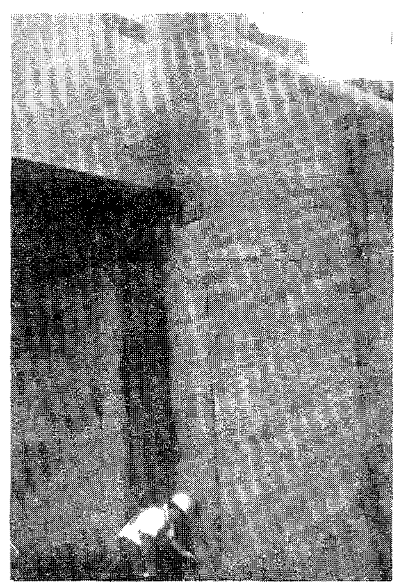
Narrative Slide

Responsibilities

- Public Safety
- Public Investment
- Inspection Program Support
- Accurate Records

Slide No. 2-2-8

Narrative Slide



Slide No. 2-2-9

Example Slide

Abutment measurements

C. BRIDGE INSPECTION PROGRAM SUPPORT

1. **The National Bridge Inspection Standards**, or NBIS, are the part of the Code of Federal Regulations that mandates Inspection Procedures, Frequency of Inspections, Qualifications of Personnel, Reporting, and Inventory.

2. **The "Surface Transportation Act of 1978"** This act established the funding mechanism for providing Federal funds for bridge replacement.

   The Act also established criteria for bridge inspections and requirements for compliance with the NBIS.

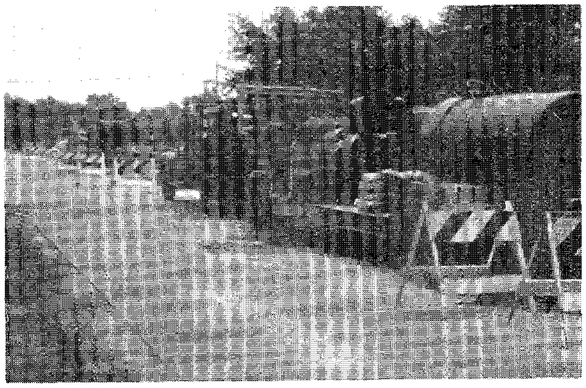
3. **Bridge Inspection Programs** are funded by public tax dollars. Therefore, the bridge inspector is financially responsible to the public.

4. **The "Intermodal Surface Transportation Efficiency Act" (ISTEA)** of 1991 establishes a funding mechanism for tolled and free bridges for bridge maintenance, rehabilitation and replacement to adequately preserve the bridges and their safety to all users.

D. ACCURATE BRIDGE RECORDS

There are three reasons why accurate bridge records are required:

1. **Structure History File**



Slide No. 2-2-10
Example Slide
Bridge repair activities

Responsibilities

- Public Safety
- Public Investment
- Inspection Program Support
- Accurate Records
- Legal Responsibilities

Slide No. 2-2-11
Narrative Slide

"The Bridge is OK"

Slide No. 2-2-12
Narrative Slide

Qualifications of Personnel

Slide No. 2-2-13
Title Slide

See Slide 2-2-10

2. **Repair Program** - To identify and assess bridge repair requirements. An individual should be able to readily determine, from the records, what repairs are needed as well as a good estimate of quantities.

3. **Maintenance Program** - To identify and assess bridge maintenance needs in a similar manner to the repair requirements.

E. LEGAL RESPONSIBILITIES

1. **The Bridge Inspection Report** - A bridge inspection report is a legal document. As such, proper language must be used in the report. Do not use vague adjectives such as good, fair, poor, general deterioration, etc. without concise descriptions. To say “the bridge is OK” just is not good enough!

For example, a vague description would be: "fair beams." The correct description may read: "Stringers in fair condition with light scaling on bottom flanges of two beams for their full length." A reviewing engineer should be able to have a clear picture in his mind from your notes.

Another example of a description to avoid would be "Deck in poor condition." A better way to state this would be: "Deck in poor condition with 30% chloride contamination and numerous spalls as indicated on field sketch."

Any visual assessments should include phrases such as "no other apparent defects" or "no other defects observed." Do not alter the original inspection report without consultation with the inspection personnel who wrote the report. Any alterations to field notes should be dated and initialed.

A bridge inspection report implies that the inspection was performed in accordance with the National Bridge Inspection Standards, unless specifically stated otherwise in the report. Proper equipment, techniques, and personnel must be used. If the inspection is a special or interim inspection, explain this explicitly in the report.

2. **Qualifications of Personnel**

The Code of Federal Regulations, Title 23, Chapter 1, Section 650-307, (23 CFR 1.650.307), lists the qualifications of personnel for the National Bridge Inspection Standards (see BITM 90, Appendix A, page A-3):

§650.307 Qualifications of Personnel

(a) The individual in charge of the organizational unit that has been delegated the responsibilities for bridge inspection, reporting, and inventory shall possess the following minimum qualifications:

(1) Be a registered professional engineer; or

(2) Be qualified for registration as a professional engineer under the laws of the State; or

(3) Have a minimum of 10 years experience in bridge inspection assignments in a responsible capacity and have completed a comprehensive training course based on the "Bridge Inspector's Training Manual," which has been developed by a joint Federal-State task force, and subsequent additions to the manual.

(b) An individual in charge of a bridge inspection team shall possess the following minimum qualifications:

(1) Have the qualifications specified in paragraph (a) of this section; or

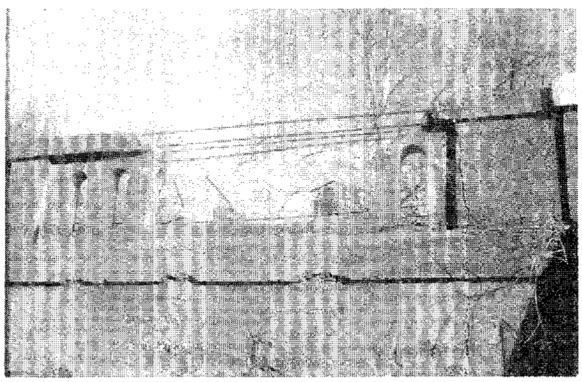
(2) Have a minimum of 5 years experience in bridge inspection assignments in a responsible capacity and have completed a comprehensive training course based on the "Bridge Inspector's Training Manual," which has been developed by a joint Federal-State task force.

(3) Current certification as a Level III or IV Bridge Safety Inspector under the National Society of Professional Engineer's program for National Certification in Engineering Technologies (NICET) is an alternate acceptable means for establishing that a bridge inspection team leader is qualified.

Consequences of Irresponsibility

Tort Liability

Slide No. 2-2-14
Title Slide



Slide No. 2-2-15
Example Slide
Deficient safety feature

II. CONSEQUENCE OF IRRESPONSIBILITY - TORT LIABILITY

The dictionary defines tort as "a wrongful act for which a civil action will lie except one involving a breach of contract."

With the elimination of sovereign immunity in most states, tort liability results. Individuals, including department heads, engineers and inspectors, are subject to personal liability. Situations that are open to litigation include, but are not limited to the following:

See Slide 2-2-15

- deficient safety features
- failed fracture critical members
- failed scour critical substructure members
- failed expansion joints, portions of decks, potholes or other hazards to the traveling public
- improper or deficient load posting procedures

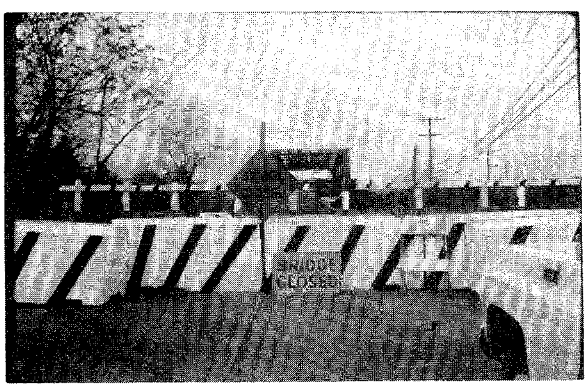
Anything you say or write could be held against you. In litigation involving a bridge, the inspection notes and reports are used as evidence. Subjectivity in a report may lead to the qualifications of the inspector being challenged. The report will be scrutinized to determine if conditions are documented thoroughly and for the "proper" reasons. An inspector should, therefore, strive to be as objective and complete as possible. Be factual - report what you see.

Summary

Slide No. 2-2-16
Title Slide

- Public Safety
- Protect Public Investment
- Bridge Inspection Program Support
- Accurate Bridge Records
- Legal Responsibilities

Slide No. 2-2-17
Narrative Slide



Slide No. 2-2-18
Example Slide
Closed bridge

III. SUMMARY

A. RESPONSIBILITIES OF THE BRIDGE INSPECTOR

1. **Maintain Public Safety and Confidence**
2. **Protect Public Investment**
3. **Bridge Inspection Program Support**
4. **Accurate Bridge Records**
5. **Legal Responsibilities**

See Slide 2-2-18

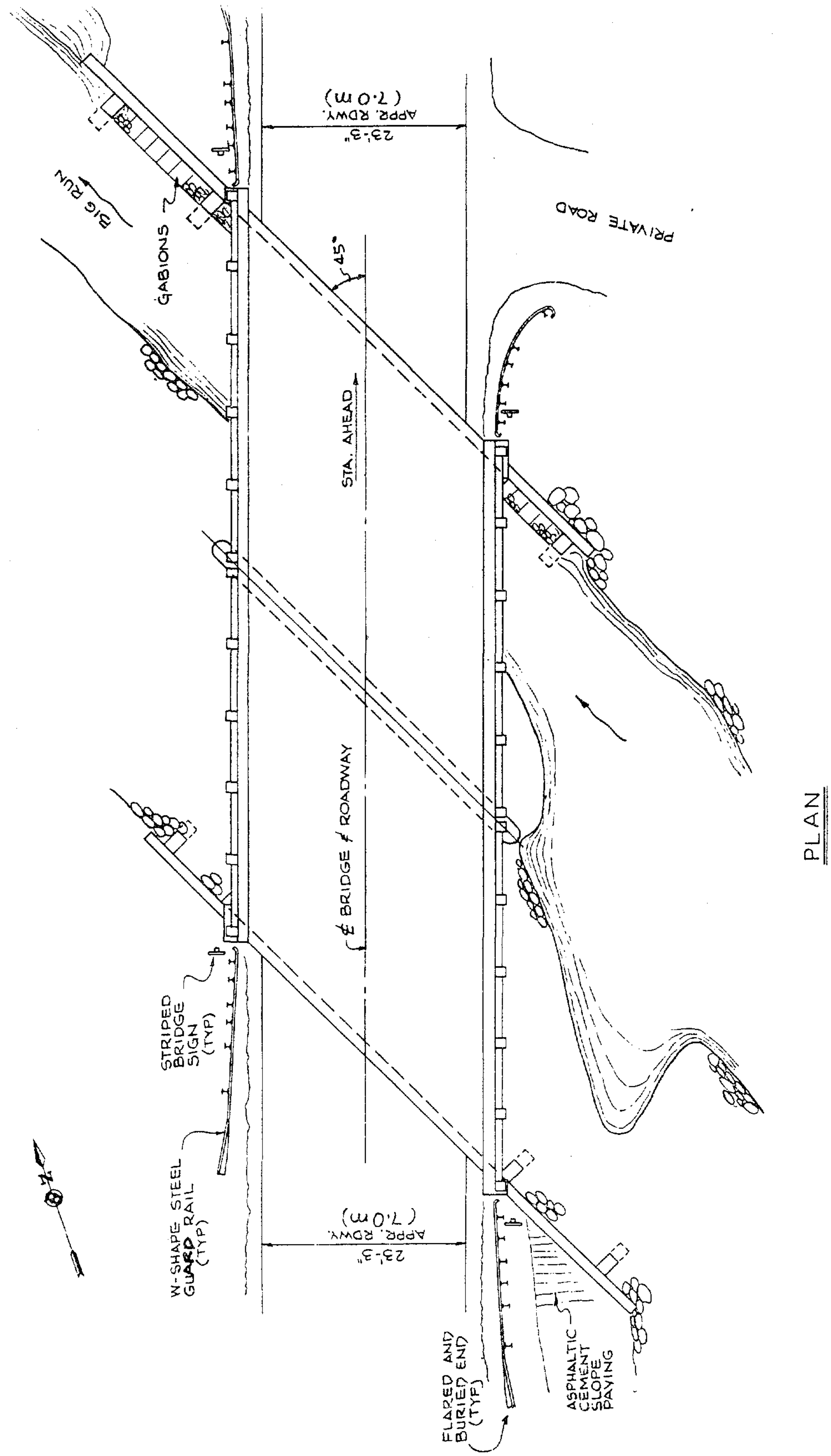
B. CONSEQUENCES OF IRRESPONSIBILITY

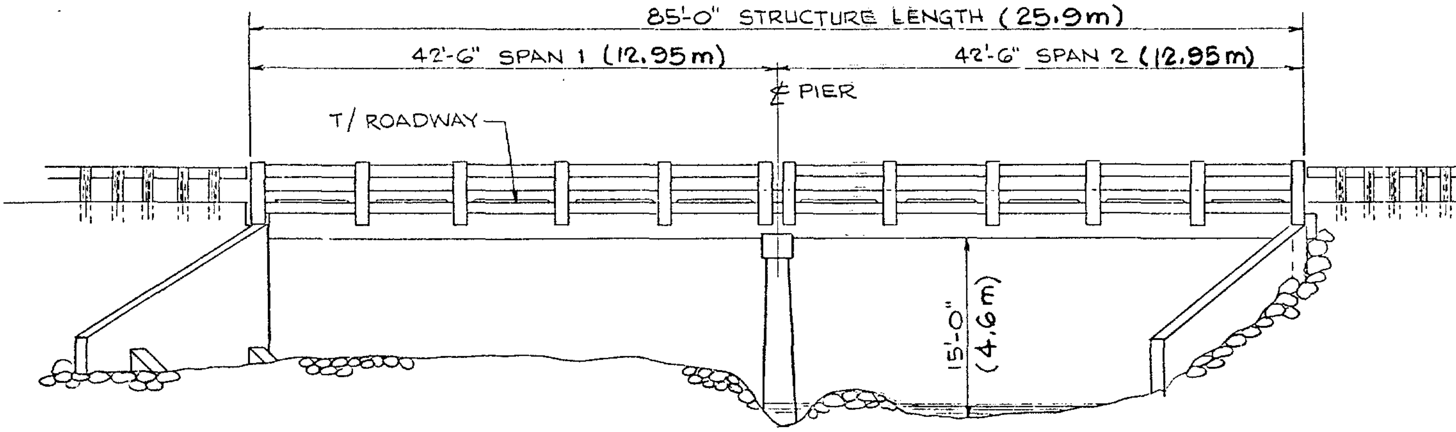
SESSION 2: BRIDGE INSPECTION PROGRAMS

TOPIC 3: CONDITION CODING EXERCISE

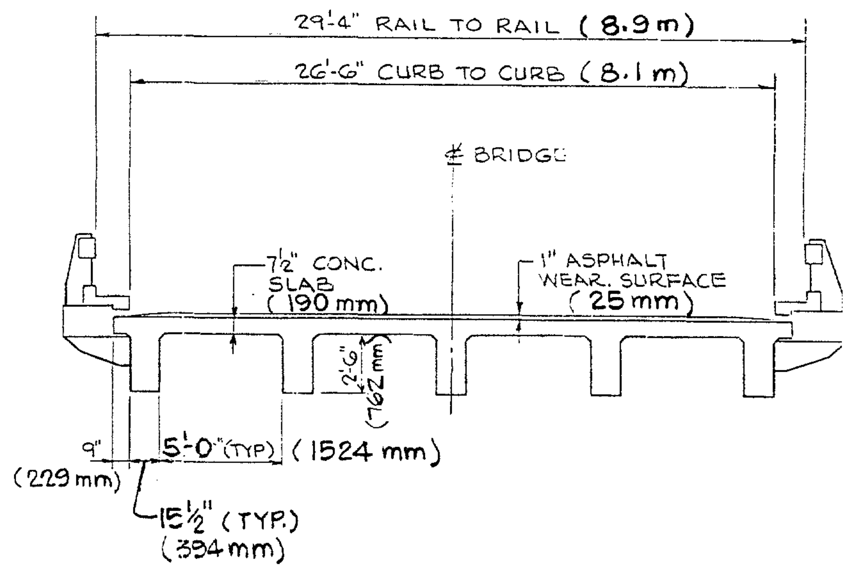
LESSON PLAN

TOPIC DURATION	60 minutes
PARTICIPANT MATERIALS	Participant Notebook
GOAL	Recognition of the thought process involved with the determination of condition and appraisal codings, and the importance of uniformity among inspectors.
OBJECTIVE	Be able to evaluate and determine the proper condition and appraisal codes for certain SI&A items.
REFERENCES	FHWA. *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges.* Washington, D.C.: United States Department of Transportation, 1988.


BIG RUN
GABIONS
PRIVATE ROAD
23'-3"
APPR. RDWY.
(7.0m)
45°
STA. AHEAD
℄ BRIDGE ℄ ROADWAY
STRIPED BRIDGE SIGN (TYP)
W-SHAPE STEEL GUARD RAIL (TYP)
23'-3"
APPR. RDWY.
(7.0m)
FLARED AND BURIED END (TYP)
ASPHALTIC CEMENT SLOPE PAVING
PLAN



ELEVATION
SCALE: 1/8" = 1'-0"



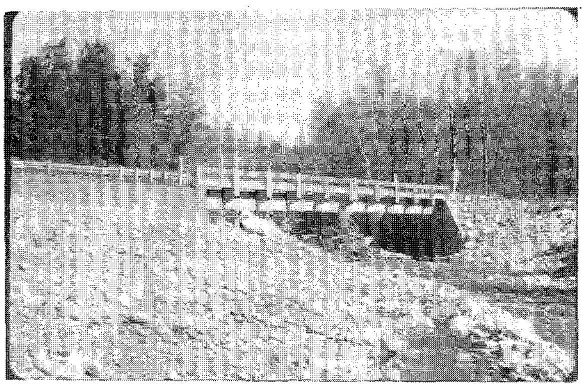
TYPICAL CROSS SECTION
SCALE: 1/4" = 1'-0

NOTES

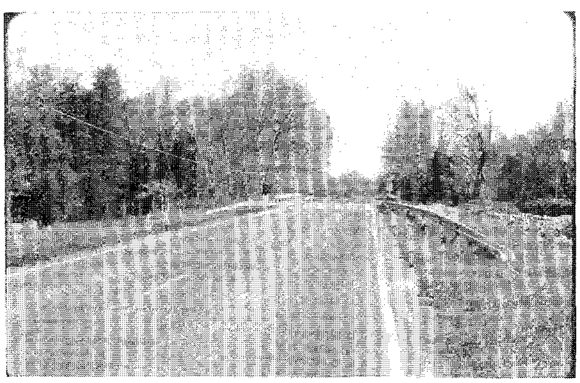
- BUILT 1940
- A.D.T. - 2300 (RECORDED 12-1985)
- DESIGN LOAD - 15 TONS (135 kN) BASED ON H - LOADING
- INVENTORY RATING - 15 TONS (135 kN) BASED ON H - LOADING
- OPERATING RATING - 20 TONS (180 kN) BASED ON H - LOADING
- NOT A DEFENSE HIGHWAY
- SKETCHES WERE MADE FROM FIELD DATA

General View

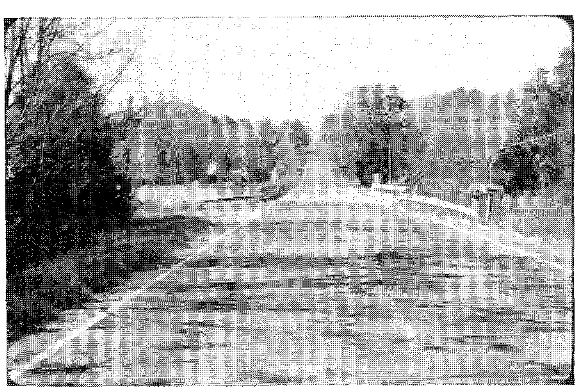
Slide No. 2-3-1
Narrative Slide



Slide No. 2-3-2
Example Slide
General View



Slide No. 2-3-3
Example Slide
South Approach



Slide No. 2-3-4
Example Slide
North Approach

I. FHWA GENERAL CONDITION RATING GUIDELINES

FHWA General Rating Guidelines

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION- some minor problems.
6	SATISFACTORY - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION - out of service - beyond corrective action.

See Slide 2-3-1

This bridge case study is presented in several sections: the deck, superstructure, substructure, and channel. Each section, or group of slides should be used to determine the most appropriate condition code for the respective item. This is a general view from the upstream side, south bank.

See Slide 2-3-3

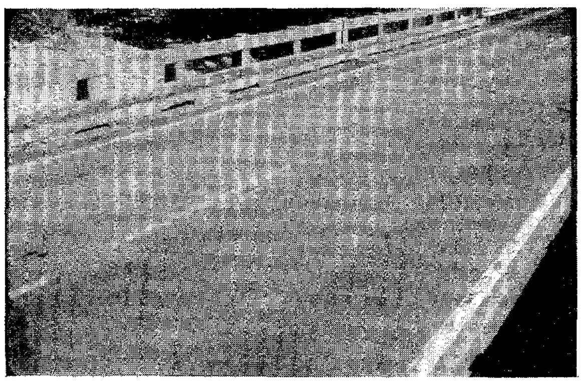
South Approach - back

See Slide 2-3-4

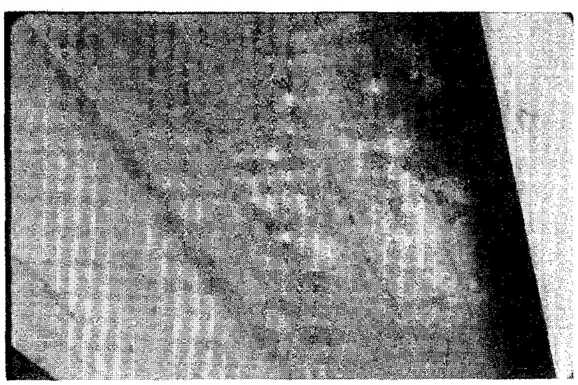
North Approach - back

Deck Condition

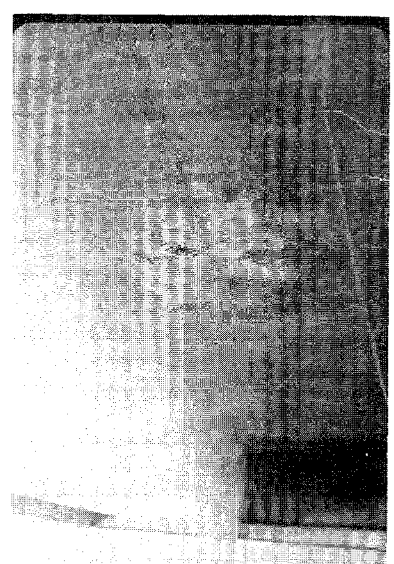
Slide No. 2-3-5
Title Slide



Slide No. 2-3-6
Example Slide
Deck pavement Span 1



Slide No. 2-3-7
Example Slide
Deck underside



Slide No. 2-3-8
Example Slide
Deck underside

II. DECK CONDITION

The deck condition should be coded according to Item No. 58 in the FHWA *Coding Guide.*

See Slide 2-3-6

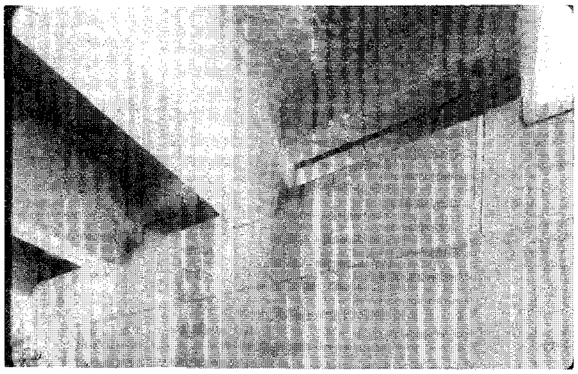
Deck pavement, Span 1
This is an asphalt wearing surface. There are no cracks in the asphalt. This is typical of the entire wearing surface.

See Slide 2-3-7

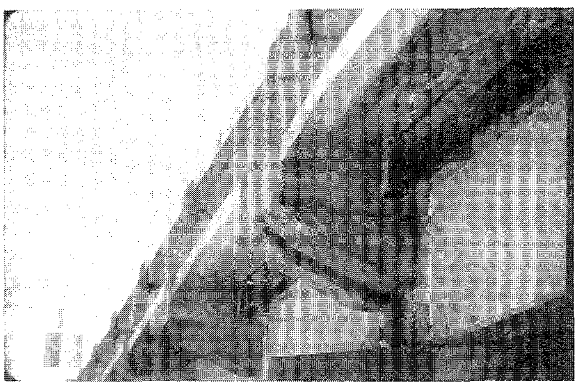
Typical underside of deck shows light efflorescence. There is no honeycombing, only some dark spots.

See Slide 2-3-8

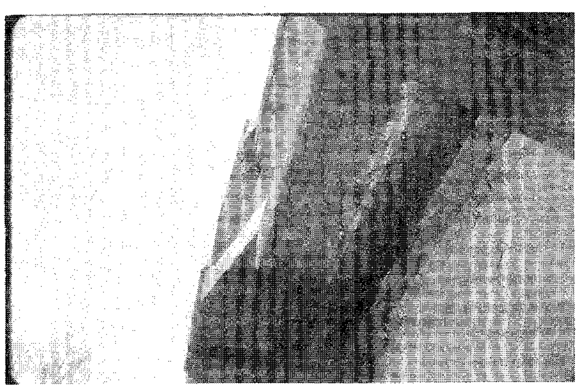
Typical underside of deck. Dark spots are visible.



Slide No. 2-3-9
Example Slide
Deck underside and diaphragm



Slide No. 2-3-10
Example Slide
Curb underside



Slide No. 2-3-11
Example Slide
Curb underside

See Slide 2-3-9

Deck underside and diaphragm at pier. This is a typical condition. The cracking of the diaphragm is the result of delaminations.

See Slide 2-3-10

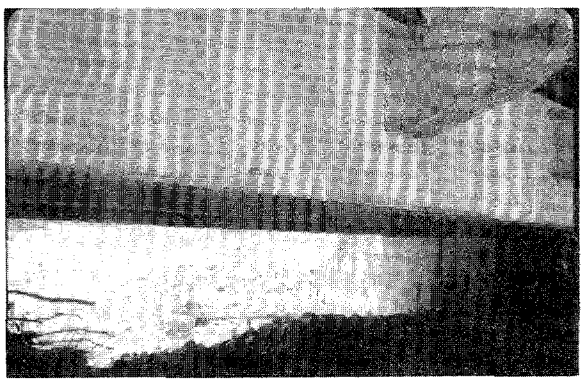
Curb section underside and cantilever support. Small corner spalls with exposed bars - typical.

See Slide 2-3-11

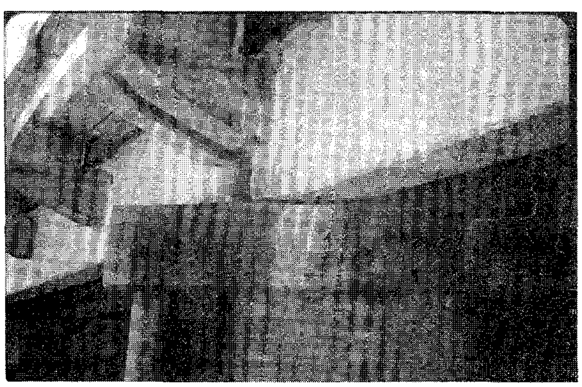
Curb section underside and cantilever support. Typical corner delamination.

Superstructure Condition

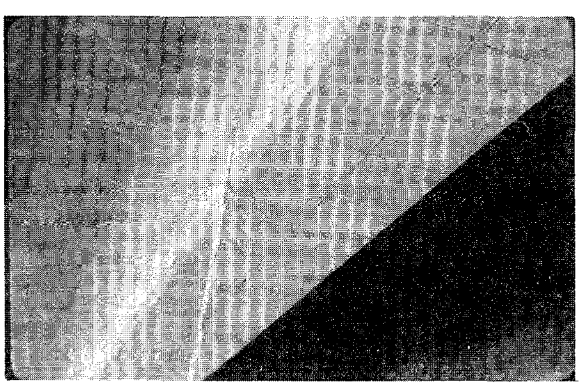
Slide No. 2-3-12
Title Slide



Slide No. 2-3-13
Example Slide
Beam No. 1, Span No. 1, at midspan



Slide No. 2-3-14
Example Slide
Beam No. 1 at pier



Slide No. 2-3-15
Example Slide
Beam No. 3, Span No. 1

III. SUPERSTRUCTURE CONDITION

The superstructure condition should be coded according to Item No. 59 in the FHWA *Coding Guide*.

See Slide 2-3-13

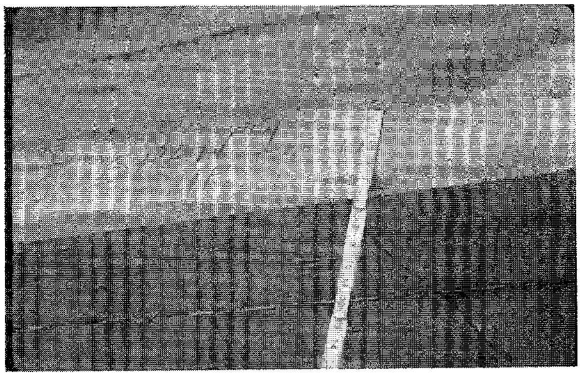
Beam No. 1, Span No. 1 at midspan. Minor surface spalls.

See Slide 2-3-14

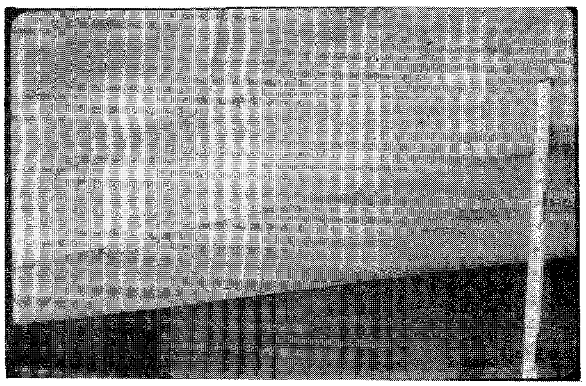
Beam No. 1, Span No. 1 at Pier. No cracks, stains. Delaminations are present at the end of the beam.

See Slide 2-3-15

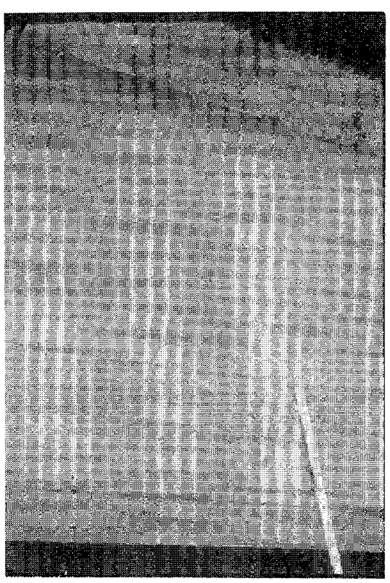
Beam No. 3, Span No. 1
Hairline vertical cracks at 9 inches± (230 mm±) spacing on bottom and 3 inches± (75 mm±) up sides, over 90% of beam length.



Slide No. 2-3-16
Example Slide
Beam No. 3 - Span No. 1



Slide No. 2-3-17
Example Slide
Beam No. 4 - Span No. 1



Slide No. 2-3-18
Example Slide
Beam No. 5 - Span No. 1

Slide No. 2-3-19
Example Slide
Beam No. 5 - Span No. 1

See Slide 2-3-16

Beam No. 3, Span No. 1
Close-up of hairline cracks.

See Slide 2-3-17

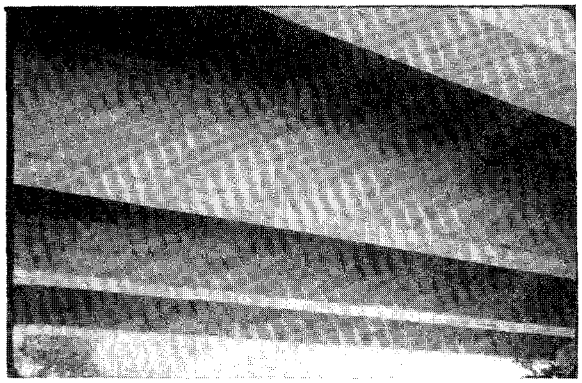
Beam No. 4 - Span No. 1
Close-up of hairline cracks.
Beam No. 4 (Span No. 1) is similar to Beam No. 3 (Span No. 1).

See Slide 2-3-18

Beam No. 5 - Span No. 1
Full height vertical hairline cracks spaced at 3 feet± (915 mm±) entire beam length. Extend across the bottom, but are not on the interior face.

See Slide 2-3-19

Beam No. 5, Span No. 1 at Pier. Small corner spall, 9 inches (230 mm) long, with minor section loss (less than 1/32 inch (1 mm)) on the exposed rebar

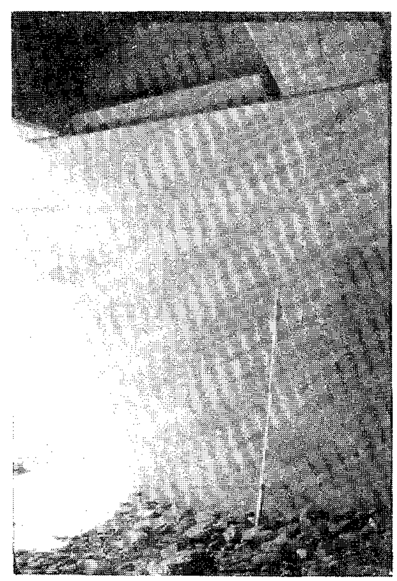


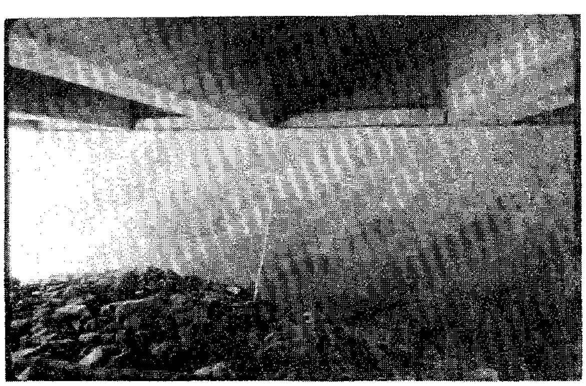
Slide No. 2-3-20
Example Slide
Span No. 2

Substructure Condition

Slide No. 2-3-21
Title Slide

Slide No. 2-3-22
Example Slide
South Abutment





Slide No. 2-3-23
Example Slide
South Abutment

See Slide 2-3-20

Typical beams in Span No. 2. Good condition - no cracks.

IV. SUBSTRUCTURE CONDITION

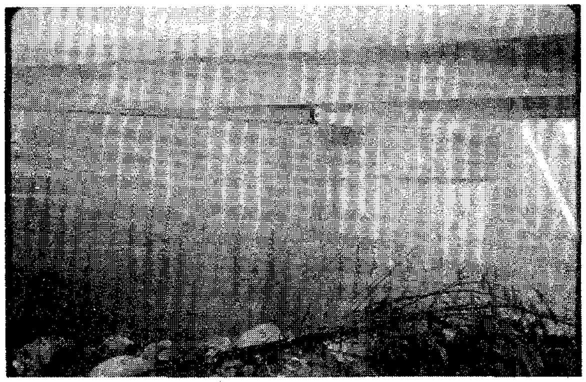
The substructure condition should be coded according to Item No. 60 in the FHWA *Coding Guide*.

See Slide 2-3-22

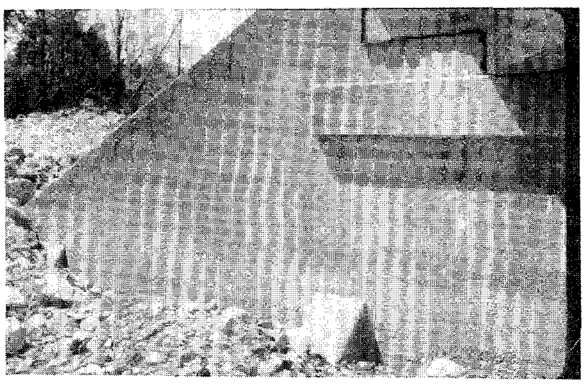
South Abutment, Face, Upstream End.
Full height vertical hairline cracks and three medium to wide (1/16 inch (2 mm) crack). No efflorescence, mud stains present. Minor abrasion of the concrete.

See Slide 2-3-23

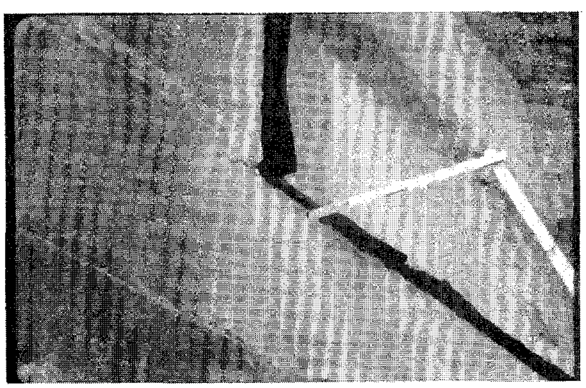
South Abutment, Face, Middle
Two cracks under Beam 3.
Plumbed vertical.



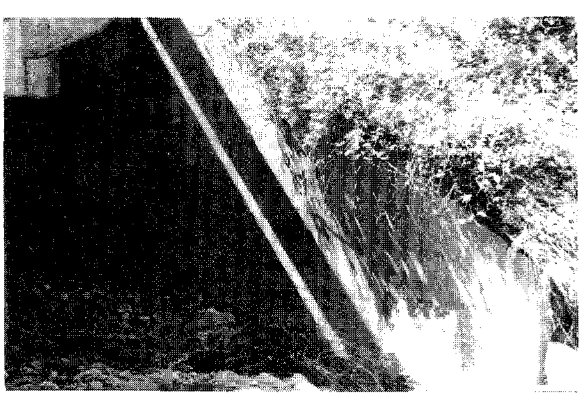
Slide No. 2-3-24
Example Slide
South Abutment



Slide No. 2-3-25
Example Slide
South Abutment
Upstream Wing Wall



Slide No. 2-3-26
Example Slide
South Abutment
Bearing Seat
Upstream Corner



Slide No. 2-3-27
Example Slide
South Abutment
Downstream Wing Wall

See Slide 2-3-24

South Abutment, Face, Downstream End
1/16 inch (2 mm) crack under Beam No. 2

See Slide 2-3-25

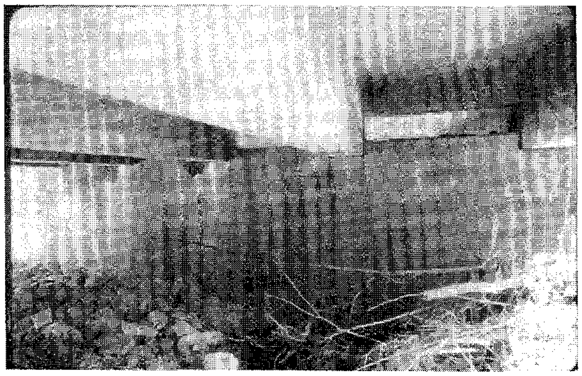
South Abutment, Upstream wingwall
Backwall is out 1/2 inch (13 mm) from face

See Slide 2-3-26

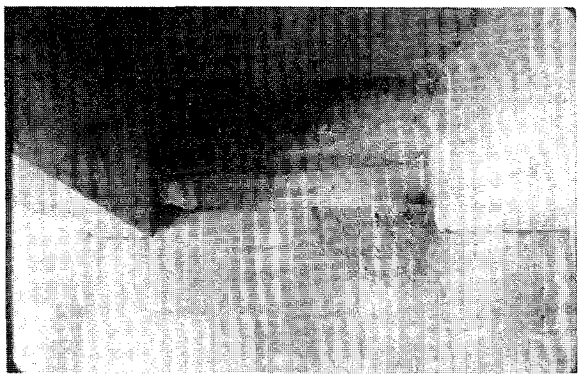
1/2 inch (13 mm) outward displacement of backwall at south abutment.

See Slide 2-3-27

South Abutment, downstream wingwall, solid and plumb. Minor abrasion of the concrete.

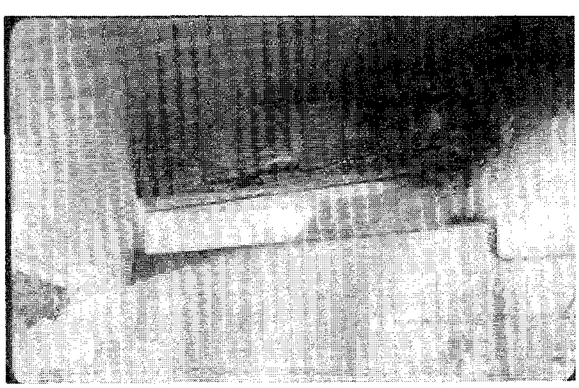


Slide No. 2-3-28
Example Slide
Pier South Face



Slide No. 2-3-29
Example Slide
Pier (South Face) at Beam No. 2

Slide No. 2-3-30
Example Slide
Pier (South Face) at Beam No. 3



Slide No. 2-3-31
Example Slide
Pier at Beam No. 4

See Slide 2-3-28

Pier - South Face.
1/16 inch (2 mm) vertical crack at Beam No. 3.

See Slide 2-3-29

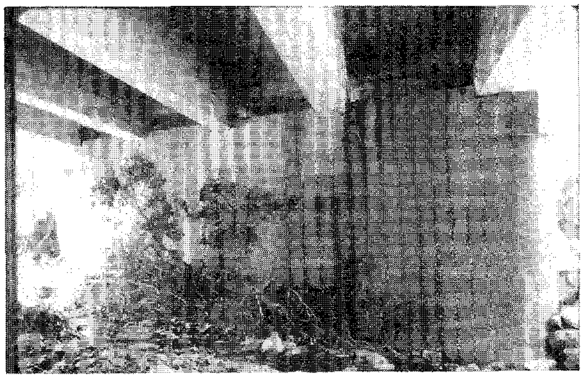
Spall at Beam No. 2, on south face of pier.
2 feet x 18 inches x 6 inches (610 mm x 455 mm x 150 mm) deep.

See Slide 2-3-30

Spall at Beam No. 3, south face of pier
2 feet x 18 inches x 6 inches (610 mm x 455 mm x 150 mm) deep.

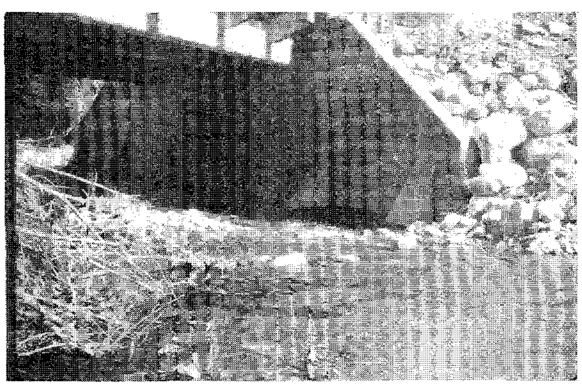
See Slide 2-3-31

Crack and delamination of pier at Beam No. 4 and deteriorated diaphragm. 12 inches x 10 inches (305 mm x 255 mm) delamination on pier below Beam No. 4.



Slide No. 2-3-32
Example Slide
Pier North Face

Slide No. 2-3-33
Example Slide
Pier North Face



Slide No. 2-3-34
Example Slide
North Abutment

Slide No. 2-3-35
Example Slide
North Abutment at Beam No. 2

See Slide 2-3-32

North face of pier.
Minor abrasion of the concrete
3 feet - 4 feet (915 mm - 1220 mm) up from channel

See Slide 2-3-33

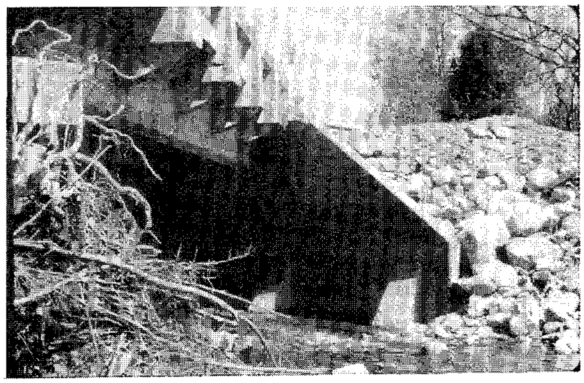
North face of pier - upstream end.
1/16 inch (2 mm) vertical crack at Beam No. 3

See Slide 2-3-34

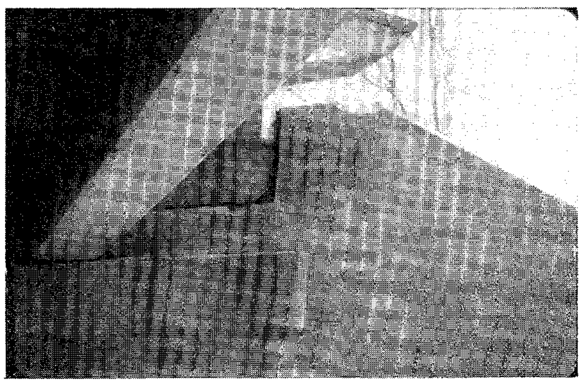
North Abutment

See Slide 2-3-35

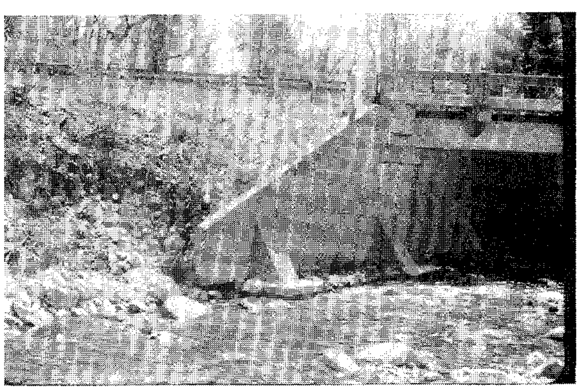
Crack, delamination, and spall at Beam No. 2 (face of North Abutment)
3 feet long x 12 inches (915 mm x 305 mm) down from bearing seat.



Slide No. 2-3-36
Example Slide
North Abutment
Upstream Wing Wall



Slide No. 2-3-37
Example Slide
North Abutment



Slide No. 2-3-38
Example Slide
North Abutment
Downstream Wing Wall

Slide No. 2-3-39
Example Slide
North Abutment

See Slide 2-3-36

Upstream wingwall of north abutment.
Solid and plumb.

See Slide 2-3-37

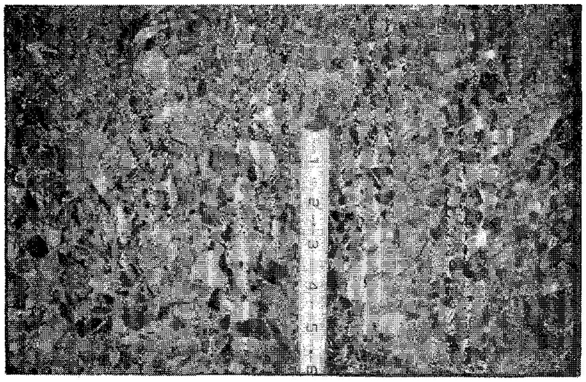
Northward displacement of Span No. 2.
Beams and backwall at north abutment 1/4 inch (6 mm) displacement.
1/16 inch (2 mm) crack diagonally in wing starting at backwall.

See Slide 2-3-38

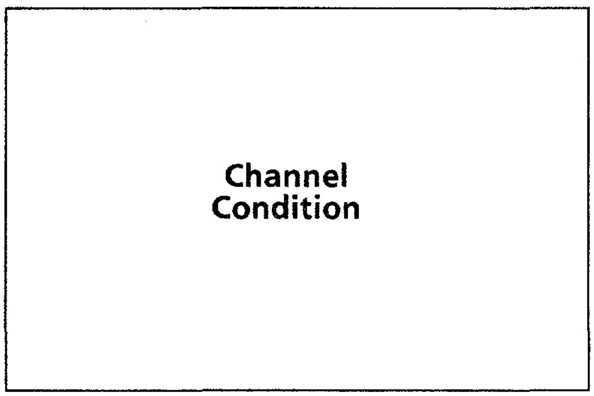
Erosion behind wall. Downstream wingwall - north abutment embankment.

See Slide 2-3-39

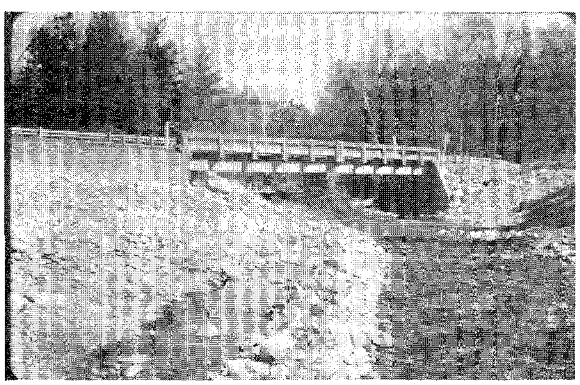
Gabion at north abutment for channel protection.



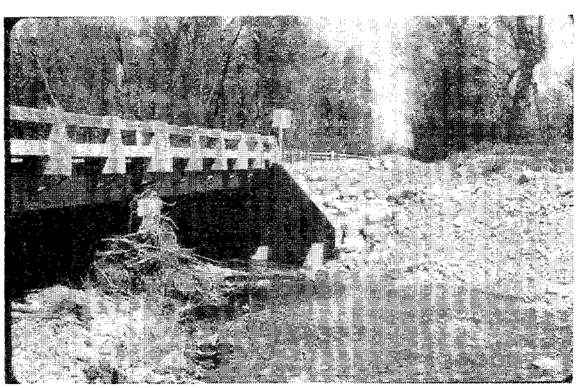
Slide No. 2-3-40
Example Slide
North Abutment Close-up



Slide No. 2-3-41
Title Slide



Slide No. 2-3-42
Example Slide
Upstream Channel



Slide No. 2-3-43
Example Slide
Upstream Channel

See Slide 2-3-40

Typical abrasion of north abutment face, up to top of pedestals.

V. CHANNEL CONDITION

The condition of the channel should be coded according to Item No. 61 in the FHWA *Coding Guide*.

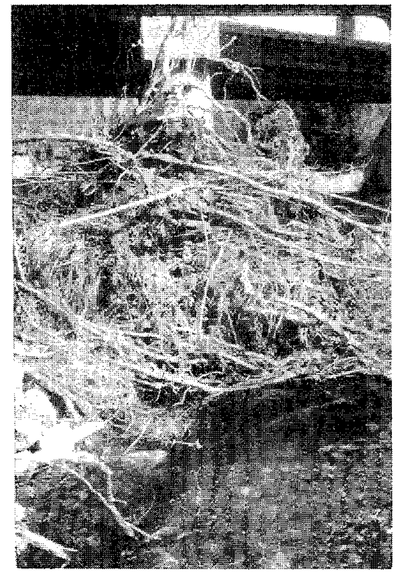
See Slide 2-3-42

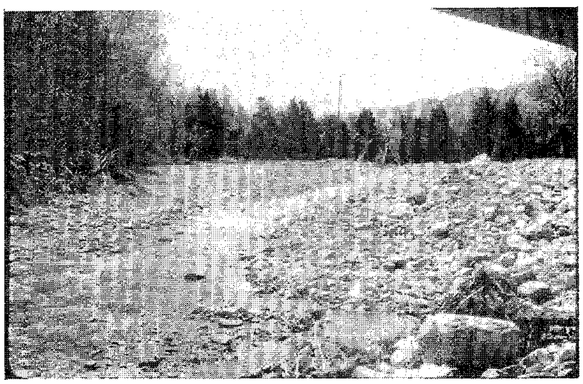
Upstream channel, looking downstream.
Note riprap and debris.

See Slide 2-3-43

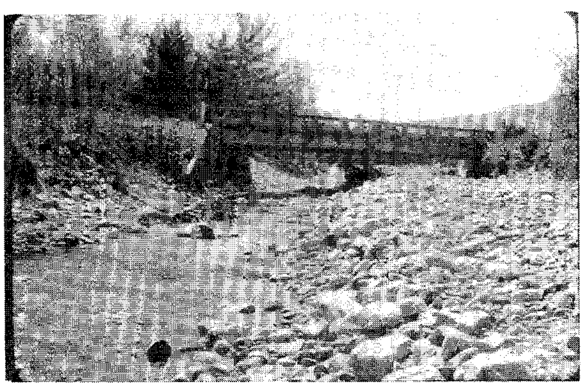
Upstream channel at bridge.

Slide No. 2-3-44
Example Slide
Debris at Pier





Slide No. 2-3-45
Example Slide
Upstream Channel



Slide No. 2-3-46
Example Slide
Downstream Channel

Slide No. 2-3-47
Example Slide
Downstream Channel

See Slide 2-3-44

Debris build-up at pier.
There is a local scour hole 3 feet (915 mm) deep at the upstream end of the pier. The footing is not exposed.

See Slide 2-3-45

Upstream channel - looking upstream from under Span No. 2.

See Slide 2-3-46

Downstream channel - looking upstream.

See Slide 2-3-47

Downstream channel - looking downstream from under Span No. 2.

VI. RESULTS

- Code the following items: (0 - 9 Rating)

  Item # 58 ____________
  Item #59 ____________
  Item#60 ____________
  Item #61 ____________

Date: ______________________
Location: ______________________

	Condition Ratings				
	Deck	Superstructure	Substructure	Channel	
9					
8					
7					
6					
5					
4					
3					
2					
1					
0					

SESSION 2: BRIDGE INSPECTION PROGRAMS

TOPIC 4: BASIC METRICATION

LESSON PLAN

SESSION DURATION	30 minutes
PARTICIPANT MATERIALS	Participant's Notebook
INSTRUCTOR MATERIALS/ EQUIPMENT	Instructor's Guide, Participant's Notebook and BITM 90

GOAL

OBJECTIVE

Slide No. 2-4-1
Title Slide

Slide No. 2-4-2
Narrative Slide
Motivation for SI

Slide No. 2-4-3
Narrative Slide
Motivation for SI

Slide No. 2-4-4
Narrative Slide
Motivation for SI

I. INTRODUCTION

There are several reasons for the United States, in general, and the highway community, specifically, to adopt the metric system:

See Slide 2-4-2

- International communication

  Fewer and fewer nations are familiar with the current U.S. measurement units and many are unwilling to overcome this hurdle to purchase and use American goods. This puts the United States at an international disadvantage.

- International competitiveness

  Many American firms that have already begun to use metric have experienced an increase in their foreign billings after they converted to metric. However, to satisfy the American market, some have to produce in both units, unnecessarily increasing production costs. The U.S. does export engineering services and road building equipment.

See Slide 2-4-3

- Increased efficiency

  The fact that Canada has had success in their conversion to metric is encouraging. Many firms were reluctant to finally convert, but they report an increased overall efficiency mainly because of a decrease in design costs, an increase in construction efficiencies, and improved dimensioning techniques. Examples of a few U.S. firms that report this benefit are IBM, the liquor industry and Otis Elevator.

- Consolidation and redesign

  In the process of converting to a new unit system, a rethinking of sizes and standards can occur. The metric system uses fewer measurements within a category.

See Slide 2-4-4

For example:

Category	English	Metric
length	inches, feet, miles	meters
volume	gallons, cubic feet	liters, cubic meters
weight	pounds, ounces	newtons

DOT and FHWA

FHWA formed a Metric Work Group

Program Elements/Activities	Target Date
• Develop FHWA metric conversion plan	Approved 10/31/91
• Initiate revision of pertinent laws and regulations that serve as barriers to metric conversion	1991

Slide No. 2-4-5

Narrative Slide

FHWA conversion plans

DOT and FHWA

FHWA formed a Metric Work Group

Program Elements/Activities	Target Date
• Conversion of FHWA manuals, documents, and publications	1994
• Data collection and reporting	1995
• Federal lands highway and Federal aid construction contracts	9/30/96

Slide No. 2-4-6

Narrative Slide

FHWA conversion plans

- Simplicity

Metric is base 10 and has fewer units than the English system. This reduces the possibility for errors.

II. GOVERNMENT ROLES

See Slide 2-4-5

In 1988, federal law mandated the metric system as the preferred system of measurement in the United States and required that metric be used in all federal procurement, grants, and business-related activities to the extent feasible by September 30, 1992. Implementation of metric conversion is the responsibility of each Federal agency. Coordination of the Federal effort has been delegated to the Department of Commerce (DOC). In 1991, the DOC removed the voluntary aspect of metric conversion and required Federal agencies to use metric measures and set up target dates for full implementation.

See Slide 2-4-6

The Department of Transportation is responsible for implementation within its structure including the Federal Highway Administration (FHWA). The FHWA has developed a conversion plan with the ultimate target date of September 1996. After that date, anyone receiving construction authorization from FHWA will be required to perform the work using SI units.

Historical records are converted only when necessary for ongoing operations and future projections. <u>Data collection and reporting</u> is scheduled to be fully SI by 1995.

III. OVERVIEW OF SI

The term "SI" is an abbreviation for International System of Units. It is the modern-day metric system which provides a standard international language to describe measurement.

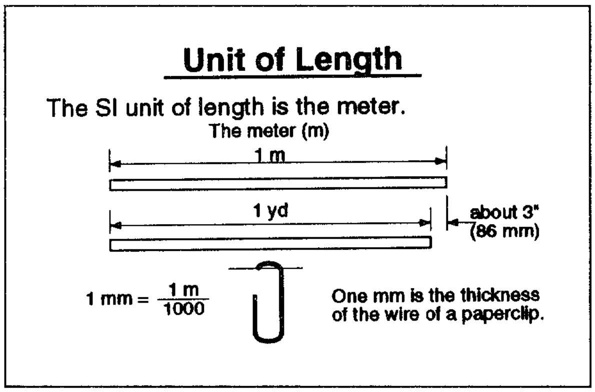
We have already acquired a broad familiarity with the metric system through the existence of metric-dimensioned products in our daily lives such as:

- 2-liter bottle of soda
- track and field (400 meter dash)
- engine size (3.2 liters)
- nutritional label (5 grams fat)
- camera lens/film (35 millimeters)

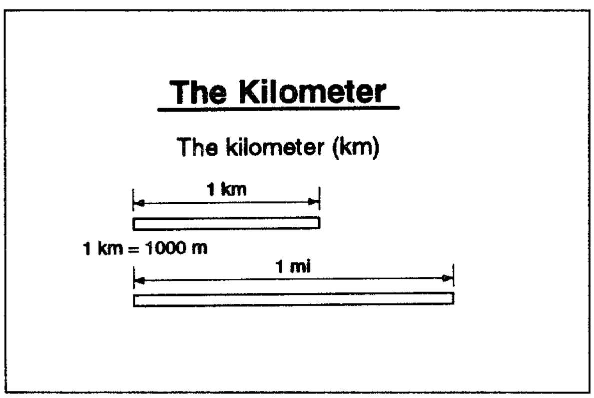
Overview of SI

Base units	Units	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electrical current	ampere	A
luminous intensity	candela	cd
amount of material	mole	mol
Derived units	many units exist	
Supplementary units		
angles in the plane	radian	rad
solid angles	steradian	sr

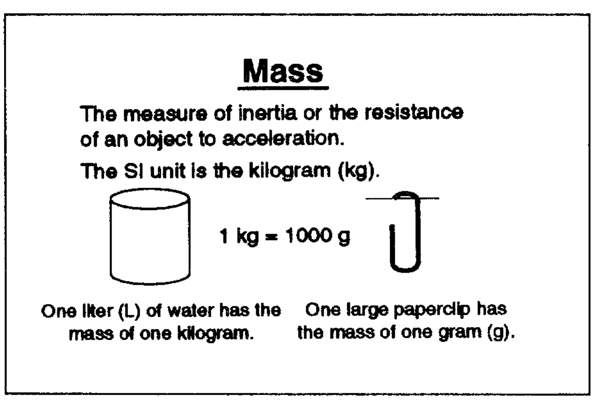
Slide No. 2-4-7
Narrative Slide
Overview of SI



Slide No. 2-4-8
Schematic Slide
Unit of length



Slide No. 2-4-9
Schematic Slide
The kilometer



Slide No. 2-4-10
Schematic Slide
Mass

A. BASE UNITS

See Slide 2-4-7

In SI, there are seven base units, many derived units, and two supplementary units. Six of these base units are used in design and construction. (The seventh, the mole, is the amount of molecular substance and is used in physics.) The base units uniquely describe a property requiring measurement.

This section discusses the base units most common to bridge inspection.

See Slide 2-4-8

1. Length

In SI, the base length unit is the meter (m).

- The meter is slightly longer than a yard.
- Other common units of length with their proper prefix are the millimeter and the kilometer.
- The millimeter is 1/1000 of a meter and is about the thickness of the wire of a paperclip.
- The kilometer is 1000 meters and is equal to about 0.6 mile. Note that the proper pronunciation is KILL'-o-meter and not kil-AHM-eter.

See Slide 2-4-9

- Avoid use of the centimeter.

See Slide 2-4-10

2. Mass

The second base unit relevant to highway applications is the kilogram which is a measure of mass. Mass is the unit quantity of matter independent of gravity. It may be thought of as the measure of an object's resistance to acceleration.

- A liter of water (slightly more than a quart) has roughly one kilogram of mass.
- One gram is about the mass of a large paper clip.

3. Time

A familiar SI base unit which is relevant to most applications is time. The second is the SI unit of time. It is the same as in the English system. The symbol for the second is "s" not "sec".

Unit of Temperature

Base Unit: kelvin
Common Unit: Celsius

	Celsius	Fahrenheit
water boils	100 °C	212 °F
body temp.	37 °C	98.6 °F
water freezes	0 °C	32 °F
		0 °F

Tips for Remembering Celsius

Sauna	Flaming forties
Hot summer day	Thirsty thirties
Mild summer day	Temperate twenties
Fall Day	Tingling tens teens

	Celsius	kelvin
water boils	100 °C	373 K
water freezes	0 °C	273 K
absolute zero	-273 °C	0 K

40 °C = 104 °F
30 °C = 86 °F
20 °C = 68 °F
10 °C = 50 °F
0 °C = 32 °F

Slide No. 2-4-11
Schematic Slide
Unit of temperature

Derived Units with Special Names

Quantity	Name	Symbol	Expression
frequency	hertz	Hertz	1 / s
force	newton	N	kg • m / s²
pressure, stress	pascal	Pa	N / m²
energy, work, heat	joule	J	N • m
power, radiant flux	watt	W	J / s
electrical charge	coulomb	C	A • s
electrical potential	volt	V	W / A
capacitance	farad	F	C / V
electrical resistance	ohm	Ω	V / A
electrical conductance	siemens	S	A / V
magnetic flux	weber	Wb	V • s
magnetic flux density	tesla	T	Wb / m
inductance	henry	H	Wb / A
luminous flux	lumen	lm	cd • sr

Slide No. 2-4-12
Narrative Slide
Derived units

Mass and Weight

	mass	weight or force of gravity	force
English	slug pound mass	pound pound-force	pound pound-force
metric	kilogram	newton	newton

Example: On Earth, the acceleration of gravity = 9.81 m/s^2
Therefore: a 1 kg object placed on a structure will impose a force of gravity of 9.81 N. It also weighs 2.2 pounds.

a 220 lb. man on Earth weighs 981 N
a 220 lb. man on Earth has a mass of 100 kg

Slide No. 2-4-13
Schematic Slide
Mass and weight

See Slide 2-4-11

4. **Temperature**

Temperature is another base unit with usage in highway applications. Kelvin is the base SI temperature with the Celsius scale being closely related.

- The Celsius scale is the metric temperature scale that the public will learn, e.g., through weather reports. It is based on freezing and boiling points of water at atmospheric pressure.

- The kelvin scale is used in science and engineering, and it is the SI temperature scale. There are no negative values.

B. DERIVED UNITS

See Slide 2-4-12

Derived units are formed by combining base units to express other characteristics. Area and volume are common derived units which have many variations. The metric unit of area is the square meter (m^2). The metric unit for volume is the cubic meter (m^3), except for liquids, which are expressed in liters (L).

See Slide 2-4-13

A subtle distinction exists between "mass" and "weight": "mass" is a base quantity while "weight" is a derived quantity related to mass and the acceleration due to gravity. Weight is sometimes referred to as the force of gravity. A person's mass does not change when walking on the moon versus the earth, but the person's weight does. The weight of an object is a function of the gravitational pull on the object.

In English units, one tends to operate in terms of weight (pounds) primarily. If mass is needed, one divides by the acceleration due to gravity (32.2 ft/s^2) to find slugs or pounds-mass. In SI units, mass is the base quantity, and force of gravity is calculated by multiplying mass by the acceleration due to gravity (9.81 m/s^2). Loosely speaking, it is common to convert pounds to kilograms by dividing by 2.2. This can only be applied on earth (home of most highway projects).

C. SUPPLEMENTARY UNITS

The radian (rad) and steradian (sr) denote plane and solid angles. They are used in lighting work and various engineering calculations. In surveying, the units degree (°), minute ('), and second (") continue in use.

Prefixes

Submultiples			Multiples		
deci	10^{-1}	d	deka	10^{1}	da
centi	10^{-2}	c	hecto	10^{2}	h
milli	10^{-3}	m	kilo	10^{3}	k
micro	10^{-6}	µ	mega	10^{6}	M
nano	10^{-9}	n	giga	10^{9}	G
pica	10^{-12}	p	tera	10^{12}	T
femto	10^{-15}	f	peta	10^{15}	P
atto	10^{-18}	a	exa	10^{18}	E
zepto	10^{-21}	z	zetta	10^{21}	Z
yocto	10^{-24}	y	yotta	10^{24}	Y

Slide No. 2-4-14
Narrative Slide
Prefixes

Rules for SI Usage

- Leave a space between a numeral and a symbol.
  Correct: 5 mm   Incorrect: 5mm
- Do not leave a space between a unit symbol and its decimal.
  Correct: 10 kg   Incorrect: 10 k g
- Do not use the plural of unit symbols, but do use the plural of written names.
  Correct: 10 kg   Incorrect: 10 kgs
  Correct: 10 kilograms

Slide No. 2-4-15
Narrative Slide
Rules for SI usage

Rules for SI Usage

- Use a symbol only with a number.
  Correct: five grams   Incorrect: five g
  Correct: 5 g
- Do not use fractions.
  Correct: 0.5 g   Incorrect: 1/2 g
- Use a zero before the decimal for values less than one.
  Correct: 0.35 g   Incorrect: .35 g
- Use spaces (not commas) to separate long numbers.
  Correct: 23 200 m   Incorrect: 23,200 m

Slide No. 2-4-16
Narrative Slide
Rules for SI usage

See Slide 2-4-14

D. NOMENCLATURE

Each unit of measure in the metric system has two parts: a prefix and a base unit.

- The prefix is the part that gives the relative size. The same prefixes are applied to all unit names. Only two decimal prefixes are commonly used with the base units in design and construction: kilo and milli.
- The base unit gives the type of measurement.

1. Rules for Writing Metric Symbols and Names

- Print unit symbols in lower case, except for liter (L), or unless the unit name is derived from a proper name, e.g., pascal (Pa) or newton (N).
- Print unit names in lower case, even those derived from a proper name. The exception to this rule is Celsius.
- Print decimal prefixes in lower case for magnitudes 10^3 and lower and print the prefixes in upper case for magnitudes 10^6 and higher.

See Slide 2-4-15

- Leave a space between a numeral and a symbol.
- Do not leave a space between a unit symbol and its decimal prefix.
- Do not use the plural of unit symbols, but do use the plural of written names.

See Slide 2-4-16

- Use a symbol only with a number.
- Do not use a period after a symbol except when it occurs at the end of a sentence.
- Do not use fractions.
- Use a zero before the decimal marker for values less than one.
- Use spaces instead of commas to separate blocks of three digits for any number over four digits. This rule may not apply to engineering drawings and financial statements.

Philosophies of Conversion

1) Soft Conversion:
Changing the label only

Example: 55 mph speed limit
becomes 88.51 km/h speed limit.

2) Hard Conversion:
Changing product size, as well as label.

Example: 55 mph speed limit
becomes 90 km/h (55.9 mph).

Slide No. 2-4-17

Narrative Slide

Philosophies of conversion

Precision and Rounding

Primary Rule: Maintain precision of a value

General Rule: When converting from English to SI units, round the value to the same number of significant digits. This will give the same implied precision.

Example where general rule applies:
5.2 mi = 8.369 km = 8.4 km

Example where primary rule governs:
8.6 mi = 13.837 km = 13.8 km

Slide No. 2-4-18

Narrative Slide

Precision and rounding

- In the United States, the decimal marker is a period; in other countries a comma is usually used.

2. Conversion

See Slide 2-4-17

Conversion from the English system of measurement to SI is an important topic for the transition period. There are two philosophies of conversion:

- Soft Conversion:

  Direct mathematical conversion. The physical dimension of a standard or product does not change, only the numerical value changes.

- Hard conversion:

  A new rounded, metric number that is convenient to work with is created. Results in changing product size as well as label.

Convert mixed English units (feet and inches, pounds and ounces) to the smaller English unit before converting to metric and rounding.

3. Precision and Rounding

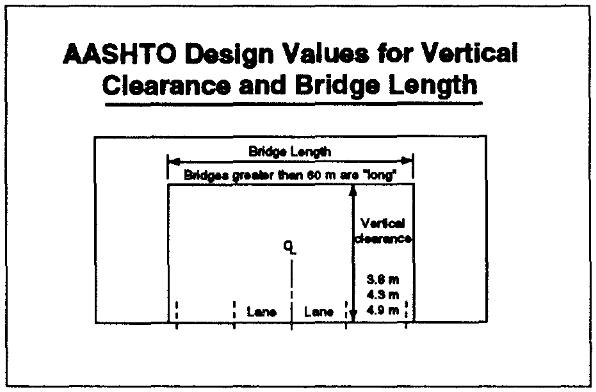
See Slide 2-4-18

Conversion to SI is a good opportunity to highlight the topics of precision and rounding. Precision of a measurement refers to the degree of mutual agreement between individual measurements such that they are reproducible. Rounding refers to the process of reducing the number of significant digits in a quantity to those appropriate for representing the precision of a quantity.

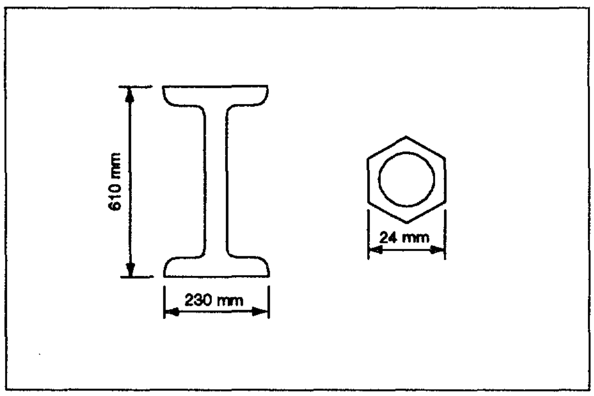
Two rules are available:

Primary rule: Maintain precision of a value. This must always be achieved.

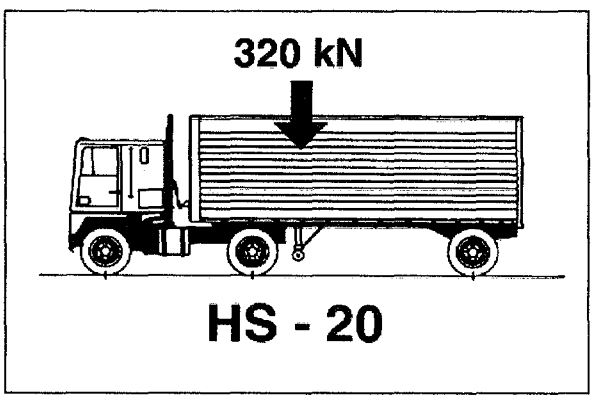
General rule: When implementing the primary rule, it is often effective to round the value to the same number of significant digits. This will approximately give the same implied precision. When maintaining the same number of significant digits provides misleading information on precision, the primary rule overrides the general rule.



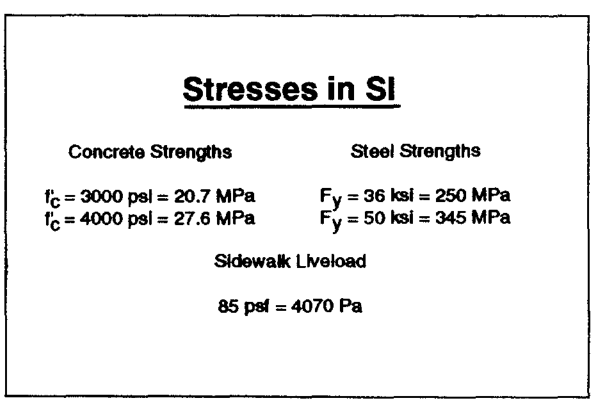
Slide No. 2-4-19
Schematic Slide
AASHTO design values for vertical clearance and bridge length



Slide No. 2-4-20
Schematic Slide
Example beam and bolt dimensions



Slide No. 2-4-21
Schematic Slide
Example loads in SI



Slide No. 2-4-22
Narrative Slide
Stresses in SI

Example A (general rule applies):
5.2 miles at 1.609 km/mi = 8.369 km = 8.4 km

Example B (primary rule governs):
8.6 miles at 1.609 km/mi = 13.837 km = 13.8 km

Generally speaking, it is a good idea to round the metric value off to the same number of significant digits as Example A shows. Example B shows that this is not always the case. In order to maintain precision, the result has three significant digits instead of two.

Example: Convert 6'-4 1/2" to metric.

1. Convert to smaller English unit (inches).
   6' - 4 1/2" = 76.5 inches

2. 76.5 inches x 25.4 mm/inch = 1943.1 mm

3. Round to 3 significant digits (same as 76.5). Answer = 1940 mm.

IV. RELATION OF SI TO BRIDGE INSPECTION

See Slide 2-4-19

Beams and truss lengths are dimensioned in meters (m). Vertical clearances are also dimensioned in meters.

See Slide 2-4-20

Smaller lengths, such as beam depths, bolt diameters, etc., may be expressed in millimeters (mm).

Large areas, such as bridge decks, may be expressed in square meters (m^2) and small areas, such as beam cross-sections, may be expressed in square millimeters (mm^2).

See Slide 2-4-21

Loads are given in either kilonewtons (kN) or meganewtons (MN) instead of pounds or tons. Forces are given in kilonewtons (kN), and distributed loads are given in kilonewtons per meter (kN/m).

See Slide 2-4-22

Stresses on a bridge are given in the metric unit of kilopascals (kPa) or megapascals (MPa).

Summary

- Government Roles
- Overview of SI
- Relation of SI to Bridge Inspection

Slide No. 2-4-23

Title Slide

V. SUMMARY

See Slide 2-4-23

A. GOVERNMENT ROLES

B. OVERVIEW OF SI

C. RELATION OF SI TO BRIDGE INSPECTION

BASIC CONCEPTS

SESSION 3: BASIC CONCEPTS

TOPIC 1: BRIDGE MECHANICS

LESSON PLAN

TOPIC DURATION	90 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 3
GOAL	To understand the various types of bridge loadings, bridge and material responses to loadings, and design features.
OBJECTIVE	Be able to apply basic knowledge of bridge mechanics to inspection and evaluations of bridges. The inspector needs to effectively communicate, using engineer's terminology, the condition of the bridge.

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Types of Loadings

1. Dead Loads
2. Primary Live Loads
3. Secondary Live Loads
4. Sidewalk, Curb, and Railing Live Loads

Slide No. 3-1-1

Narrative Slide

Dead Loads

- Have constant magnitude
- Remain in one position

Slide No. 3-1-2

Narrative Slide

I. INTRODUCTION

Bridge mechanics is a branch of physical science that can help us as inspectors understand how a bridge functions and why certain defects affect the capacity of a bridge. Mechanics deals with energy and forces and their relationships to the equilibrium, deformation and motion of bodies.

The first step in learning about bridge mechanics is being familiar with bridge design loadings.

Bridge design loadings are loads that a bridge is proportioned to carry or resist and which determine the size and configuration of its members.

In the design of new structures, loads which apply to the structure are specified by the AASHTO (American Association of State Highway and Transportation Officials) specifications.

II. BRIDGE DESIGN LOADINGS

Highway bridge loadings are divided into four principal categories:

- dead loads
- primary live loads
- secondary live loads
- sidewalk, curb, and railing live loads

The loads in these four categories may be concentrated or distributed depending on the way in which they are applied to the structure.

A concentrated load or point load is applied at a single location. A wheel load is a concentrated load.

A distributed load is spread out over an area. An asphalt overlay is a distributed load.

A. DEAD LOADS

A dead load is a load of constant magnitude which remains in one position, or in one area.

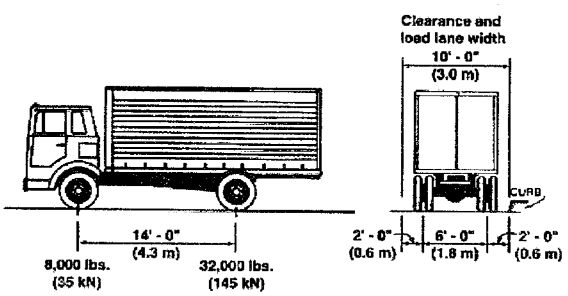
Dead loads are primarily due to the weight of the object itself. Dead loads:

- do not vary with time
- are always present, or full time forces.

Primary Live Loads

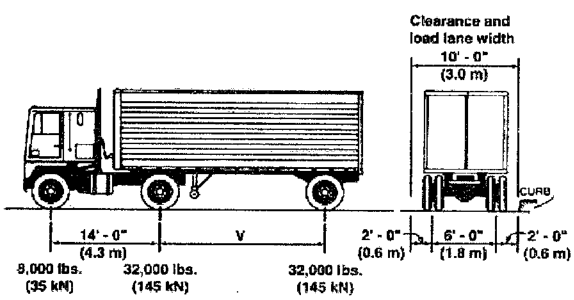
- Have varying location
- Have varying magnitude

Slide No. 3-1-3
Narrative Slide



Standard H - 20 Loading

Slide No. 3-1-4
Schematic Slide
H20 Vehicle



Standard HS - 20 Loading

Slide No. 3-1-5
Schematic Slide
HS20 Vehicle

Dead loads can be broken down into two groups: initial and superimposed.

- Initial dead loads are loads which are applied before the concrete deck is hardened, including the beam itself and the concrete deck. Initial deck loads must be resisted by the non-composite action of the beam alone (further described later in this topic).

- Superimposed dead loads, are loads which are applied after the concrete deck has hardened (on a composite bridge), including parapets and any anticipated future deck pavement. Superimposed dead loads are resisted by the beam and the concrete deck acting compositely (further described later in this topic).

B. PRIMARY LIVE LOADS

Live loads are loads that move, or do not remain in one position. They are temporary or part time loads. The magnitude of live load forces vary. Primary live loads on bridges are vehicular traffic.

The primary design live loads on highway bridges consist of standard trucks, or lane loads which are equivalent to truck trains. Two systems of AASHTO truck loadings are common in bridge design, the H loading and HS loading.

See Slide 3-1-4

1. The H Loading

This loading consists of a single unit type vehicle, with two axles spaced at 14'-0" (4.3 m). The loading is designated H for highway truck and followed by a number indicating the gross vehicle weight in tons.

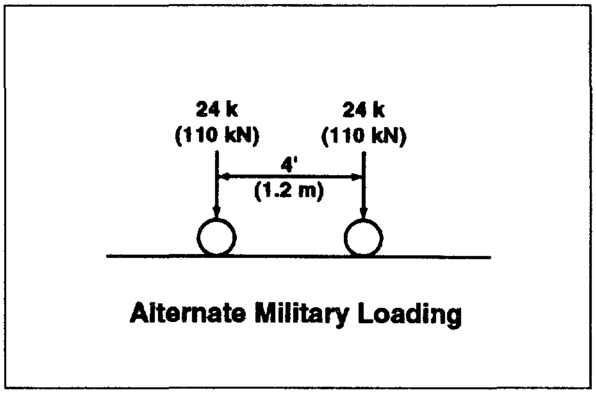
See Slide 3-1-5

2. The HS Loading

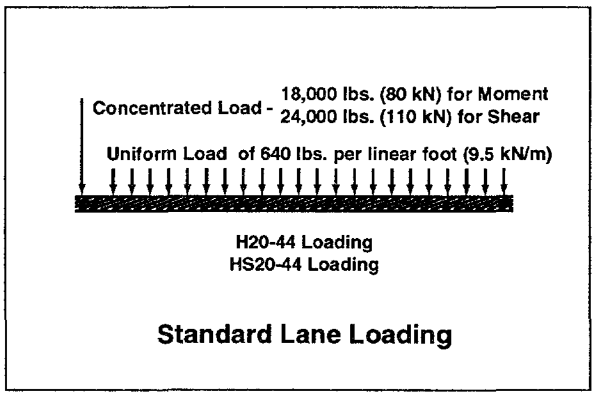
This loading consists of a tractor truck with a semi-trailer. The HS designation is followed by a number indicating the gross weight in tons carried by the tractor only.

The tractor axles are spaced at 14'-0" (4.3 m) similar to the H vehicle, but the rear axle spacing varies from 14'-0" to 30'-0" (4.3 to 9.1 m).

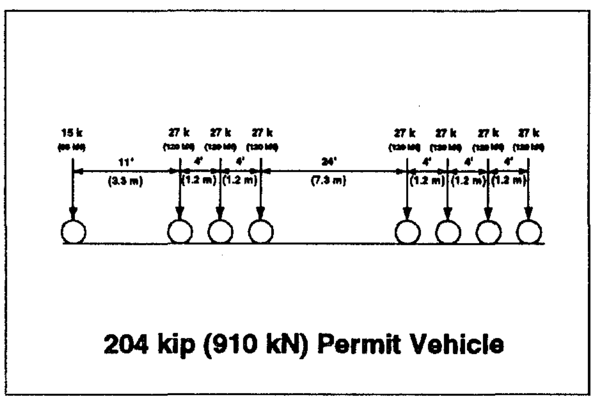
The H and HS vehicles do not represent actual vehicles, but can be considered as "umbrella" loads. The wheel spacings, weight distributions, and clearance of the Standard Design Vehicles were developed to give a simpler method of analysis, based on a good approximation of actual live loads.



Slide No. 3-1-6
Schematic Slide
Alternate military loading



Slide No. 3-1-7
Schematic Slide
Lane loading



Slide No. 3-1-8
Schematic Slide
204 kip (910 kN) permit vehicle

Secondary Live Loads

Slide No. 3-1-9
Title Slide

The H and HS vehicle loads are the most common loadings for design, analysis and rating, however other loading types are used in special cases.

See Slide 3-1-6

3. The Alternate Military Loading

The Alternate Military Loading is a single unit type vehicle with two axles spaced at 4'-0" (1.2 m) and weighing 12 tons (110 kN) each.

See Slide 3-1-7

4. Lane Loading

The system of lane loads was developed in order to provide a simple method of calculating bridge response to a series, or "train", of trucks.

Both the H and HS loadings have corresponding lane loads.

See Slide 3-1-8

5. Permit Vehicles

A permit vehicle is a truck with a gross weight which exceeds standard truck design loads. In order to travel a state's highways, its operator must apply for a permit from that state. These are usually heavier trucks which have varying axle spacings depending upon the design of the individual truck.

C. SECONDARY LIVE LOADS

Secondary live loads are occasional loads commonly caused by nature. The engineer analyzes the structure for a combination of loads - and considers those which produce the maximum stresses. Secondary live loads, which may or may not be present at all times, are taken into account as they apply. Common secondary live loads are as follows:

- Wind Loads
- Thermal forces
- Longitudinal Loads
- Earth Pressure
- Buoyancy
- Centrifugal Force
- Stream Flow
- Ice Pressure
- Earthquake Loads
- Impact Loads

Slide No. 3-1-10

Narrative Slide

1. **Wind Loads**

   Wind load is a moving uniformly distributed live load applied to the exposed area of the structure. Exposed area is defined as the surface which can be seen in elevation of 90° to the length of the bridge. Wind loads are used generally for long span bridges.

2. **Thermal Forces**

   Thermal forces are forces created by movement of the structure produced from the change in temperature.

3. **Longitudinal Loads from Traffic**

   A longitudinal load is a load in the direction of traffic created by the "braking action" of vehicles.

4. **Earth Pressure**

   Substructure units which retain earth such as abutments and retaining walls are proportioned to withstand the horizontal earth pressure which will tend to overturn the structure.

5. **Buoyancy Force**

   Buoyancy is the tendency of an object to "float" or rise when submerged in a fluid. This force is not great enough to cause the components to actually float, but reduces their dead load weight.

6. **Centrifugal Force**

   A centrifugal force is an "outward force" a vehicle exerts on a bridge which is curved.

7. **Stream Flow**

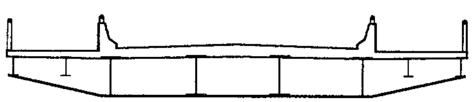
   Stream flow is considered a uniform pressure exerted on bridge components which are located in water, created by the force of flowing water.

8. **Ice Pressure**

   In areas where potential for freezing occurs, ice pressures are to be considered on submerged bridge components.

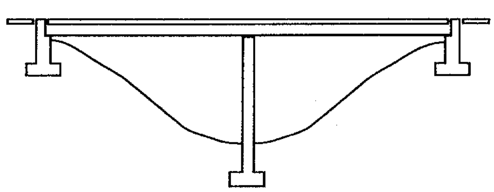
Sidewalk,
Curb, and
Railing Live Loads

Slide No. 3-1-11
Narrative Slide



Typical Bridge Cross Section

Slide No. 3-1-11A
Schematic Slide
Typical bridge cross section



Typical Bridge Elevation

Slide No. 3-1-11B
Schematic Slide
Typical bridge elevation

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9. **Earthquake Loads**

In regions where earthquakes may be anticipated, structures are designed to resist forces caused by earthquake motion.

10. **Impact Loads**

The dynamic effect of suddenly receiving a live load; this additional force can be up to 30% of the applied primary live load force.

D. SIDEWALK, CURB, AND RAILING LIVE LOADS

Individual elements of the superstructure may also receive specific design live loads.

See Slide 3-1-11A

- Sidewalk loading

  Sidewalk floors and their immediate supports are designed for a pedestrian live load.

- Curb loading

  Curbs are designed to resist a lateral force.

- Railing loading

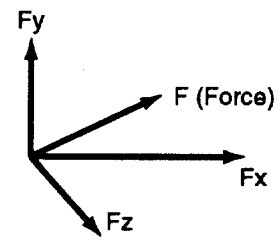
  Railings are provided along the edges of structures for protection of traffic and pedestrians.

E. SUMMARY

See Slide 3-1-11B

Types of Loadings:

- Dead Loads - initial and superimposed
- Primary Live Loads - standard trucks, lane loads and permit loads
- Secondary Live Loads - occasional loads generally caused by nature
- Sidewalk, curb, and railing live loads



Basic Force Components

Slide No. 3-1-12
Schematic Slide
Basic force components
(horizontal and vertical)

Stress

Stress is a force per unit area and denotes the intensity of an internal force.

Slide No. 3-1-13
Narrative Slide
Definition of stress

Examples:
100 pounds applied over 1 square inch = 100 psi
100 pounds applied over 10 square inches = 10 psi
(1000 N applied over 1 square meter = 1000 N/m^2 = 1 kPa)

Deformation

Deformation is the local distortion or change in shape of a material due to stress.

Slide No. 3-1-14
Narrative Slide
Definition of deformation

Strain

Strain is the measure of deformation and denotes the amount an object deforms with respect to its original dimension.

Slide No. 3-1-15
Narrative Slide
Definition of strain
(tensile or compressive)

III. MATERIAL RESPONSE TO LOADINGS

The next required step in the study of bridge mechanics is a basic understanding of how materials, in general, respond to loadings.

A. FORCE

An applied load which results in a material response is referred to as force.

See Slide 3-1-12

Force has both direction and magnitude, and is sometimes thought of as one body acting on another.

- The basic English unit of force is called pound (lbs.)
  The basic metric unit of force is called Newton (N).

- A common unit of force which is used among engineers is a kip, which is 1000 lbs. In the metric system the kilonewton (1000 Newtons) is used.

B. MATERIAL RESPONSES

A material will exhibit various responses when subjected to an applied load or force.

1. Stress

Stress is the basic unit of measure of the intensity of an internal force. It is defined as a force per unit area and denotes the intensity of an internal force.

- It is calculated by simply dividing the force by the area on which it operates.

2. Deformation (Internal)

Another material response to a force is internal deformation. Deformation is the local distortion or change in shape of a material due to stress.

For example, if an eraser is twisted or bent, the shape is changed or deformed.

- **Strain**

  Strain is the measure of deformation and denotes the degree to which an object deforms with respect to its original dimension.

Modulus of Elasticity

Modulus of Elasticity is the ratio between the stress applied and the resulting elastic strain.

Slide No. 3-1-16

Narrative Slide

Definition of Modulus of Elasticity

$$\text{Unit Strain} = \frac{\text{change in length}}{\text{original length}}$$

There are two kinds of strain:

- **Elastic Strain (deformation)**

  Elastic strain is the measure of temporary deformation as a result of applied stress. It is sometimes termed reversible strain because it disappears after the stress is removed.

  Generally, if the strain is elastic there is a direct proportion between the amount of strain and the applied stress.

- **Plastic Strain (deformation)**

  Plastic strain is the measure of permanent deformation. It is sometimes termed irreversible or permanent strain because the deformation remains even after the loading has been removed.

  Plastic strain is not directly proportional to the given applied stress as is the case with the elastic strain.

  For example, a car runs into a brick wall. The deformation that occurs in the fenders and bumper is plastic deformation because it remains even after the car is backed away from the wall.

3. Stress-Strain Relationships

Stress-strain relationships are very important in defining the limits of elastic (temporary) and plastic (permanent) strain.

The point where stress is no longer proportional to strain is called the proportional limit or yield point.

Beyond this limit, strains become permanent and increase rapidly with small increase in stress.

- **Modulus of Elasticity**

  The modulus of elasticity, termed Young's Modulus, is the ratio between the stress applied and the resulting elastic strain. It is the slope of the elastic portion of the stress-strain curve.

Creep

Creep is a gradual, continuing, irreversible deformation due to a constant stress level below yield stress.

Slide No. 3-1-17
Narrative Slide
Definition of creep

Fatigue

Fatigue is a material failure which occurs at a stress level below the elastic limit and is due to repetitive loading.

Slide No. 3-1-18
Narrative Slide
Definition of fatigue

Fracture

- Ductile
- Brittle
- Combination

Slide No. 3-1-19
Narrative Slide

4. Creep

Creep is a material response that results from a sustained or constant loading.

Creep is a gradual, continuing irreversible deformation due to a constant stress level below yield stress.

It is caused by the molecular readjustments in a material under constant load.

The creep rate is the change in strain (plastic deformation) over a certain period of time.

5. Fatigue

Fatigue describes the tendency of a material to break when subjected to repetitive loading. It is a material response which occurs at a stress level below the elastic limit and is due to repetitive loading.

Such repetitive loading causes an effect that can only be described as the material becoming "tired".

6. Fracture

There are three basic types of material failures:

- **Ductile Fracture:**

  Ductile fracture involves a considerable amount of plastic deformation (e.g. reduction in cross-sectional area) before material rupture occurs. This deformation often results in some distortion of the member, providing visual warning of impending failure.

- **Brittle Fracture:**

  Brittle fracture involves a material rupture with little or no plastic deformation. There is no visual warning of this type of failure.

- **Combination:**

  Many material failures show a combination of ductile and brittle fracture behavior.

Yield Strength

Yield Strength is the stress level defined by a materials yield point.

Slide No. 3-1-20

Narrative Slide

Definition of yield strength

Tensile Strength

Tensile Strength is the stress level defined by the maximum load that a material can resist without failure.

Slide No. 3-1-21

Narrative Slide

Definition of tensile strength

Ductility

Ductility is the amount of plastic deformation a material undergoes prior to breaking.

Slide No. 3-1-22

Narrative Slide

Definition of ductility

Toughness

Toughness is a measure of the energy required to break a material.

Slide No. 3-1-23

Narrative Slide

Definition of toughness

C. MECHANICS OF MATERIALS

Materials respond to loadings in a manner dependent on their mechanical properties.

In characterizing materials, certain mechanical properties must be defined.

1. Yield Strength

The ability of a material to resist plastic (permanent) deformation is called the yield strength.

Yield strength corresponds to stress level defined by a material's yield point.

2. Tensile Strength

The tensile strength of a material is the stress level defined by the maximum load that it can resist without failure.

Tensile strength corresponds to the highest ordinate on the stress-strain curve and is sometimes referred to as the ultimate strength.

3. Ductility

Ductility is a measure of the amount of plastic (permanent) strain or deformation a material can undergo prior to breaking. It has the same units as strain.

- **Nonductile Materials:**

  A nonductile material will not deform plastically before breaking.

  Examples are cast iron, concrete, and glass.

- **Ductile Materials:**

  A ductile material has an elastic limit or yield point beyond which plastic deformation occurs. Structural steel usually is ductile.

4. Toughness

Toughness is a measure of the energy required to break a material. It is related to ductility.

Bridge Member Response

- Axial Force
- Bending Forces
- Shear Forces
- Torsional Forces

Slide No. 3-1-24

Narrative Slide

Axial Force

Axial Force is force which acts through the longitudinal axis of a member

Slide No. 3-1-25

Narrative Slide

Definition of axial force

Moment

Moment is a force developed when an external load applied transversely to a bridge member causes it to bend.

Slide No. 3-1-26

Narrative Slide

Definition of moment

Toughness is not necessarily related to strength. A material might have high strength but little toughness.

A ductile material with the same strength as a nonductile material will require more energy to break and thus exhibit more toughness.

For highway bridges, the CVN (Charpy V-notch) toughness is the toughness value usually used. It is an indicator of the ability of the steel to resist crack propagation in the presence of a notch or flaw.

IV. BRIDGE RESPONSE TO LOADINGS

A. BRIDGE MEMBER RESPONSES

Bridge structures are made up of various members which receive and transmit loadings.

Bridge members accomplish this task by resisting or "carrying" four basic types of forces.

- Axial Forces (tension or compression)
- Bending Forces (tension and compression)
- Shear Forces
- Torsional Forces

1. Axial Forces

Axial Force is a force which acts through the longitudinal axis of a member. The longitudinal axis defines the length and direction of a member.

There are two forms of axial force: tension and compression.

- Tension is an axial force which tends to pull a member apart.
- Compression is an axial force which tends to shorten a member. It can also cause a member to buckle. Buckling is the tendency to bend out-of-plane when subjected to compressive force. As length and slenderness increase, the likelihood of buckling also increases.

2. Bending Forces

Bending forces in bridge members are caused by moment.

Shear

Shear is a force which results from equal but opposite transverse forces which tend to slide one section of a member past an adjacent section

Slide No. 3-1-27

Narrative Slide

Definition of shear

Torsion

Torsion is a force resulting from an external moment which tends to rotate or twist a member about its longitudinal axis.

Slide No. 3-1-28

Narrative Slide

Definition of torsion

Moment is developed when an external load applied transversely to a bridge member causes it to bend.

The greatest bending moment that a member can resist is generally the governing factor which determines the size and material of the member.

Bending produces both tension and compression stresses at any given cross-section along the member. Moment is primarily resisted by the flanges.

3. Shear Forces

Shear is a force which results from equal but opposite transverse forces which tend to slide one section of a member past an adjacent section.

Shear forces develop in members at the same time bending forces or moments are developed. Shear forces occur in the horizontal and vertical direction with equal magnitude. In a beam or girder, most of the shear is resisted by the web.

4. Torsional Forces

Torsion is a force resulting from an external moment which tends to rotate or twist a member about its longitudinal axis.

Torsional forces develop in bridge members which are interconnected and experience unbalanced loadings.

Torque is the common name for torsional force. Units are the same as for moment.

B. BRIDGE MOVEMENTS

Bridges move because of many factors - some are anticipated others are not.

Unanticipated movements generally result from settlement, sliding and rotation of foundations.

Anticipated movements include live load deflections, thermal expansions and contractions, shrinkage and creep, earthquakes, rotations, wind drifting, and vibrations.

Of these movements, the three major anticipated movements are live load deflections, thermal movements and rotational movements.

Live Load Deflections

Slide No. 3-1-29
Title Slide

Thermal Movements

Slide No. 3-1-30
Title Slide

Rotational Movements

Slide No. 3-1-31
Title Slide

Reaction

A reaction is a force provided by a support that is equal but opposite to the force applied to the support.

Slide No. 3-1-32
Narrative Slide
Definition of a reaction

1. Live Load Deflections

Deflection produced by live loading should not be excessive because of aesthetics, user discomfort, and possible damage to the whole structure.

Limitations are generally expressed as a deflection-to-span ratio. AASHTO generally limits live load bridge deflection to 1/800, i.e. 1 inch (25 mm) vertical movement per 800 inches (20.3 m) of span length.

2. Thermal Movements

The longitudinal expansion and contraction of a bridge is dependent on the range of temperature change, length of bridge, and most importantly, materials used in construction.

Thermal movements are accommodated using expansion joints and movable bearings.

To accommodate thermal movements, AASHTO recommends the designer allow 1-1/4 inches (32 mm) of movement for each 100 feet (30.5 m) of span length for steel bridges.

3. Rotational Movements

Rotational movement in bridges is a direct result of live load deflection and occurs with the greatest magnitude at the bridge supports.

This movement can be accommodated using bearing devices which permit rotation.

C. REACTIONS

A reaction is a force provided by a support that is equal but opposite to the force applied to the support.

Bridge reactions are commonly vertical forces provided by support elements.

The reaction at a support is the measure of force that it must transmit to the ground.

The reaction at a support increases in magnitude as live load moves closer to that support.

Basic Design Features

- Design Method
- Span Classification
- Roadway Interaction
- Redundancy
- Foundation Design

Slide No. 3-1-33

Narrative Slide

Basic Design Features

Working Stress Design (WSD)

Slide No. 3-1-34

Title Slide

Load Factor Design (LFD)

Load and Resistance Factor Design (LRFD)

Slide No. 3-1-35

Title Slide

V. DESIGN FEATURES

Bridge design is a complicated procedure that involves the application of standard guidelines and numerous computations of stress levels.

There are, however five basic design features that a bridge inspector should be aware of:

- **Design Method**
- **Span Classifications**
- **Bridge Roadway Interaction**
- **Redundancy**
- **Foundation Design**

A. DESIGN METHOD

Bridge engineers use various design methods that incorporate safety factors to account for uncertainties and random deviations in material strength, fabrication, construction, durability, and loadings.

1. Working Stress Design

Working stress design (WSD) is a method in which the stress a particular member may carry is limited to an "allowable stress".

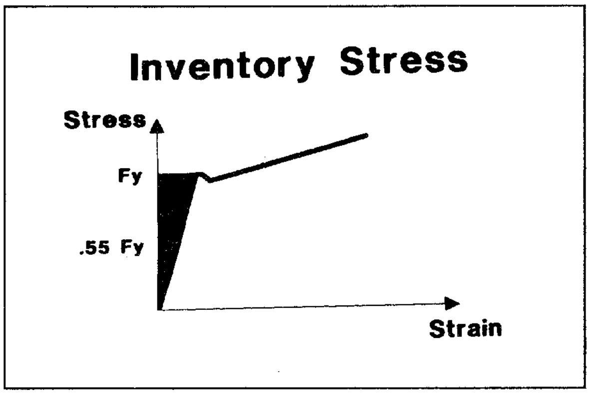
For example, the allowable tensile stress for a steel tension member is 0.55 times the steel yield stress. This results in a safety factor of 1.8.

2. Load Factor Design

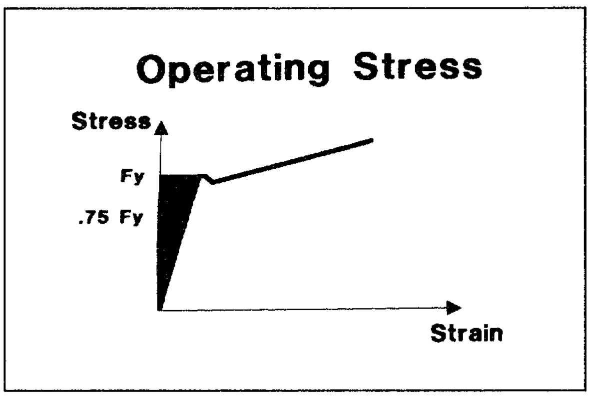
Load Factor Design (LFD) is a method in which the ultimate strength of a material is considered; however, the applied loadings are increased by selected multipliers that provide a factor of safety.

3. Load and Resistance Factor Design

Load and Resistance Factor Design (LRFD) is a design procedure based on the actual strength, rather than on an arbitrary calculated stress. It is an ultimate strength concept where both working loads and resistance are multiplied by factors, and the design performed by assuming the strength exceeds the load. (The load multipliers used in LRFD are not the same multipliers that are used in LFD.)



Slide No. 3-1-36
Schematic Slide
Inventory stress



Slide No. 3-1-37
Schematic Slide
Operating stress

Span Classifications

- Simple
- Continuous
- Cantilever

Slide No. 3-1-38
Narrative Slide
Span classifications

Simple Span

A simple span is a span with only two unrestraining supports which are located at or near the span ends

Slide No. 3-1-39
Narrative Slide
Definition of simple span

These design methods are conservative due to safety factors and limit the stress in bridge members to a level well within the material's elastic range, provided that the structural members are in good condition. That is why it is important for inspectors to accurately report any deficiency found in the members.

These design methods are related to levels or criteria for rating bridges after they are inspected.

4. **Rating Levels**

See Slide 3-1-36

There are two rating levels that are considered. These can be used with either WSD or LRFD:

- **Inventory Rating**

  The inventory rating determines a load level which can safely be used on the bridge for an indefinite period of time.

See Slide 3-1-37

  For steel bridges, the inventory stress level is equal to the allowable stress of .55 times the steel's yield stress.

- **Operating Rating**

  The operating rating determines the maximum load level which can safely be used on the bridge.

  For steel bridges, the operating stress level is .75 times the steel's yield stress and results in a safety factor of 1.33.

  The usable live load capacity of a bridge can only be determined by an actual calculated design analysis.

B. SPAN CLASSIFICATION

The second basic design feature of a bridge is its span classification.

There are three span classifications for bridge design; simple, continuous and cantilever.

1. **Simple Spans**

A simple span is a span with only two unrestraining supports which are located at or near the span ends.

Loads on a simple span produce positive moment and shear forces throughout the length of the span.

Continuous Span

A continuous span is a span configuration with one or more intermediate supports and the behavior of the individual spans created is dependent on its adjacent span

Slide No. 3-1-40

Narrative Slide

Definition of continuous

- **Deflected Shape**

  The deflected shape is downward.

- **Shear**

  Maximum shear force occurs at the supports and diminishes to zero at midspan.

- **Moment**

  The moment in a simple span is all positive with the maximum occurring at midspan.

  This creates compression in the top fibers and tension in the bottom fibers.

2. Continuous Spans

A continuous span is a span configuration with one or more intermediate supports and the behavior of each individual span is dependent on its adjacent spans.

Loads on a continuous span also provide moment and shear throughout the length of the span.

- **Deflected Shape**

  The deflected shape is downward at midspans and upward at intermediate supports.

- **Shear**

  Shear forces in continuous spans are highest at the support with the maximum shear forces occurring at intermediate supports.

- **Moment**

  Both positive and negative moments occur in continuous spans.

  Maximum positive moment occurs near midspan of each individual span, similar to a simple span response.

  Near the intermediate supports, however, the moment becomes negative and is maximum at these supports.

Cantilever Span

A cantilever span is a span with one end restrained against deflection and rotation and the other end completely free

Slide No. 3-1-41

Narrative Slide

Definition of cantilever span

Non-Composite

A non-composite structure is one in which the roadway portion is independent and does not contribute to the load carrying capacity of the bridge

Slide No. 3-1-42

Narrative Slide

Definition of non-composite

Negative moment creates compression in the bottom fibers and tension in the top fibers.

3. **Cantilever Spans**

A cantilever span has one end restrained against deflection and rotation and the other end completely free.

Loads on a cantilever generally produce negative moment and shear which are resisted by the fixed support.

- **Deflected Shape**

  The span deflects downward without rotation at the support. In actual practice, the support may not be completely rigid, so some rotation may occur.

- **Shear**

  Shear force is zero at the free end and maximum at the support.

- **Moment**

  The moment is negative throughout the span and increases from zero at the free end to a maximum at the support.

  When cantilever spans are used in a bridge, they are commonly extensions of a continuous span.

C. BRIDGE ROADWAY INTERACTION

The third basic design feature of a structure is the bridge roadway interaction.

There are two types of roadway interactions; non-composite and composite.

1. **Non-Composite**

A non-composite structure is one in which the roadway portion is independent and is generally assumed (for design and rating purposes) not to contribute to the load carrying capacity of the bridge.

Composite

A composite structure is one in which the roadway portion acts together with the main load carrying elements to resist load

Slide No. 3-1-43
Narrative Slide
Definition of composite

Redundancy

Redundancy in bridge design is a configuration where a bridge or bridge member has three or more independent load paths so that failure of one member or member element would not result in total failure

Slide No. 3-1-44
Narrative Slide
Definition of redundancy

Load Path Redundancy

Slide No. 3-1-45
Title Slide

Structural Redundancy

Slide No. 3-1-46
Title Slide

2. Composite

A composite structure is one in which the roadway portion acts together with the main load carrying members to resist load.

Whether a bridge is composite or non-composite can only be determined from the plans.

D. REDUNDANCY

The fourth basic design feature of a bridge structure is its redundancy.

1. Definition

Redundancy in bridge design is a configuration in which a bridge or bridge member has three or more independent load paths so that failure of one member or member element would not result in total failure.

2. Types Of Redundancy

There are three types of redundancy in bridge design.

- **Load Path Redundancy**

  Bridge designs that are load path redundant have three or more main load carrying members or load paths.

  If one member were to fail, load would be redistributed to the other members and bridge failure would not occur.

  Bridge designs that are non-redundant have two or fewer main load carrying members or load paths.

- **Structural Redundancy**

  Most bridge designs which provide continuity of load path from span to span are referred to as structurally redundant.

  Some continuous span two-girder bridge designs are structurally redundant. In the event of a member failure, loading from that span can be redistributed to the adjacent spans and total bridge failure would not occur.

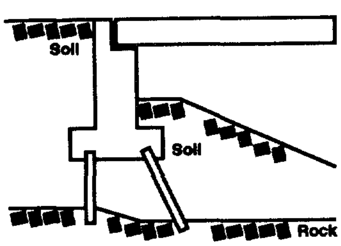
Internal Redundancy

Slide No. 3-1-47
Title Slide

Foundation Designs

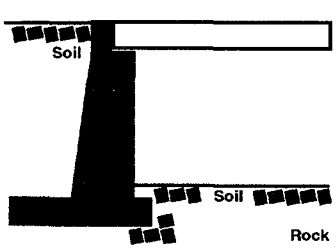
- Piles
- Spread Footing

Slide No. 3-1-48
Narrative Slide



Pile Foundation

Slide No. 3-1-49
Schematic Slide
Pile foundation



Spread Footing Foundation

Slide No. 3-1-50
Schematic Slide
Spread footing

- **Internal Redundancy**

  Internal redundancy is when a bridge member contains several elements which are mechanically fastened together so that multiple load paths are formed.

  Failure of one member element would not cause total failure of the member.

E. FOUNDATION DESIGN

The fifth basic design feature of a bridge structure pertains to the foundation.

1. Definition

Foundation designs are critical to the stability of the bridge, as the foundation ultimately supports the entire bridge.

2. Types of Foundations

There are two types of foundation designs used on bridges.

See Slide 3-1-49

- **Pile Foundation** - This type of foundation design is used when the soil is not suited for supporting a bridge, or when the bedrock layers are not close to the ground surface. Piles are long, slender supports, and they can be made from timber, concrete, or steel.

See Slide 3-1-50

- **Spread Footings** - This type of foundation design is typically made of reinforced concrete and is characterized by a flat slab or pad. The spread footing is supported directly on rock or well compacted soil.

Slide No. 3-1-51
Example Slide
Bridge damage caused by scour

Summary

- Bridge Design Loadings
- Material Response to Loadings
- Bridge Response to Loadings
- Design Features

Slide No. 3-1-52
Title Slide

See Slide 3-1-51

3. Scour Problems

Flooding is the most common cause of bridge failures, and the scouring of bridge foundations is the result of the flooding.

Scour is the removal of material from the streambed or embankments as a result of the erosive action of streamflow.

If the soil surrounding the piles, or the soil or rock supporting the spread footing is washed away, the foundation is likely to fail, which could lead to a collapse of the bridge.

VI. SUMMARY

A. **BRIDGE DESIGN LOADINGS**

B. **MATERIAL RESPONSE TO LOADINGS**

C. **BRIDGE RESPONSE TO LOADINGS**

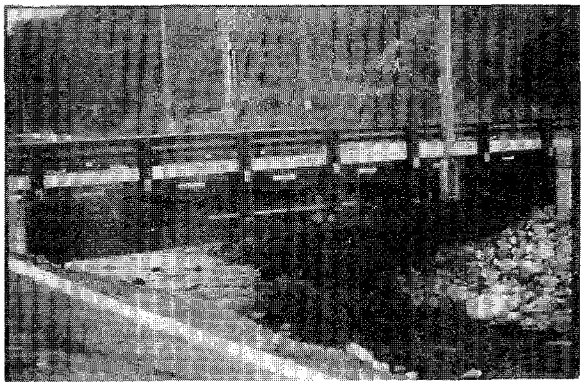
D. **DESIGN FEATURES**

SESSION 3: BASIC CONCEPTS

TOPIC 2: BRIDGE MATERIALS

LESSON PLAN

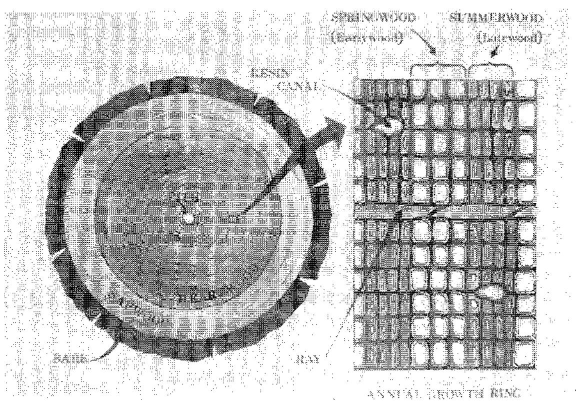
TOPIC DURATION	3 1/2 hours
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 4
GOAL	To perform a mental review of bridge material characteristics and problems.
OBJECTIVE	Participant should be able to apply a knowledge of bridge materials and recognize the types of defects which can occur.
REFERENCES	1. Ritter, M. A. *Timber Bridges, Design, Construction, Inspection and Maintenance.* USDA - Forest Service EM 7700-B, 1990.
	2. Derucher, K.N. and Korfiatis, G.P. *Materials For Civil and Highway Engineers, 2nd Edition.* Englewood Cliffs, New Jersey: Prentice Hall, 1988.
	3. McGannon, H.E. *The Making, Shaping and Treating of Steel, 9th Edition.* Pittsburgh, Pennsylvania: the United States Steel Corporation, 1971.
	4. Derucher, K.N. and Korfiatis, G.P. *Materials For Civil and Highway Engineers, 2nd Ed.* Englewood Cliffs, New Jersey: Prentice Hall, 1988.



Slide No. 3-2-1

Example Slide

Modern timber bridge



Slide No. 3-2-1A

Schematic Slide

Anatomy of wood

I. TIMBER

A. INTRODUCTION

In 1990, there were approximately 50,000 timber bridges in the United States, equivalent to 8 to 9% of the total number of bridges in the U.S.

See Slide 3-2-1

Wood is an excellent engineering material for use in bridges. Perhaps foremost is that it is a renewable resource. In addition, wood is:

- very stiff/strong for its weight,
- relatively inexpensive,
- esthetically pleasing,
- readily available in many locations,
- easy to fabricate and construct,
- resistant to deicing agents,
- cannot be damaged by freezing and thawing,
- can sustain overloads for short periods of time.

These characteristics stem from the unique basic properties of wood which vary with the species and grade of the timber.

Although wood is an excellent material for use in bridges, it does have its limitations and it is not infallible. It is vulnerable to damage from fungi, parasites, fire, chemical attack, and accidents. The degree of vulnerability varies with the species and grade of the timber. Bridge inspectors must be able to recognize the signs of the various types of damage and be able to evaluate their effect on the structures.

See Slide 3-2-1A

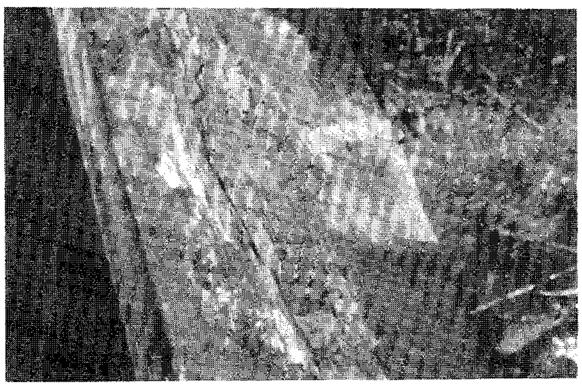
Physical Properties:

1. hardwood vs. softwood
2. non-homogeneous
3. growth features can adversely affect strength
4. moisture content can:

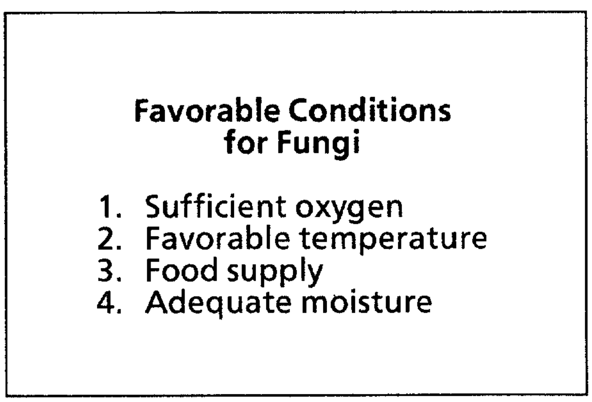
    a. cause dimensional instability and fluctuation in weight
    b. affect the strength of the wood
    c. affect the decay resistance of the wood

Mechanical Properties:

1. non-homogeneous, orthotropic
2. less sensitive to fatigue or repeated loading
3. more resistant to impact loads
4. susceptible to creep



Slide No. 3-2-2
Example Slide
Decay of wood by fungi



Slide No. 3-2-3
Narrative Slide
Favorable conditions required for fungi to grow

Types of damage to timber bridges should include the following:

- damage to wood by fungi - decay
- damage to wood by parasites
- chemical attack
- fire
- impact or collisions
- abrasion or mechanical wear
- overstress
- weathering

B. DAMAGE TO WOOD BY FUNGI - DECAY

See Slide 3-2-2

Decay is the primary cause of timber bridge replacements, whether the structure has served a long or short period.

1. **Origin of Fungi** - Decay is caused by living fungi, which are simple plants that feed on the cell walls of wood.

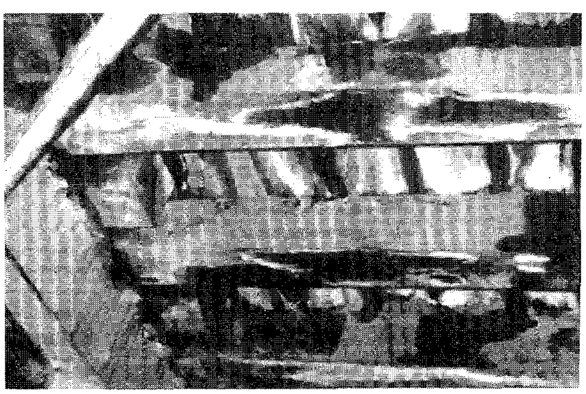
   The initial infection is caused by spores, or microscopic seeds, that are produced by the billions by fruiting bodies (e.g. mushrooms and conks). The spores are distributed by wind, water, insects or any other means.

   Spores that survive and experience favorable growth conditions can penetrate timber bridge members in a few weeks.

2. **Favorable Conditions** - Favorable conditions for fungi to grow can only occur when four essential requirements exist:

   - **Oxygen** - Sufficient oxygen must be available for the fungi to breathe. A minimal amount of free oxygen can sustain them in a dormant state but at least 20 percent of the volume of wood must be occupied by air for fungi to become active. Absence of oxygen in bridge members would only occur in piling or bents placed below the permanent low water elevation or water table.

   - **Temperature** - A favorable temperature range must be available for the growth of fungi to occur. Below 32°F (0 °C), the fungi becomes dormant but resumes its growth as the temperature rises above freezing to the 75°F to 85°F (24°C to 29 °C) range, where growth is at its maximum. Above 90°F (32 °C), growth tapers off rapidly, and temperatures in excess of 120°F (49 °C) become lethal to the fungi. These killing temperatures



Slide No. 3-2-4
Example Slide
Mold and stain on underside of timber bridge

could only occur in bridge members during kiln drying or preservative treating.

- **Food** - An adequate food supply must be available for the fungus to feed on. As the entire bridge serves as the food supply, the only prevention is to poison the wood supply with preservatives or to use of a type of wood that has a natural resistance to decay. Although the latter solution is initially adequate, the durability of the wood breaks down and the fungus usually wins in the end.

- **Moisture** - The fourth and probably the most important essential requirement is an adequate supply of water. The term "dry-rot" is misleading because dry wood will not rot.

  Wood must have a moisture content of 20 percent or greater for the growth of fungi to become active.

  The most direct source of wetting wood is from rain or snow melt.

  Secondary sources are condensation, ground water and stream water.

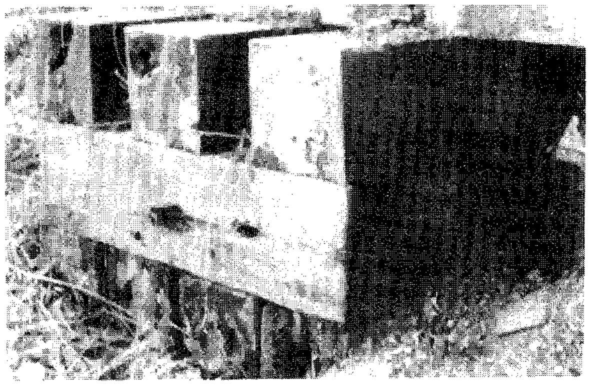
  Seasoning checks, the joints between timber members, and fastener holes are ideal for localized moisture accumulation.

3. Types of Fungi

See Slide 3-2-4

- **Mold and Stain Fungi** - Mold and stain fungi stain and discolor the wood surface (i.e., nondecay). They feed on cell contents but not on the cell walls. Therefore, they do not adversely affect the strength of the wood, except that advanced stain fungi growth may degrade the wood, causing decreased toughness and increased permeability. However, their presence can indicate conditions favorable to more serious decay fungi.

- **Decay Fungi** - Early decay is often present, though masked by stain and/or mold. Decay fungi can rapidly destroy wood substance and can seriously reduce the strength of the wood. Soft rots and brown and white rots are forms of decay fungi.



Slide No. 3-2-5
Example Slide
Brown and white rot

Natural Decay
Resistance of Wood

Slide No. 3-2-6
Title Slide

Heartwood vs. Sapwood

- Fungi-Toxic Compounds

Slide No. 3-2-7
Title Slide

Heartwood Decay Resistance

Very Resistant	Moderately Resistant	Slightly Resistant
Cedars	Douglas-fir	Hemlocks
Redwood	Western larch	Ponderosa pine
	Eastern white pine	Spruces
	Longleaf pine	True firs
	White oak	Red oak

Slide No. 3-2-8
Narrative Slide
Comparative resistance of heartwood to decay

- **Soft Rots** - Another type of fungus that attacks only the surface wood, thus not significantly weakening the member, is known as soft rots. The wood surface becomes soft and spongy, but again, if the wood is damp enough for this decay to occur, other decay of a more serious nature is probably also present.

See Slide 3-2-5

- **Brown and White Rots** - This type of fungus is the most serious because the resulting decay weakens the timber member.

  This type of decay is difficult to detect because it usually occurs inside the members.

4. **Natural Decay Resistance of Wood** - The natural decay resistance of wood exposed under conditions favorable for decay is distinctly variable, and it can be an important factor in the service life of wood bridges.

   The heartwood of many tree species possesses a considerable degree of natural durability, while the sapwood of all commercial species is nondurable.

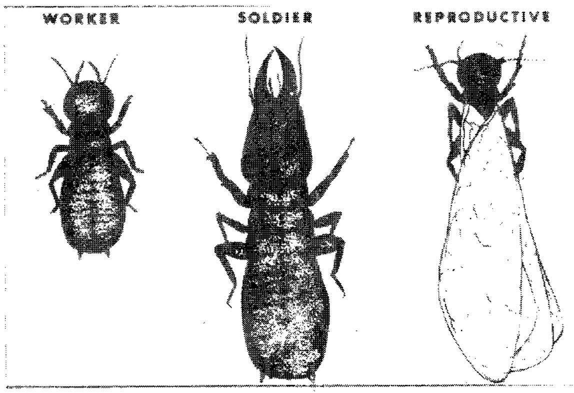
   The fungi-toxic compounds which provide natural decay resistance are not present in the sapwood but are deposited with other compounds in the inner layer of living sapwood, as it dies each year, and is converted to heartwood.

See Slide 3-2-8

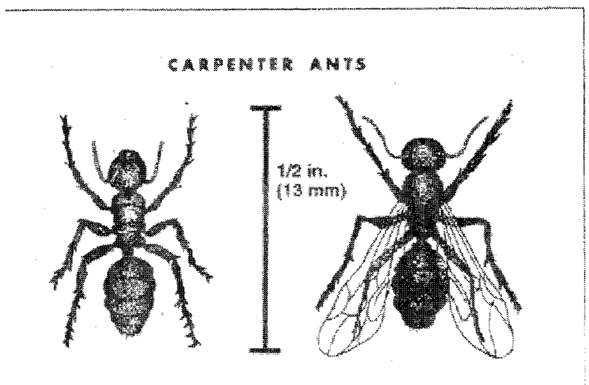
   Most existing wood bridges in this country have been constructed from either Douglas fir or southern pine. Older bridges may contain such additional species as western red cedar, larch, various pines, and red and white oak.

   Except for western red cedar and white oak, all the above named species are classified as moderately decay resistant.

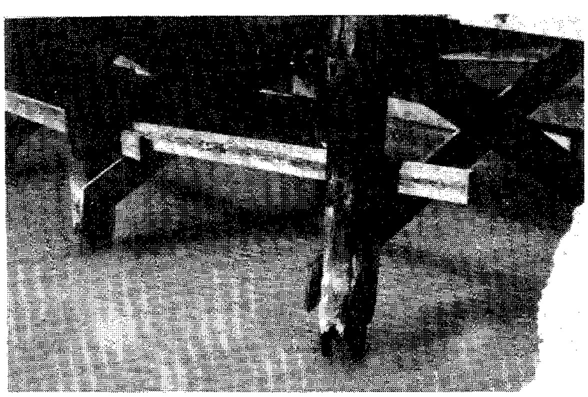
   In the last 25 years, wood bridge materials have been obtained increasingly from smaller trees in young-growth timber stands. As a result, recent supplies of lumber and timbers have contained increased percentages of decay-susceptible sapwood.



Slide No. 3-2-9
Example Slide
Termites



Slide No. 3-2-10
Example Slide
Carpenter ants



Slide No. 3-2-11
Example Slide
Marine borer damage to wood piling

Slide No. 3-2-12
Example Slide
Shipworms (mollusks)

See Slide 3-2-9

C. DAMAGE TO WOOD BY PARASITES

1. **Termites** feed on wood, However, termite attack of bridge members is rare or nonexistent in frequently used bridges throughout most of the country.

2. **Carpenter Ants** - Carpenter ants have been found in bridge members. These large, dark colored ants are up to 3/4 inches (19 mm) long. The ants do not use the wood for food but build their galleries in the moist and soft or partially decayed wood.

See Slide 3-2-10

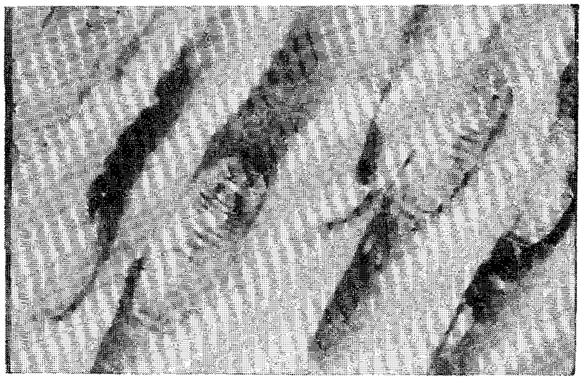
3. **Powder-post Beetles** - Both live in and feed on wood. These larvae of the Lyctus beetles bore through the wood for food and shelter.

See Slide 3-2-11

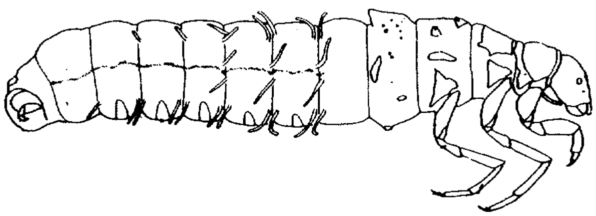
4. **Marine Borers** - Marine borers are found in sea water. They can be very destructive to wood and have been known to ruin piles and framing in just a few months.

See Slide 3-2-12

- **Mollusks** - The mollusks (teredo or "shipworm") attack the wood by boring holes through the member, causing abrupt failures. These are gray, slimy worms that can be up to 1 inch (25 mm) in diameter and 4-6 feet (1.2 - 1.8 m) long.



Slide No. 3-2-13
Example Slide
Limnoria burrowing in wood



Slide No. 3-2-14
Schematic Slide
Caddisfly

Chemical Attack

Slide No. 3-2-15
Title Slide

Slide No. 3-2-16
Example Slide
Fire damaged timber member

See Slide 3-2-13

- **Crustaceans (Limnoria)** - The crustaceans destroy the wood by building galleries in the surface layers of the wood. These borers are about 1/8-1/4 inches (3-6 mm) long and 1/16-1/8 (2-3 mm) inches wide.

  As this layer is washed away by the waves, a new layer is exposed and attacked.

  The timber members soon appear to look like an hourglass as the wood is washed away at the waterline.

See Slide 3-2-14

5. **Caddisflies** - Bacterial and fungal decay not only weaken timber, but also make the timber attractive to caddisfly.

   The caddisfly is an aquatic insect that is closely related to the moth and butterfly. The caddisfly is generally found in fresh water but can also tolerate brackish water. In water during the larva and pupa stages of their life cycle, the caddisfly will dig small holes in timber piling for protection. The larvae do not feed on the timber, but rather use it as a foundation for their silken shelters. This explains why caddisfly larvae have been known to exist on creosote treated timber.

   The combination of bacterial and fungal decay, aquatic insect infestation, and the abrasive action of tidal currents can reduce the cross section of the timber piles, significantly weakening the member.

D. CHEMICAL ATTACK

Wood is unaffected by chemicals present in the atmosphere, as far as structural degradation is concerned. Organic liquids and petroleum oils and solvents are generally harmless to wood.

Wood resists the effects of acids better than many materials and is often used for acid storage tanks.

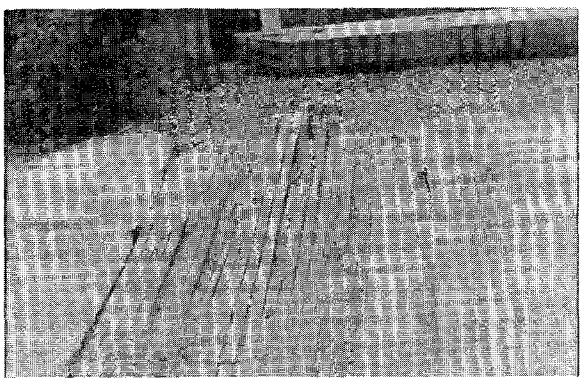
Mild alkalies do little harm to wood, but strong alkalies will destroy wood fairly rapidly.

E. DAMAGE FROM OTHER SOURCES

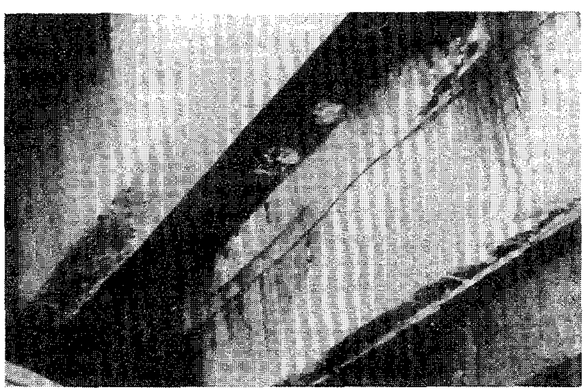
See Slide 3-2-16

1. **Fire** - Fire consumes wood at a rate of about 0.05 inches (1 mm) per minute during the first 30 minutes of exposure, and 0.021 inches (0.5 mm) per minute thereafter. Large timbers build a protective coating of char (carbon). Small size timbers do not have enough volume to do this before they are, for all practical purposes, consumed. Preservative treatments are available to retard fire damage.

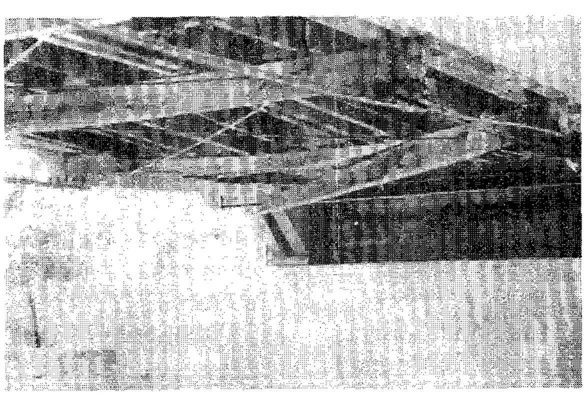
Slide No. 3-2-17
Example Slide
Impact/collision damage to a timber member



Slide No. 3-2-18
Example Slide
Abrasion damage on a timber deck



Slide No. 3-2-19
Example Slide
Horizontal shear failure in timber member



Slide No. 3-2-20
Example Slide
Failed timber floor beam

See Slide 3-2-17

2. **Impact or Collisions** - Bridges can receive a sudden jolt (impact) as traffic passes from the approach roadway to the bridge deck. Repeated impacts can eventually cause physical damage to the structure. Severe damage can occur to trusses, railings, etc. when an errant vehicle strikes them.

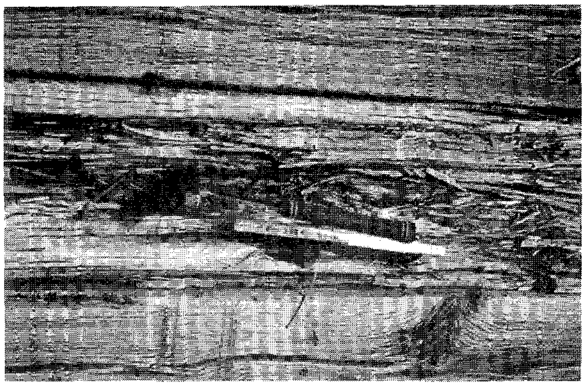
See Slide 3-2-18

3. **Abrasion or Mechanical Wear** - Abrasion of the relatively soft timber deck is caused by the tires riding on it. Mechanical wear of timber members sometimes occurs due to movement of the fasteners against their holes when connections become loose.

See Slide 3-2-19

See Slide 3-2-20

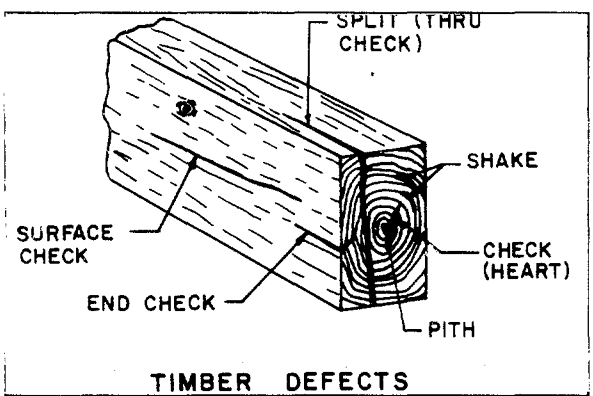
4. **Overstress** - Each timber member has a certain ultimate load capacity. If this load capacity is exceeded, the member will fail.



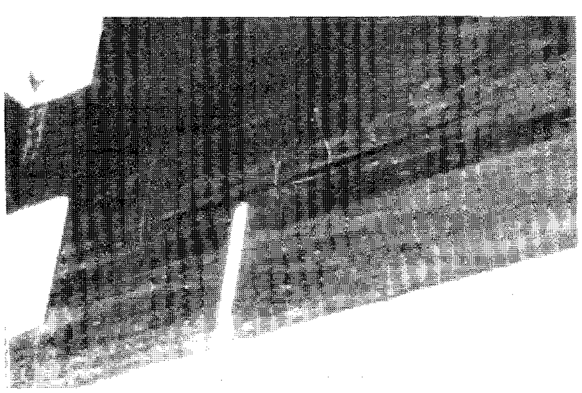
Slide No. 3-2-21
Example Slide
Affect of weathering on timber deck

Visual Examination for Signs of Distress

Slide No. 3-2-22
Title Slide



Slide No. 3-2-23
Schematic Slide
Timber defects such as checks, splits, and shakes



Slide No. 3-2-24
Example Slide
Delamination in a laminated timber member

See Slide 3-2-21

5. **Weathering or Warping** - Weathering is affected by light, water, and heat. Weathering can change the equilibrium moisture content in the wood, thereby resulting in changes in the strength and dimensions of the wood. Reduction in moisture content causes shrinkage, which can lead to warping, checking, splitting, or loosening of connectors.

F. **VISUAL EXAMINATION**

1. **Deflection** - Minor deflection (sagging) can be expected when traffic crosses the member. Excessive deflection under live load or significant permanent deformation/ sagging is a sign of structural weakness. Failure of the member may be imminent.

See Slide 3-2-23

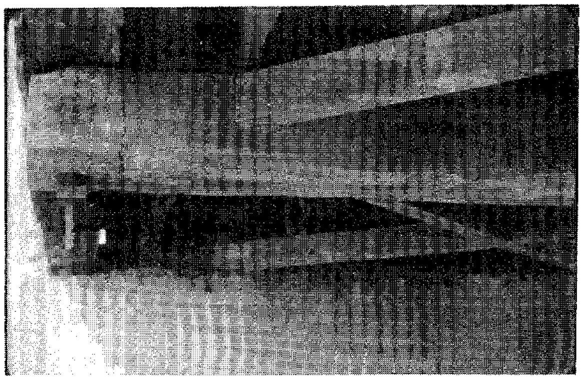
2. **Checks, Splits, Shakes**

- **Checks** are separations of the wood fibers, normally occurring across or through the annual growth rings, and generally parallel to the grain direction.
- **Splits** are similar to checks except the separations of the wood fibers extend completely through the piece of wood. A split is also known as a through check.
- **Shakes** are separations along the grain, which occur between the annual growth rings.

These three visible defects provide openings for decay to begin and/or indicate reduced strength of the member.

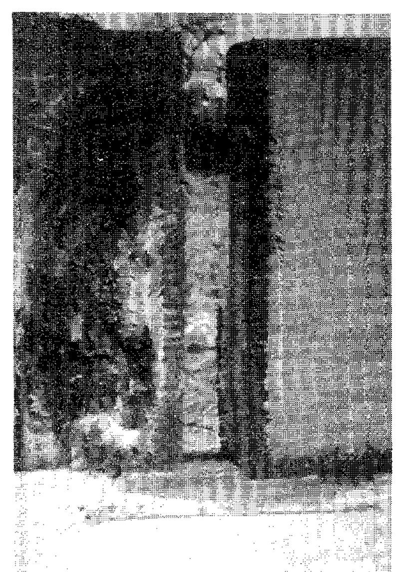
See Slide 3-2-24

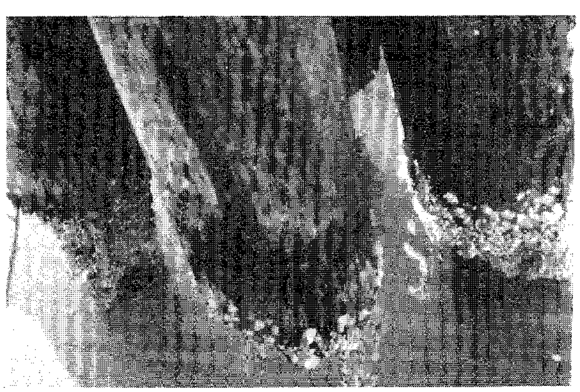
3. **Delaminations** - Occur in laminated members when the layers separate due to failure within the adhesive or at the bond between the adhesive and the laminae. They provide openings for decay to begin and may cause a reduction in strength.



Slide No. 3-2-25
Example Slide
Hanger connection on a timber floorbeam

Slide No. 3-2-26
Example Slide
Carpenter ant damage to a timber member





Slide No. 3-2-27
Example Slide
Marine borer damage to a timber pile

See Slide 3-2-25

4. **Loose Connections** - May be due to shrinkage of the wood, due to crushing of the wood around the fastener, or due to repetitive impact loading (working) of the connection.

   Loose connections can reduce the bridge's load carrying capacity.

5. **Evidence of Fungus Decay** - Stains and discolorization, softening or sponginess of wood, and "sunken" faces of wood are evidences of decay in various stages.

6. **Damage by Parasites**

   - **Termite** damage occurs inside the wood and is usually not visible until it results in the crushing, sagging, or failure of the member. White mud tubes or runways extending up from the ground to the wood may be the only visible sign of termite presence. Discarded wings may also be a sign of termite presence.

See Slide 3-2-26

   - **Carpenter ants** - may leave accumulations of sawdust on the ground at the base of the timber. Sometimes the insects themselves can be seen. Since the ants require a nearly saturated atmosphere in their nest, an ant infestation may indicate a moisture/decay problem in the wood.

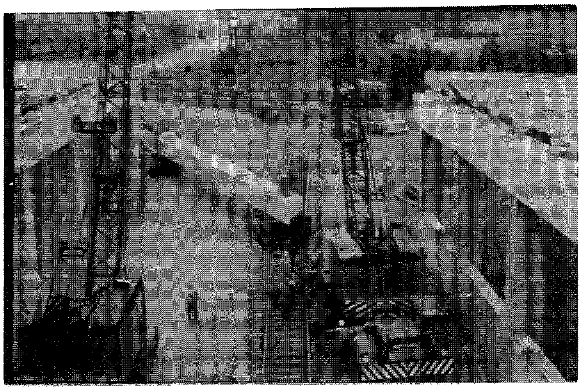
   - **Powder post beetles** - cause the outer surface of the timber member to be pockmarked with numerous small holes (1/32-1/8 inch (1 - 3 mm) in diameter), from which floury sawdust is sometimes dislodged. They usually attack large-pored hardwoods.

   - **Marine Borers** - Most severe damage occurs on timber piles in the area located between high and low water, but it may extend to the mud line.

See Slide 3-2-27

     Shipworms are hard to detect since they enter the timber at an early stage of life and remain inside for their remaining life.

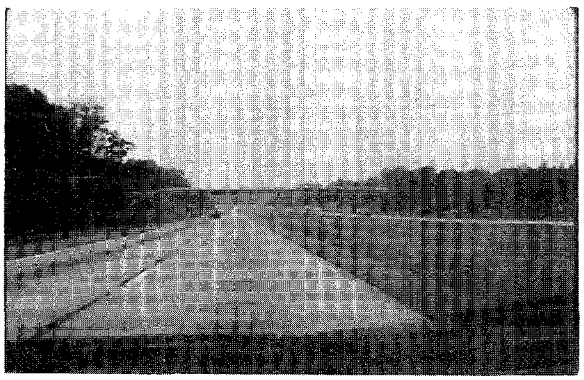
     Crustaceans (limnoria) bore into the surface of the wood to a shallow depth. Wave action breaks down the thin timber shell outside the burrows causing the borer to go deeper into the wood. This repeated combination of burrowing and wave action causes the timber poles to take on an hourglass shape between the tide levels.



Slide No. 3-2-28

Example Slide

Construction of a bridge



Slide No. 3-2-29

Example Slide

Concrete pavement

Physical Properties of Concrete

- Formability
- Volume Changes
- Permeability
- Fire Resistance

Slide No. 3-2-30

Narrative Slide

Mechanical Properties of Concrete

- High Compressive Strength
- Limited Elasticity
- Creep
- Isotropy

Slide No. 3-2-31

Narrative Slide

- **Caddisfly Larvae** burrow into the surface of timber piles, particularly those softened by bacterial or fungal decay. They are found in fresh and occasionally in brackish water, and have been known to attack creosoted timber. The combination of decay, insect infestation and tidal action reduces the diameter of the piles, lessening their carrying capacity.

G. PHYSICAL EXAMINATION

(Videotape presentation)

For a free copy of Timber Bridges, Design, Construction, Inspection and Maintenance, call USDA Forest Service, Timber Bridge Information Resource Center at (304) 285-1591.

II. CONCRETE

See Slide 3-2-28

A. INTRODUCTION

A large percentage of the bridge structures in the Nation's highway network are constructed of concrete. It is important that the bridge inspector understand the basic characteristics of concrete in order to efficiently inspect and evaluate a concrete bridge structure.

See Slide 3-2-29

"Concrete" is a construction material generally associated with a roadway pavement, a driveway, a sidewalk or porch steps. It is also a material that is very commonly mislabeled as "cement". Concrete is a mixture of various components that when mixed together in the proper proportions, chemically react to form a strong durable construction material ideally suited for certain bridge components. Cement is only one component of concrete.

Other components of concrete are air, water, and aggregates.

Concrete has physical properties which include:

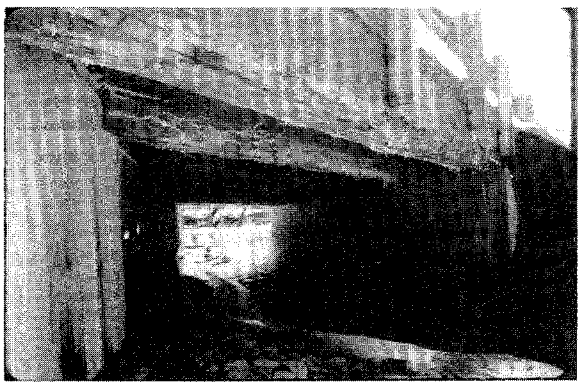
- Formability (i.e., it can be molded to any shape)
- Generally fire resistant
- Somewhat permeable to water
- It is subject to changes in volume due to temperature changes or absorption or moisture

The mechanical properties of concrete include:

- Isotropic (uniform mechanical properties in all directions)
- Creeps under sustained load
- Limited ability to deform elastically
- High compressive, but low tensile and shear strengths

Types of Concrete Deterioration

Slide No. 3-2-32
Title Slide



Slide No. 3-2-33
Example Slide
Deteriorated concrete bridge

Cracks are linear fractures in concrete. They may be structural or non-structural.

Slide No. 3-2-34
Title Slide

Structural Cracks

- Flexural
- Shear

Slide No. 3-2-35
Narrative Slide

See Slide 3-2-33

In order to properly inspect a concrete bridge, the inspector must be able to recognize the various types of defects associated with concrete. The inspector must also understand the causes of the defects and how to examine them.

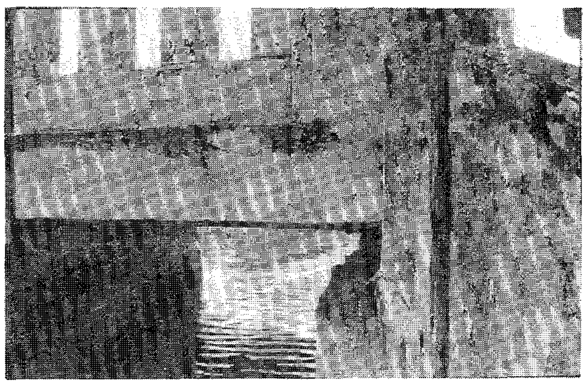
B. CRACKS

A crack is a linear fracture in concrete. It may extend partially or completely through the member. There are two basic types of cracks: structural and non-structural cracks.

Structural cracks result from imposed load. Non-structural cracks result from internal stresses due to dimensional changes.

1. **Structural Cracks** - Structural cracks are caused by dead load and live load stresses. They have the potential to be a serious problem because they can affect the structural capacity of the member. There are two type of structural cracks:

Slide No. 3-2-36
Example Slide
Flexure crack on a tee beam

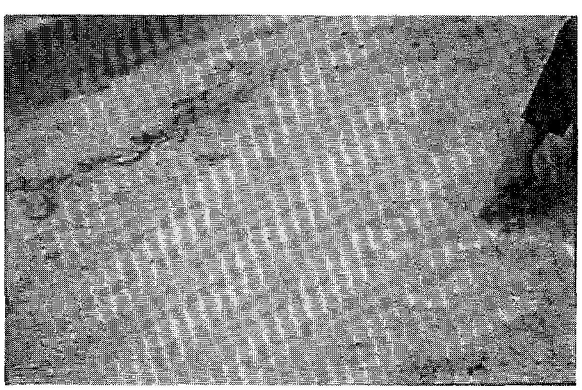


Slide No. 3-2-37
Example Slide
Shear crack

Non-Structural Cracks

- Temperature
- Shrinkage

Slide No. 3-2-38
Narrative Slide



Slide No. 3-2-39
Example Slide
Temperature cracks

See Slide 3-2-36

- **Flexural cracks** - start in the maximum tension zone or the maximum moment region and proceed toward the compression zone.

See Slide 3-2-37

- **Shear cracks** - are the diagonal cracks that usually occur in the web of a member near the supports.

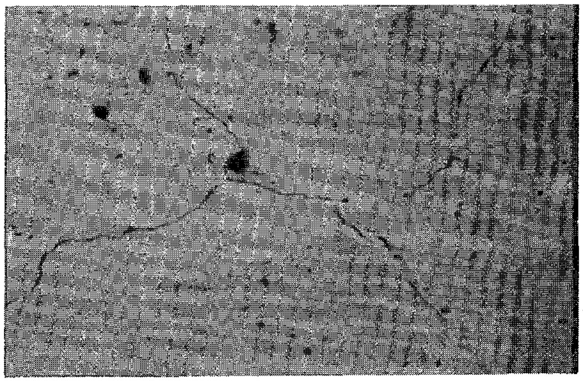
Although structural cracks are typically caused by dead load and live load forces, they can also be caused by stresses in members whose expansion or contraction is restricted (such as by frozen bearings) or by forces due to the expansion of a slab or backwall.

2. **Non-Structural Cracks** - Non-structural cracks are a minor problem themselves and do not affect the load carrying capacity of the member. They can, however, provide openings for water and contaminants which can lead to serious problems.

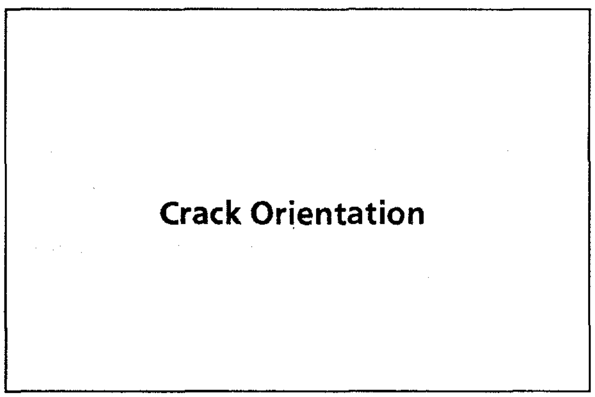
There are two types of non-structural cracks:

See Slide 3-2-39

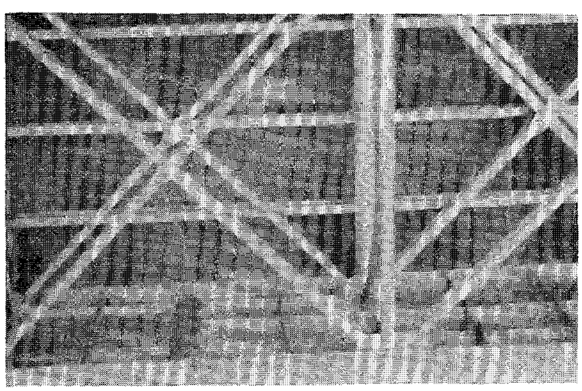
- **Temperature cracks** are caused by the thermal expansion and contraction of the concrete.



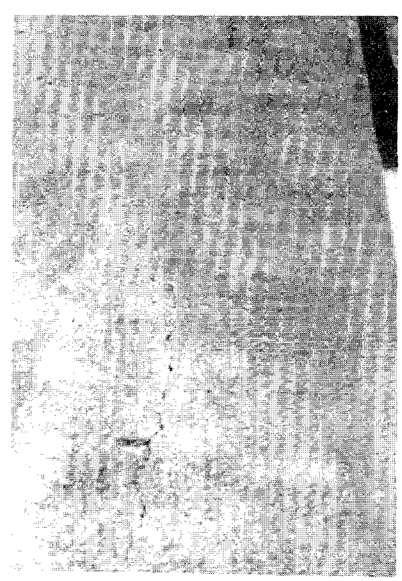
Slide No. 3-2-40
Example Slide
Shrinkage cracks



Slide No. 3-2-41
Title Slide



Slide No. 3-2-42
Example Slide
Transverse crack



Slide No. 3-2-43
Example Slide
Longitudinal crack

See Slide 3-2-40

- **Shrinkage cracks** - are caused by the contraction of the concrete during the curing process.

  Temperature and shrinkage cracks are considered minor cracks and typically do not significantly affect the structural strength of a concrete member.

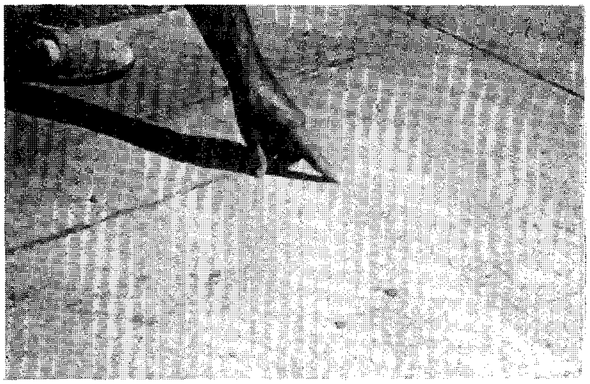
3. **Crack Orientation** - In addition to classifying cracks as either structural or non-structural, inspectors must also describe the orientation of the cracks.

See Slide 3-2-42

- **Transverse Cracks** - These are fairly straight cracks that are roughly perpendicular to the centerline of the member.

See Slide 3-2-43

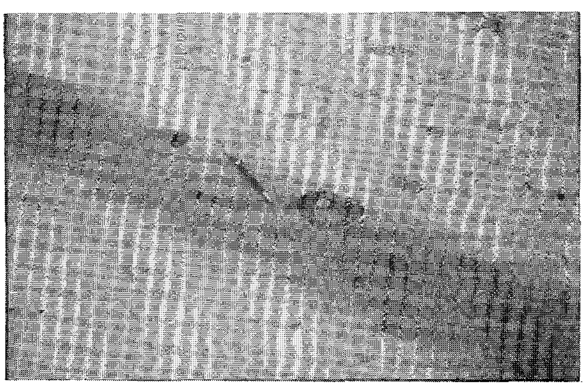
- **Longitudinal Cracks** - These are fairly straight cracks that run parallel to the centerline of the member.



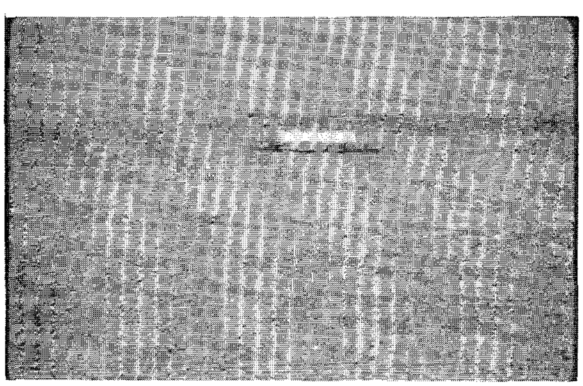
Slide No. 3-2-44
Example Slide
Pattern or map cracking

Scaling is the gradual and continued disintegration of surface mortar over an area.

Slide No. 3-2-45
Title Slide



Slide No. 3-2-46
Example Slide
Light scaling



Slide No. 3-2-47
Example Slide
Medium scaling

- **Diagonal Cracks** - These cracks are skewed (at an angle) to the centerline of the bridge.

See Slide 3-2-44

- **Pattern or Map Cracking** - These inter-connected cracks form networks of varying size. They vary in width from barely visible, fine cracks to cracks with a well defined opening.

- **Random Cracks** - These are meandering, irregular cracks. They have no particular form and do not logically fall into any of the types described above.

C. **SCALING**

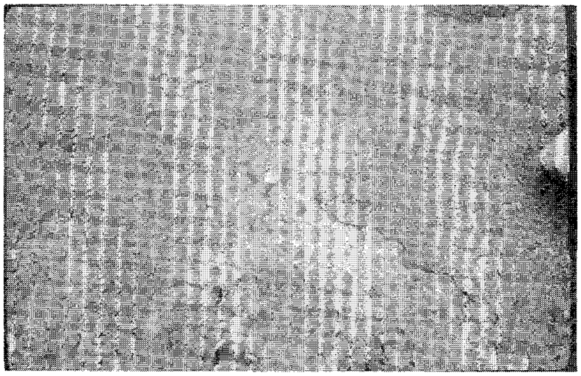
Scaling is the gradual and continued loss of surface mortar (cement paste and fine aggregate) over an area. It is basically a chemical disintegration. There are four categories of scaling.

See Slide 3-2-46

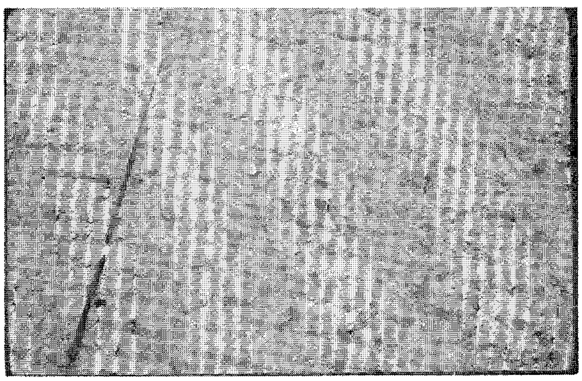
1. **Light Scaling** - Loss of surface mortar up to 1/4 inch (6 mm) deep, with surface exposure of coarse aggregates.

See Slide 3-2-47

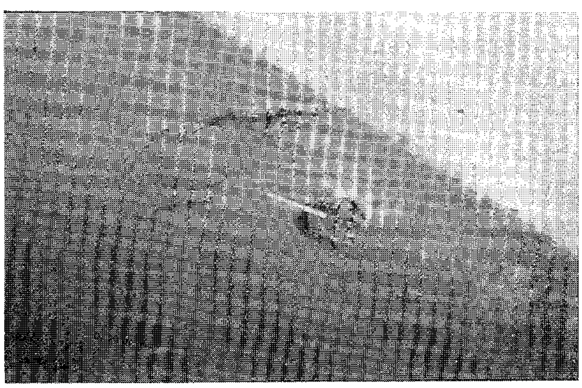
2. **Medium Scaling** - Loss of surface mortar from 1/4 inch (6 mm) to 1/2 inch (13 mm) deep, with some additional mortar loss between the coarse aggregates.



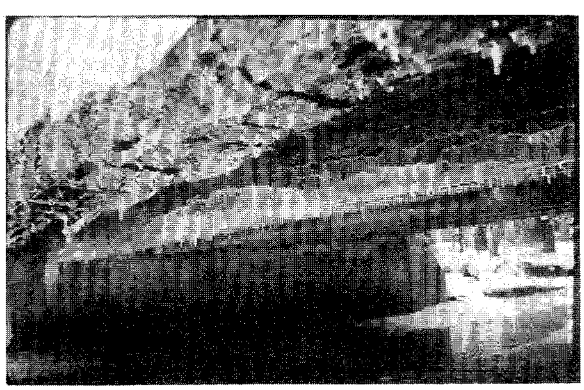
Slide No. 3-2-48
Example Slide
Heavy scaling



Slide No. 3-2-49
Example Slide
Severe scaling



Slide No. 3-2-50
Example Slide
Spall



Slide No. 3-2-51
Example Slide
Efflorescence

See Slide 3-2-48

3. **Heavy Scaling** - Loss of surface mortar surrounding course aggregates of 1/2 inch (13 mm) to 1 inch (25 mm) deep. Coarse aggregates are clearly exposed and stand out from the concrete.

See Slide 3-2-49

4. **Severe Scaling** - Loss of coarse aggregates as well as surface mortar and the mortar surrounding the coarse aggregates. Depth of loss exceeds 1 inch (25 mm).

D. DELAMINATION

Delamination occurs when a layer of concrete separates from bridge decks or beams at or near the level of the outermost layer of reinforcing. Its major cause is expansion of corroding reinforcing steel. A delaminated area gives off a hollow sound when struck with a hammer. When the delaminated layer of concrete is completely separated from the member, the resulting hole is called a spall.

See Slide 3-2-50

E. SPALL

A spall is a roughly circular or oval depression in the concrete. Spalls are formed by the separation and removal of a portion of the surface concrete revealing a fracture roughly parallel to the surface. Reinforcing steel is often exposed. The common shallow pothole is considered a spall.

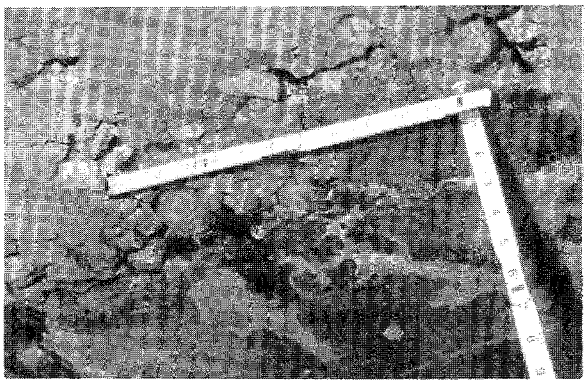
F. POP-OUTS

Pop-outs are conical fragments that break out of the surface of the concrete leaving small holes. Generally, a shattered coarse aggregate particle will be found at the bottom of the hole, with a part of the fragment still adhering to the small end of the pop-out cone. Pop-outs are generally caused by aggregates which expand with absorption of moisture.

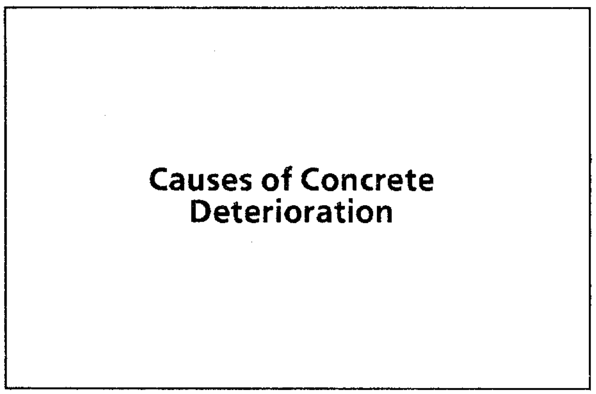
See Slide 3-2-51

G. EFFLORESCENCE

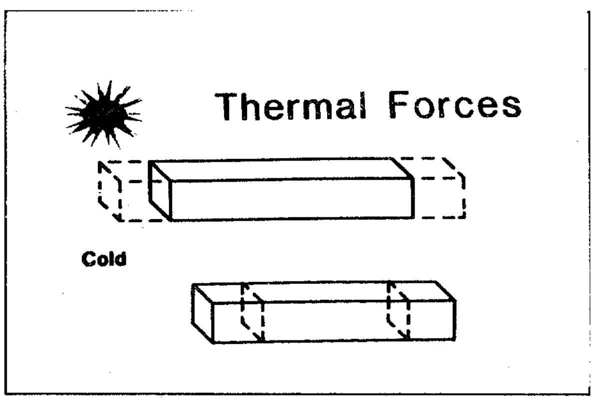
Efflorescence is a light colored deposit on concrete caused by crystallization of carbonates brought to the surface by moisture in the concrete. Efflorescence is not always the result of re-crystallization of deicing chemicals.



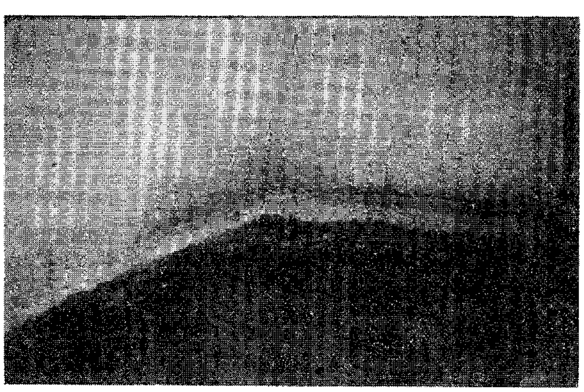
Slide No. 3-2-52
Example Slide
Honeycomb



Slide No. 3-2-53
Title Slide



Slide No. 3-2-54
Schematic Slide
Thermal forces



Slide No. 3-2-55
Example Slide
Freeze-thaw damage on a river pier

See Slide 3-2-52

H. HONEYCOMB

Honeycombs are hollow spaces or voids that may be present within the concrete. Honeycombs can be the result of improper or insufficient vibration during construction, resulting in the segregation of the coarse aggregates from the fine aggregates and cement paste.

I. ABRASION

When concrete is gradually worn away by erosive action of water (or wind) carried fine particles (sand), it is called abrasion. This will usually occur near the water line on concrete piers. Abrasion damage can be accelerated by freeze-thaw cycles.

J. CAUSES OF CONCRETE DETERIORATION

See Slide 3-2-54

1. Temperature Changes

- **Expansion/Contraction** - Concrete expands or contracts as its temperature rises or falls. If the concrete is prevented from contracting, due to friction or because it is being held in place, it will crack under tension.

  Inoperative bearing devices and clogged expansion joints can also cause this to occur.

See Slide 3-2-55

- **Freezing and Thawing** - Freezing and thawing are common causes of concrete deterioration.

  Porous concrete absorbs water, and when this water freezes, high expansive pressures are created due to the larger volume created by ice formation. These pressures often produce cracking.

Causes of Concrete Deterioration

- Temperature changes
- Chemicals attack
- Moisture absorption
- Shrinkage forces
- Elongation of reinforcement
- Corrosion of reinforcement

Slide No. 3-2-56

Narrative Slide

Slide No. 3-2-57

Example Slide

Corroded rebar

Causes of Concrete Deterioration

- Foundation movement
- Overload
- Collision damage

Slide No. 3-2-58

Title Slide

2. **Chemical Attack**

- **Salt and Chemical Deicing Agents** - The use of salt or chemical deicing agents contributes to weathering through recrystallization. This is quite similar to the effects of freezing and thawing.

- **Sulfate Compounds in Soil and Water** - Sodium, magnesium, and calcium sulfates react with compounds in cement paste and cause rapid deterioration of the concrete.

3. **Moisture Absorption** - All concrete is porous and will absorb water to some degree. As water is absorbed, the concrete will swell. If restrained, the restraining material will burst or the concrete will crack.

4. **Shrinkage Forces** - Shrinkage takes place over a long period of time as the chemical reactions in the hardening of concrete take place. As the concrete mass shrinks, tensile forces may develop, causing cracks to appear.

5. **Elongation of Reinforcement** - Steel reinforcing is placed in the tension areas. Small cracks therefore appear in concrete where the tensile stress is greatest.

   This condition is considered fairly normal for reinforced concrete (for example, in T-beams) as long as the cracks are small and there are no rust stains or other signs of deterioration present.

   These cracks may be observed to open up under a load and close again as the load passes. This is called a "working" crack.

See Slide 3-2-57

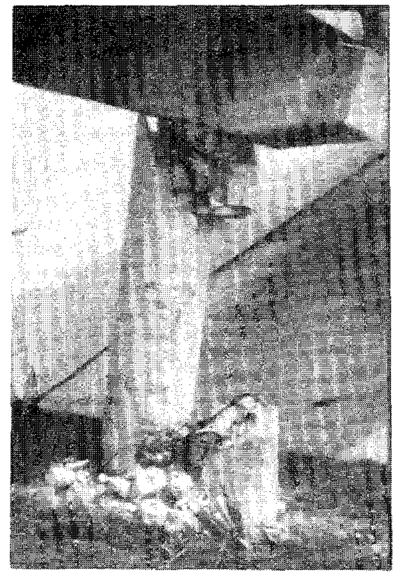
6. **Corrosion of Reinforcement** - Corrosion of steel reinforcing bars in the concrete causes tremendous expansion pressures.

   The concrete surrounding the steel reinforcing bars will crack and delaminate due to such expansion pressures.

7. **Foundation Movement** - Foundation movements will cause serious cracking in concrete structures.

8. **Overload** - Concrete decks, beams, and girders are all subject to damage from overload conditions.

Slide No. 3-2-59
Example Slide
Collision damage



Causes of Concrete Deterioration

- Poor design details
- Construction details
- Fire
- Wear and abrasion

Slide No. 3-2-60
Narrative Slide

See Slide 3-2-59

9. **Collision Damage** - Almost every type of concrete structure component which can be reached by a moving vehicle has suffered damage by collision at one time or another. Impact damage to concrete piers can be caused by boats and ships.

10. **Design and Construction Deficiencies** - Some conditions which can cause concrete to deteriorate are:

    - **Insufficient Reinforcement Bar Cover** - Insufficient concrete cover over rebars may lead to early corrosion of the steel bars.

    - **Weep Holes and Scuppers** - Improper placement or inadequate sizing of scuppers and weep holes can cause an accumulation of water with its deleterious effects.

    - **Deck Joints**

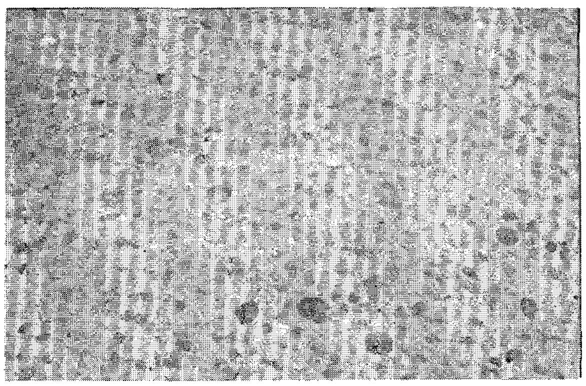
    - **Improper Curing** - A primary cause of concrete deterioration.

    - **Soft Spots** - Soft spots in the subgrade of an approach slab will cause the slab to settle and crack.

    - **Premature Form Removal** - If the formwork is removed between the time the concrete begins to harden and the specified time for formwork removal, cracks will probably occur.

    - **Improper Vibration** - If the concrete is not properly vibrated, internal settling of the concrete mix can cause surface cracking above the reinforcing bars as the mix settles around the bars. Excessive vibration may cause segregation (separation of water, aggregate and cement) of the concrete mix.

    - **Impurities** - The inclusion of clay or soft shale particles in the concrete mix will cause small holes to appear in the surface of the concrete as these particles dissolve. These holes are known as mudballs.



Slide No. 3-2-61
Example Slide
Wear on concrete deck

Examination of Concrete

Slide No. 3-2-62
Title Slide

- **Internal Voids** - If reinforcing bars are too closely spaced, voids, which collect water, can occur under the reinforcing mat if the mix is not properly vibrated.

11. **Fire Damage** - Extreme heat will damage concrete. High temperatures (above 700°F (370 °C)) will cause a weakening in the cement paste and lead to cracking.

See Slide 3-2-61

12. **Wear and Abrasion** - Concrete surfaces disintegrate over extended periods of time due to continued wear from traffic. The scraping action of snow plows, sweepers, and tire chains also cause damage. High velocity water and ice can cause concrete to suffer abrasion damage.

K. EXAMINATION OF CONCRETE

1. Visual Examination

The previous types of concrete deterioration can be observed and examined visually.

Their locations should be noted in the inspection report.

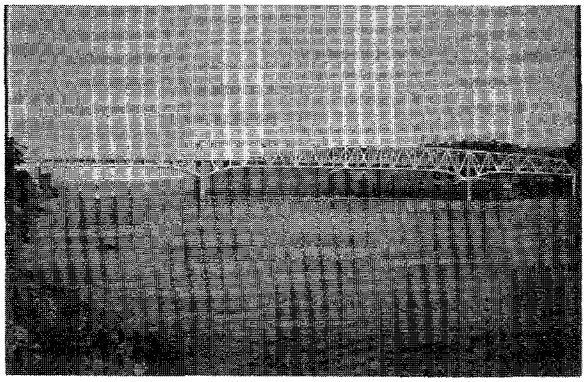
The report should also note the approximate length and width of honeycombed and delaminated areas, and the length, width, and depth of scale, and spall areas.

Cracks should be noted by type, size, length, direction, location, and appearance.

Rust stains should also be noted in the report.

2. Physical Examination

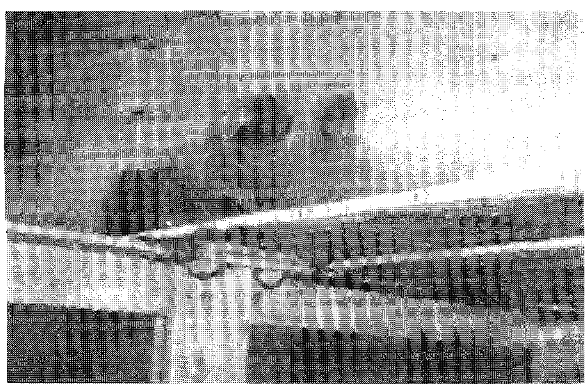
(Videotape presentation)



Slide No. 3-2-63
Example Slide
Steel truss bridge

Deterioration of Steel

Slide No. 3-2-64
Title Slide



Slide No. 3-2-65
Example Slide
Steel Corrosion

III. STEEL

See Slide 3-2-63

A. INTRODUCTION

Steel, has great strength, elasticity, and shock resistance, and is available as wire, cable, plates, bars, and rolled shapes.

In order to properly inspect a steel bridge, the inspector must be able to recognize the various types of steel defects and deterioration. The inspector must also understand the causes of the defects and how to examine them.

B. CORROSION

See Slide 3-2-65

The most common and most easily recognized type of steel deterioration is corrosion, commonly called rust. Inspectors should be familiar with corrosion since it can lead to a substantial reduction in member strength.

Rust is the primary cause of section loss in steel members.

Types of Corrosion

- Environmental
- Stray Current
- Bacteriological
- Stress Induced
- Fretting
- Chemical

Slide No. 3-2-66

Narrative Slide

Fatigue Cracking

Slide No. 3-2-67

Title Slide

Corrosion is caused by a number of different factors:

1. **Differential environmental conditions**
2. **Stray direct currents**
3. **Bacteria**
4. **Residual, applied, load or welding stresses**
5. **Fretting or vibration between closely fitting parts**
6. **Direct chemical attack**

The most common causes of corrosion is the wet/dry cycles of exposed steel. The presence of deicing chemicals accelerates the effects of moisture.

C. FATIGUE CRACKING

Another type of deterioration in steel is fatigue cracking.

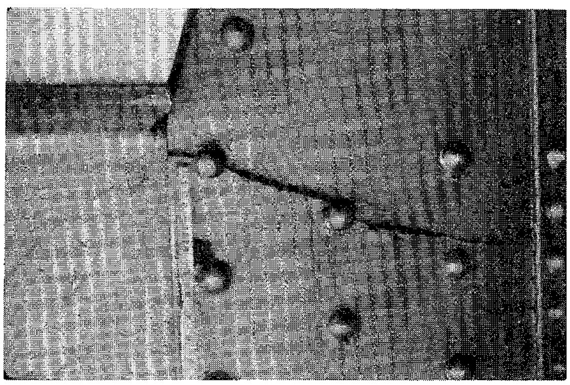
1. **General** - Fatigue cracking is known to have occurred in several types of bridge structures around the nation. This type of cracking can lead to sudden and catastrophic failure, therefore the bridge inspector should know how to recognize fatigue cracks.

Fatigue

The failure of material which occurs at a stress below the yield stress and is due to repeated loading.

Slide No. 3-2-68

Narrative Slide



Slide No. 3-2-69

Example Slide

Fatigue crack

Factors Affecting Fatigue Cracks

- Truck Traffic
- Age of the Structure
- Stress Range
- Design Details
- Fracture Toughness

Slide No. 3-2-70

Narrative Slide

Overload Damage

Slide No. 3-2-71

Title Slide

2. **Fatigue** - Failure of material which occurs at a stress below the yield stress and is due to repeated loading.

See Slide 3-2-69

Fatigue cracks develop in bridge structures due to repeated truck loadings.

3. **Factors Influencing the Development of Fatigue Cracks:**

- Frequency of truck traffic
- Age or load history of the bridge
- Magnitude of stress range
- The type of detail
- The quality of the fabricated detail
- Material fracture toughness
- Presence of welding

D. OVERLOADS

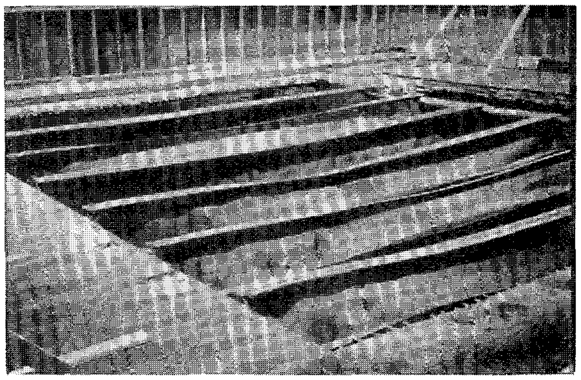
1. **General** - An overload force can cause the steel to deform or elongate and remain in this condition after the force has been removed. This type of deformation is considered to be plastic deformation.

If the force is left on the member, the member will continue to elongate until the tensile strength is reached. At this point, complete failure of the member will occur.

2. **Indications** - plastic deformation may be encountered in both tension and compression members.

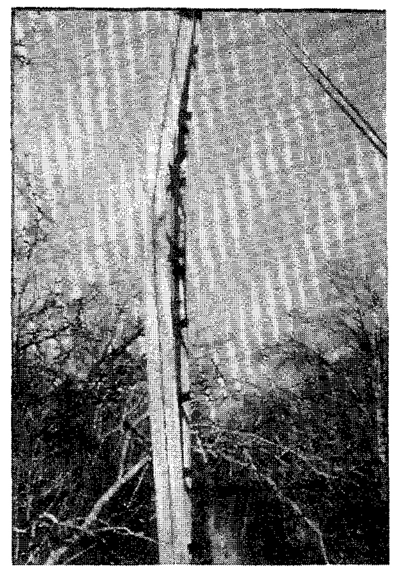
- The symptom in tension members is elongation, a decrease in cross section commonly called "necking down".

- The symptom in compression members is buckling in the form of a single or double bow.



Slide No. 3-2-72
Example Slide
Heat damage

Slide No. 3-2-73
Example Slide
Collision damage



Examination of Steel

Slide No. 3-2-74
Title Slide

Visual Examination

You MUST remove dirt and debris to properly examine the steel!

Slide No. 3-2-75
Narrative Slide

Complete failure in an overload situation causes complete failure of a member.

E. HEAT DAMAGE

See Slide 3-2-72

1. **General** - Steel members will undergo serious deformation upon exposure to extreme heat.

2. **Indications** - In addition to sagging, or elongation of the metal, intense heat often causes members to buckle and twist; rivets and bolts may fail at connection points.

   Buckling could be expected where the member is under compression, particularly in thin sections such as the web of a girder.

F. COLLISION DAMAGE

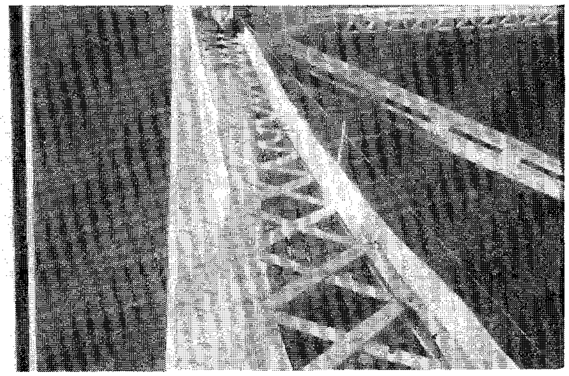
See Slide 3-2-73

Distorted and damaged members caused by vehicles.

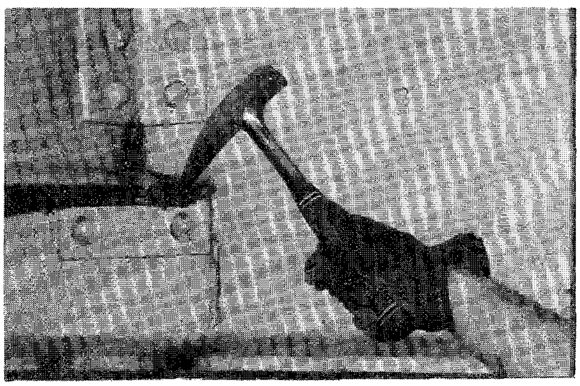
G. VISUAL EXAMINATION

Examination of steel begins with a visual examination.

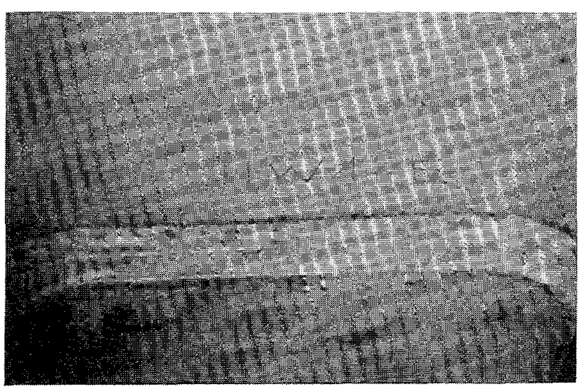
Dirt and debris must be removed to properly examine the steel.



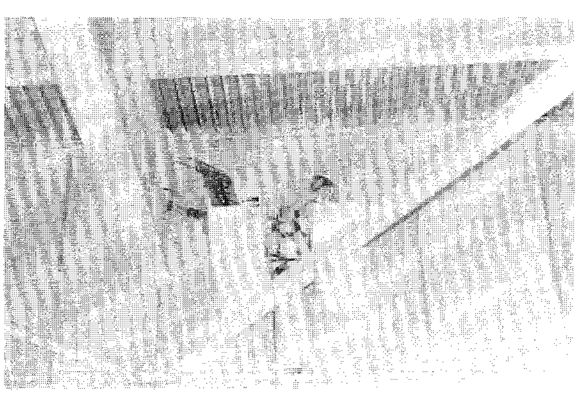
Slide No. 3-2-76
Example Slide
Bent member



Slide No. 3-2-77
Example Slide
Corroded member



Slide No. 3-2-78
Example Slide
Fatigue crack



Slide No. 3-2-79
Example Slide
Inspector verifying member size

1. Visual examination can reveal -

See Slide 3-2-76

- Bent or Damaged Members

See Slide 3-2-77

- Corrosion

See Slide 3-2-78

- Fatigue Cracks

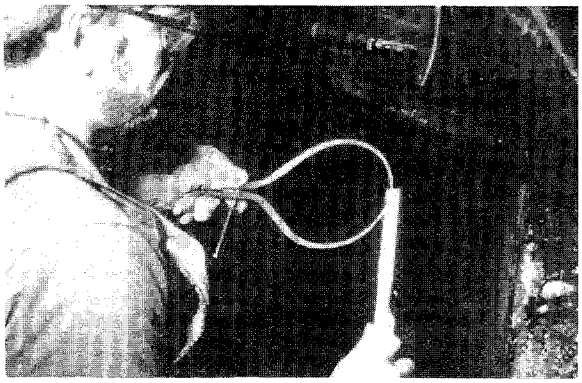
- Non-Fatigue Cracks - such as caused by collision damage.

Examination of steel also includes:

2. Member Size Verification

See Slide 3-2-79

- Check for any replacement members or reused members from other earlier bridges.



Slide No. 3-2-80
Example Slide
Inspector measuring section loss using calipers and rule

Non-Destructive Testing

Slide No. 3-2-81
Title Slide

Dye Penetrant Inspection

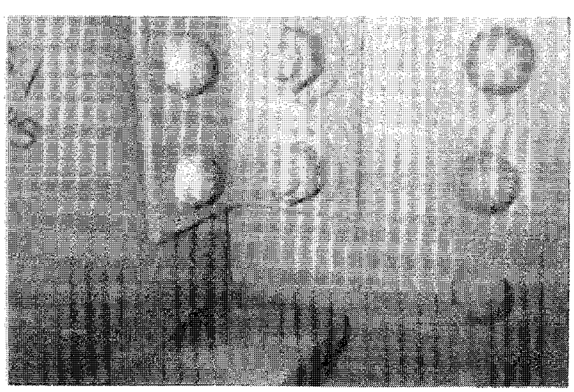
Advantages

- Fast
- Inexpensive
- Minimum Training Required

Disadvantages

- Only surface connected discontinuities are detectable
- Smooth surface required

Slide No. 3-2-82
Narrative Slide



Slide No. 3-2-83
Example Slide
Suspected crack

See Slide 3-2-80

3. **Detecting and Measuring Section Loss**

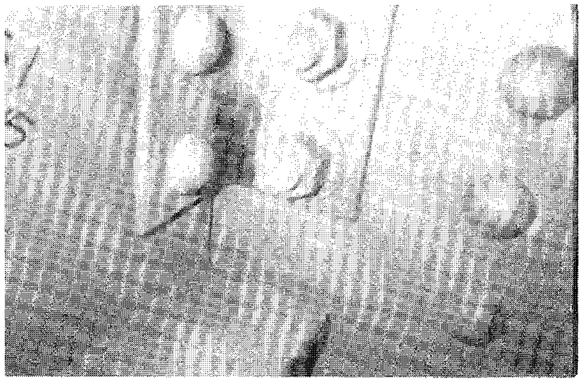
4. **Non-Destructive Testing**

Methods of non-destructive testing are:

- **Dye Penetrant Test**

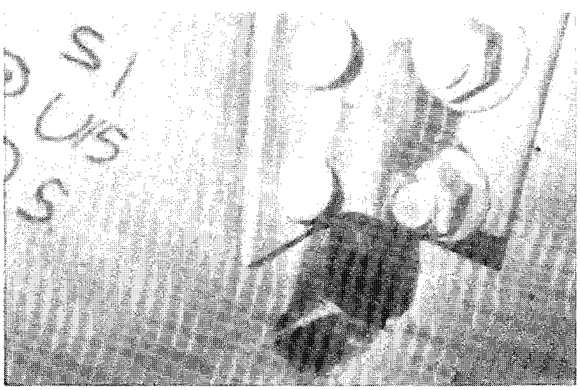
See Slide 3-2-83

How It Works



Slide No. 3-2-84
Example Slide
Crack area cleaned

Slide No. 3-2-85
Example Slide
Dye penetrant applied to crack



Slide No. 3-2-86
Example Slide
Developer applied and crack defined by dye

ULTRASONIC TESTING

Advantages

- Ability to inspect entire cross section
- Generally need access to only one side
- Portable equipment
- Safe
- Ability to perform thickness measurements

Disadvantages

- Dependent on an operator ability
- Inconsistent results

Slide No. 3-2-87
Narrative Slide

See Slide 3-2-84

Area to be penetrated by dye is cleaned to bare metal

See Slide 3-2-85

A penetrant is applied and adequate time allowed for penetration

Excess penetrant is removed from the surface

See Slide 3-2-86

A developer is applied which draws the dye out of the irregularities

The dye defines the extent and size of any surface flaws

This method does not reveal the depth of the cracks or any subsurface flaws

- **Magnetic Particle Testing**

  A magnetic field induced in a steel member will be altered by discontinuities within the steel. This is made visible by iron powder placed on the steel surface.

- **Ultrasonic Testing (UT)**

  High frequency sound waves are introduced to the specimen by a sending transducer. This is to detect small internal flaws.

  Discontinuities in the specimen are detected by an interruption of the sound beam.

Summary

- Timber
- Concrete
- Steel

Slide No. 3-2-88

Title Slide

IV. SUMMARY

A. **TIMBER**

B. **CONCRETE**

C. **STEEL**

SESSION 3: BASIC CONCEPTS

TOPIC 3: BRIDGE COMPONENTS AND ELEMENTS

LESSON PLAN

TOPIC DURATION	60 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 6
GOAL	To perform a review of the components and elements which make up a bridge.
OBJECTIVE	Participant should be able to identify, on sight, various bridge types and their basic component parts.

Major Bridge Components

- Deck
- Superstructure
- Substructure

Slide No. 3-3-1

Narrative Slide

Basic Member Shapes and Connections

Slide No. 3-3-2

Title Slide

I. MAJOR BRIDGE COMPONENTS

Most bridges can be divided into three basic parts or components:

- Deck
- Superstructure
- Substructure

A. DECK

The deck is that component of a bridge to which the live load from traffic is directly applied.

Besides carrying traffic safely and smoothly, transferring the live load to other bridge components is the basic function of the deck.

B. SUPERSTRUCTURE

The superstructure is that portion of the bridge which supports the deck or riding surface of the bridge.

C. SUBSTRUCTURE

The substructure is that component of a bridge which includes all the elements which support the superstructure.

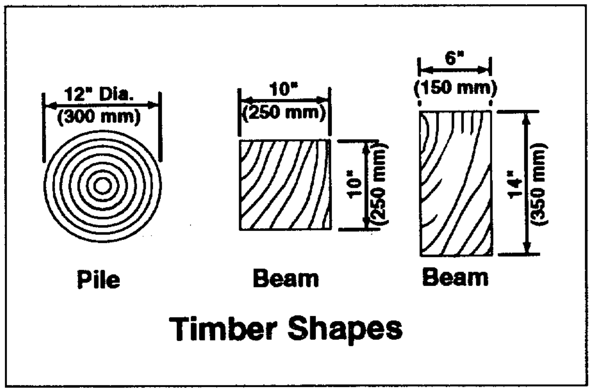
The purpose of the substructure is to transfer the loads from the superstructure to the foundation soil or rock.

Various types of decks, superstructures, and substructures will be described later in this lecture.

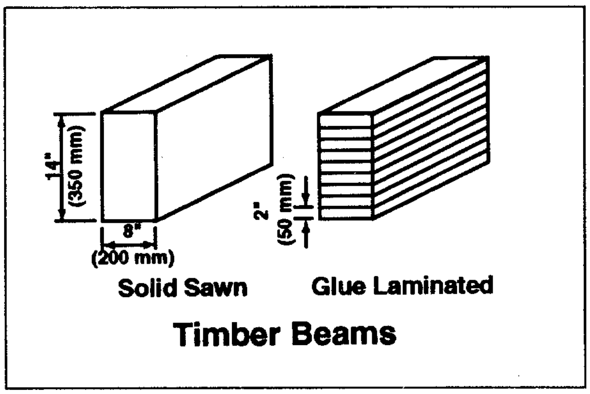
II. BASIC MEMBER SHAPES AND CONNECTIONS

Every bridge member has a particular function: to carry tension, compression or bending loads. These loads cause the two basic kinds of member stress: tension and compression. Bending causes a combination of these two stresses in a member.

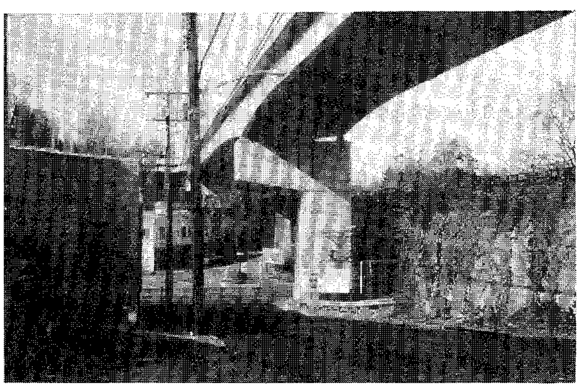
Certain shapes and materials have distinct characteristics in resisting the applied loads.



Slide No. 3-3-3
Schematic Slide
Timber shapes



Slide No. 3-3-4
Schematic Slide
Timber beams



Slide No. 3-3-5
Example Slide
Unusual concrete shapes

A. TIMBER SHAPES

See Slide 3-3-3

Timber bridge members are made into three basic shapes:

1. **Piles** - used as substructure elements.
2. **Planks** - Planks are of elongated rectangular dimensions. For example, 12 inch (300 mm) width and 2 inch (50 mm) thickness.
3. **Beams** - Timbers beams are of square or more equal rectangular dimensions.

See Slide 3-3-4

Timbers can be either solid sawn or glue laminated.

Glue laminated timbers are advantageous in that they can be fabricated from smaller, more readily available pieces. Glue lamination also allows larger rectangular members to be formed without the presence of natural defects such as knots.

See Slide 3-3-5

B. CONCRETE SHAPES

Concrete is a unique material for bridge members because it can be formed in an infinite variety of shapes.

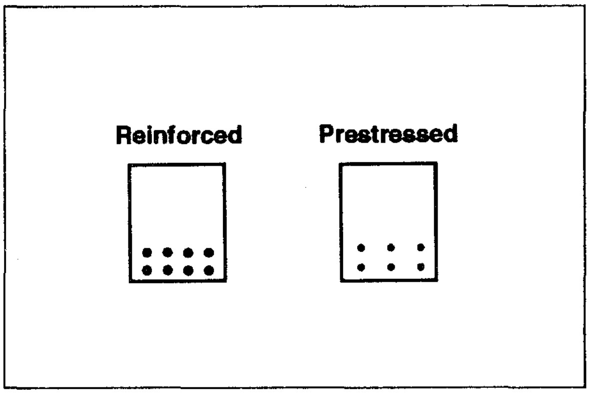
Concrete members are used to carry axial loads and also loads in bending.

Members typically are reinforced with either mild (reinforced concrete) or high strength (prestressed concrete) steel.

1. Mild Steel Reinforced Shapes

The most common shapes of concrete members using mild steel reinforcing are:

- Slabs
- Rectangular Beams
- Tee-Beams
- Channel Beams

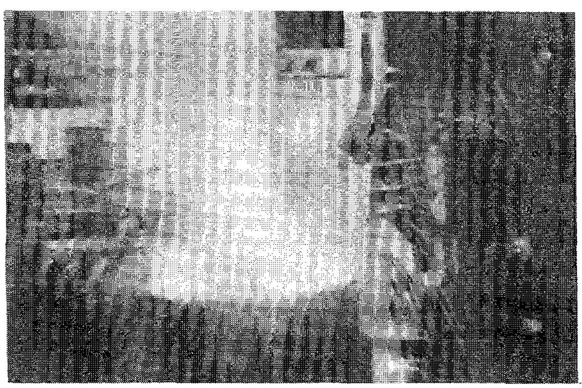


Slide No. 3-3-6
Schematic Slide
Mild steel reinforced concrete vs.
Precast prestressed concrete

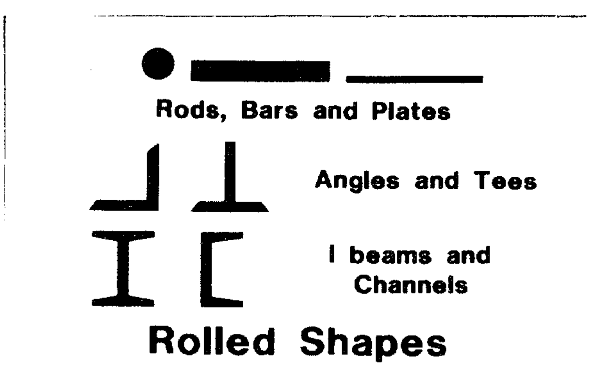
Prestressed Concrete Shapes

- Voided slabs
- I-beams
- Box beams
- Box girders

Slide No. 3-3-7
Narrative Slide



Slide No. 3-3-8
Example Slide
Steel making operation



Slide No. 3-3-9
Schematic Slide
Rolled shapes

See Slide 3-3-6

2. Prestressed Concrete Shapes

The most common shapes using prestressing steel tendons are:

- Voided slabs
- I-beams
- Box beams
- Box girders

Prestressed concrete is generally more economical than conventionally reinforced concrete because the prestressing force lowers the neutral axis, putting more of the concrete section into compression. Also, the prestress steel is very high strength, so fewer pounds of steel are needed.

See Slide 3-3-8

C. STEEL SHAPES

Steel bridge members began to be used in the United States in 1874, and by 1900, steel had virtually replaced iron as a bridge material.

Steel quality has improved since the early 1900's. Early grades of steel, A7, for example, have been replaced by stronger A36, A572 and A588 steels. These stronger grades are now all classified under the A709 designation for use in bridges.

Steel shapes are either rolled or built-up.

See Slide 3-3-9

1. **Rolled Steel Shapes** - Rolled shapes commonly used on bridges include:

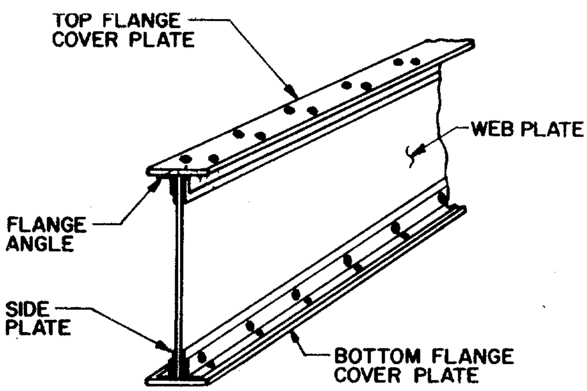
- Bars and Plates

  Bars - are normally considered to be up to 8 inches (205 mm) in width. Lacing bars on a truss are an example. Steel eyebars are another common application.

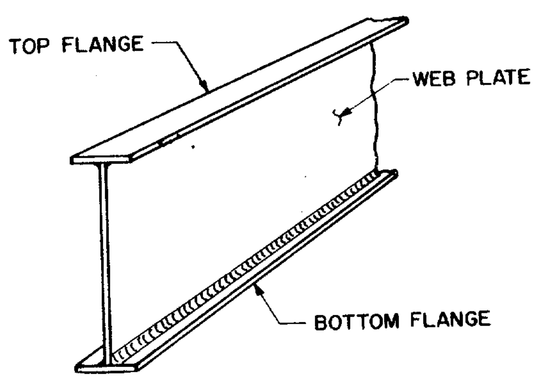
  Plates - are designated as flat plates over 8 inches (205 mm) wide. Gusset plates on trusses are examples.

- Angles

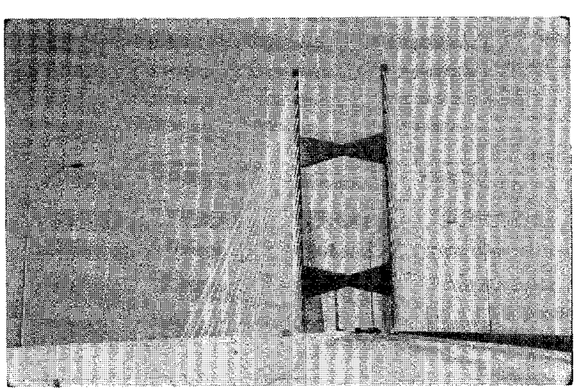
  Angles range in size from 1 inch x 1 inch x 1/4 inch (25 mm x 25 mm x 6 mm) to 8 inches x 8 inches x 1 1/8 inches (203 mm x 203 mm x 29 mm). Angles range in weight from less than 1 pound per foot (1.5 kg/m) to almost 60 pounds per foot (89.3 kg/m).



Slide No. 3-3-10
Schematic Slide
Riveted plate girder



Slide No. 3-3-11
Schematic Slide
Welded plate girder



Slide No. 3-3-12
Cable supported bridge

- Channels

These are squared-off "C" shaped members and are used as diaphragms, struts, or built-up members.

Standard channels range from depths of 3 inches to 15 inches (76 mm to 381 mm) and weights from less than 5 lbs. to 50 lbs. per foot (7.4 kg to 74.4 kg per m). Non-standard sections (called miscellaneous channels, MC), are rolled up to 24 inch (610 mm) depths, weighing 60 pounds per foot (89.3 kg per m).

- Beams

Some of the more common designations for rolled beams are:

S = American Standard Beam (e.g., S24x100)
W = Wide Flange Beam (e.g., W36x230)
WF = Wide Flange Beam
CB = Carnegie Beam
M = Miscellaneous Beam
HP = "H"-Pile (e.g., H14x117)

"I" beams typically range from 3 inches to 36 inches (76 mm to 914 mm) deep and from 6 pounds per foot (8.9 kg per m) to over 300 pounds per foot (446.4 kg per m). Larger, "jumbo" shapes are now rolled for use in building construction. (Bethlehem Steel 40" (1016mm) rolled beam was introduced in Fall of 1991.)

See Slide 3-3-10

2. **Built-up Shapes** - can be exactly sized; however are more expensive to fabricate

- Riveted shapes

Typical riveted shapes include riveted girders and riveted boxes.

See Slide 3-3-11

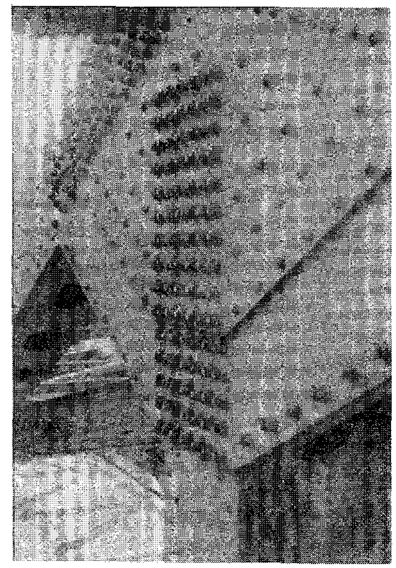
- Welded Shapes

Welded shapes include welded girders and welded boxes.

See Slide 3-3-12

3. **Cables** - Steel cables are used in suspension and cable-stayed bridges.

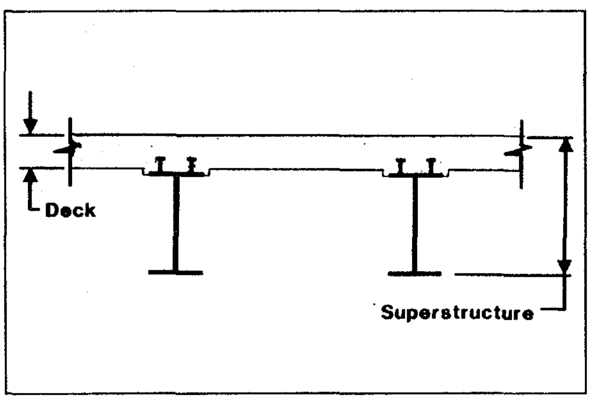
Slide No. 3-3-13
Example Slide
Truss connection



Purpose of Decks

- Provide a roadway over which traffic can move
- Distribute traffic and deck weight loads to underlying supporting elements

Slide No. 3-3-14
Narrative Slide



Slide No. 3-3-15
Schematic Slide
Composite deck

Slide No. 3-3-15A
Example Slide
Shear studs on top flange of girder before concrete deck is poured

See Slide 3-3-13

D. CONNECTIONS

Typical connections used in steel bridges are:

- Pin Connections
- Riveted Connections
- Bolted Connections
- Welded Connections
- Pin and Hanger Connections

III. DECKS

A. PURPOSE OF DECKS

Bridge decks provide a roadway over which traffic can move, and they distribute traffic or vehicular loads and their own weight to the underlying supporting elements.

B. FUNCTION OF DECKS

Decks function in one of two ways:

See Slide 3-3-15

See Slide 3-3-15A

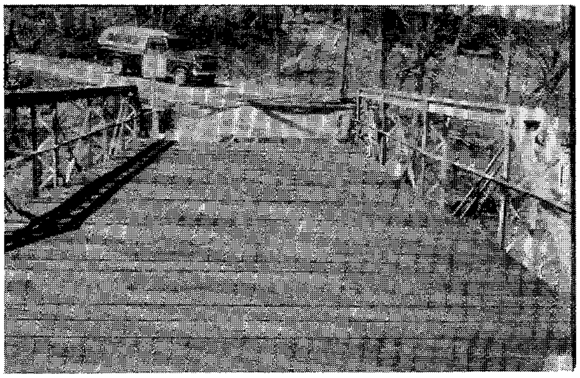
1. **Composite Deck**

   Composite decks act integrally with their supporting members and increase superstructure strength.

2. **Non-composite Deck**

   Non-composite decks are not integral with their supporting members and they do not contribute to structural capacity.

Deck materials may be timber, concrete, steel, or a combination of these materials.



Slide No. 3-3-16

Example Slide

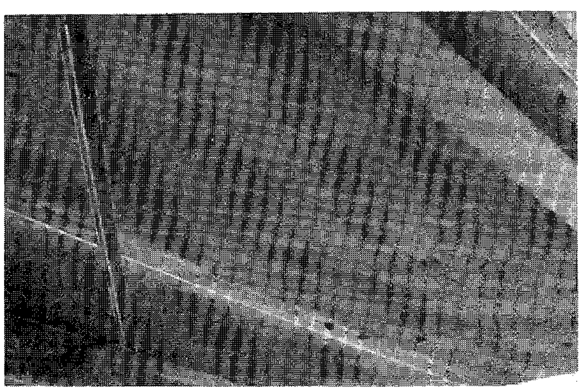
Plank deck

Timber Decks

- Plank
- Nailed Laminated
- Glued Laminated Planks
- Prestressed Laminated/Stressed Timber

Slide No. 3-3-17

Narrative Slide



Slide No. 3-3-18

Example Slide

Concrete deck

CONCRETE DECKS

- Cast-in-place (CIP)
- Precast
- Precast Panels With CIP Topping

Slide No. 3-3-19

Narrative Slide

See Slide 3-3-16

C. TIMBER DECKS

Timber decks are normally referred to as decking or timber flooring and the term is limited to the roadway portion which receives vehicular loads.

The four basic types of timber decks are:

1. **Plank Deck**

2. **Nailed Laminated Deck**

3. **Glued Laminated Deck Planks**

4. **Prestressed Laminated Deck/Stressed Timber Deck**

See Slide 3-3-18

D. CONCRETE DECKS

Concrete permits casting in various shapes and sizes and has provided the bridge designer and the bridge builder with a variety of construction methods.

Because concrete is weak in tension, it is used together with reinforcement to resist the tensile stresses.

There are three common types of concrete decks:

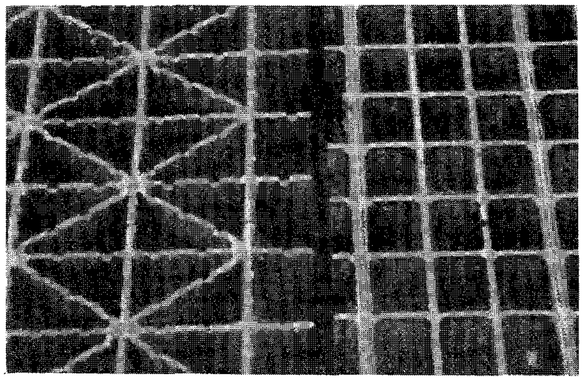
1. **Reinforced Cast-in-Place (CIP)**

   There are two types of forms used:

   - Removable
   - Stay-in-Place

2. **Precast**

3. **Precast Deck Panels With Cast-in-Place Topping**



Slide No. 3-3-20

Example Slide

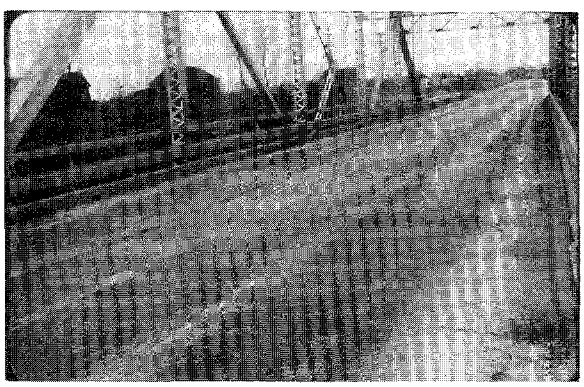
Steel grid deck

STEEL DECKS

- Corrugated Steel Flooring
- Orthotropic
- Grid
- Buckle Plate

Slide No. 3-3-21

Narrative Slide



Slide No. 3-3-22

Example Slide

Asphalt wearing surface on a concrete deck

See Slide 3-3-20

E. STEEL DECKS

Steel decks are decks composed of either solid steel plate or steel grids.

There are four common types of steel decks:

1. **Corrugated Steel Flooring**

2. **Orthotropic Deck**

3. **Grid Deck**

   - Open
   - Filled, or
   - Partially filled

4. **Buckle Plate Deck**

   Still exist on some older bridges but are no longer used.

See Slide 3-3-22

F. WEARING SURFACES

Constant exposure to the elements makes weathering a significant cause of deck deterioration. In addition, vehicular traffic produces damaging effects on the deck surface. For these reasons a wearing surface is often applied to the surface of the deck. The wearing surface is the topmost layer of material applied upon the deck to provide a smooth riding surface and to protect the deck from the effects of traffic and weathering.

1. **Wearing Surfaces for Timber Decks**

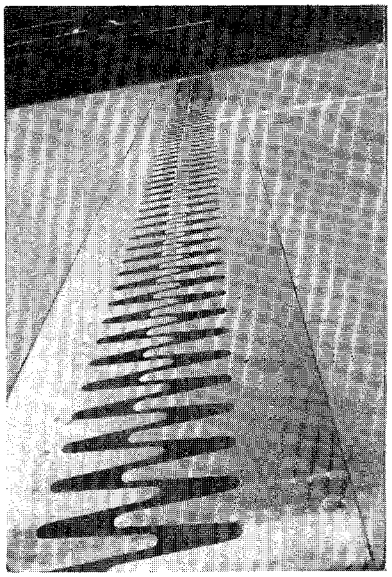
   A timber deck may have one of the following wearing surfaces:

   - Timber Planks
   - Bituminous

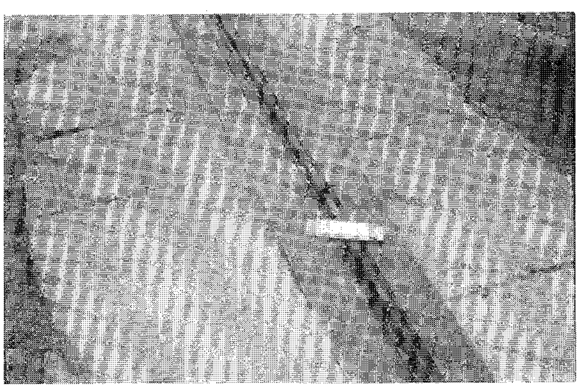
2. **Wearing Surfaces for Concrete Decks**

   Concrete decks may have wearing surfaces of:

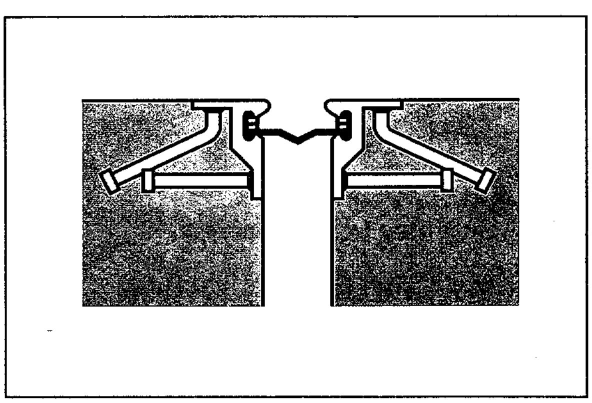
   - Concrete
     LMC - Latex Modified Concrete
     LSDC - Low Slump Dense Concrete
   - Asphalt
   - Epoxy overlay with broadcast aggregate



Slide No. 3-3-23
Example Slide
Top view of a finger plate joint



Slide No. 3-3-24
Example Slide
Top view of an armored compression seal in place



Slide No. 3-3-24A
Example Slide
Strip seal

3. **Wearing Surfaces for Steel Decks**

Steel decks may have wearing or riding surfaces of:

- Serrated Steel
- Concrete
- Asphalt

IV. DECK JOINTS AND DRAINAGE

See Slide 3-3-23

The primary function of a deck joint is to accommodate the expansion contraction, and rotation of the superstructure. The joint must also provide a smooth transition from an approach roadway to a bridge deck, or between adjoining segments of bridge deck.

There are two major categories of deck joints:

- **Unsealed joints**
- **Sealed joints**

A. UNSEALED JOINTS

Unsealed joints allow water and debris to pass through them.

There are two types of unsealed joints:

1. **Formed Joints**
2. **Finger Plate Joints**

B. SEALED JOINTS

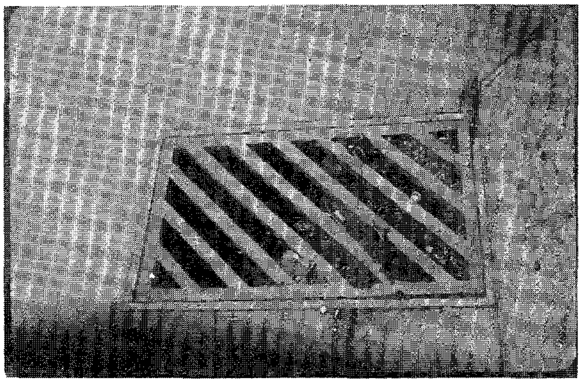
See Slide 3-3-24

Sealed joints are designed so water and debris do not pass through them.

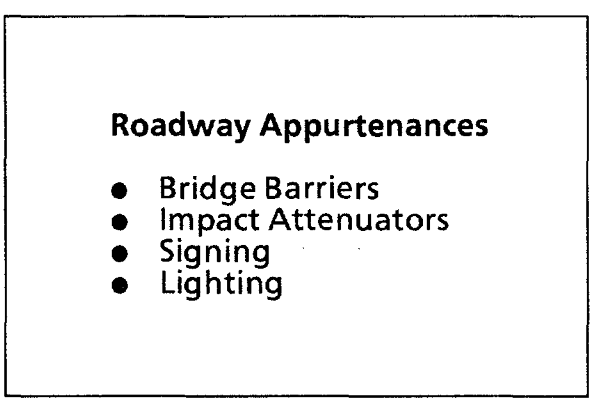
There are six types of sealed joints:

1. **Poured Joint Seal**
2. **Compression Seal**
3. **Cellular Seal (closed cell foam)**
4. **Sliding Plate Joint**
5. **Prefabricated Elastomeric Seal - which can be a:**
   - Plank Seal
   - Sheet Seal
   - Strip Seal

See Slide 3-3-24A



Slide No. 3-3-25
Example Slide
Grate on an inlet box



Slide No. 3-3-26
Narrative Slide

6. **Modular Elastomeric Seal**

C. **DRAINAGE SYSTEMS**

See Slide 3-3-25

1. **Introduction to Drainage Systems**

The primary function of a drainage system is to remove water from the bridge deck, from under unsealed deck joints and from behind abutments and wingwalls.

2. **Components of a Deck Drainage System**

A deck drainage system has the following components.

- Deck Drains
- Outlet Pipes - To lead water away from drain.
- Downspouts Pipes - To transport runoff to storm sewers.
- Cleanout Plugs - for maintenance.

3. **Joint Drainage System**

A joint drainage system is typically a separate gutter or trough used to collect water passing through a finger plate or sliding plate joint.

Combining all these drainage components forms a complete deck drainage system.

4. **Substructure Drainage Systems**

Substructure drainage allows the fill material behind an abutment or wingwall to drain any accumulated water.

Substructure drainage is accomplished with weep holes or substructure drain pipes.

V. ROADWAY APPURTENANCES

The proper and effective use of roadway appurtenances minimizes any hazard for traffic on the highways as well as waterways.

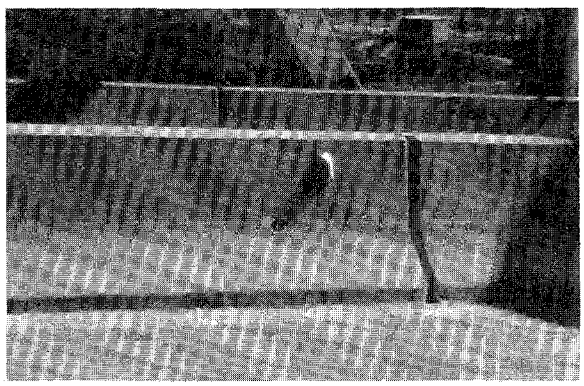
This brief discussion will list and show examples of:

- Bridge Barriers
- Impact Attenuators
- Signing
- Lighting

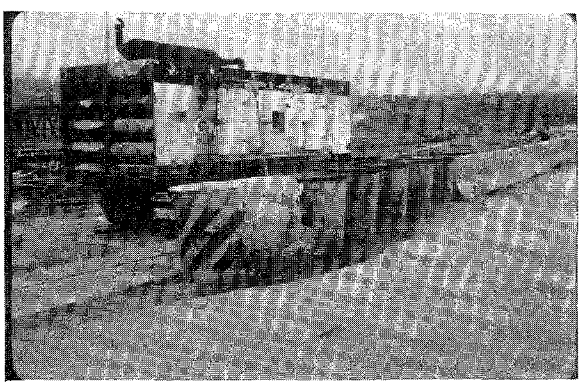
Barriers

- Bridge Railing
- Pedestrian Railing

Slide No. 3-3-27
Narrative Slide



Slide No. 3-3-28
Example Slide
New Jersey barrier



Slide No. 3-3-29
Example Slide
Attenuator

Slide No. 3-3-30
Example Slide
Weight limit sign

A. BRIDGE BARRIERS

Bridge barriers can be broken down into two categories:

1. **Bridge Railing** - to guide, contain, and redirect errant vehicles.

2. **Pedestrian Railing** - to protect pedestrians.

Examples of railing include:

- Timber plank rail
- Steel angles and bars
- Pigeon hole parapet
- Combination bridge/pedestrian aluminum or steel railing
- New Jersey barrier - a very common barrier which meets current performance requirements.

See Slide 3-3-28

B. IMPACT ATTENUATORS

See Slide 3-3-29

Unlike the New Jersey barrier that is designed to take a glancing hit from a vehicle, an impact attenuator is designed to take a direct, head-on hit. It is a device that does not redirect the vehicle but gradually slows it to a stop.

Some of the most common impact attenuators are:

1. **Water Filled**

2. **Foam Filled**

3. **Sand Filled**

See Slide 3-3-30

C. SIGNING

Signing serves to inform the motorist about bridge or roadway conditions that may be hazardous.

Among the various types of signs likely to be encountered are:

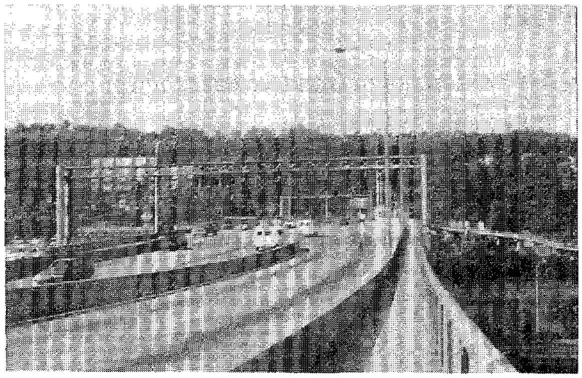
1. **Weight Limit**

2. **Vertical Clearance**

3. **Lateral Clearance**

4. **Narrow Underpass**

5. **Speed Traffic Marker**

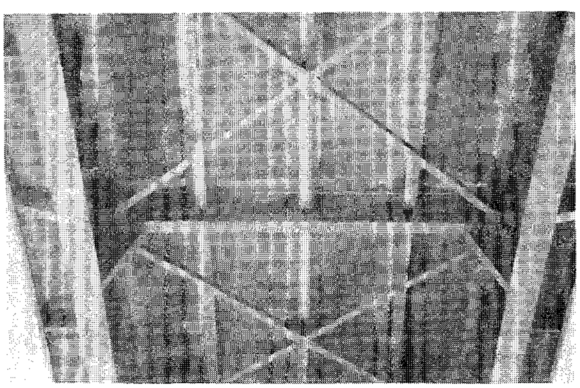


Slide No. 3-3-31
Example Slide
Bridge lighting

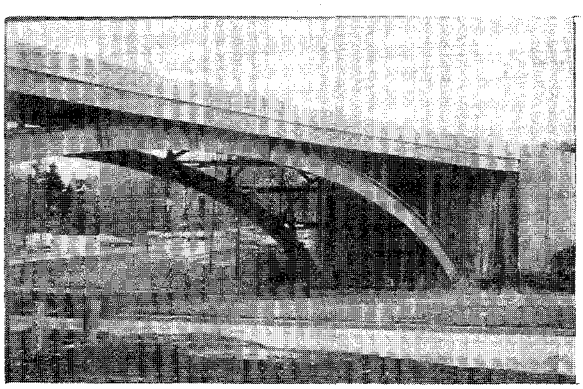
Superstructure

The entire portion of a bridge which primarily receives and supports highway or other traffic loads and transfers the reactions to the substructure.

Slide No. 3-3-32
Narrative Slide



Slide No. 3-3-33
Example Slide
Floor system



Slide No. 3-3-34
Example Slide
Main supporting elements of deck arch

D. LIGHTING

See Slide 3-3-31

There are five types of lighting that may be encountered on a bridge:

1. **Highway Lighting**

2. **Traffic Control Lights**

3. **Aerial Obstruction Lights**

4. **Navigation Lights**

5. **Signing Lights**

VI. SUPERSTRUCTURES

A. PURPOSE AND FUNCTION

The superstructure includes the entire portion of a bridge which primarily receives and supports highway or other traffic loads and transfers the reactions to the substructure.

B. PRIMARY ELEMENTS

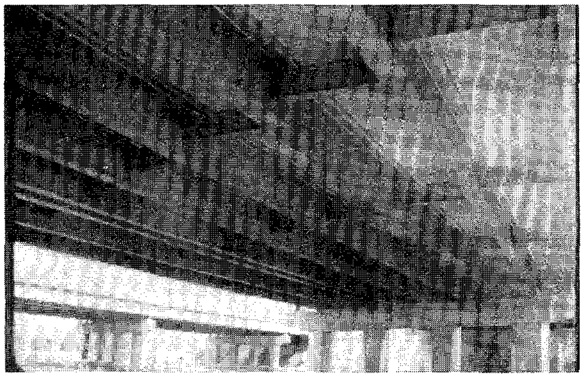
Most all superstructures are made up of two basic elements.

See Slide 3-3-33

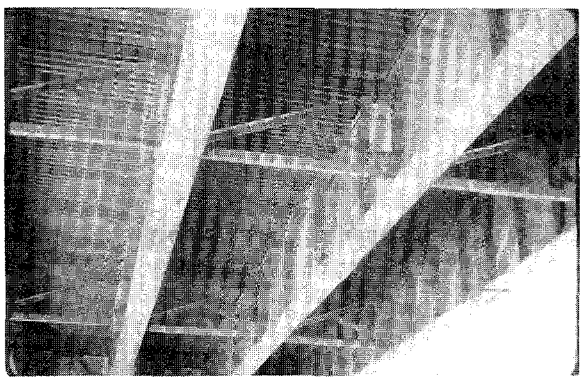
1. **Floor System** - The floor system receives traffic loads from the deck and distributes them to the main supporting elements.

See Slide 3-3-34

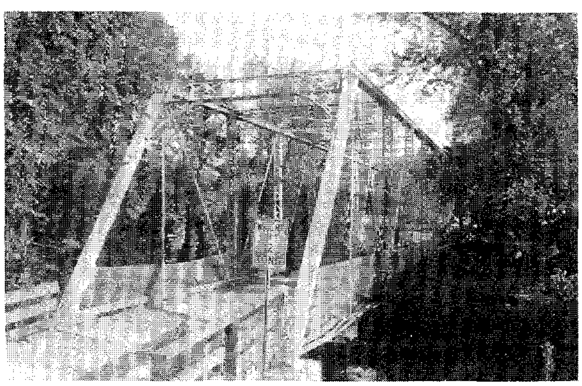
2. **Main Supporting Elements** - The main supporting elements transfer all loads to the substructure units.



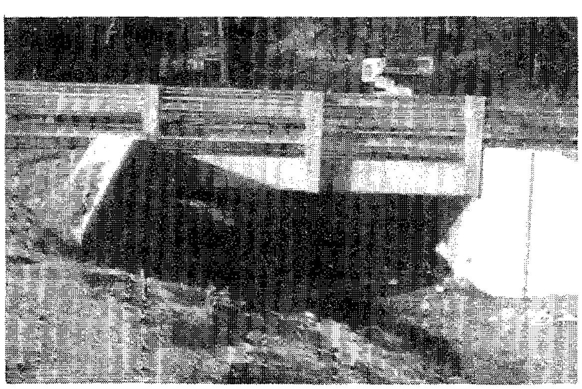
Slide No. 3-3-35
Example Slide
Diaphragm



Slide No. 3-3-36
Example Slide
X-bracing



Slide No. 3-3-36A
Example Slide
Sway bracing



Slide No. 3-3-37
Example Slide
Slab bridge

C. SECONDARY ELEMENTS

Secondary elements are elements which do not normally carry traffic loads directly.

See Slide 3-3-35

Typical secondary elements are:

1. **Diaphragms**

See Slide 3-3-36

2. **Cross or X-Bracing**

3. **Lateral Bracing**

See Slide 3-3-36A

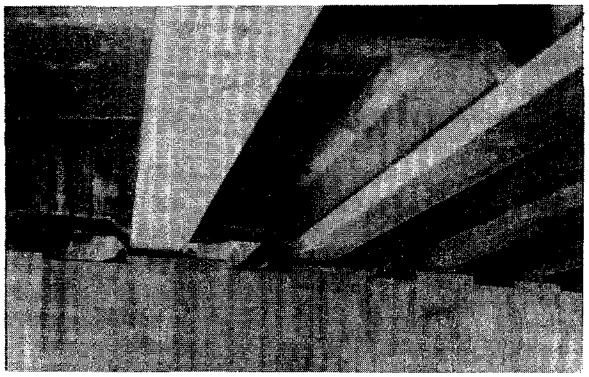
4. **Sway/Portal Bracing**

D. TYPES OF SUPERSTRUCTURES

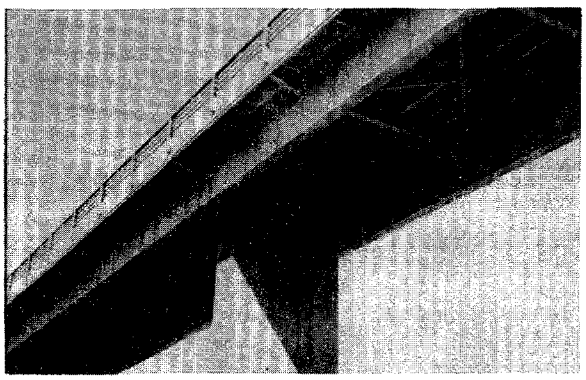
The following are various types of superstructures.

See Slide 3-3-37

1. **Slab Bridge**



Slide No. 3-3-38
Example Slide
Prestressed concrete multi-beam bridge



Slide No. 3-3-39
Example Slide
Girder floorbeam stringer bridge

Slide No. 3-3-40
Example Slide
Tee beam bridge

Slide No. 3-3-41
Example Slide
Adjacent box beam bridge

See Slide 3-3-38

2. Multi-Beam Bridge

See Slide 3-3-39

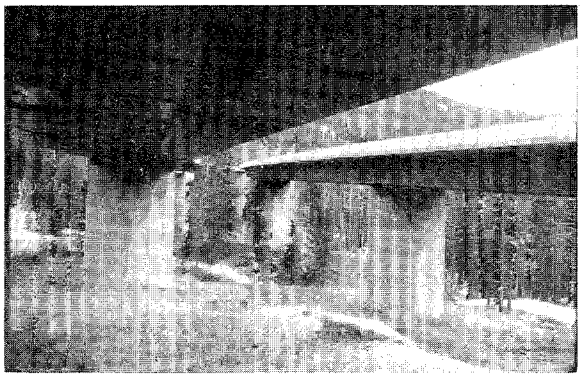
3. Girder Floorbeam Bridge

See Slide 3-3-40

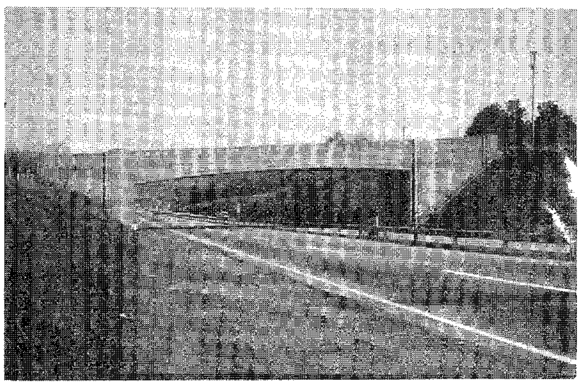
4. Tee Beam Bridge

See Slide 3-3-41

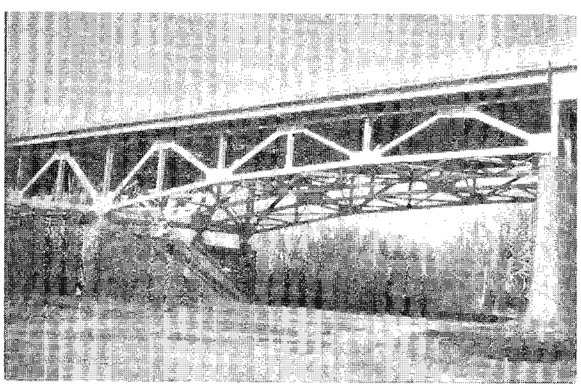
5. Multiple Box Beam Bridge



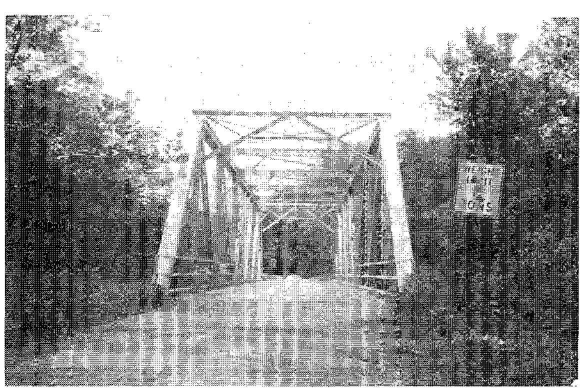
Slide No. 3-3-42
Example Slide
Steel box girder bridge



Slide No. 3-3-43
Example Slide
Reinforced concrete frame bridge



Slide No. 3-3-44
Example Slide
Deck truss bridge



Slide No. 3-3-45
Example Slide
Through truss bridge

See Slide 3-3-42

6. Box Girder Bridge

See Slide 3-3-43

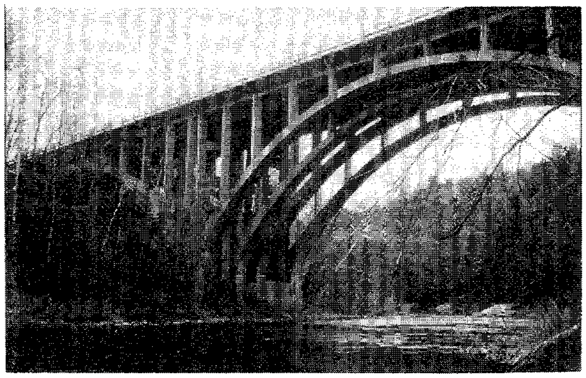
7. Frame Bridge

See Slide 3-3-44

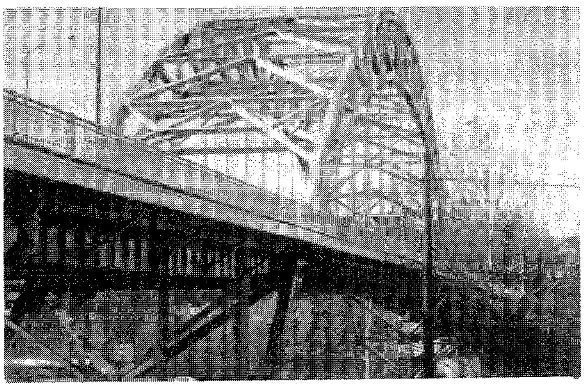
8. Deck Truss Bridge

See Slide 3-3-45

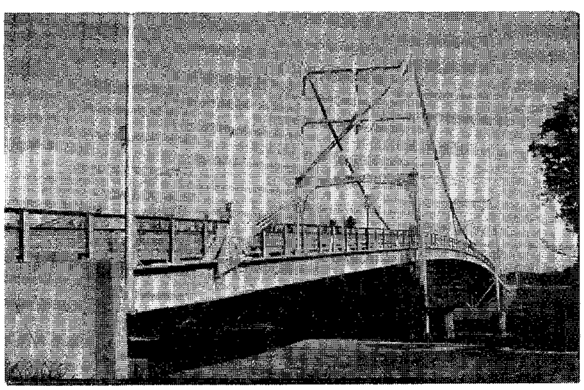
9. Through Truss Bridge



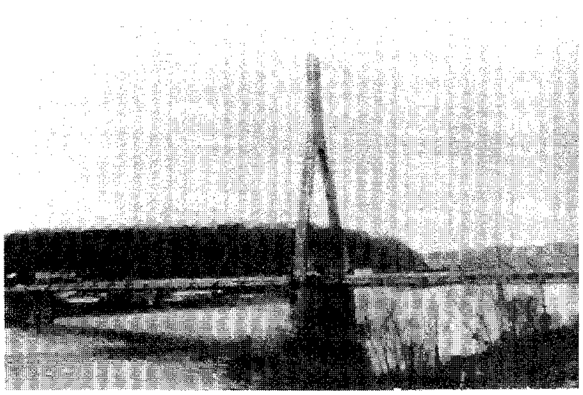
Slide No. 3-3-46
Example Slide
Deck arch bridge



Slide No. 3-3-47
Example Slide
Through arch bridge



Slide No. 3-3-48
Example Slide
Suspension bridge



Slide No. 3-3-49
Example Slide
Cable-stayed bridge

See Slide 3-3-46

10. Deck Arch Bridge

See Slide 3-3-47

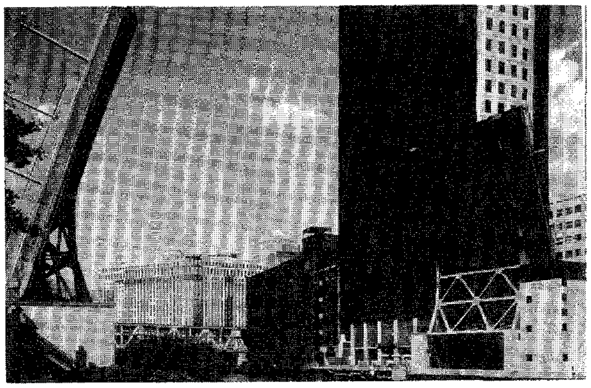
11. Through Arch Bridge

See Slide 3-3-48

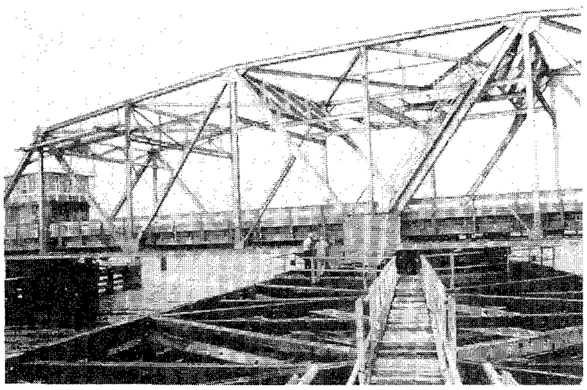
12. Suspension Bridge

See Slide 3-3-49

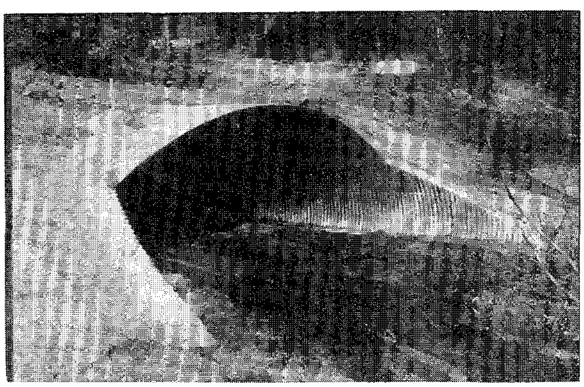
13. Cable-Stayed Girder Bridge



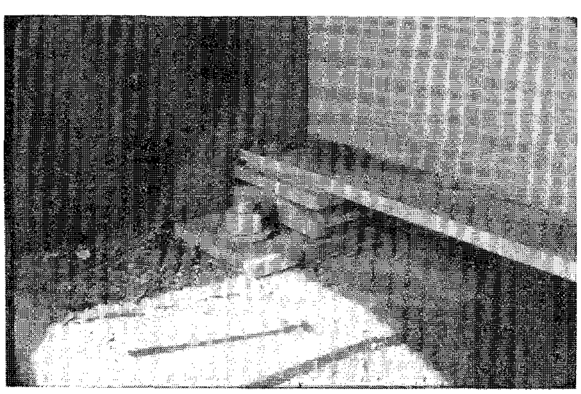
Slide No. 3-3-50
Example Slide
Bascule bridge



Slide No. 3-3-50A
Example Slide
Swing bridge



Slide No. 3-3-51
Example Slide
Culvert



Slide No. 3-3-52
Example Slide
Typical bearing showing four basic elements

See Slide 3-3-50

See Slide 3-3-50A

14. **Movable Bridge**

See Slide 3-3-51

15. **Culverts**

Although culverts are not classified as a superstructure, they provide a similar function.

Culverts are an entity to themselves. They do not have a deck, superstructure, or substructure.

VII. BEARINGS

See Slide 3-3-52

A. DEFINITION

A bridge bearing is a superstructure element which provides an interface between the superstructure and the substructure.

B. PRIMARY FUNCTION

There are three primary functions of a bridge bearing:

1. **Transmit all loads** from the superstructure to the substructure.

2. **Permit longitudinal movement** of the superstructure due to thermal expansion and contraction.

3. **Allow rotation** caused by dead and live load deflection.

Bearings that do not allow for translation or movement of the superstructure are referred to as fixed bearings.

Bearings that allow for the displacement of the structure are known as expansion bearings.

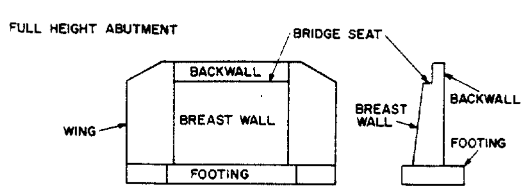
Both fixed and expansion bearings permit rotation.

Substructure

The abutments and piers that support the bridge superstructure.

Slide No. 3-3-53

Narrative Slide



Slide No. 3-3-54

Example Slide

Cantilever abutment

C. BASIC ELEMENTS

A bridge bearing can be broken down into four basic elements:

- Sole plate
- Masonry plate
- Bearing or bearing surfaces
- Anchorage

D. BEARING TYPES

Various bearing types have evolved out of the need to accommodate superstructure movement.

1. **Sliding Plate Bearings**
2. **Roller Bearings**
3. **Rocker Bearings**
4. **Pin and Link Bearings**
5. **Elastomeric Bearings**
6. **Pot Bearings**
7. **Restraining Bearings**

VIII. SUBSTRUCTURES

The substructure is the abutments and piers that support the bridge superstructure.

The substructure includes those parts of the bridge structure which transmit the loads from the bridge span to the supporting ground below. Typically the substructure includes all elements below the bearings.

The loads are then distributed to the earth or to supporting piles through the footing. The footing is the enlarged, or spread out, lower portion of a substructure and is most commonly a thick concrete slab.

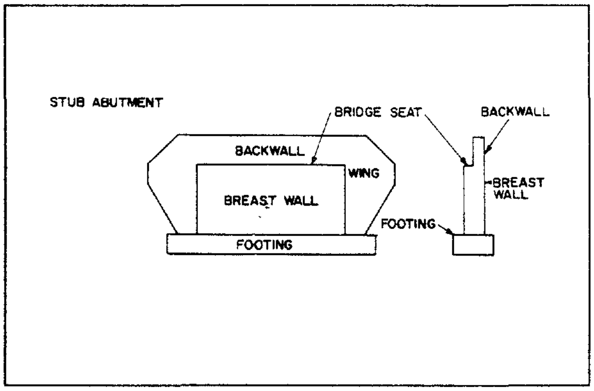
A. ABUTMENTS

The function of an abutment is to provide end support for the bridge and retain the approach embankment.

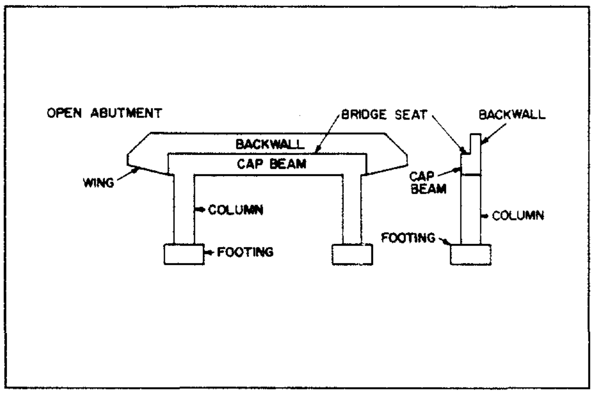
Basic Types of Abutments

See Slide 3-3-54

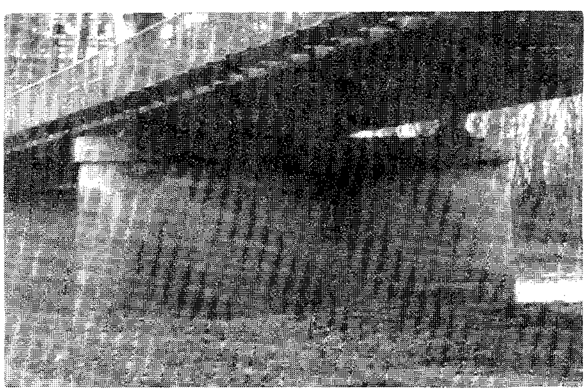
1. **A Full Height Abutment** - will extend from the grade line of the roadway or waterway below, to that of the road overhead.



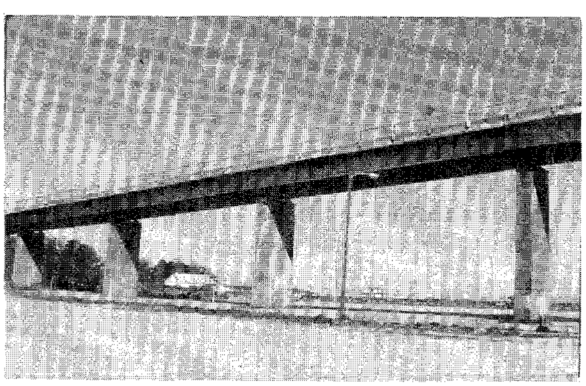
Slide No. 3-3-55
Example Slide
Stub abutment



Slide No. 3-3-56
Example Slide
Open abutment



Slide No. 3-3-57
Example Slide
Solid shaft pier



Slide No. 3-3-58
Example Slide
Column pier

See Slide 3-3-55

2. **Stub, Semi-Stub or Shelf Abutment** - will be located within the topmost portion of the end of an embankment or slope. In the case of a stub, you will see less of the breastwall or stem than in the case of the full height. Most new construction uses this type of abutment. These abutments may be required to be supported on piles.

See Slide 3-3-56

3. **Spill-Through or Open Abutment** - consists of columns, and has no solid wall, but rather, is open to the embankment material. The approach embankment material is usually rock.

See Slide 3-3-57

B. PIERS AND BENTS

The function of a bridge pier is to support the bridge spans with a minimum obstruction to the flow of traffic or water. Functionally there is no difference between a pier and a bent. The difference is in the physical appearance. We will first discuss piers.

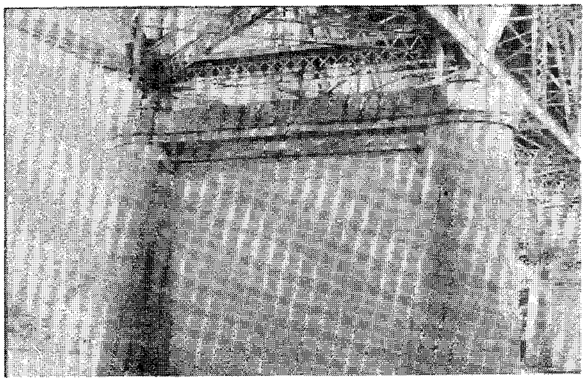
1. Basic Types of Piers

There are four basic types of piers:

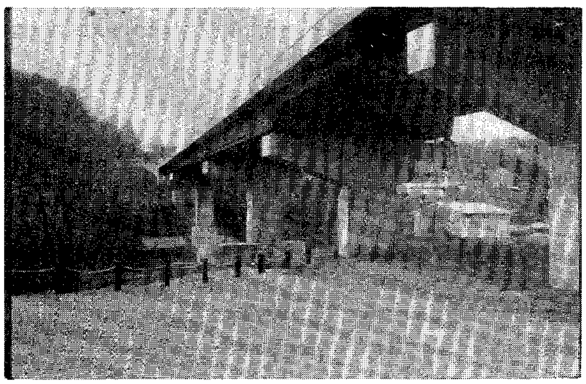
- Solid Shaft Pier

See Slide 3-3-58

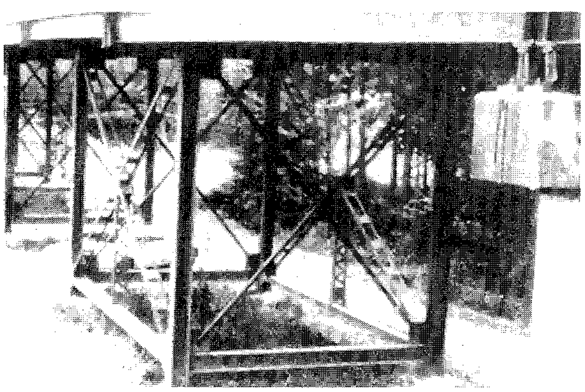
- Column Pier



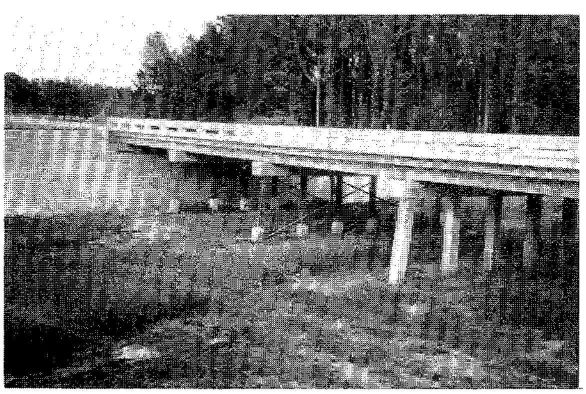
Slide No. 3-3-59
Example Slide
Column pier with webwall



Slide No. 3-3-60
Example Slide
Hammerhead pier



Slide No. 3-3-61
Example Slide
Column Bent



Slide No. 3-3-62
Example Slide
Pile bent (H-piles and prestressed concrete piles)

See Slide 3-3-59

- Column Pier With Web Wall

See Slide 3-3-60

- Cantilever or Hammerhead Pier

See Slide 3-3-61

2. Basic Types of Bents

There are two basic types of bents:

- Column Bents

See Slide 3-3-62

- Pile Bent

Summary

- Major Bridge Components
- Basic Member Shapes and Connections
- Decks
- Deck Joints and Drainage
- Roadway Appurtenances
- Superstructures
- Bearings
- Substructures

Slide No. 3-3-63
Title Slide

IX. SUMMARY

A. MAJOR BRIDGE COMPONENTS

B. BASIC MEMBER SHAPES AND CONNECTIONS

C. DECKS

D. DECK JOINTS AND DRAINAGE

E. ROADWAY APPURTENANCES

F. SUPERSTRUCTURES

G. BEARINGS

H. SUBSTRUCTURES

FUNDAMENTALS OF BRIDGE INSPECTION

SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION

TOPIC 1: DUTIES OF THE BRIDGE INSPECTOR

LESSON PLAN

TOPIC DURATION	15 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 5
GOAL	Awareness and an understanding of the duties required for a proper bridge inspection.
OBJECTIVE	To be able to list the duties of the bridge inspector.

Duties of the Bridge Inspector

- Planning
- Preparation
- Inspection
- Report
- Recommendations

Slide No. 4-1-1

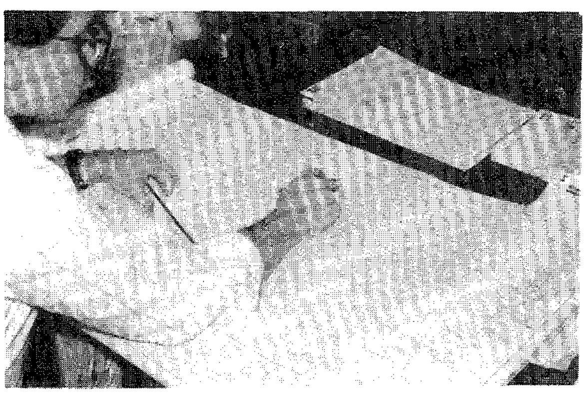
Narrative Slide

Duties of the Bridge Inspector

- Planning

Slide No. 4-1-2

Narrative Slide



Slide No. 4-1-3

Example Slide

Office personnel planning an inspection while overlooking design drawings.

Duties of the Bridge Inspector

- Planning
- Preparation

Slide No. 4-1-4

Narrative Slide

I. INTRODUCTION

There are five basic duties of the bridge inspector:

- Planning the inspection
- Preparation for the inspection.
- Performing the inspection.
- Reporting the inspection findings.
- Providing appropriate repair or maintenance recommendations.

The duties of the inspector are simply the tasks that must be performed in order to fulfill the responsibilities that come with the job.

What are the basic activities the inspector must do in each of these tasks or duties?

II. DUTIES

A. PLANNING

See Slide 4-1-3

Planning the inspection is necessary for an organized, cost-effective effort which will result in a thorough and complete inspection.

Basic activities are:

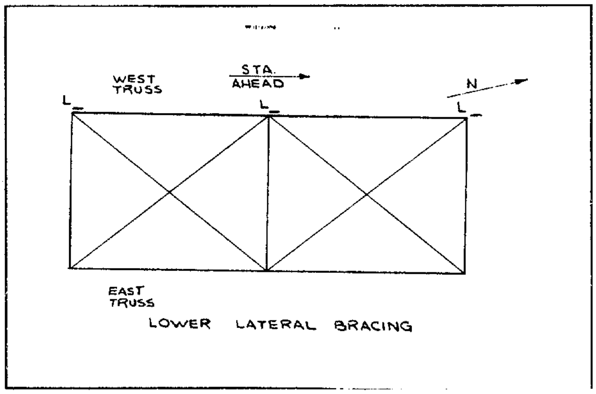
- Determine type of inspection
- Selection of the inspection team
- Evaluation of required activities
- Development of an inspection sequence
- Establishment of a schedule

B. PREPARATION

Preparing for the inspection enables the inspector to work efficiently and make accurate evaluations at the bridge site.

Basic activities are:

- Review bridge structure file (including as-built plans)
- Organize tools and equipment
- Arrange for or sub-contract special activities



Slide No. 4-1-5

Schematic Slide

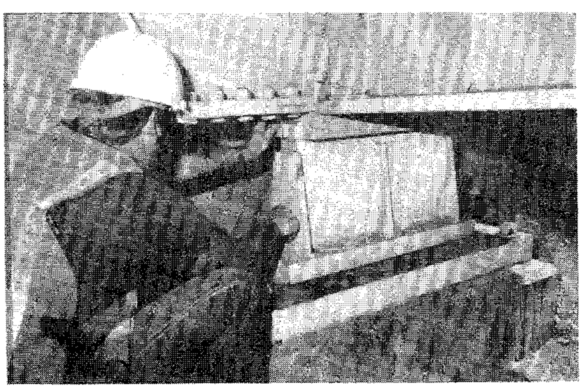
Premade field sketches for data collection

Duties of the Bridge Inspector

- Planning
- Preparation
- Inspection

Slide No. 4-1-6

Narrative Slide



Slide No. 4-1-7

Example Slide

Bridge inspector examining a bearing

Duties of the Bridge Inspector

- Planning
- Preparation
- Inspection
- Report

Slide No. 4-1-8

Narrative Slide

See Slide 4-1-5

- Prepare field sketches and notes for data collection
- Hold an inspection team meeting and review inspection procedures

C. INSPECTION

This duty is the physical work of accessing and examining bridge components and it makes up about 75% of an inspector's job.

Most inspectors incorrectly limit their job description to "performing the inspection".

Inspection procedures as per NBIS should always be followed.

Basic activities are:

See Slide 4-1-7

- Visual examination of bridge components
- Physical examination of bridge components
- Evaluation of bridge components

After inspection of a bridge component, the inspector mentally forms an evaluation based on the findings.

For the inspector's evaluation to be substantiated, all inspection findings must be documented or recorded. Documentation is referred to as the "report."

D. REPORT

Report preparation is a duty which reflects the effort that the inspector puts into performing the inspection. Both must be comprehensive. The report is a record of the bridge condition and the inspector's work.

Basic activities are:

- Completion of agency forms
- Objective documentation of all inspection findings
- Providing photo references and sketches
- Objective evaluation of bridge components

Duties of the Bridge Inspector

- Planning
- Preparation
- Inspection
- Report
- Recommendations

Slide No. 4-1-9

Narrative Slide

E. RECOMMENDATIONS

The final basic duty is providing repair/maintenance recommendations.

The inspector must make proper recommendations to ensure public safety and maximize the life of the bridge.

III. SUMMARY

In summary, these five basic duties of the bridge inspector are an accurate job description.

Each duty is essential to a comprehensive bridge inspection.

A good inspector will be familiar with these duties.

SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION

TOPIC 2: SAFETY PRACTICES

LESSON PLAN

TOPIC DURATION	60 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 5
GOAL	An understanding of the importance of a proper attitude awareness toward safe inspection practices. To understand the causes of accidents.
OBJECTIVE	Be able to list and describe the use of personal safety equipment and safety precautions recommended for bridge inspections.
PARTICIPATION	Participants with inspection experience will be encouraged to give examples of safety problems they have encountered.

Why Safety?

Slide No. 4-2-1
Title Slide

Why Safety?

Bridge Inspection is
Hazardous Work

Slide No. 4-2-2
Narrative Slide

Why Safety?

Accidents Cost Money

Slide No. 4-2-3
Narrative Slide

Fundamental Safety Rule

Practice Good Work Habits

Slide No. 4-2-4
Narrative Slide

I. GENERAL AWARENESS

A. WHY SAFETY?

1. **Bridge Inspection can be Hazardous Work** - To reduce the probability of accidents, we all need to be concerned about safety.

   Reasons for concern

   - pain, suffering, death
   - family hardship

   A worker's family also suffers hardship when an accident occurs. Not only is there loss of income, there is the inability to participate in family activities, or even, in the case of major disability, placing the burden of caring for the injured person on family members.

2. **Accidents Cost Money** - There is a price to pay in dollars for every accident.

   - **Equipment** - Repair or replacement of damaged equipment is costly.

   - **Lost Production** - The employer not only loses revenues associated with the employee's work, but also loses time and money spent on safety training and equipment.

   - **Medical Expenses** - Whether coverage is an employee benefit, personal insurance or out of pocket, someone has to pay.

Ultimately, the tax-paying public pays the bill for accidents through higher insurance premiums.

Inspectors should constantly be aware of safety concerns.

Spending the effort to be safe pays big dividends in avoided expenses and grief.

B. SAFETY FUNDAMENTALS

The most important factor in inspecting bridges safely is the inspector's concern for creating a safe working environment. A safe working environment is comprised of the proper safety attitude and suitable working conditions.

Safety Responsibilities

Slide No. 4-2-5
Title Slide

Employer Responsibilities

- Regulations and guidelines
- Training
- Proper equipment

Slide No. 4-2-6
Narrative Slide

Supervisor Responsibilities

- Job procedures
- Safety procedures guidance
- Equipment use guidance
- Enforcement of safety regulations

Slide No. 4-2-7
Narrative Slide

1. **Good Work Habits** - lead to a safe working environment.

   The inspector must:

   - Maintain proper mental and physical condition - be well rested and alert
   - Use proper tools
   - Keep work areas neat and uncluttered
   - Establish systematic procedures early in the job and practice them so everyone knows what to expect of one another
   - Follow safety rules and regulations established by OSHA, other agencies (State DOT, etc.) and your employer if you work for a consultant or contractor.
   - Use common sense and good judgement - do not engage in horseplay and do not take foolish chances

2. **Prohibit Alcohol and Drugs Use**

C. SAFETY RESPONSIBILITIES

1. **Employer** - The employer is responsible for providing a safe working environment.

   - Clear safety regulations and guidelines
   - Safety training
   - Proper tools and equipment

2. **Supervisor** - The supervisor is responsible for maintaining a safe working environment.

   - Supervision of established job procedures
   - Guidance in application of safety procedures
   - Guidance in proper use of equipment
   - Enforcement of safety regulations

Inspector Responsibilities

- Personal safety
- Co-worker's safety
- Reporting

Slide No. 4-2-8

Narrative Slide

3. **Bridge Inspector** - Each inspector is ultimately responsible for his or her own safety.

The individual bridge inspector is responsible for knowing the rules and requirements of the job. If you do not understand something or do not feel qualified to perform a particular task safely, it is your responsibility to stop and ask questions.

If a procedure appears to be unsafe, question it and constructively try to develop a better way.

Do not blindly trust your life to other people's equipment, skills and expertise. Learn about access vehicles and techniques of rigging so that you can recognize problems.

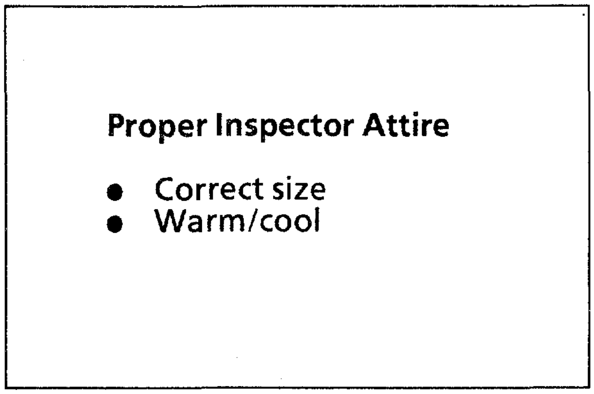
Each inspector is responsible for the safety of fellow workers.

Do not endanger coworkers by your actions. Also, warn them if you see them doing something unsafe.

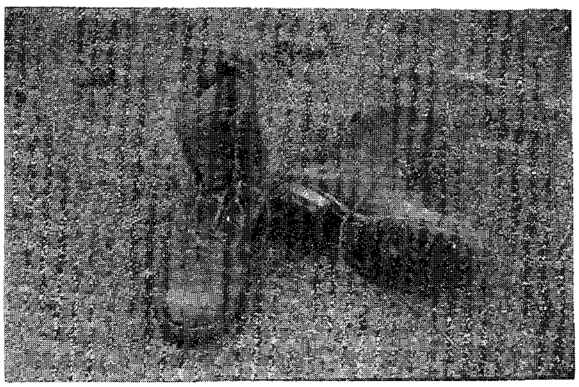
Reporting an accident:

If there is an accident, it is essential to report it to a designated individual in your agency or company within the prescribed time frame (usually 24 hours).

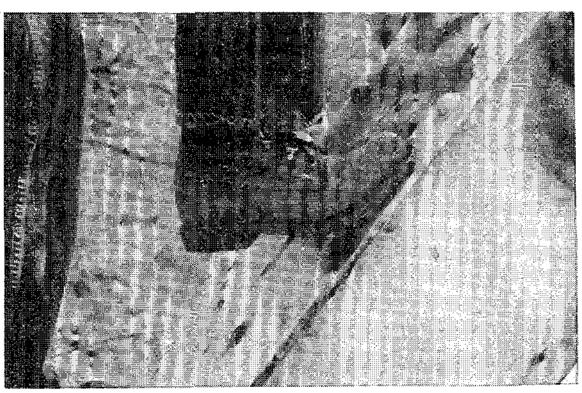
Any injury must be promptly reported in order to assure coverage, if necessary, under workmen's compensation or other insurance.



Slide No. 4-2-9
Narrative Slide



Slide No. 4-2-10
Example Slide
Traction-lug leather boot for general inspection



Slide No. 4-2-11
Example Slide
Non-slip soled leather boot for climbing inspection

Slide No. 4-2-12
Example Slide
Leather gloves used during climbing

II. PERSONAL PROTECTION

A. PROPER INSPECTION ATTIRE

It is important to dress properly for the job.

1. **Field clothes should be properly sized for the individual.**

   Loose clothing can be dangerous due to snagging.

   Tight clothing reduces mobility and comfort.

2. **Field clothes should be appropriate for the climate.**

   Daily temperature variations should be considered. Layered clothing should be worn so the inspector can make adjustments.

   An inspector can perform a safer inspection without the distraction of being cold or being hot.

See Slide 4-2-10

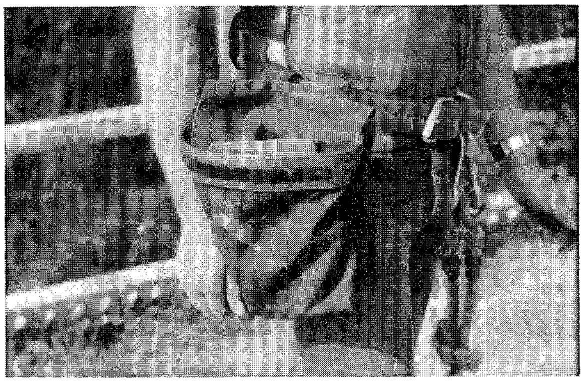
3. **Shoes** - For general inspection activities, the inspector should wear leather boots with traction lug soles.

See Slide 4-2-11

   For climbing of bridge components, the inspector should wear leather boots with a steel shank. The boots should have non-slip soles without heavy lugs (smooth soles).

See Slide 4-2-12

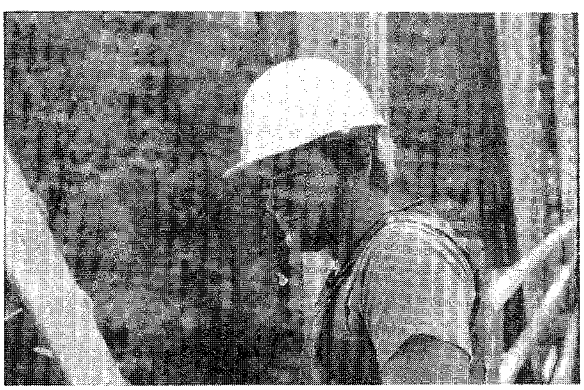
4. **Leather Gloves** - During climbing inspections, the inspector should wear leather gloves for protection against sharp edges and cold steel.



Slide No. 4-2-13
Example Slide
Tool pouch on inspector

**Inspection
Safety
Equipment**

Slide No. 4-2-14
Title Slide



Slide No. 4-2-15
Example Slide
Hard hat on an inspector

See Slide 4-2-13

5. **Tool Pouch** - Wearing a tool pouch enables the inspector to carry tools and notes, keeping the hands free. Climbing, and other inspection activities can be performed with greater safety.

B. INSPECTION SAFETY EQUIPMENT

Safety equipment is designed to prevent injury.

The inspector must use the equipment to get protection.

What are some common pieces of safety equipment?

See Slide 4-2-15

1. **Hard Hat** - Wearing a hard hat can prevent serious head injuries in two ways.

   First, it provides protection against falling objects.

   The bridge site environment during inspection activities is prone to incidences of falling objects.

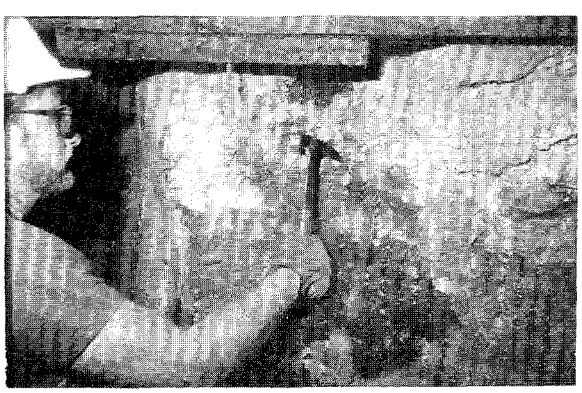
   Main concerns are:

   - Deteriorated portions of bridge components dislodged during inspection
   - Equipment dropped by overhead co-workers
   - Debris discarded by passing motorists

   During the inspection, the inspector never knows when protection is needed, therefore, a hard hat should be worn at all times.

   Secondly, a hard hat protects the inspector's head from accidental impact with bridge components.

Slide No. 4-2-16
Example Slide
Inspector on bridge deck with reflective safety vest



Slide No. 4-2-17
Example Slide
Close-up of inspector with safety goggles performing inspection with a hammer

When inspections involve climbing or access equipment, the inspector is constantly dodging various configurations of superstructure elements.

These superstructure elements can be sharp edged and are always unyielding.

A hard hat with chin strap should be worn for protection.

If the inspector makes a mistake in judgement during a maneuver, and impacts the structure, a hard hat may prevent serious injury.

See Slide 4-2-16

2. **Reflective Safety Vest** - Inspection activities near traffic require using a safety vest.

The vest should be bright orange with reflective strips.

When the motorist is aware of the inspector's presence, safety is improved.

See Slide 4-2-17

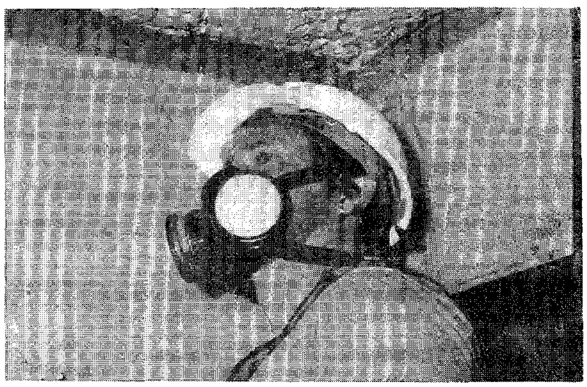
3. **Safety Goggles** - Eye protection is necessary when the inspector is exposed to flying particles.

This includes activities such as:

- Using a hammer
- Using a scraper or wire brush
- Grinding
- Shot or sand blasting
- Cutting
- Welding

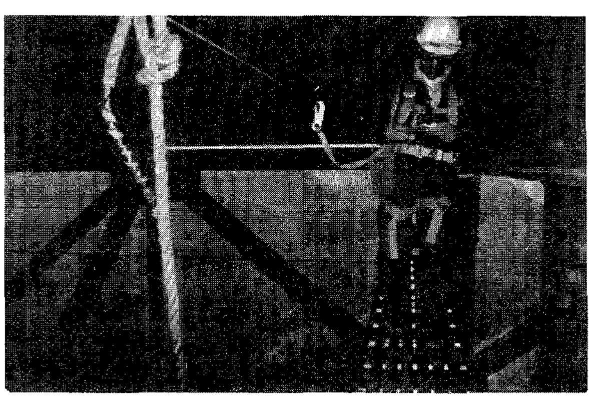
Glasses with shatterproof lenses are not adequate if side protection is not provided.

Slide No. 4-2-18
Example Slide
Inspector with life jacket working over water



Slide No. 4-2-19
Example Slide
Close-up of inspector wearing a respirator

Slide No. 4-2-20
Example Slide
Inspector wearing a safety belt with lanyard (Navajo Bridge over Grand Canyon, Arizona)



Slide No. 4-2-20A
Example Slide
Safety harness and shock absorber lanyard (New River Gorge Bridge, West Virginia)

See Slide 4-2-18

4. **Life Jacket** - A life jacket should always be worn when working over water or in a boat. If an accident occurs, good swimmers may drown if burdened with inspection equipment.

If unconscious or injured due to a fall, a life jacket will keep you afloat.

See Slide 4-2-19

5. **Respirator/Dust Mask** - A respirator or dust mask can protect the inspector from harmful airborne contaminants.

Conditions when a respirator should be used include:

- Sand blasting
- Painting
- Exposure to dust from pigeon droppings (exposure to pigeon droppings may result in hystioplasonosis, a potentially very serious illness)

Agency or OSHA regulations should be consulted for approved types and their uses.

See Slide 4-2-20

6. **Safety Belt and Lanyard** - This piece of safety equipment is the inspector's life line in the event of a fall. Use this equipment as required by conditions. Make sure you satisfy agency/OSHA requirements.

For example, one agency requires that safety belt or harness be worn in the following situations:

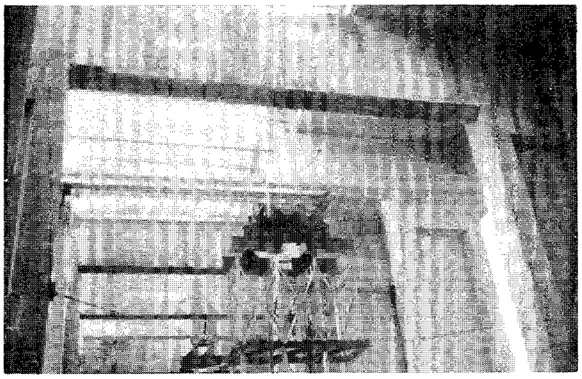
- At heights over 20 feet (6.0 m)
- Above water
- Above traffic

Just as with automobile seat belts, some people claim that safety belts cause injuries. This is partly true in that injury is possible. However, the alternative is nearly always death.

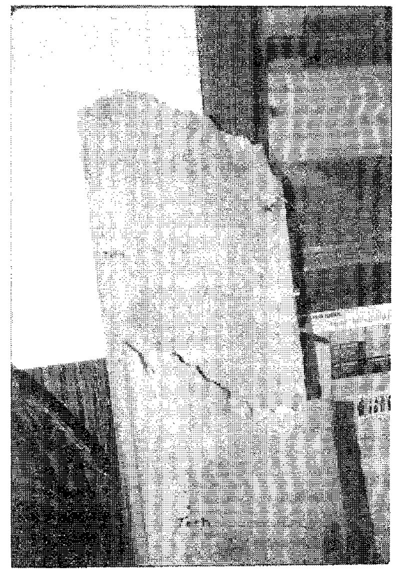
To reduce the possibility of injury, the maximum lanyard length limits a fall to six feet (1.8 m) (per OSHA regulations).

See Slide 4-2-20A

Further protection can be achieved using a shock absorber between the lanyard and the belt or harness. The shock absorber reduces g-forces through the controlled extension of nylon webbing which is prefolded and sewn together.



Slide No. 4-2-21
Example Slide
The construction site where the tragedy occurred



Slide No. 4-2-22
Example Slide
The broken plank which caused a construction worker's death because he was not tied off

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DON'T' BE SORRY

TIE OFF!

Slide No. 4-2-23
Narrative Slide

Cause of Accidents

- Human Error
- Equipment Failure

Slide No. 4-2-24
Narrative Slide

The safety belt should be tied off to a solid structural member or to a safety line rigged for this purpose.

See Slide 4-2-21

Do not tie off to scaffolding or its supporting cable.

See Slide 4-2-22

One of the reasons for tying off is to limit your fall in case the rigging or scaffold fails.

When working from a snooper or bucket truck, tie off to the structure if possible. Extreme caution must be exercised not to allow the equipment to be moved out from under someone tied to the bridge. If the machine is being moved frequently, it is best to tie off to the bucket or boom.

DON'T BE SORRY - TIE OFF.

III. CAUSES OF ACCIDENTS

A. GENERAL

Accidents are usually caused by human error or equipment failure.

Almost all accidents are due to human failings. People are not machines We all make mistakes. Part of safety awareness is acknowledging this and planning ahead to minimize the effects of those mistakes.

Accidents are sometimes caused by equipment failure not attributable to operator or user error. Inspection, maintenance, and update of equipment can minimize failures.

Improper Attitude

Slide No. 4-2-25
Title Slide

Personal Limitations

Slide No. 4-2-26
Title Slide

Physical Impairment

Slide No. 4-2-27
Title Slide

Boredom

Slide No. 4-2-28
Title Slide

B. SPECIFIC CAUSES

1. **Improper Attitude** - Distraction, carelessness, worry over personal matters.

2. **Personal Limitations** - Lack of knowledge or skill, exceeding physical capabilities.

3. **Physical Impairment** - Previous injury, illness, side effect of medication, alcohol or drugs.

4. **Boredom** - Falling into an inattentive state while performing repetitive, routine tasks increases the chances of an accident.

Thoughtlessness

Slide No. 4-2-29
Title Slide

Short-cuts

Slide No. 4-2-30
Title Slide

Faulty Equipment

- Damaged ladders
- Worn ropes
- Frayed cables

Slide No. 4-2-31
Narrative Slide

Intoxicants

Slide No. 4-2-32
Title Slide

5. **Thoughtlessness** - Lack of safety awareness and not recognizing hazards.

6. **Short Cuts** - Sacrificing safety for time.

7. **Faulty Equipment** -

- Damaged ladder rungs
- Worn ropes
- Frayed cables

IV. SAFETY PRECAUTIONS

A. GENERAL PRECAUTIONS

Some general guidelines for safe inspections are as follows:

1. **Avoid Use of Intoxicants** - Intoxicants impair judgement, reflexes and coordination.

Medication

Slide No. 4-2-33
Title Slide

Electricity

Slide No. 4-2-34
Title Slide

Assistance

Slide No. 4-2-35
Title Slide

Inspection Over Water

Slide No. 4-2-36
Title Slide

2. **Medication** - Prescription and over the counter medications can cause drowsiness or other unwanted, potentially dangerous side effects.

3. **Electricity** - A potential killer. All cables and wires should be assumed hot (live), even if they appear to be telephone cables .

   The conditions encountered on many bridges are conducive to electric shock. These conditions include steel members, humidity, perspiration, and damp clothing.

   Transmission lines on a structure should be identified prior to the inspection. All power lines should be shut down.

   In rural areas, electric fences can be a hazard and should be avoided.

4. **Assistance** - Always work in pairs. An inspector should not take any action without someone else there to help in case of an accident.

   Always make sure someone else knows where you are. If someone seems to be missing, locate that person.

5. **Inspection over water** - A safety boat must be provided when working over bodies of water.

   It should be equipped with a life ring and have radio communication with the inspection crew.

Waders

Slide No. 4-2-37
Title Slide

Inspection Over Traffic

Slide No. 4-2-38
Title Slide

Dark Areas

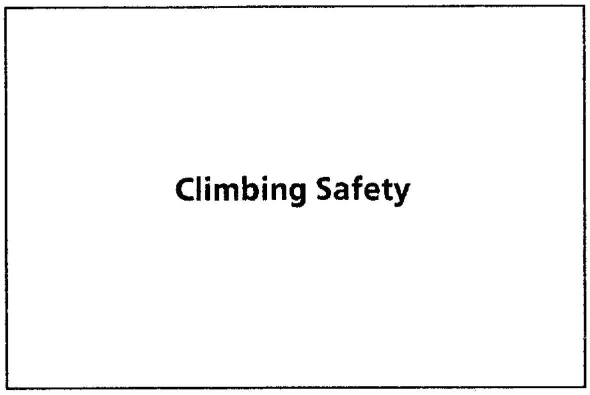
Slide No. 4-2-39
Title Slide

6. **Waders** - Caution should be used when wearing waders. If the inspectors falls into a scour hole, they can fill with water, making swimming impossible.

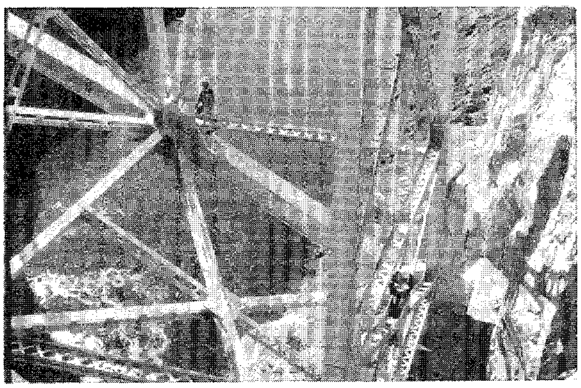
7. **Inspection over Traffic** - Note that it is best to avoid working above traffic.

   If it cannot be avoided, tools, notebooks, etc. should be tied off.

8. **Entering Dark Areas** - Use a flashlight to illuminate dark areas prior to entering as a precaution against falls, snakebites, and stinging insects.

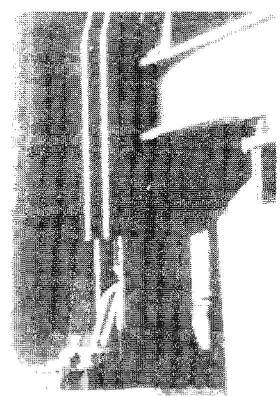


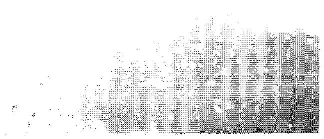
Slide No. 4-2-40
Title Slide



Slide No. 4-2-41
Example Slide
Intricate climbing inspection showing need for organization (Navajo Bridge over Colorado River at Grand Canyon, Arizona)

Slide No. 4-2-42
Example Slide
Wet weather conditions





Slide No. 4-2-43
Example Slide
Wet weather conditions

B. CLIMBING SAFETY

There are three areas of preparation necessary for a safe climbing inspection:

See Slide 4-2-41

1. **Organization of the Inspection** - A good inspection procedure incorporates a climbing strategy that minimizes climbing time. For example: beginning the day with an inspection of a truss span from one bent and finishing at the next bent by lunch time eliminates unproductive climbing across the span.

   The inspection procedure should have an inspection plan so the inspector knows where to go, what to do, and what tools needed to perform the inspection. An organized inspection reduces the chance of the inspector falling or getting stuck in a position unable to get down.

See Slide 4-2-42

   Weather conditions are a primary consideration when organizing a climbing inspection. Moderate temperatures and a sunny day are desirable.

   Rain conditions warrant postponement of steel bridge inspections as wet steel is extremely slippery.

   After a rainy day, the inspector must be sure that boots are free of mud and use extreme caution in areas where debris accumulation may cause a slippery surface.

See Slide 4-2-43

   Traffic should not be obstructed during bad weather.

Equipment Check

Slide No. 4-2-44
Title Slide

Slide No. 4-2-45
Example Slide
Proper ladder use

2. **Equipment Check** - The inspection team should be well equipped.

Personal attire should be checked for suitability to the job.

- **Clothing** - proper for climbing activities and temperature

- **Jewelry** - rings, bracelets, and necklaces should never be worn.

  In an accident, jewelry can become snagged and cause additional injury.

- **Eyeglasses** - Only single lens glasses should be worn. Bifocals should not be worn because split vision impairs the inspector's ability to climb safely.

Inspection equipment should be checked for proper use and condition.

See Slide 4-2-45

- **Ladders** - Accidents involving ladders are the most common.

  In order to use a ladder properly, these things are needed:

  Sufficient length for the job.

  3:1 tilt with blocked bottom.

  An assistant for ladders over 25 feet (7.6 m), and making sure the top is tied off.

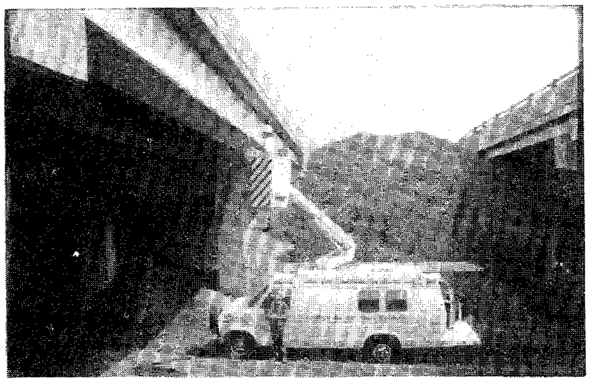
  Inspecting the ladder, prior to use, for cracked or defective rungs and rails.

  Correct climbing technique using both hands, facing the ladder, and keeping your belt buckle over the rungs.

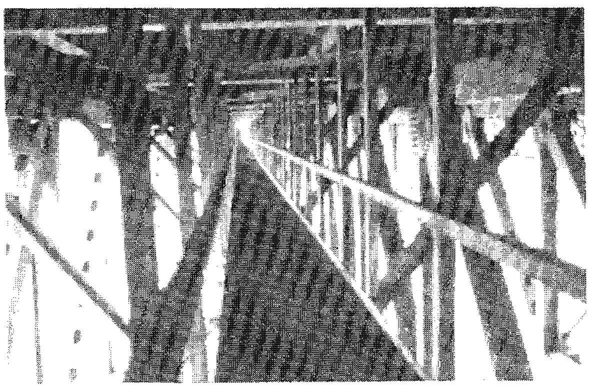
  Using a hand line to lift equipment or tools.

- **Scaffolding** - Scaffolding should be checked for the height and capacity necessary to support the inspection team.

  Load tests can be performed on the ground with planned equipment and personnel.

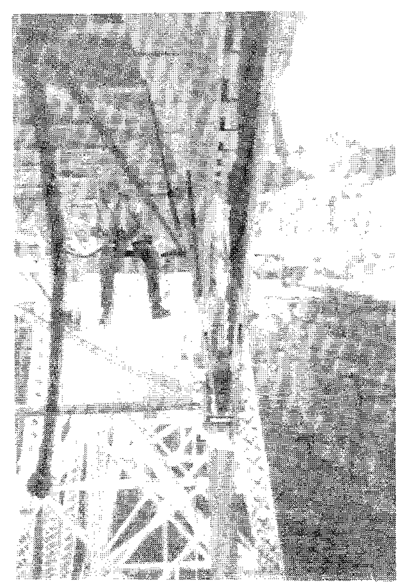


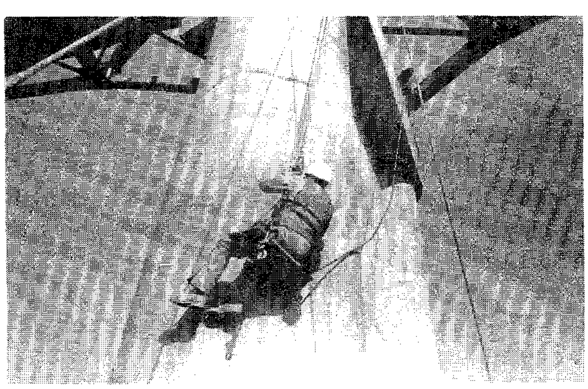
Slide No. 4-2-46
Example Slide
Bucket truck inspection



Slide No. 4-2-47
Example Slide
Inspection catwalk

Slide No. 4-2-48
Example Slide
Inspection rigging





Slide No. 4-2- 48A
Example Slide
Bosun's chair
(James Rumsey Bridge, West Virginia)

A daily inspection for cracks, loose connections, and weak areas should be performed prior to use.

- **Timber Planks** - Single planks should never be used. Two or more planks securely cleated together should be used. Plank ends should be securely attached to their supports. All planks should be inspected for knots, splits, cracks and deterioration prior to use.

See Slide 4-2-46

- **Inspection Vehicles** - If possible, use platform trucks, bucket trucks and snoopers. Confirm that they are in safe operating condition.

See Slide 4-2-47

- **Catwalks and Travelers** - Permanent inspection access devices are ideal. However, the inspector should be on guard for deterioration of elements - flooring, hand hold rods, cables, etc.

See Slide 4-2-48

- **Rigging** - The inspector should be familiar with proper rigging techniques.

  Support cables should be 1/2 inch (13 mm) in diameter.

  The working platform or "stage" should be at least 20 inches (510 mm) wide.

  A separate safety line or tie-off cable is mandatory.

See Slide 4-2-48A

  Use common sense with regard to rigging. Do not trust your life blindly to the riggers. If you feel a procedure is unsafe or doubtful, question it and get it changed if necessary. Do not rely on ropes or planks left on the bridge by prior work. They may be rotted or not properly attached.

Mental Attitude

Slide No. 4-2-49
Title Slide

Confined Spaces

Slide No. 4-2-50
Title Slide

Safety Concerns

- Lack of oxygen
- Toxic gases
- Explosive gases

Slide No. 4-2-51
Narrative Slide

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3. **Mental Attitude** - The inspector must be mentally prepared to do a climbing inspection. A good safety attitude is of foremost importance.

Three precautions that must be addressed are:

- **Avoid Emotional Distress** - Do not climb when emotionally upset. The Inspector who climbs must have complete control, otherwise the chances of falling increase.

- **Know where you are** - Always be aware of where you are and what you are doing when climbing. Do not become so engrossed in the job that you step into mid-air.

- **Do not do anything you are not confident of doing safely.** If there is a feature you cannot safely inspect with the equipment available, do not do it. Highlight this fact in the notes so that appropriate equipment can be scheduled if necessary. Do not hide the fact that something was not inspected.

C. CONFINED SPACES

1. **Safety Concerns** - The basic structure types where inspection must be performed in a "confined space" are:

- Box girder bridges and hollow pier caps

- Long culverts

There are three main concerns when inspecting within a confined space:

- The first concern is lack of oxygen. Oxygen content must be above 19% for the inspector to remain conscious.

- The second concern is toxic gases. Toxic gases are generally produced by work processes such as painting, burning and welding.

- The third concern is explosive gases. Explosive gases such as natural gas and methane are produced by natural oxidation of organic matter.

2. **Safety Procedures** - When a confined area must be inspected, the appropriate safety procedure should be followed.

Safety Procedures

- Pre-entry tests
- Mechanical ventilation
- Tests during occupancy

Slide No. 4-2-52

Narrative Slide

Precautions

Slide No. 4-2-53

Title Slide

Pre-entry air tests:

- Test for oxygen at two separate locations with an approved oxygen testing device.

- Test for other gases.

  - Carbon monoxide
  - Hydrogen sulfide
  - Methane
  - Natural gas
  - Combustible vapors

Mechanical ventilation:

- **Pre-entry** - Oxygen and gas levels must be acceptable for a minimum of 15 minutes prior to entry.

- **During Occupancy** - Ventilation should be continuous regardless of activities.

Post-entry air tests:

- Test for oxygen and other gases at 15 minute intervals during occupancy.

3. Precautions

- Follow basic safety procedures.

- Avoid use of flammable liquids in the confined area.

- Position inspection vehicles away from the area entrance to avoid carbon monoxide fumes.

- Position gasoline powered generators "down-wind" of operations.

- Operations producing toxic gases should be performed "down-wind" of the operator and the inspection team.

- Use approved air-breathing apparatus when ventilation is not possible and/or detection equipment is not available.

Safety First

- Safety conscious attitude
- Common sense

Slide No. 4-2-54
Narrative Slide

PLEASE

BE

CAREFUL

Slide No. 4-2-55

D. SUMMARY

Safety is the first concern in the field. Working safely cannot be replaced by the desire to get the job finished. Bridge inspection is inherently dangerous and therefore requires continual vigilance on the part of every member of the inspection team. Two of the more important factors are:

- Common sense
- Safety conscious attitude

Remember - safety must be practiced at all times to be effective.

PLEASE BE CAREFUL

All of these requirements for traffic control devices. have been factored into the various agencies' guidelines for work area traffic control. These guidelines represent sincere efforts by trained people. It is simpler to follow the direction given than to make up your own traffic patterns. It is also your legal and moral duty.

B. TYPES OF TRAFFIC CONTROL DEVICES

1. Signs

See Slide 4-3-14

- Regulatory - "Speed Limit 40 mph (65 km/hr)"; "DO NOT PASS"
- Warning - "Road Construction"; "Work Area Ahead"; "Slow"
- Guide Signs - Directional and destination signs. Not used for bridge inspection traffic control unless a detour is established.

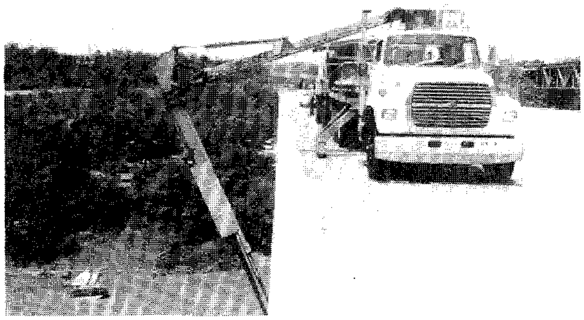
2. Channelizing Devices

The functions of channelizing devices are to warn and alert drivers of hazards created by construction or maintenance activities in or near the traveled way, and to guide and direct drivers safely past the hazards. Channelizing devices include but are not limited to cones, vertical panels, wands, drums, barricades, and barriers.

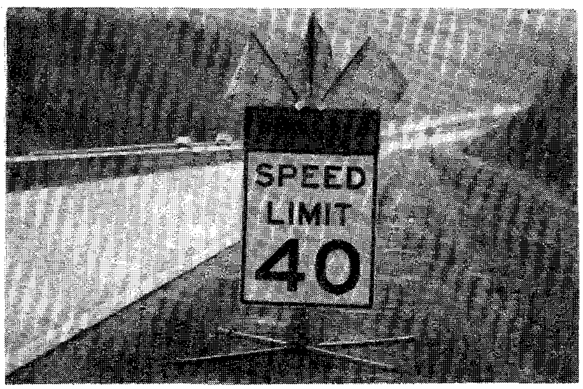
See Slide 4-3-16

Devices used for channelization should provide a smooth and gradual transition in moving traffic from one lane to another, onto a bypass or detour, or in reducing the width of the traveled way. They should be constructed so as not to inflict any undue damage to a vehicle that inadvertently strikes them. The objective is a traffic control plan which uses a variety of traffic control measures and devices in whatever combination necessary to assure smooth, safe vehicular movement past the work area and at the same time provide safety for the equipment and the workers on the job.

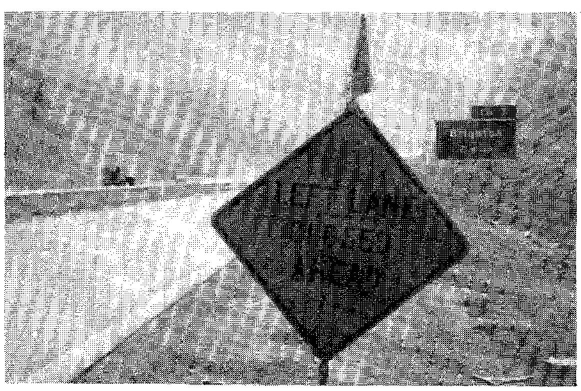
Channelizing devices are elements in a total system of traffic control devices for use in highway construction and maintenance operations. These elements shall be preceded by a subsystem of warning devices that are adequate in size, number, and placement for the type of highway on which the work is to take place.



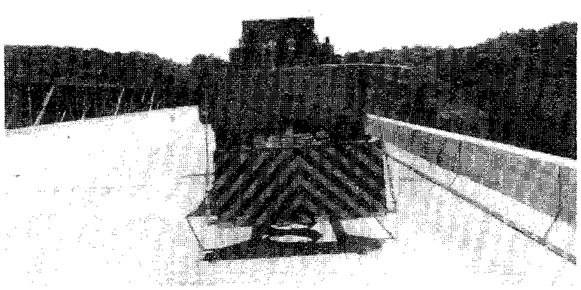
Slide No. 4-3-1
Example Slide
A Snooper truck can be a hidden object to the motorist



Slide No. 4-3-2
Example Slide
A speed reduction sign



Slide No. 4-3-3
Example Slide
Lane shift signs provide smooth flow of traffic through work area



Slide No. 4-3-4
Example Slide
Shadow vehicle

I. INTRODUCTION

Bridge inspection, like construction and maintenance activities on bridges, often presents motorists with unexpected and unusual situations. Most state agencies have adopted the federal *Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD).* Some states and local jurisdictions, however, issue their own manuals.

When working in an area exposed to traffic, the bridge inspector should check, and follow, the existing standards. These standards will prescribe the minimum procedures for a number of typical applications and the proper use of standard traffic control devices such as cones, signs, and flashing arrow-boards.

II. PURPOSE AND OBJECTIVES

A. PHILOSOPHY

The idea of a good traffic control plan is the safe and efficient movement of traffic and the protection of bridge inspectors at work areas. To accomplish this plan we must address four important issues:

See Slide 4-3-1

1. **Inform the motorist** - give adequate warning of what to expect in the roadway; avoid the sudden surprise.

See Slide 4-3-2

2. **Control the motorist** - to reduce speed.

See Slide 4-3-3

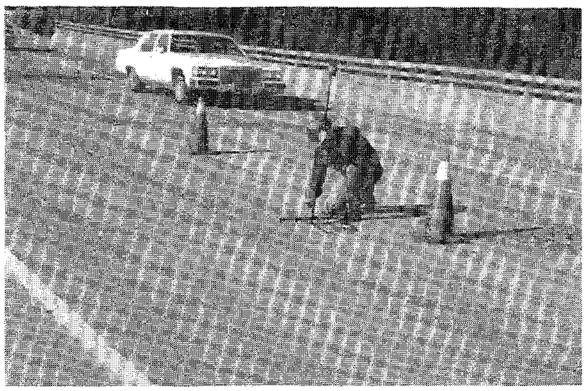
3. **Provide a clearly marked path** to permit traffic to flow through the work zone.

See Slide 4-3-4

4. **Use positive protection**, such as a shadow vehicle (crash truck) with an attenuator.

Inspector Safety

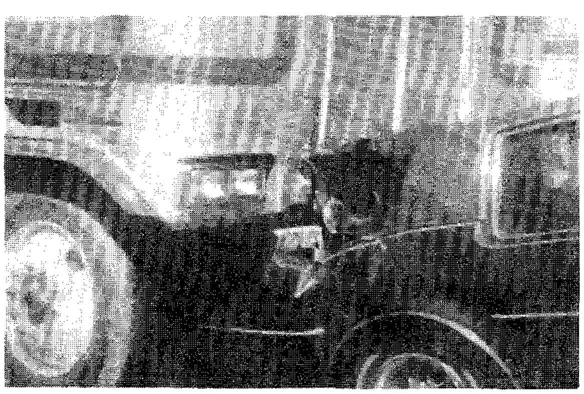
Slide No.5
Title Slide



Slide No. 4-3-6
Example Slide
Inspector with safety vest and hard hat but unsafely exposing himself outside the work zone

Public Safety

Slide No. 4-3-7
Title Slide



Slide No. 4-3-8
Example Slide
Traffic accident during a bridge inspection

B. INSPECTOR SAFETY

1. **Traffic** - represents as great, or even greater, threat to the inspector's safety than climbing high steel. The work zone is intended to be a safe haven from traffic so the inspectors can concentrate on doing their jobs.

   As such, the work zone needs to be clearly marked so as to guide the motorist around it, and, insofar as possible, physically prevent errant vehicles from entering. The work zone should be as compact as possible to minimize traffic disruption, but must be wide enough and long enough to permit access to the area to be inspected and allow for safe movement of workers and equipment.

2. **Inspection vehicles** - need to be made visible to the motorist with flashing marker lights or arrow boards as appropriate.

See Slide 4-3-6

3. **Individuals in a work zone** must wear approved safety vests and hard hats for visibility and identification. They also help make the inspector look "official" to the public. (People sometimes get upset if they see someone climbing around on a bridge and call the police to report a "jumper".) The inspectors should also stay within the work zone for their own safety.

C. PUBLIC SAFETY

Since the fundamental goal of bridge inspection is to enhance public safety, it would make little sense to endanger that same public by inadequate traffic control measures. Traffic control does take time, money and effort. It is, however a necessary part of the business of bridge inspection. A taxpayer killed running into the back of a snooper truck is just as dead as one crushed by a falling bridge!

See Slide 4-3-8

In the broadest sense, the motorist is the customer of everyone in the transportation industry. Like everyone else, bridge inspectors need to treat customers well, inconveniencing them as little as possible and protecting their safety. This means providing well thought out, clear, and effective maintenance of traffic measures.

Pedestrians also must be considered. If a walkway must be closed, it should be properly signed and barricaded. An alternate route for the walker should be indicated, if necessary through, or preferably around the work zone.

Slide	Description
Responsibility	Slide No. 4-3-9 Title Slide
Protect Yourself - Follow the Book	Slide No. 4-3-10 Narrative Slide
Traffic Control Devices	Slide No. 4-3-11 Title Slide
Decision Process • Sensing • Perceiving • Analyzing • Deciding • Responding	Slide No. 4-3-12 Narrative Slide Decision process

D. RESPONSIBILITY

Legally and morally it is your responsibility to follow the regulations and guidelines of the agency having jurisdiction.

The primary goal of good traffic control is to prevent accidents. A secondary goal is to be able to defend yourself and your employer should there be an accident. Accidents bring lawsuits. Lawsuits bring inquiries about who did what. Anything not done in accordance with published regulations and directives brings blame upon whoever violated the regulation. Being blamed for an accident is expensive.

Lawsuits aside, no one wants to be responsible for death or injury to someone else. It behooves all of us to do the best we can all the time to make work areas safe for ourselves, our fellow workers, and our fellow citizens: the motorists and pedestrians.

PROTECT YOURSELF - FOLLOW THE BOOK

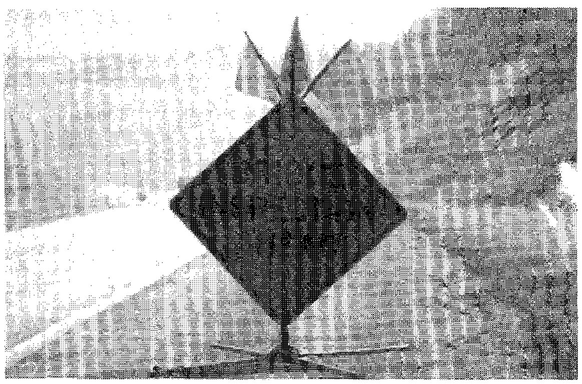
III. TRAFFIC CONTROL DEVICES

A. THERE ARE SOME BASIC REQUIREMENTS FOR EFFICIENT TRAFFIC CONTROL DEVICES.

1. **They must be visible and attention getting.**
2. **They must give clear direction.**
3. **They must command respect.**
4. **They must elicit the proper response at the proper time.**
   - "The decision process includes the classical chain of sensing, perceiving, analyzing, deciding, and responding"
   - Perception-reaction time 2.5 seconds
   - Traffic control has to accommodate wide range of vehicles - little cars to huge combination tractor-trailers- and driver skills, which may be impaired by alcohol, drugs, drowsiness, etc.

Signs

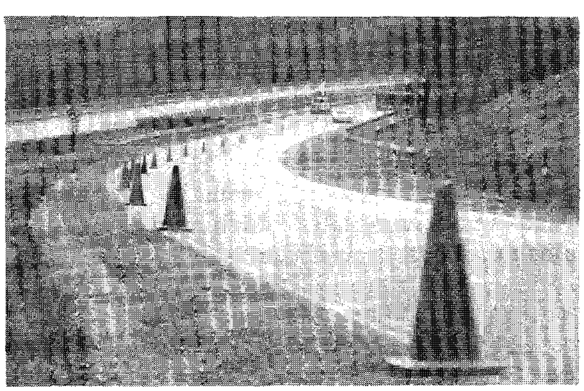
Slide No. 4-3-13
Title Slide



Slide No. 4-3-14
Example Slide
Warning signs

Channelizing Devices

Slide No. 4-3-15
Title Slide



Slide No. 4-3-16
Example Slide
Cones used to channel traffic for lane closure

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See Slide 4-3-16

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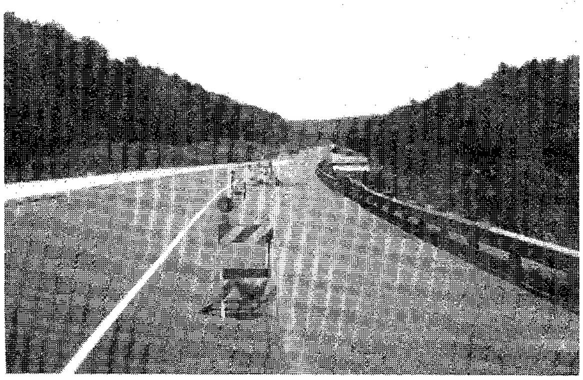
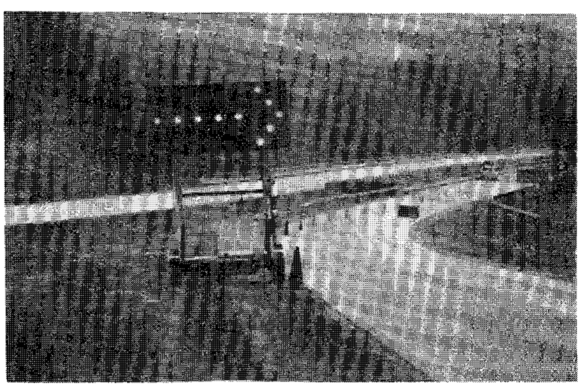
Lighting

Slide No. 4-3-17
Title Slide



Slide No. 4-3-18
Example Slide
Flashers attached to channelizing devices



Slide No. 4-3-19
Example Slide
Arrow board

Flaggers

Slide No. 4-3-20
Title Slide

Typical channelizing devices:

- Cones
- Drums
- Wands
- Vertical panels
- Barricades
- Portable concrete barrier sections - these are seldom applicable to bridge inspection due to the short duration of the work.

3. Lighting - another type of control device.

See Slide 4-3-18

- Flashers - attached to signs or other devices to attract attention or for night visibility.

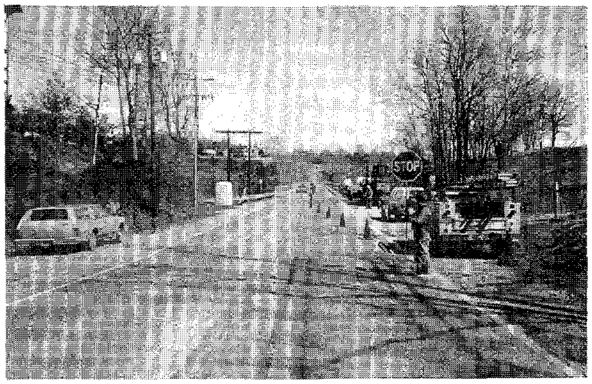
See Slide 4-3-19

- Arrowboards - for lane control.

- Floodlights - to illuminate work area at night and/or assist motorists in negotiating a restricted area. Should only be required for bridge inspection in emergencies or in extremely high traffic volume areas where lane restrictions are only feasible at night.

4. Flaggers

A number of hand signals such as STOP/SLOW paddles, lights, and red flags are used to control traffic through work zones. The sign paddle bearing the clear messages STOP or SLOW provides motorists with more positive guidance than flags and is generally the primary hand signaling device. Flag use shall be limited to emergency situations and at spot locations which can best be controlled by a single flagger, if permitted by the Agency.



Slide No. 4-3-21
Example Slide
Flagger

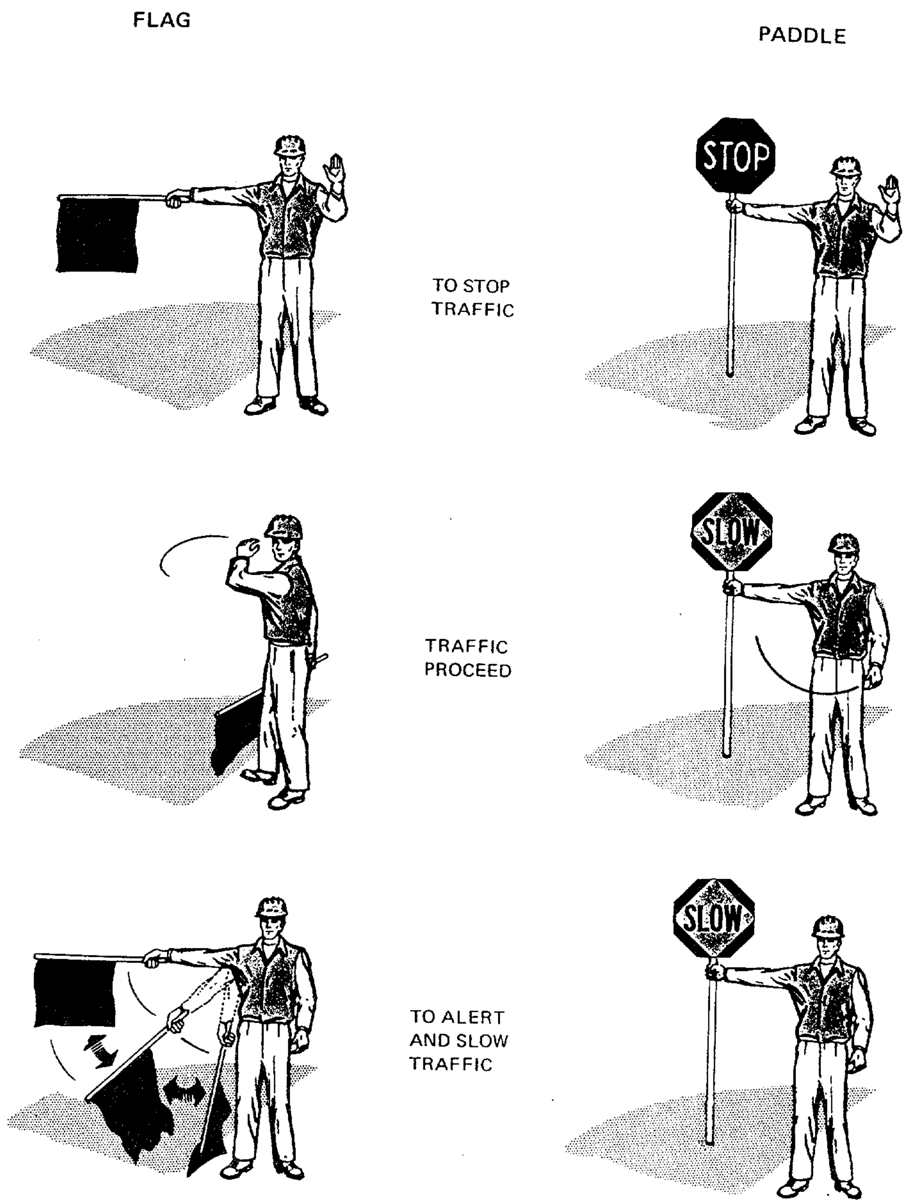
See Slide 4-3-21

Since flaggers are responsible for human safety and make the greatest number of public contacts of all construction personnel, it is important that qualified personnel be selected. A flagger should possess the following minimum qualifications:

- Good common sense
- Good physical condition, including sight and hearing
- Mental alertness
- Courteous but firm manner
- Neat appearance
- Sense of responsibility for safety of public and crew

The use of hard hat and orange clothing such as a vest, shirt, or jacket should be required for flaggers. For nighttime conditions similar outside garments should be reflectorized.

Flaggers are provided at work sites to stop traffic intermittently as necessitated by work progress or to maintain continuous traffic past a work site at reduced speeds to help protect the work crew. For both of these functions the flagger must, at all times, be clearly visible to approaching traffic for a distance sufficient to permit proper response by the motorist to the flagging instructions and to permit traffic to reduce speed before entering the work site (generally several hundred feet, depending on site conditions). In positioning flaggers consideration must be given to maintaining color contrast between the work area background and the flagger's protective garments.



Use of Hand Signaling Devices by Flagger (From MUTCD, 1988 Edition, page 6F-3)

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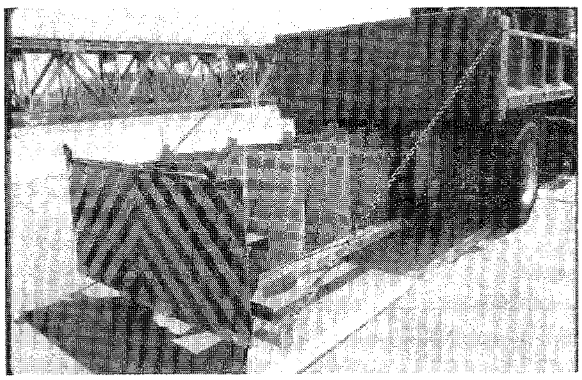
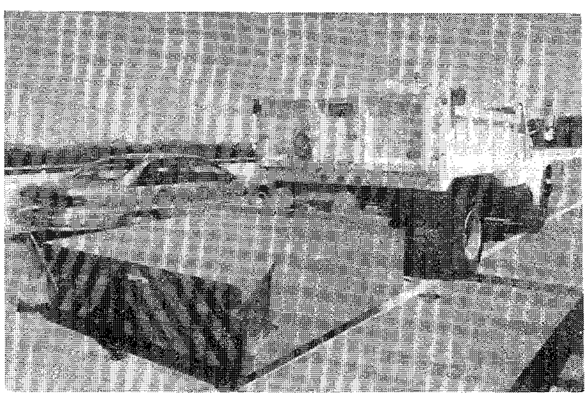
Shadow Vehicles with TMA's

Slide No. 4-3-22
Title Slide



Slide No. 4-3-23
Example Slide
Shadow vehicle with attenuator



Slide No. 4-3-24
Example Slide
Shadow vehicle with attenuator

Traffic Control

Slide No. 4-3-25
Title Slide

See Slide 4-3-23

5. **Shadow Vehicles (Crash Trucks) with Truck Mounted Attenuators (TMA's)** - Used to prevent vehicles from entering the work zone if the operator ignores the lane closure signs and channelization. Each agency has its own specific requirements, but a shadow vehicle should generally be employed any time a shoulder or travel lane will be occupied by workers or equipment.

   - The requirements for the truck itself vary, but high visibility with flashing lights, a striped panel or an arrow board on the rear of a vehicle of a specified minimum weight are generally required.

See Slide 4-3-24

   - Some jurisdictions use truck or trailer mounted attenuators. This protects the motorist, as well as the inspectors.

IV. TRAFFIC CONTROL

A. FUNDAMENTAL PRINCIPLES

All traffic control devices used on street and highway construction or maintenance work should conform to the applicable specifications of the MUTCD and the Agency.

Work areas can present to the motorist unexpected or unusual situations as far as traffic operations are concerned. Because of this, special care should be taken in applying traffic control techniques in these areas.

Principles and Procedures

Slide No. 4-3-26
Title Slide

Traffic Safety is a High Priority

Slide No. 4-3-27
Narrative Slide

Traffic Movement Should be Inhibited As Little As Practical

Slide No. 4-3-28
Narrative Slide

Principles and procedures in which experience has tended to enhance the safety of motorist and workers in the vicinity of work areas include the following:

1. **Traffic safety in work zones should be an integral and high priority element of every inspection project** from planning to performance. The safety of the motorist, pedestrian, and worker must be kept in mind at all times.

   - **The basic safety principles** governing the design of permanent roadways and roadsides should also govern the design of inspection sites. The goal should be to route traffic through such areas with geometrics and traffic control devices as nearly as possible comparable to those for normal highway situations.

   - **A traffic control plan**, in detail appropriate to the complexity of the work project, shall be prepared and understood by all responsible parties before the site is occupied. Any changes in the traffic control plan should be approved by an official trained in safe traffic control practices.

2. **Traffic movement should be inhibited as little as practical.**

   - **Traffic control in work sites** should be designed on the assumption motorists will only reduce their speeds if they clearly perceive a need to do so. Reduced speed zoning should be avoided as much as practical.

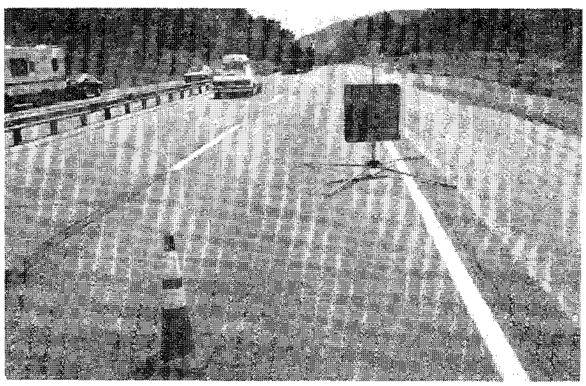
   - **Frequent and abrupt changes in geometrics**, such as lane narrowing, dropped lanes, or main roadway transitions which require rapid maneuvers should be avoided.

   - **Provisions should be made for the safe operation of work vehicles**, particularly on high speed, high volume roadways.

   - **Inspection time** should be minimized to reduce exposure to potential hazards.

Motorists Should Be Guided Clearly

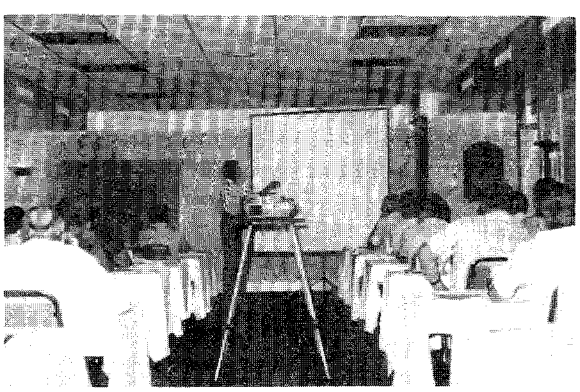
Slide No. 4-3-29
Narrative Slide



Slide No. 4-3-30
Example Slide
End work area

Training

Slide No. 4-3-31
Title Slide



Slide No. 4-3-32
Example Slide
Training session

3. **Motorists should be guided** in a clear and positive manner while approaching and traversing work areas.

Adequate warning, delineation, and channelization by means of proper signing and other devices which are effective under varying conditions of light and weather should be provided to assure the motorist positive guidance in advance of and through the work area.

All traffic control devices shall be removed immediately when no longer needed.

See Slide 4-3-30

The maintenance of roadside safety requires constant attention during the life of the work because of the potential increase in hazards.

- **To accommodate run-off-the-road incidents**, disabled vehicles or other emergency situations, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical.
- **Channelization of traffic** should be accomplished by the use of signing, flexible posts, barricades, and other lightweight devices which will yield when hit by errant vehicles.
- **Housekeeping** - Whenever practical, equipment, and materials, should be stored in such a manner as not to be vulnerable to run-off-the-road vehicle impact. When safe storage is not available, adequate attenuation devices shall be provided.

B. **TRAINING**

See Slide 4-3-32

Each person whose actions affect maintenance and construction zone safety -- from the upper-level management personnel through construction and maintenance field personnel -- should receive training appropriate to the job decisions each individual is required to make. Only those individuals who are qualified by means of adequate training in safe traffic control practices and have a basic understanding of the principles established by applicable guidelines and regulations should supervise the selection, placement, and maintenance of traffic control devices in bridge safety inspection, maintenance and construction areas.

Good traffic control is important -it saves lives - maybe yours!

Summary

- Purpose and Objectives
- Traffic Control Devices
- Traffic Control Principals

Slide No. 4-3-33
Title Slide

V. SUMMARY

A. PURPOSE AND OBJECTIVES OF A TRAFFIC CONTROL PLAN

B. TRAFFIC CONTROL DEVICES

C. TRAFFIC CONTROL PRINCIPLES

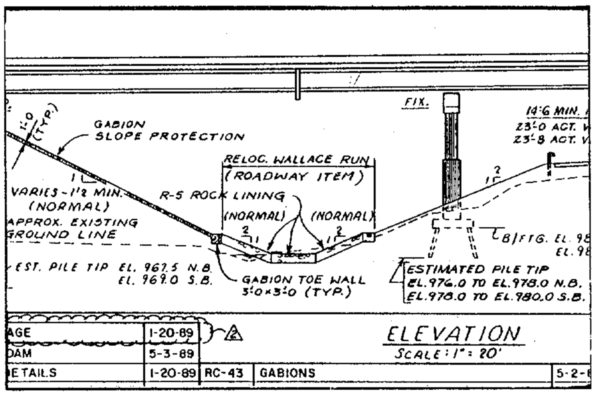
SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION

TOPIC 4: INSPECTION PROCEDURES

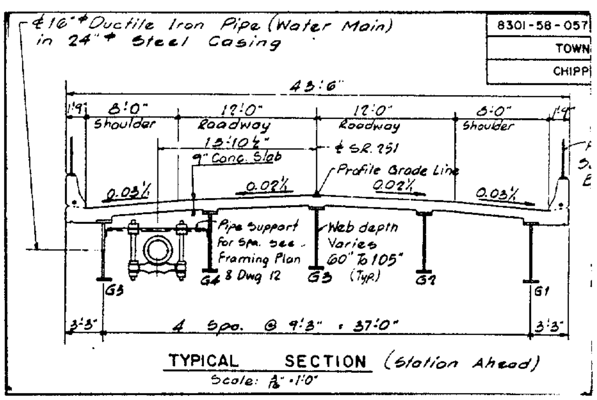
LESSON PLAN

TOPIC DURATION	30 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 5
GOAL	An understanding of the procedures used to inspect bridges.
OBJECTIVE	The participant should be able to describe inspection procedures used on a variety of bridge types.
PARTICIPATION	Participants with inspection experience will be encouraged to give examples of the procedures they use for bridge inspections.
REFERENCES	1. AASHTO. *Manual for Maintenance Inspection of Bridges*, 1983.

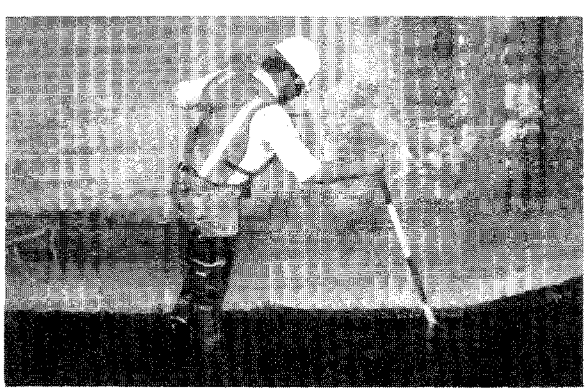
Slide No. 4-4-1
Example Slide
Inspectors in action



Slide No. 4-4-2
Example Slide
Bridge plans



Slide No. 4-4-3
Example Slide
Bridge plans



Slide No. 4-4-4
Example Slide
Inspector in action

I. INTRODUCTION

See Slide 4-4-1

Bridge inspections involve sifting through a great deal of information, as you have heard and seen this week, in order to make proper decisions in the field. The material that has been presented to you must be committed to memory if you are to become a good inspector.

A good inspection demands that the inspectors be organized.

II. BASIC GUIDELINES

A. SITE ORIENTATION

See Slide 4-4-2

1. **Identifying Numbers or Letters** - Identifying numbers or letters should be used to code components and elements of the structure. These marks should be crayoned or painted on the bridge either before or during the inspection.

See Slide 4-4-3

2. **Purpose** - The purpose of the marks is to keep track of the inspector's location and to guard against overlooking any portion of the structure. Also establish the direction of inventory, compass directions, and direction of waterway flow.

See Slide 4-4-4

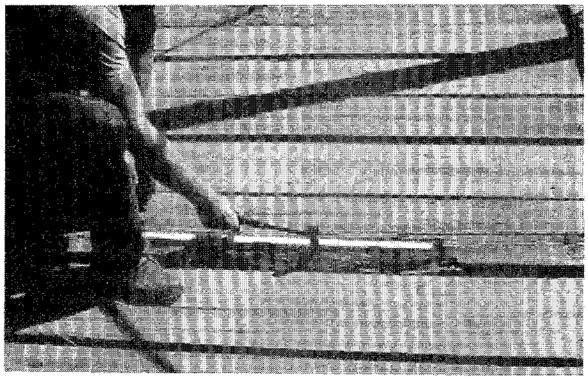
B. GENERAL

1. **Begin On-Site Inspection** - After you have completed the preparations for all phases of the inspection, you are ready to begin actual field work.

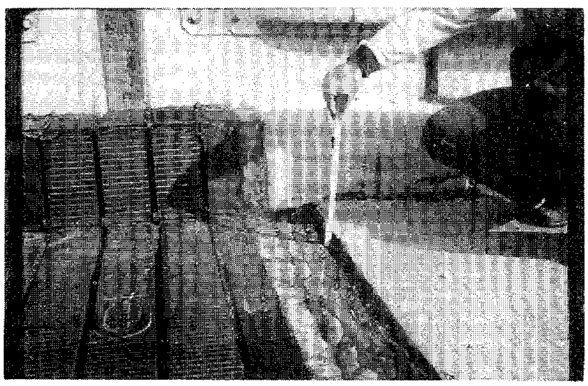
2. **Be Careful and Attentive** - When making observations, be careful and attentive to the work at hand. It is imperative that no areas of the bridge are overlooked.

3. **Critical Areas** - While all areas on the bridge are important, some are critical to the structural integrity of the bridge. These critical areas require special attention during the inspection.

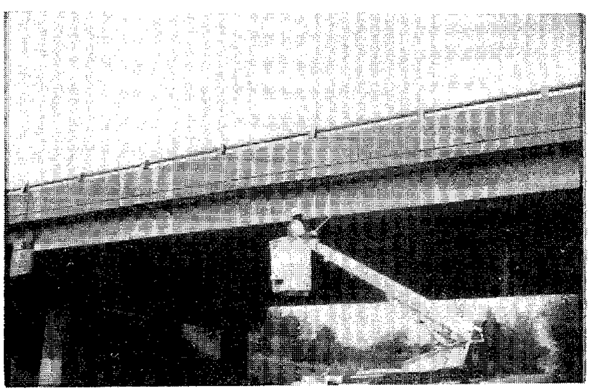
4. **Thorough and Complete Recording** - The prudence used for inspection must be combined with careful recording. A very careful inspection is worth no more than the records kept during that inspection. You must be thorough and complete in recording every item inspected.



Slide No. 4-4-5
Example Slide
Deck inspection



Slide No. 4-4-6
Example Slide
Inspection of expansion joint



Slide No. 4-4-7
Example Slide
Superstructure inspection - Inspector in a bucket truck (looking for flexure cracks at midspan on bottom flange)

Slide No. 4-4-8
Example Slide
Superstructure inspection - Inspector checking deteriorated bottom flange

See Slide 4-4-5

C. DECKS

1. **Approaches** - Check the approach pavement for unevenness, settlement, or roughness. Check the condition of the shoulders, slopes, drainage, and approach guardrail.

2. **Structural Portion of Decks** - Examine decks for various defects noting size, type, extent and location of each deficiency. Use the centerline, shoulder line, and span number as references for describing locations.

See Slide 4-4-6

3. **Expansion Joints** - Examine the joint for sufficient clearance and determine if it is adequately sealed to prevent material from accumulating that may clog the joint. Record the measurement of the width of the opening on both left and right curb lines, temperature of the superstructure, and weather at the time of the inspection, including the air temperature.

4. **Signing and Lighting** - Check to see that the proper signs and lights are present and in good repair.

5. **Drainage** - Check for signs of proper water runoff.

See Slide 4-4-7

D. SUPERSTRUCTURES

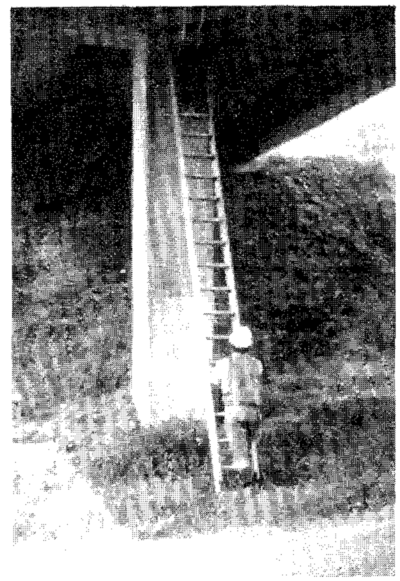
1. **Main Supporting Members** - Inspect the main supporting members very thoroughly since their failure could cause the bridge to collapse.

   Some of these main members are:

   - Main girder and beams
   - Box girders
   - T-beams
   - Trusses
   - Hangers and cables
   - Eyebars
   - Arch ribs
   - Frames
   - Main slabs
   - Floor beams
   - Slabs

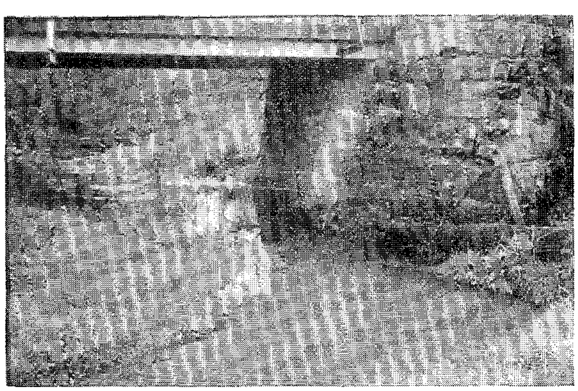
See Slide 4-4-8

Slide No. 4-4-9
Example Slide
Bearing inspection



Slide No. 4-4-10
Example Slide
Substructure inspection

Slide No. 4-4-11
Example Slide
Substructure inspection



Slide No. 4-4-12
Example Slide
Waterway inspection

See Slide 4-4-9

2. **Bearing Devices** - Examine and measure the difference between the rocker tilt and the fixed reference line. Record the temperature of the superstructure and the weather at the time of inspection, including the air temperature.

See Slide 4-4-10

E. SUBSTRUCTURES

1. **Piers, Abutments and Bents** - Should be examined with respect to both horizontal and vertical dimensions and compared with the "as built" plans if available.

See Slide 4-4-11

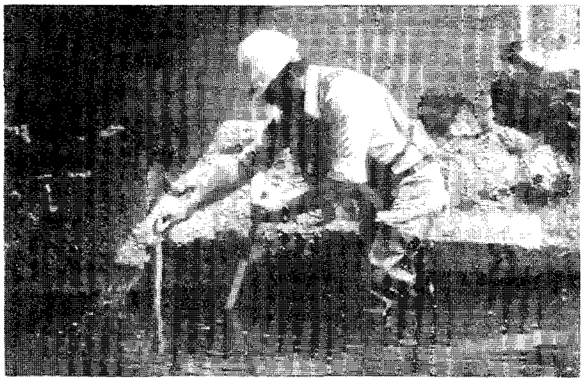
2. **Visual Inspection** - Inspection of a bridge is primarily by visual means, therefore, dirt, leaves, animal waste and debris should be removed to permit close observation and evaluation. Visual inspection may be supplemented by appropriate special devices and techniques such as closed circuit television, photography, and mirrors. (Visual inspection also applies to the superstructures.)

3. **Undermining** - Checking for undermining of substructure units should be done in conjunction with the scour inspection of the waterway. Document any loss of foundation material with length, width and depth measurements and indicate the location of the undermining.

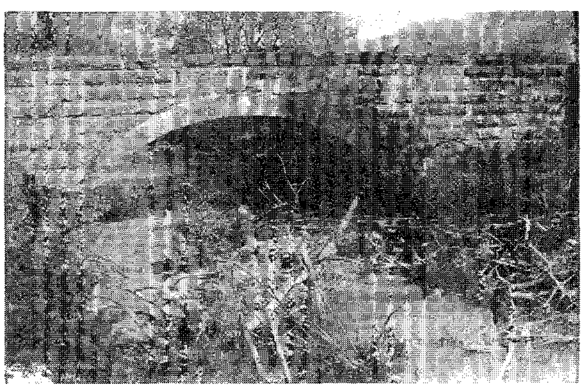
See Slide 4-4-12

F. WATERWAYS

1. **Channel Alignment** - Maintain a record of the channel profile. Check the alignment of the stream with respect to the structure as well as documenting any meandering of the channel both upstream and downstream. Report any improper location or skew of piers or abutments.



Slide No. 4-4-13
Example Slide
Waterway Inspection



Slide No. 4-4-14
Example Slide
Waterway inspection

Summary

- Plan
- Inspect
- Record
- Report

Slide No. 4-4-15
Narrative Slide

See Slide 4-4-13

2. **Scour** - Use lead lines or probe the channel bottom to detect the existence of scour. Mark the substructure units with reference lines to indicate grid line locations. Document the location of scour on the corresponding grid on a sketch. This is done by indicating the depth of the channel bottom at each grid point on the sketch.

3. **Embankment Erosion** - Report any erosion along the banks both upstream and downstream of the bridge. Indicate to what extent these banks have been eroded. Be specific using length, width and depth estimates.

4. **Channel/Embankment Protection** - Document the existence of any protection devices, such as

   - Dolphins
   - Fenders
   - Channel/embankment paving
   - Gabions
   - Rip-rap or other rock protection

   Report any deficiencies of these devices by indicating the type, size, location and extent of the defects present.

See Slide 4-4-14

5. **Debris and Vegetation** - Note the existence of any debris or excessive vegetation in the channel. Again, be specific about type, size, extent and location.

6. **High Water Mark** - Indicate in the inspection report whether or not high water marks exist, and if so, where they were found. Measurements should be tied to a fixed reference, such as the bottom of a superstructure.

III. SUMMARY

An inspector should organize the entire inspection in a systematic manner. The most common procedure used is to go from the top down, i.e., deck, superstructure, substructure, etc. However, another sound method is to inspect the bridge in the order that it was built which is opposite to that just mentioned. In either case, if you are completely organized, then you will ensure that attention is given to each bridge component in accordance with its importance.

- Preparation for the inspection is according to the inspection plan.

- Observations are careful and attentive.

- Every item and defect is recorded.

- Report results, deterioration, and measurements are consistent on all reports.

Think about the reasons for your actions. If you do this and use common sense, you will be able to relate what you have learned to the job at hand, and remember the important aspects of bridge inspection.

SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION

TOPIC 5: INSPECTION EQUIPMENT

LESSON PLAN

TOPIC DURATION	45 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 5
GOAL	Awareness and familiarity with the equipment necessary to perform NBIS inspections.
OBJECTIVE	To explain the types of tools and equipment required for the inspection.
PARTICIPATION	Participants will be randomly asked to identify usage of each piece of equipment.

I. BASIC EQUIPMENT

A. PURPOSE

In order for an inspector to perform an accurate, comprehensive inspection, the proper tools must be used.

B. STANDARD TOOLS

Standard tools that an inspector should have available at the bridge site can be grouped into 7 categories:

1. Tools for Cleaning

- **Wisk broom** - removing loose dirt and debris.
- **Wire brush** - removing loose paint and corrosion from steel elements.
- **Scraper** - removing corrosion or growth from element surfaces.
- **Flat bladed screwdriver** - general cleaning and probing
- **Shovel** - removing dirt and debris from bearing areas.

2. Tools for Inspection

- **Pocket knife** - general duty.
- **Ice pick** - surface examination of timber elements.
- **Hand brace and bits** - boring suspect areas of timber elements.

- **Increment borer** - internal examination of timber elements.
- **Chipping hammer with leather holder** - (16-22 ounce (0.45 - 0.62 kg) geologist pick) loosening dirt, rust scale, sounding concrete and checking for sheared or loose fasteners.
- **Plumb bob** - to measure vertical alignment of a superstructure or substructure element.
- **Tool belt with tool pouch** - for convenient holding and access of small tools.
- **Chain drag** - to identify areas of delamination on concrete decks.
- **Life jacket** - for safety use over water.
- **Range pole/probe** - for probing for scour holes.

3. **Tools for Visual Aid**

- **Binoculars** - preview areas prior to inspection activity.
- **Flashlight** - examination of dark areas.
- **Lighted magnifying glass (5x and 10x)** - for close examination of areas prone to cracking. i.e., welded connections.
- **Inspection Mirrors** - for inspection of inaccessible areas. i.e., underside of deck joints.

4. **Tools for Measuring**

- **Pocket tape/6 foot (2 m) rule** - measure defect, element and joint dimensions.
- **100 foot (30 m) tape** - measuring component dimensions.
- **Calipers** - measuring the thickness of an element beyond an exposed edge.
- **Optical crack gauge** - precise measurement of crack widths in prestressed concrete members.
- **Paint film (dry) gauge** - checking paint thickness.

- **Protractor** - measuring the angle of bearing tilt.
- **Thermometer** - atmospheric thermometer for measuring ambient air temperature and surface thermometer for measuring superstructure temperature.
- **4 foot (1.2 m) carpenter's level** - measuring deck cross-slopes and approach pavement transitions.
- **Line level and string line**

5. **Tools for Documentation**

- **Inspection forms, clipboard and pencils** - record keeping for an average bridge.
- **Field books** - additional recordkeeping for complex structures.
- **Straight edges** - drawing concise sketches.
- **35 mm camera** - visual documentation of the bridge site and conditions.
- **Polaroid camera** - instant documentation for serious conditions which require immediate review by office personnel.
- **Chalk, keel, paint sticks or markers** - element and defect identification, for improved organization and photo documentation
- **Center punch** - applying reference marks to steel elements for movement documentation. i.e., bearing tilt and joint openings.
- **"P•K" Nails** - Parker Kalon masonry survey nails for establishing a reference point necessary for movement documentation of substructures and large cracks.

6. **Tools for Access**

- **Ladders** - for substructures and various areas of the superstructure.
- **Boat** - for soundings and inspection.
- **Rope** - to aid in climbing.

- **Waders** - for shallow streams.

7. **Miscellaneous Equipment**

- **"C"-clamps** - provide a "third hand" when taking difficult measurements.
- **Penetrating oil** - aids removal of fasteners, lock nuts and pin caps when necessary.
- **Insect repellent** - reduces attack by mosquitoes, ticks and chiggers.
- **Wasp and hornet killer** - elimination of nest and hives to permit inspections.
- **First-Aid kit** - for small cuts, snake bites and bee stings.

One of the most important pieces of equipment that no one mentioned is ...

Toilet Paper

II. SPECIAL EQUIPMENT

For routine inspection of the average bridge, special equipment is usually not necessary. However, with some structures special inspection activities require special tools. These special activities are often subcontracted by the agency responsible for the bridge.

The inspector should be familiar with special equipment and its application.

A. SURVEY EQUIPMENT

Special circumstances may require the use of a transit, a level, incremental rod, or other survey equipment. This equipment establishes a component's **exact location** relative to other components as well as a standard reference point.

B. NON-DESTRUCTIVE TESTING EQUIPMENT

Non-destructive testing (NDT) is the inplace examination of a material for structure integrity without damaging the material.

NDT equipment allows the inspector to "see" inside a bridge element and assess deficiencies that may not be visible with

the naked eye. Generally, a trained technician is necessary to operate and interpret the results of NDT equipment.

C. UNDERWATER INSPECTION EQUIPMENT

Underwater inspection is the examination of substructure units and the channel below the waterline.

When the waterway is shallow, underwater inspection can be performed from above water with a simple probe. The probe, can be a piece of rebar, survey rod, folding rule or even a tree limb.

When the waterway is deep, underwater inspection must be performed under the water by trained divers. This requires special diving equipment that includes a working platform, air supply systems, radio communication and sounding equipment.

D. OTHER SPECIAL EQUIPMENT

An inspection may require special equipment to prepare the bridge prior to the inspection:

1. **Air/Water Jet Equipment** - used to clean surfaces of dirt and debris.

2. **Sand or Shot Blasting Equipment** - to clean steel surfaces to bare metal.

3. **Burning, Drilling and Grinding Equipment.**

III. SUMMARY

A. BASIC EQUIPMENT

B. SPECIAL EQUIPMENT

SESSION 4: FUNDAMENTALS OF BRIDGE INSPECTION

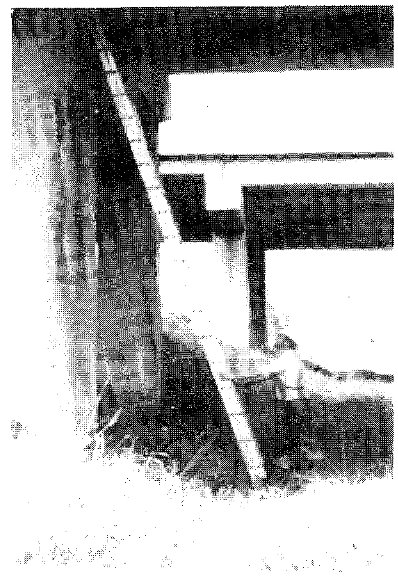
TOPIC 6: METHODS OF ACCESS

LESSON PLAN

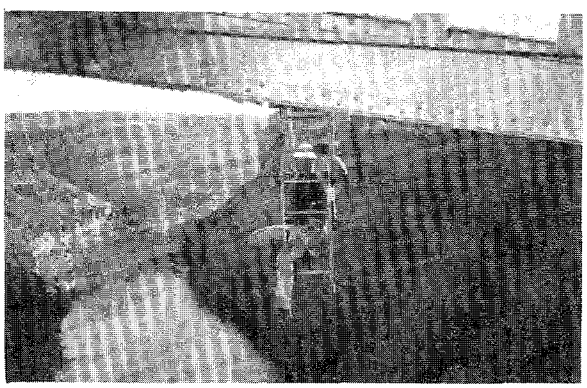
TOPIC DURATION	30 minutes
PREREQUISITES	Understand basic bridge types and the requirements for an in-depth inspection.
PARTICIPANT MATERIALS	Participant's Notebook, BITM 90 - Chapter 5
GOAL	Awareness and familiarization with various methods of access used during bridge inspections.
OBJECTIVE	To identify various access techniques utilized during bridge inspections, including ladders, free climbing and specialized inspection access equipment such as motorized climbers and underbridge inspection vehicles.
PARTICIPATION	Participants will be asked to discuss their experiences with access equipment.

Access Equipment

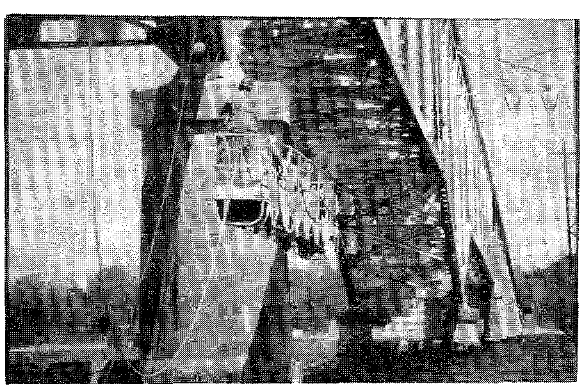
Slide No. 4-6-1
Title Slide



Slide No. 4-6-2
Example Slide
Inspection with a ladder



Slide No. 4-6-3
Example Slide
Use of hook-ladder



Slide No. 4-6-4
Example Slide
Rigging

I. ACCESS EQUIPMENT

A. PURPOSE

Access equipment is necessary to position the inspector close enough to the bridge component so that a "hands-on" inspection can be performed.

The following equipment items may be required to gain access to hard to reach areas on a bridge:

See Slide 4-6-2

B. LADDERS

Ladders can be used for inspecting the underside of a bridge or for substructure units. The inspection area should include only those portions that can be reached comfortably, without undue leaning.

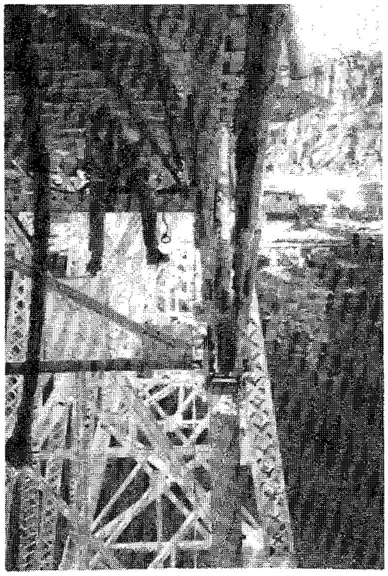
See Slide 4-6-3

Ladders can also be used to climb down to access elements of the bridge. In this use it is known as a hook-ladder.

See Slide 4-6-4

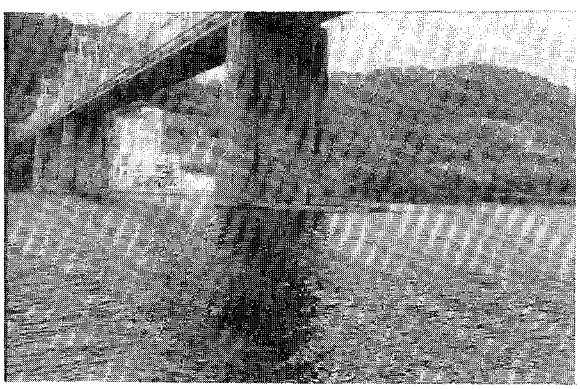
C. RIGGING

Rigging of a structure with cables and platforms is used to gain access to floor systems and the bottom of main load carrying members in areas where access by other means is not feasible.



Slide No. 4-6-5
Example Slide
Rigging

Slide No. 4-6-6
Example Slide
Scaffold



Slide No. 4-6-7
Example Slide
Inspection operations from a barge

See Slide 4-6-5

Structures over water, those over busy highways or railroads where enough clearance exists, and bridges that are over 40 feet (12 m) high are all good candidates for rigging.

See Slide 4-6-6

D. SCAFFOLDS

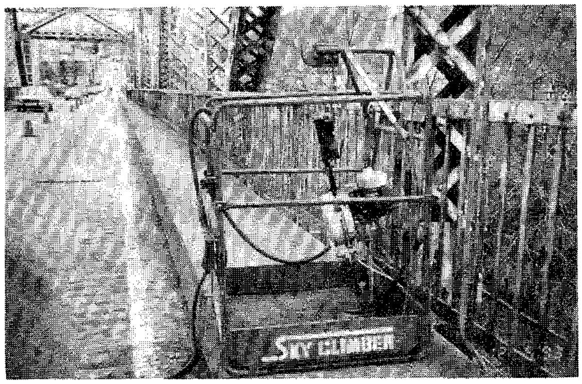
On structures that are less than about 40 feet (12 m) high and over level ground with little or no traffic, scaffolds may be an efficient access alternative.

See Slide 4-6-7

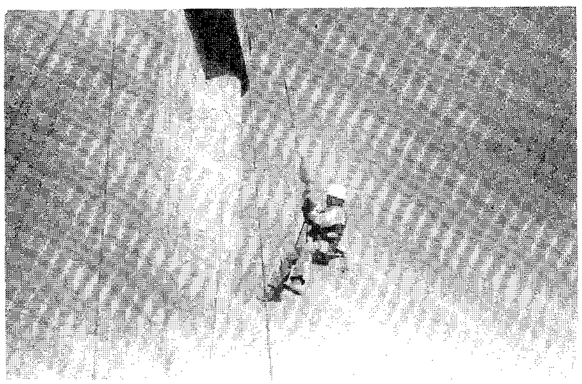
E. BOAT OR BARGE

For structures over water, a boat or barge may be needed for access. Some inspection as well as photo taking can be done from the boat.

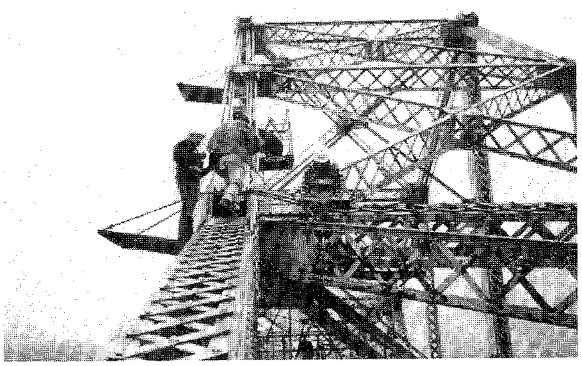
A barge is also used as a work platform for underwater inspection.



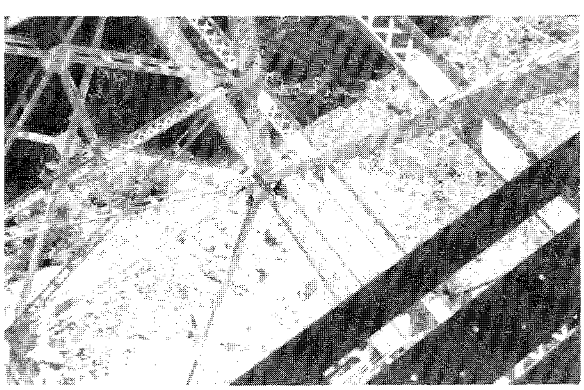
Slide No. 4-6-8
Example Slide
Climber



Slide No. 4-6-9
Example Slide
Bosun chair (James Rumsey Bridge, West Virginia)



Slide No. 4-6-10
Example Slide
Float



Slide No. 4-6-11
Example Slide
Climbing

See Slide 4-6-8

F. CLIMBERS

Climbers are mobile inspection platforms that "climb" steel cables. They are well suited for inspection of high piers or other long vertical faces of bridge members. Climbers are sometimes referred to as "spiders".

See Slide 4-6-9

G. FLOATS

A float is a wood plank work platform hung by ropes to provide access. Floats are used in operations where the inspector will be at a particular location for a relatively long period of time.

See Slide 4-6-10

H. BOSUN (OR BOATSWAIN) CHAIRS

These chairs are suspended from cables or ropes and carry one inspector. They can be raised and lowered with block and tackle devices.

See Slide 4-6-11

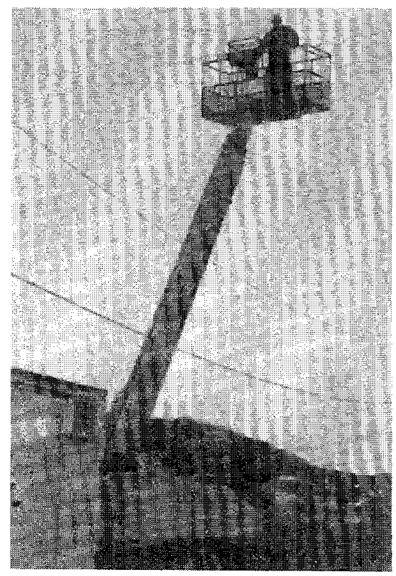
I. CLIMBING

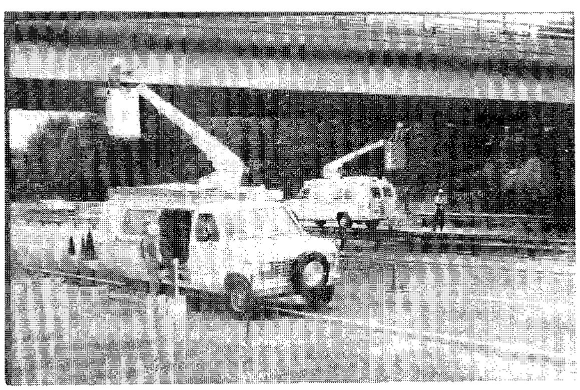
On some structures, if other methods of access are not practical, inspectors must climb the bridge elements. Safety awareness should be foremost in the inspector's mind when utilizing this technique.

Access Vehicles

Slide No. 4-6-12
Title Slide

Slide No. 4-6-13
Example Slide
Manlift





Slide No. 4-6-14
Example Slide
Bucket Truck

II. ACCESS VEHICLES

There are many types of vehicles available to aid the inspector in accessing bridge elements. Our discussion is limited to the most common types.

See Slide 4-6-13

A. MANLIFT

A manlift is a vehicle with a platform or bucket capable of holding one or more inspectors. The bucket is attached to a hydraulic boom that is mounted on a carriage. An inspector "drives" the carriage using controls in the bucket. This type of vehicle is usually not licensed for use on highways. Some manlifts are very nimble and can operate on a variety of terrains.

See Slide 4-6-14

B. BUCKET TRUCK

1. Description

A bucket truck is similar to a manlift. However, it can be driven on the highway, and the inspector only controls the bucket.

2. Features and Variations

- **Lift Capability** - Varies 25 to 50 feet (7.5 to 15 m).

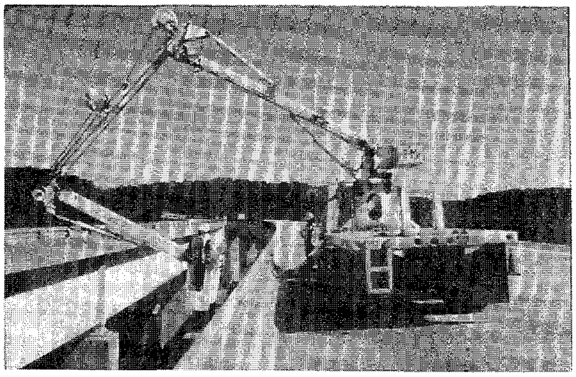
- **Rotating Turret** - Turning range (i.e., the rotational capability of the turret) varies with each vehicle.

- **Outriggers** - Bucket trucks that offer extended reach and turning range have outriggers or supports that are lowered from the chasis of the vehicle to help maintain stability.

- **Telescoping Boom** - Some booms may be capable of extending and retracting, providing a greater flexibility and reach area from a given truck location.

- **Truck Movement** - Some vehicles offer stable operations without outriggers and can move along the bridge during inspection activities.

  Vehicles which require outriggers for stable operations cannot be moved during the inspection unless the outriggers have wheels.



Slide No. 4-6-15

Example Slide

Typical underbridge inspection vehicle

- **Multiple Booms** - Some bucket trucks have more than one boom, and provide reach, up to 50 feet (15 m).

See Slide 4-6-15

C. UNDERBRIDGE INSPECTION VEHICLE

1. Description

An underbridge inspection vehicle is a specialized bucket truck with three or more booms designed to reach under a structure while parked on the deck.

2. Features and Variations

Many of the features on a an underbridge inspection vehicle are standardized on all models. Some of the common features include:

- **Rotating Turret** - Provides maximum flexibility.

- **Outriggers with Wheels** allow for moving the truck during operations.

- **Telescoping Third Boom** - Usually the third boom has the capability for extending and contracting. This allows for greater reach under a structure.

Variations and options available on different models include:

- **Capacity** - Some underbridge inspection vehicles have a one- or two-person bucket on the end of the third boom. Other models are equipped with a multiple-person platform on the third boom with a ladder on the second boom. Still other models may have the capability of interchanging a bucket and a platform in the shop.

- **Telescoping Second Boom** - Some underbridge inspection vehicle models have a second boom that can extend and contract, providing greater movement in the vertical direction.

- **Articulated Third Boom** - Some underbridge inspection vehicle models have a small fourth boom that allows for greater vertical movement under the structure. This option is particularly useful on bridges with deep superstructure members.

Summary

- Access Equipment
- Access Vehicles

Slide No. 4-6-16

Summary Slide

D. ACCESS VEHICLES VS. ACCESS EQUIPMENT

In most cases, even the most sluggish lift device will be quicker than using a ladder or rigging to inspect a structure. The time saved, however, must offset the high costs associated with operating the vehicle.
In assessing the time-saving effectiveness of a lift device the following questions should be answered:

- What type of vehicle is available?
- How much of the bridge can be inspected using the vehicle?
- How much of the bridge can be inspected from one setup?
- How much time does it take to inspect at each setup?
- How much time does it take to move from one setup to the next?
- Does the vehicle require an operator or driver other than the inspector?
- Will the use of the vehicle require special traffic control?

The inspection time and vehicle costs can then be compared to costs associated with using standard access equipment.

III. SUMMARY

A. ACCESS EQUIPMENT

B. ACCESS VEHICLES

BRIDGE INSPECTION REPORTING SYSTEM

SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

TOPIC 1: STRUCTURE INVENTORY, CONDITION, AND APPRAISAL

LESSON PLAN

TOPIC DURATION	90 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 14
GOAL	To introduce the student to the structure inventory, condition, and appraisal system.
OBJECTIVE	To provide insight into proper coding of condition and appraisal ratings.

I. STANDARD FORMS

A. NBIS REQUIREMENTS

1. **NBIS** - National Bridge Inspection Standards mandates that the findings and results of a bridge inspection are recorded on standard forms.

2. **Coding Guide** - NBIS specifically references the Federal Highway Administration's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges (Coding Guide),* dated January 1979, as a source for the Structure Inventory and Appraisal Sheet (SI&A sheet). This publication was revised and reissued in December, 1988.

B. STRUCTURE INVENTORY AND APPRAISAL SHEET

1. **SI&A sheet** is found in Appendix A of the *Coding Guide.*

2. **Is not intended to be an inspection form.**

3. **It is a list** of bridge data items that each state must report to the FHWA for each bridge in their inventory.

4. **A proper inspection** - will include gathering data beyond what is reported to the FHWA.

C. SUBSTITUTES FOR SI&A SHEET

1. **Substitutes** - NBIS allows the use of suitable substitutes for the SI&A form. The only requirement is that the forms must be standardized.

2. **Many states have their own version of the SI&A Form.**

   - Some states simply reprint the federal form with the same items and item numbers.

   - A few states have elaborate Bridge Management Systems (BMS) with different item numbers that collect all the data listed on the SI&A form plus additional items not reported to the FHWA.

D. OTHER FORMS

1. **Related Forms** - Most states have developed other related forms to help standardize the inspection reporting process.

2. **Inspection Notes** - Many forms list specific components and elements with blank lines for narrative descriptions of the inspection findings.

3. **Sketches and Photos** - Standardized sketch sheets and photo sheets are available to some inspectors for report generation.

4. **Software** - Some agencies have developed their forms on software packages for use on portable computers.

II. INVENTORY ITEMS

The items on the SI&A form are divided into three main categories:

- Inventory items
- Condition rating items
- Appraisal rating items

A. INVENTORY ITEMS

As previously stated, there are many variations on the SI&A Form. This discussion of the inventory items will follow the *Coding Guide*. The items are grouped into nine different categories:

- Identification
- Structure type and material
- Age and service
- Geometric data
- Navigation data
- Classification
- Load rating and posting
- Proposed Improvements
- Inspections

B. IDENTIFICATION ITEMS

This group of items identifies the structure using location codes and descriptions.

C. STRUCTURE TYPE AND MATERIAL ITEMS

These items categorize the structure based on the material, design and construction and indicate the number of spans and wearing surface information.

D. AGE AND SERVICE ITEMS

Information showing when the structure was constructed or reconstructed, what the structure carries and crosses, and traffic information are recorded in this category.

E. GEOMETRIC DATA ITEMS

This is a series of items recording pertinent dimensions for the bridge.

F. NAVIGATION DATA ITEMS

This group of items identifies the existence of navigation control, pier protection and clearance measurements relative to a waterway.

G. CLASSIFICATION ITEMS

The classification of the structure and the facility carried by the structure are identified with these items. The sufficiency rating and status items shown directly above this category on the SI&A form will be discussed later.

H. LOAD RATING AND POSTING ITEMS

These items identify the load capacity of the bridge and the current posting status.

I. PROPOSED IMPROVEMENTS ITEMS

This group of items will reflect work proposed and estimated costs for all bridges eligible for the Highway Bridge Replacement and Rehabilitation Program, and other structures the highway agency opts to include.

J. INSPECTIONS ITEMS

The date of the latest inspection, the designated inspection frequency and critical features requiring special inspections or special emphasis during inspection are identified with these items.

C. CONDITION RATING GUIDELINES

1. FHWA General Rating Guidelines

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION- some minor problems.
6	SATISFACTORY - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION - out of service - beyond corrective action.

2. Application of Condition Ratings

- The condition rating guidelines just given are general in nature and can be applied to any condition item component and any material type.
- Component specific guidelines are provided for Item 61, Channel and Channel Protection, on page 38 of the *Coding Guide*.
- Likewise, starting on page 39, there are specific coding guidelines for Item 62, Culverts.

- Some instructions for the proper application of these guidelines are provided in the *Coding Guide*. These will be discussed in more detail here.

- Each element of the component must be addressed (i.e., good, fair, or poor). The proper way to assign a condition rating is to evaluate the component as a whole and not based on isolated problems. The conditions determined for every element must be combined to establish the overall component condition rating. If a numerical system is used to evaluate elements it would be incorrect to assign a component rating based on a mathematical average of the individual element ratings.

- If the bridge has multiple spans the inspector must evaluate all elements both quantitatively and qualitatively.

- In some cases, a deficiency will occur on a single element or in a single location. If the deficiency reduces the structural (strength) capacity of the component, then the element can be considered a "weak link" in the structure, and the component should be rated accordingly.

- A bridge's load-carrying capacity (by itself) will not be used in the evaluation of the condition rating. The fact that a bridge was designed for less than current legal loads, and may even be posted, should have no influence upon the condition rating. This means that a bridge could be in "good condition" but still be posted. Posting reflects the ability of the bridge to carry the legal loads - or the bridge's load carrying capacity.

- Condition descriptions are general in nature and can apply to any material or component type for ratings 9 through 6.

- For ratings of 5 through 1, specific types of defects or deterioration are mentioned that usually apply only to certain material types or components.

"Section loss"	-	usually applies to steel members or reinforcing steel
"Cracking" "Spalling"	-	usually are used to describe concrete
"Fatigue Crack"	-	applies to steel members
"Scour"	-	can apply to substructure or channels
"Shear Crack"	-	usually applies to concrete but may apply to timber as well

- Using the material and component specific supplemental rating guidelines helps to clarify how each type of defect affects the condition rating.

- Do not be too quick to "pigeonhole" the rating based on only one word or phrase. Be sure to read down the ratings list far enough.

- One suggested method for coming up with the proper rating is to identify phrases that describe the component by progressing down the rating scale until encountering phrases that describe conditions that are more severe than what actually exists. The correct rating number then is one number higher. This procedure should generally work with all of the condition rating guidelines.

3. Supplemental Rating Guidelines

Supplemental rating guidelines may also have been developed by your state:

Supplemental rating guidelines are intended to be used in addition to the *Coding Guide* to make it easier for the inspector to assign the most appropriate condition rating to the component being considered.

4. **Precedence of Rating Guidelines**

- Which set of rating guidelines should be used? Which take precedence?

- Supplemental guidelines should not conflict with the condition rating guidelines in the *Coding Guide*; they are just intended to be more component and material specific.

- Therefore, the inspector should use both the guidelines contained in the *Coding Guide* and the appropriate set of supplemental guidelines for maximum guidance in assigning the proper condition rating.

IV. APPRAISAL RATING ITEMS

A. GENERAL

1. **Appraisal rating items** include the following SI&A items:

- Item 67 - Structural Evaluation
- Item 68 - Deck Geometry
- Item 69 - Underclearances, Vertical and Horizontal
- Item 71 - Waterway Adequacy
- Item 72 - Approach Roadway Alignment

2. **Appraisal items are used to evaluate the structure based on the level of service it provides on the highway system.** The structure should be compared to a new one built to current standards for that particular type of road.

3. **Item 72, Approach Roadway Alignment,** is the one exception. Special guidelines will be presented for this item.

4. **Appraisal rating guidelines** are found on pages 42 and 43 of the *Coding Guide.*

- The guidelines are for information only.
- In the past, the wording contained in these guidelines has made it very difficult to arrive at the proper rating. Consequently, Items 67, 68, 69 and 71 now have tables that should always be used to code these items. If the site conditions do

not agree completely with the criteria in the tables, use the table or column that most closely agrees with the situation.

- Some states have certain level of service goals that vary within the state for various highway classifications, traffic volume, etc. and among states for a given situation.

- Because of these variations, the charts have been developed to promote uniformity and consistency in evaluating appraisal ratings.

- By using the charts to establish an appraisal rating, you will establish a number that closely matches the descriptions assigned to the ratings on page 42 and 43.

- Since the charts and tables are so specific, some states now program their computerized bridge management system to automatically calculate some of the appraisal rating items. Thus, some inspectors are not responsible for coding these items.

B. ITEM 67 - STRUCTURAL EVALUATION

1. **Description** - This item evaluates the overall condition of the structure based on all major deficiencies, and its ability to carry inventory loads.

2. **Explanation** - This item is given on page 44 and the appropriate table is shown on page 45.

3. **Evaluation** - The correct way to evaluate this item for bridges is to consider three codes.

    - The lowest rating dictated by Item 59 - Superstructure, Item 60 - Substructure or Table 1, will govern this appraisal rating.

    - For culverts, the lower of Item 62 - Culverts or Table 1 will give the proper ratings.

    - The use of Table 1 requires information from Item 29 - ADT and Item 66 - Inventory rating. The ADT figure points out which of the three columns to use.

C. ITEM 68 - DECK GEOMETRY

1. **Description** - The deck geometry appraisal evaluates the curb to curb bridge roadway width and the minimum vertical clearance over the bridge roadway.

2. **Explanation** - This item is coded by determining two appraisal ratings, one for bridge roadway width and one for the minimum vertical clearance. The lower of these two is the appraisal rating.

3. **Evaluation** - There are four tables in the Coding Guide to choose from for the bridge roadway width comparison.

   - Table 2A is for bridges with two lanes carrying two-way traffic.
   - Table 2B is for one lane carrying two-way traffic.
   - All other two-way traffic situations use Table 2C.
   - One way traffic is covered by Table 2D.

D. ITEM 69 - UNDERCLEARANCES, VERTICAL AND HORIZONTAL

1. **Description** - This item refers to the vertical and horizontal underclearances from the through roadway under the structure to the superstructure or substructure units. It is discussed on pages 50-52 of the *Coding Guide*.

2. **Evaluation** - This item is similar to Item 68 in that two different codes are developed: one for vertical underclearance using Table 3A and one for horizontal underclearance using Table 3B.

E. ITEM 71 - WATERWAY ADEQUACY

1. **Description** - Waterway adequacy is appraised with respect to passage of flow through the bridge. The rating is tied to flood frequencies and traffic delays.

2. **Evaluation** - Appraisal ratings are assigned by the table contained on pages 54 and 55 based on the functional classification of the road carried by the structure, hydraulic and traffic data for the structure, and site conditions.

F. ITEM 72 - APPROACH ROADWAY ALIGNMENT

This appraisal is based on comparing the alignment of the bridge approaches to the general highway alignment of the section of roadway that the structure is on. This appraisal rating will be discussed further in Session 6.

V. SUFFICIENCY RATING (S.R.)

A. DEFINITION

Sufficiency Rating - is a calculated numeric value used to indicate the sufficiency of a bridge to remain in service. The rating is calculated using the sufficiency rating formula. Sufficiency rating is discussed in detail in Appendix B of the *Coding Guide*.

B. SUFFICIENCY RATING FORMULA

1. $S.R. = S_1 + S_2 + S_3 - S_4$

   $0\% \leq S.R. \leq 100\%$
   (entirely deficient) (entirely sufficient)

2. Four factors are used to determine the S.R.:

   S_1 = 55% max.; based on structural adequacy and safety (i.e., superstructure or substructure condition and load capacity)

   S_2 = 30% max.; deals with serviceability and functional obsolescence (items such as deck condition, clearances, roadway alignment and width, etc.).

S_3 = 15% max.; concerns essentiality for public use (items such as detour length, average daily traffic, and defense highway designation).

S_4 = 13% max.; deals with special reductions based on detour length, traffic safety features, and structure type.

3. About 19 different inventory items are used to calculate these four factors which therefore determine the S.R.

4. S.R. is not normally calculated manually. Usually, it is included in the agency's inventory computer program and is calculated automatically by the computer based upon the inventory data collected by the bridge inspector.

C. USES

1. S.R. is used by the Federal and State agencies to determine the relative sufficiencies of all of the Nation's bridges.

2. In the recent past, eligibility for federal funding with highway bridge rehabilitation and replacement program funds has been determined by the following deficiencies:

   S.R. < 80 Eligible for rehabilitation
   S.R. < 50 Eligible for replacement

3. Some states use the S.R. as the basis for establishing priority for repair or replacement of bridges: the lower the rating, the higher the priority. This use is being discouraged in favor of bridge management procedures now being developed in many states.

4. The FHWA is now discouraging the use of the S.R. as a tool for establishing priorities for selecting bridge projects because the S.R. does not give appropriate weight to such level-of-service parameters as traffic volume and class of highway.

V. SUMMARY

A. STANDARD FORMS

B. INVENTORY FORMS

C. CONDITION RATING ITEMS

D. APPRAISAL RATING ITEMS

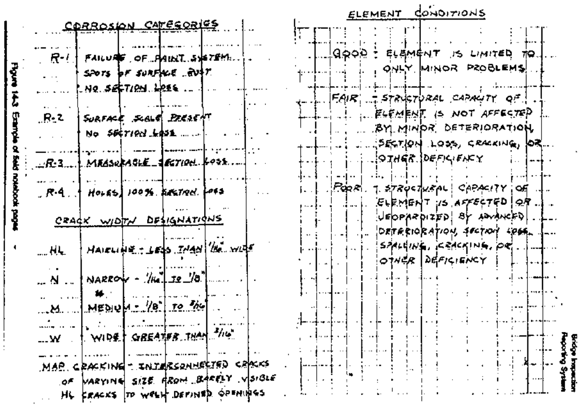
E. SUFFICIENCY RATING

SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

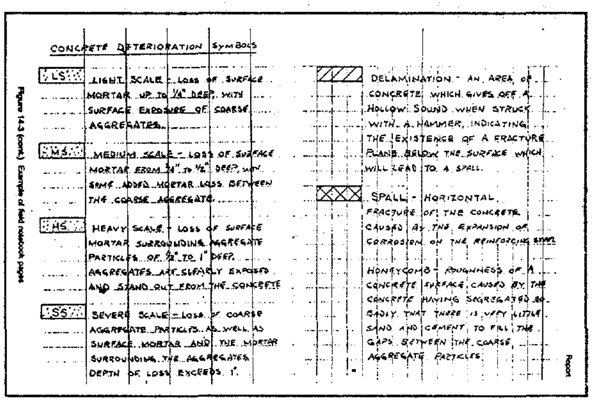
TOPIC 2: RECORDKEEPING AND DOCUMENTATION

LESSON PLAN

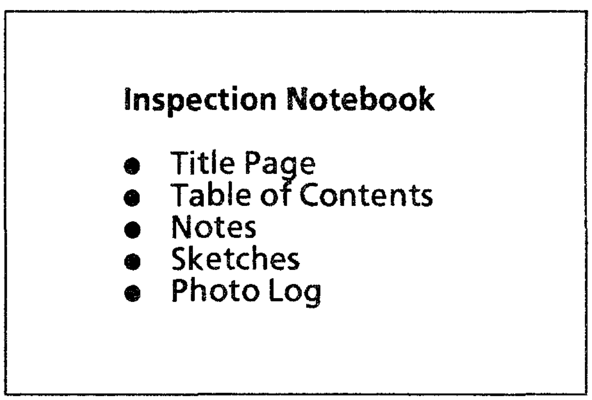
TOPIC DURATION	60 minutes
PARTICIPANT MATERIALS	Participant Notebook; BITM 90 - Chapter 14
GOAL	Comprehension of pertinent parameters needed to properly identify elements and defects.
OBJECTIVE	To identify the specific measurements and recording techniques the bridge inspector must perform to ensure a comprehensive inspection.



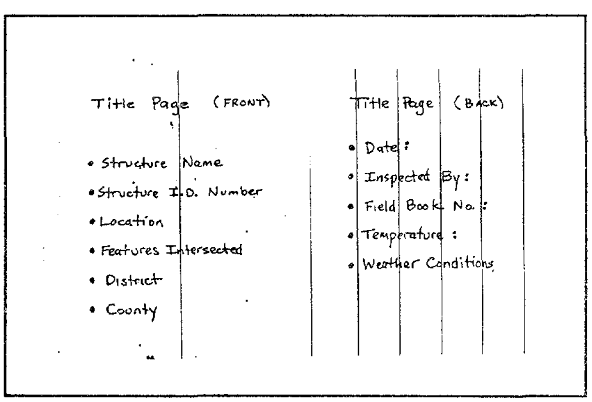
Slide No. 5-2-1
Schematic Slide
Sample notation system
(BITM 90, page 14-14)



Slide No. 5-2-2
Schematic Slide
Sample notation system
(BITM 90, page 14-15)



Slide No. 5-2-3
Narrative Slide



Slide No. 5-2-4
Schematic Slide
Sample notebook title page

I. INSPECTION NOTEBOOK

See Slide 5-2-1

See Slide 5-2-2

A. GENERAL

While the inspection of small bridges usually only requires the use of the standard inspection form, the inspection of large or complex bridges requires the use of an inspection notebook, in addition to any standard inspection forms. The notebook should include:

1. **Standard notation system** for indicating the condition of the elements or members.

2. **Sketches** of elements or members showing typical and deteriorated conditions. Some of these can be premade to allow more expediency during the inspection.

3. **Standard nomenclature** and abbreviations for identifying the elements of members and the components made up of these members.

4. **Log or index for photographs.**

5. **Brief narrative descriptions** of general and component conditions.

B. NOTEBOOK CONTENTS

Many agencies require a specific format for inspection notebooks. However, an example of the contents and format for the notebook is as follows:

See Slide 5-2-4

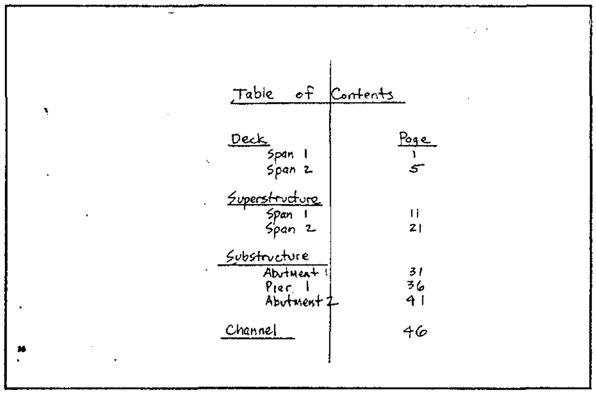
1. **Title Page**

Front should contain:

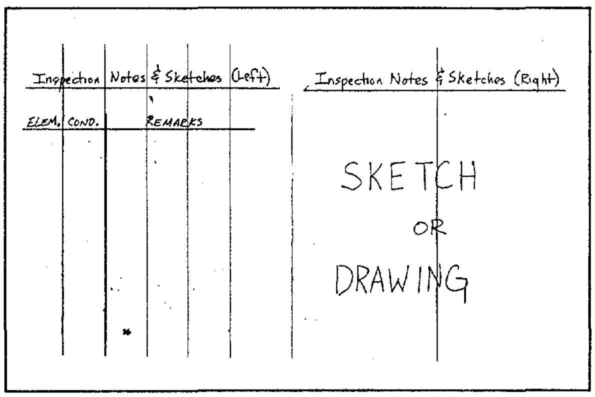
- Name of structure
- Structure identification number
- Location
- Features intersected
- District
- County

Back should contain:

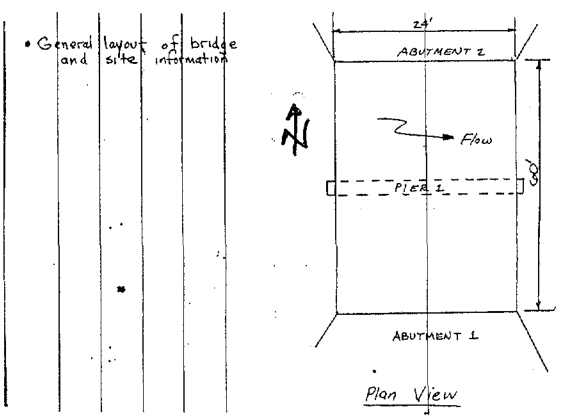
- Date
- Names of inspectors (indicating the team leader)
- Field book number
- Temperature
- Weather conditions



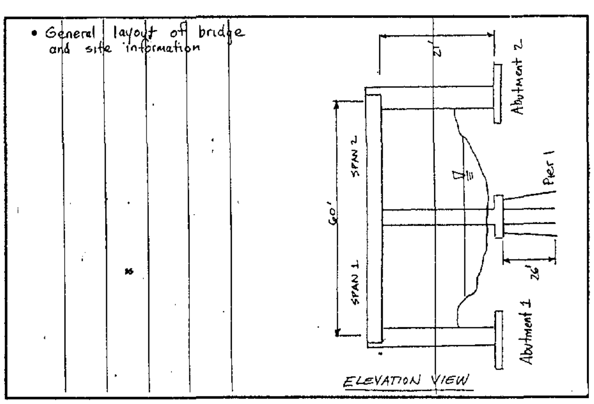
Slide No. 5-2-5
Schematic Slide
Sample notebook table of contents page



Slide No. 5-2-6
Schematic Slide
Sample notes and sketches page layout



Slide No. 5-2-7
Schematic Slide
Sample general plan sketch



Slide No. 5-2-8
Schematic Slide
Sample general elevation sketch

See Slide 5-2-5

2. Table of Contents

See Slide 5-2-6

3. Inspection Notes and Sketches

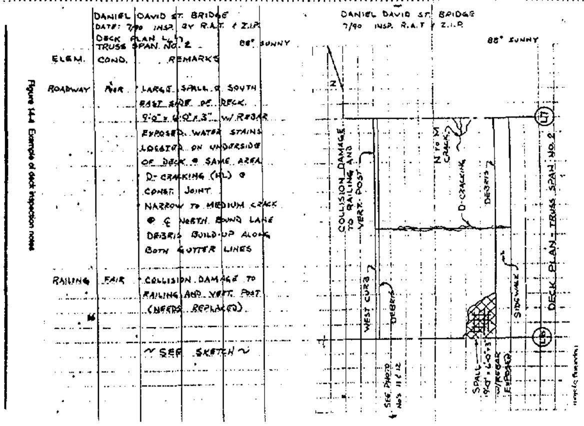
- **Left page** - should contain element identification, descriptive rating (good, fair, poor), and comments.

- **Right page** - should be reserved for sketches or drawings of the elements.

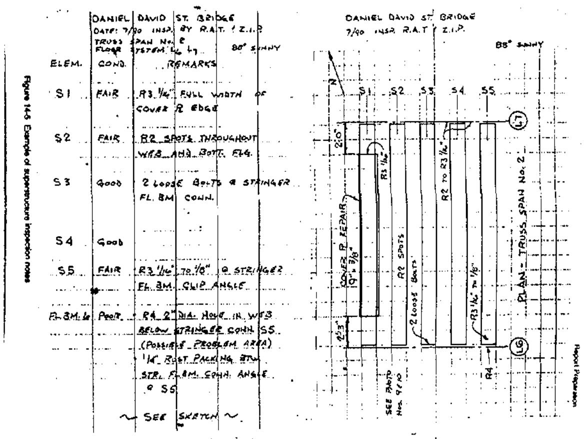
See Slide 5-2-7

See Slide 5-2-8

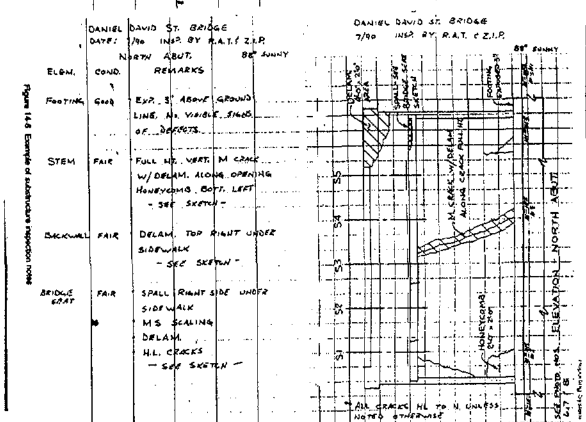
  - General layout of bridge and site information



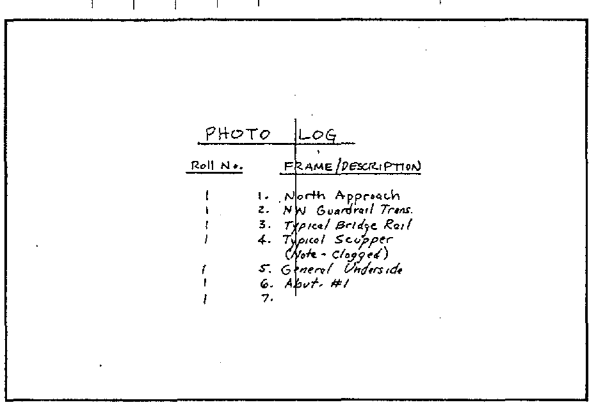
Slide No. 5-2-9
Schematic Slide
Sample deck inspection notes
(BITM 90, page 14-16)



Slide No. 5-2-10
Schematic Slide
Sample superstructure inspection notes (BITM 90, page 14-17)



Slide No. 5-2-11
Schematic Slide
Sample substructure inspection notes
(BITM 90, page 14-18)



Slide No. 5-2-12
Schematic Slide
Sample photo log

See Slide 5-2-9

- Deck sketches

See Slide 5-2-10

- Superstructure framing plan and cross section

See Slide 5-2-11

- Substructure units

See Slide 5-2-12

4. Photo Log

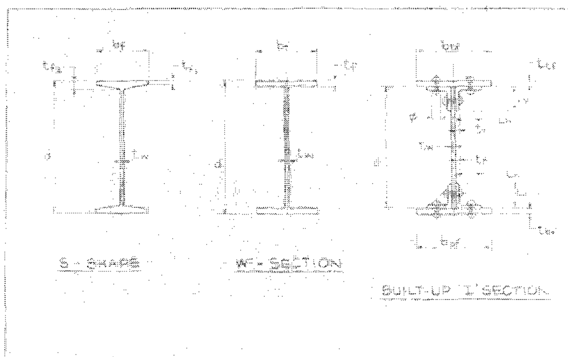
Include:

- Date
- Photo number
- Photo description (be very specific)

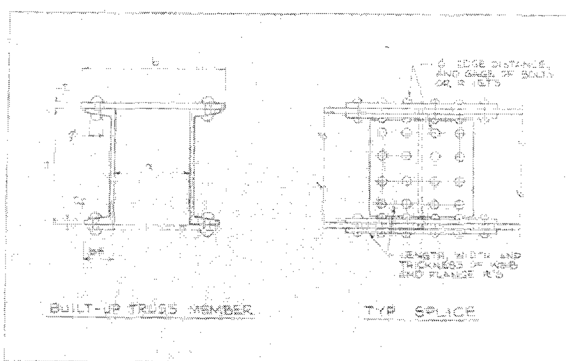
Elements

- Identification
- Orientation
- Dimensioning

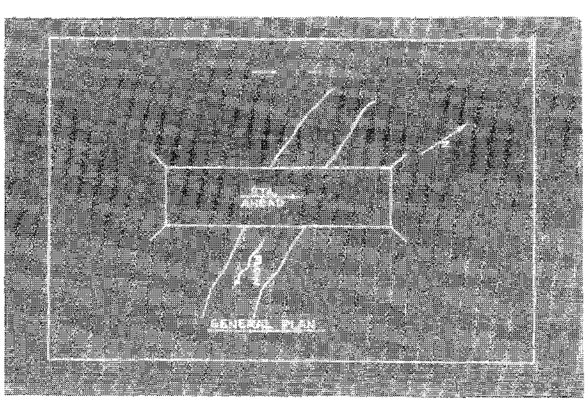
Slide No. 5-2-13
Narrative Slide



Slide No. 5-2-14
Schematic Slide
Steel beam and girder dimensions



Slide No. 5-2-15
Schematic Slide
Truss member and field splice dimensions



Slide No. 5-2-16
Schematic Slide
Sample structure orientation sketch

II. ELEMENTS

A. IDENTIFICATION

Elements should be identified by the type of material and the method of constructing that material, and by the function that each element performs.

1. Material Types and Construction Methods

Construction methods employed in utilizing the following materials include:

- **Timber**

  solid sawn
  laminated

- **Concrete**

  cast-in-place: voided or solid
  precast: regular reinforcement or prestressed

See Slide 5-2-14

- **Steel**

  rolled
  welded
  riveted
  bolted

See Slide 5-2-15

2. Element Functions

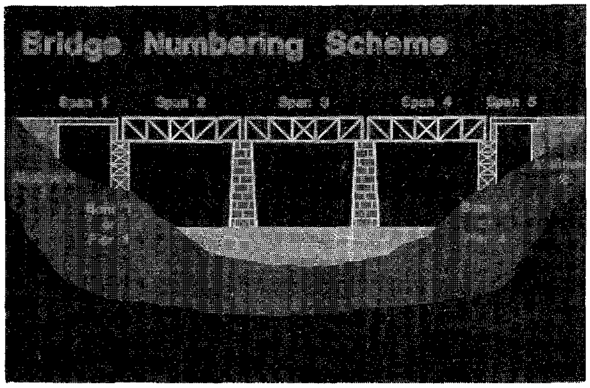
Some examples:

- Multi-beam
- Deck slab
- Stringer
- Floorbeam
- Girder
- Truss chord
- Truss diagonal
- Secondary bracing
- Arch
- Spandrel column
- Spandrel wall
- Abutment
- Pier

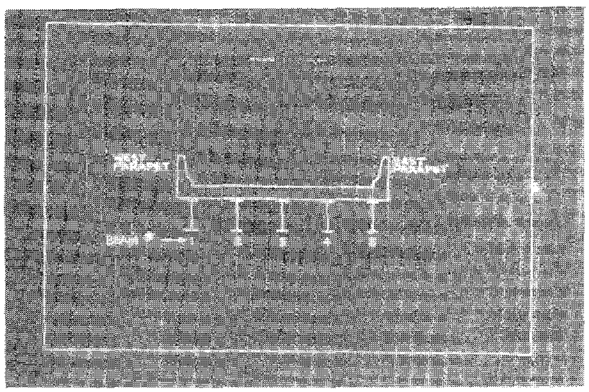
B. ORIENTATION

See Slide 5-2-16

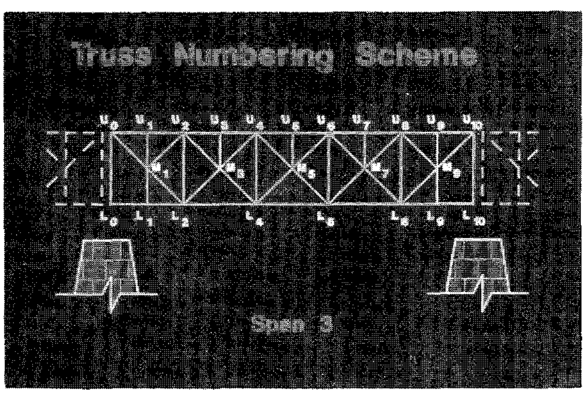
1. **Structure orientation** is normally established according to highway direction of inventory, mile markers, or stationing.



Slide No. 5-2-17
Schematic Slide
Sample bridge numbering scheme
(BITM 90, page 5-6)



Slide No. 5-2-18
Schematic Slide
Sample typical section numbering scheme



Slide No. 5-2-19
Schematic Slide
Sample truss numbering scheme
(BITM 90, page 5-7)

Defects

- Identification
- Dimensioning
- Location
- Reference Point Dimension

Slide No. 5-2-20
Narrative Slide

2. **Identify substructure units** and sides of floorbeams with near/far, north/south, or east/west designations. Alternately, number the substructure units, such as Abutment #1, Pier #3, etc.

3. **Direction** - Sides of members can be identified by direction, i.e. "south side of floorbeam #2", or "northeast elevation of beam #4."

See Slide 5-2-17

4. **Span numbers** and bay numbers should be used to identify general areas on the bridge.

See Slide 5-2-18

5. **Element and Member Identification** - Individual beams or stringers should be numbered left to right, facing in the direction of inventory.

6. **Stream Flow Direction** - Upstream or downstream designators can be assigned to two-member structures over waterways. For example, "upstream truss", "downstream girder," or "upstream arch."

See Slide 5-2-19

7. **Truss Panel Points** - For truss elements, identify the member with joint designations. Number floorbeams in accordance with the panel point numbers.

C. DIMENSIONING

Sufficient dimensions must be documented to establish the cross section and other pertinent dimensions of elements:

1. **Beam or slab sizes** - length, width and depth of each; spacing and span length.

2. **Columns** - width and depth (for rectangular shapes), diameter (for round columns), length, spacing, pile batter and spacing.

3. **Caps and struts** - width, depth, clear span, cantilever span.

III. DEFECTS

A. IDENTIFICATION

Defects should be identified by their specific types:

1. **Timber**

Defects that are likely to occur to timber elements include:

- decay - caused by either fungi or insects
- checks - partial depth
- splits - full depth
- knots
- cracks
- wear - caused by traffic or water
- fire damage

2. Concrete

Typical concrete defects to look for are:

- delaminations
- spalls
- scaling
- cracks
- exposed rebar or prestressing strands
- collision damage
- camber (for pre-stressed beams)

3. Steel

Some of the defects you may encounter on steel and wrought iron elements include:

- corrosion
- cracks
- deformation
- buckling
- collision damage

B. DIMENSIONING

Documenting of defects by an inspector should include enough information to determine the following:

1. Severity of Defects

- Cracks - record length, width, depth
- Section loss - record the remaining section dimensions
- Deformation - record amount of misalignment

2. Quantity of Defects

- Spalling - record dimensions of affected areas
- Scaling - record dimensions of affected areas
- Delamination - record dimensions of affected areas
- Decay - record dimensions of affected areas

C. LOCATION

1. Exact Position on the Element

Examples:

- Left side of web, top half, 3 feet (915 mm) from north bearing
- Bottom of top flange, from 3 feet to 6 feet (915 mm to 1830 mm) west of Pier 2.

2. Location Importance

The accuracy of the load capacity analysis depends on precise location information for defects.

- **Bending Moment** - maximum at or near midspan for simple span structures. Maximum negative moment occurs at the intermediate supports where the structure is continuous.

- **Shear** - maximum at or near the supports.

- **Axial Compression Members** - the capacity of the member to resist compressive forces is reduced by any deformation or change in cross section. The potential capacity reduction is not dependent on where on the member the defect is located. All segments are critical.

- **Axial Tension Members** - These members experience a reduction in capacity through loss of section or from cracking. As with the axial compressive members, these tensile members are equally susceptible regardless of the location of the defect.

- **Combinations** - While axial members are critical at all locations, it is not always apparent which members are loaded only in an axial direction. In fact, due to the dead load of the member itself, most are not. Other factors can also contribute to bending forces that will create varying moments, shears, compression, and tension areas within a member that is primarily axial. Because of this, inspectors should identify the exact position of defects in all members using reference points, regardless of the forces acting on the member

Summary

- Inspection Notebook
- Elements
- Defects

Slide No. 5-2-21
Narrative Slide

Recordkeeping and Documentation Exercises

Slide No. 5-2-22
Title Slide

D. REFERENCE POINT DIMENSION

Locating a defect includes tying it to an established permanent reference. Avoid using references that can change over time.

Some examples of proper referencing include:

- 7 feet - 3 inches (2210 mm) from fixed bearing on beam #3 at Abutment #1.
- 3 feet - 1 inch (940 mm) from west corner of Abutment #2
- 2 feet - 6 inches (760 mm) below bridge seat on south face of Column #1, Pier #2

Reference points to avoid:

- expansion rocker faces
- ground levels, especially those that may be exposed to water
- water levels

IV. SUMMARY

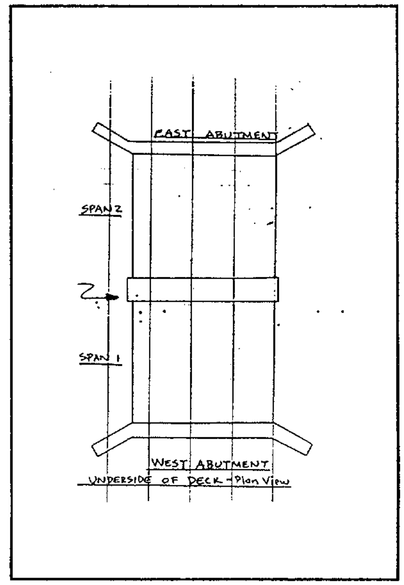
A. **INSPECTION NOTEBOOK** - standard notations, inspection notes, sketches, photo log

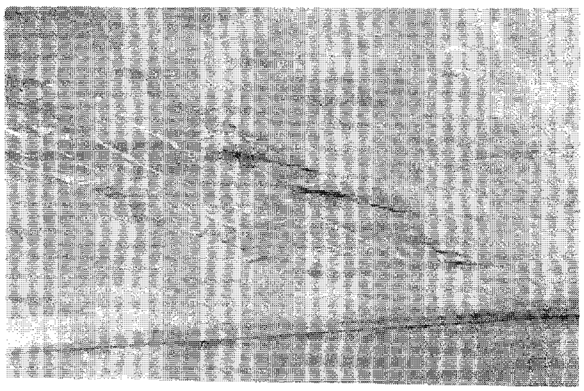
B. **ELEMENTS** - identification, orientation, dimensioning

C. **DEFECTS** - identification, dimensioning, location, reference point

V. RECORDKEEPING AND DOCUMENTATION EXERCISES

Slide No. 5-2-23
Schematic Slide
Blank deck defect sketch





Slide No. 5-2-24
Example Slide
Deck defects

A. CONCRETE DECK RECORDKEEPING EXAMPLE

See Slide 5-2-23

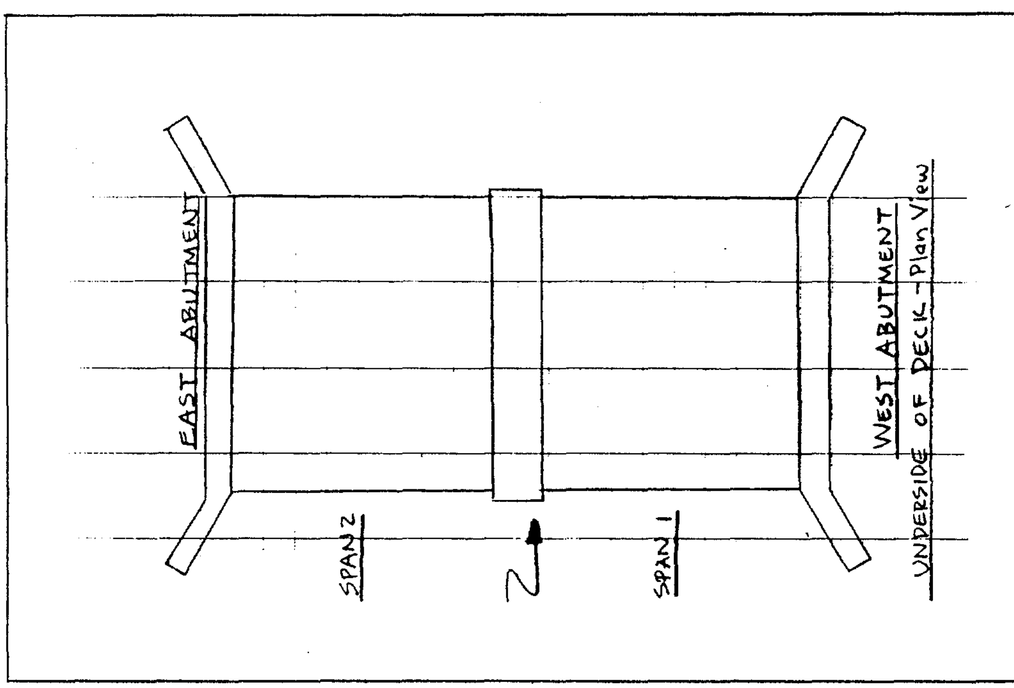
This is a field sketch of a two-span cast-in-place reinforced concrete slab bridge.

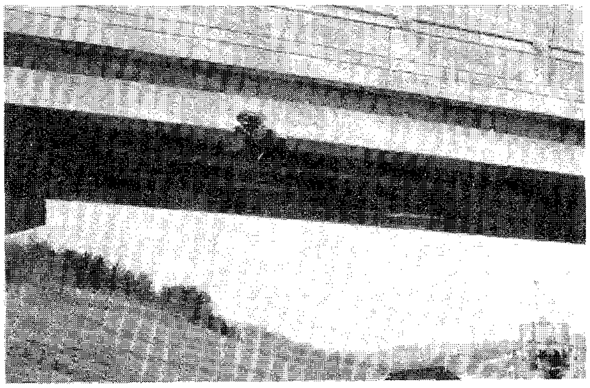
Defects observed:

See Slide 5-2-24

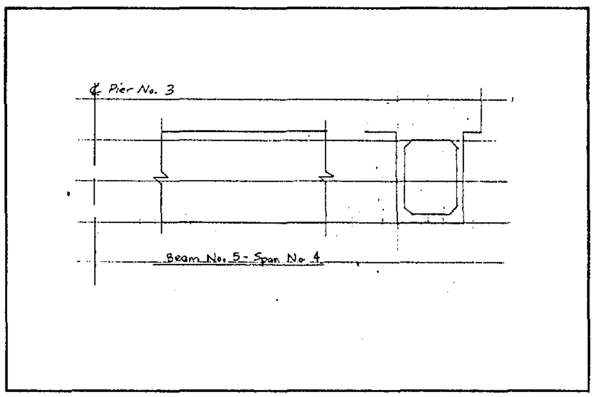
- 2 feet x 12 feet (610 mm x 3660 mm) delaminated area with hairline cracks, efflorescence, and rust staining on the bottom of the deck in Span No. 1. The area begins 2 feet (610 mm) from the west abutment and 8 feet - 3 inches (2515 mm) from the downstream edge of the deck.

Sketch:





Slide No. 5-2-26
Example Slide
P/S box beam with collision damage



Slide No. 5-2-27
Schematic Slide
Blank P/S beam defect sketch

B. PRESTRESSED BEAM COLLISION DAMAGE RECORDKEEPING EXERCISES

See Slide 5-2-26

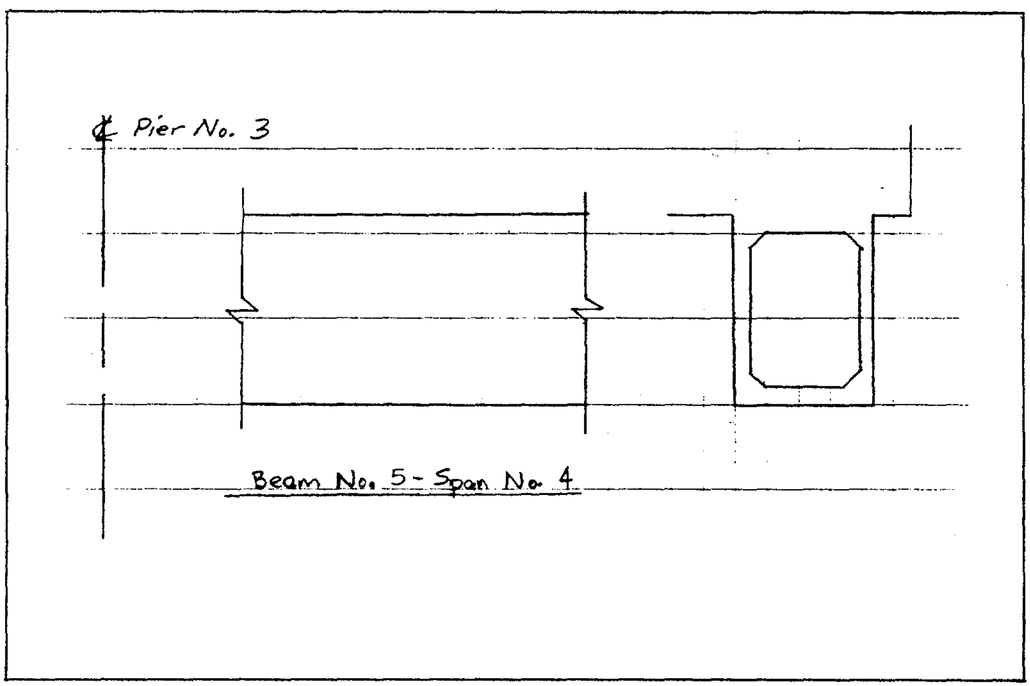
This is a five-span prestressed concrete spread box beam bridge.

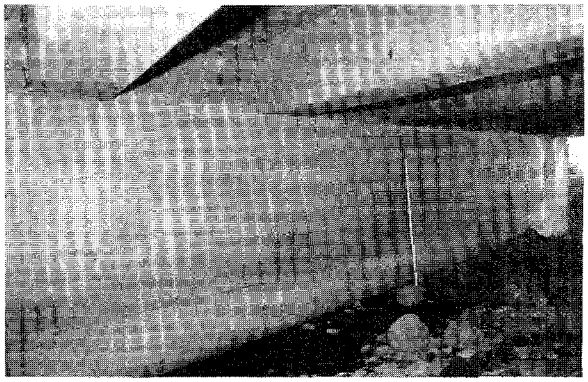
Defects observed:

- Severe collision damage to Beam No. 5 in Span No. 4 at a point located 25 feet - 4 inches (7.7 m) from the centerline of Pier No. 3. The damaged area is 1 foot - 5 inches (430 mm) high and varies in width from 1 foot - 0 inch (305 mm) at the top to 2 feet - 5 inches (740 mm) at the bottom. About 1 foot - 0 inches (305 mm) of the bottom flange width remains undamaged. Sixteen prestressing strands are exposed. All exhibit surface rust. Six strands in the bottom outermost corner of the beam are completely severed.

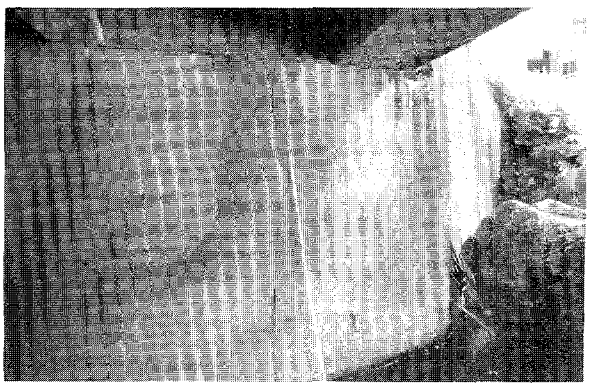
See Slide 5-2-27

Sketch:

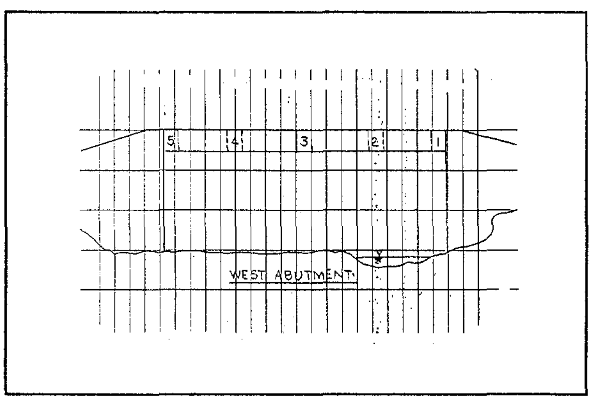




Slide No. 5-2-29
Example Slide
Abrasion defect on face of abutment



Slide No. 5-2-30
Example Slide
Crack and other defects on face of abutment



Slide No. 5-2-31
Schematic Slide
Blank abutment defects sketch

C. CONCRETE ABUTMENT RECORDKEEPING EXAMPLE

This is the west/near reinforced concrete cantilever abutment on a concrete tee-beam bridge.

Defects observed:

See Slide 5-2-29

- 1/8 inch (3 mm) maximum depth abrasion of stem front face for a 14 inches (360 mm) height at the bottom.

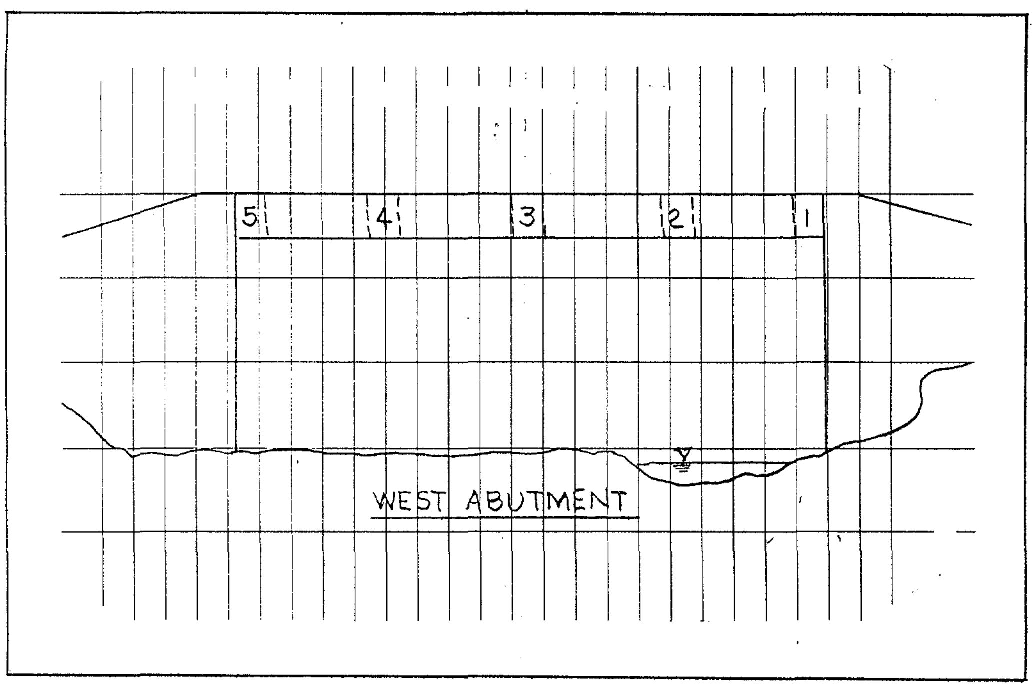
See Slide 5-2-30

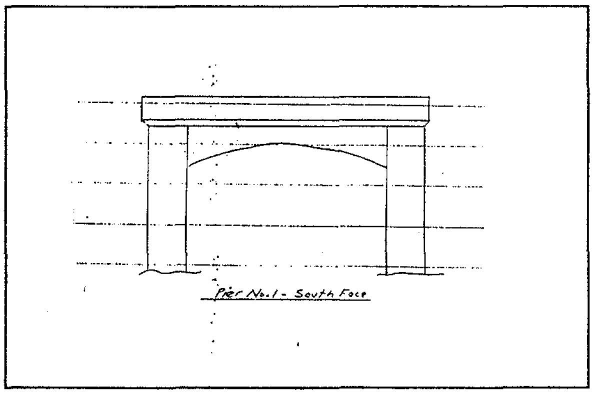
- 1/8 inch (3 mm) wide full height diagonal crack, beginning 42 inches (1070 mm) from the north wing at the base, and ending 30 inches (760 mm) from the north wing at the top.

- 4 inches x 18 inches (100 mm x 460 mm) delaminated area along the south side of the crack, near the top and a 2 inches x 6 inches x 1 inch (50 x 150 x 25 mm) spall near the bottom of the crack.

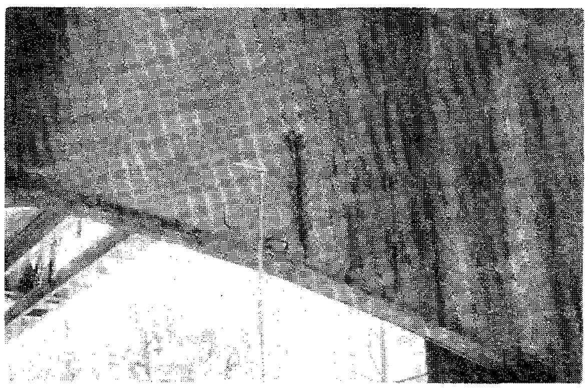
See Slide 5-2-31

Sketch:

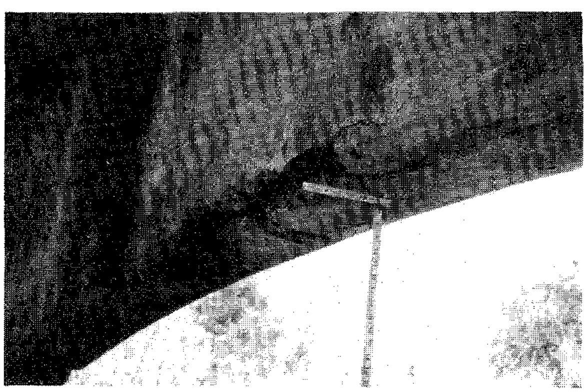




Slide No. 5-2-33
Schematic Slide
Blank pier defects sketch

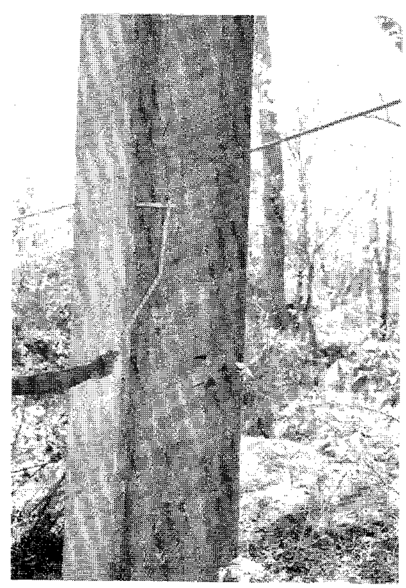


Slide No. 5-2-34
Example slide
Defects in pier cap at stirrups



Slide No. 5-2-35
Example Slide
Defects in pier cap

Slide No. 5-2-36
Example Slide
Defects in pier column



D. CONCRETE PIER RECORDKEEPING EXAMPLE

See Slide 5-2-33

This is a reinforced concrete pier.

Defects observed:

See Slide 5-2-34

- Four 3/4 inch D x 3 inches W (19 x 76 mm) cover spalls on the cap at the stirrups. Starting at the right with the first spall which is located 3 feet (915 mm) from the east column, the spalls measure 18 inches, 36 inches, 30 inches, 24 inches (460, 915, 760, 610 mm) long, respectively. The stirrups, which were originally #5 bars spaced a 12 inches (305 mm), now measure 7/16 inch (11 mm) in diameter.

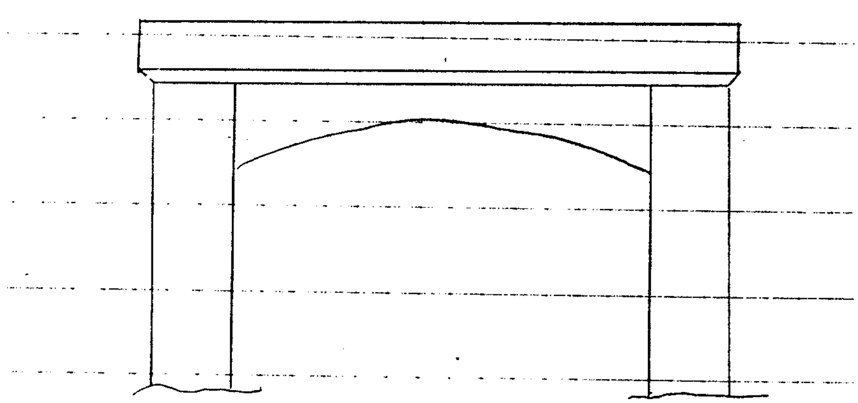
See Slide 5-2-35

- Corner spall on the south face of the cap at the bottom starting 7 feet - 3 inches (2.2 m) from the west column. The spall measures 3 inches x 18 inches x 3 inches (76 x 460 x 76 mm). A #8 rebar now measuring 1/2 inch (13 mm) in diameter is exposed. There is also a 1/16 inch (2 mm) crack extending 20 inches (510 mm) beyond the end of the spall.

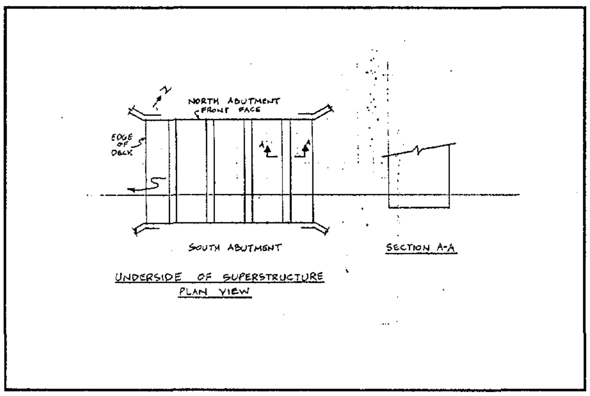
See Slide 5-2-36

- 1/8 inch (3 mm) full height vertical crack located 6 inches (150 mm) from the southwest corner of the east column on the south and west faces.

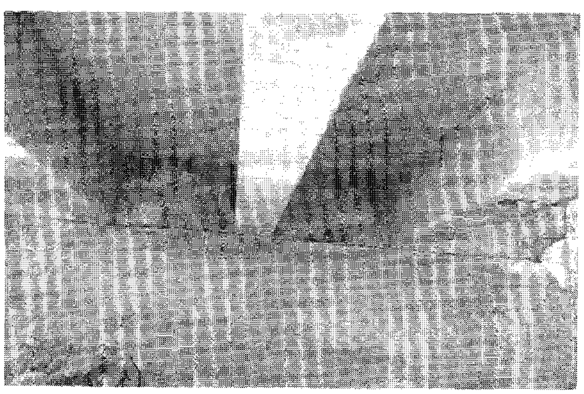
Sketch:



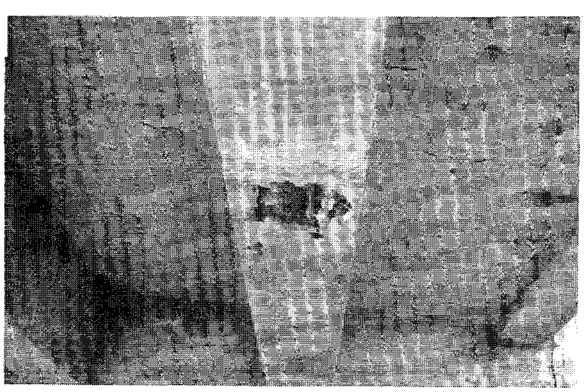
Pier No. 1 - South Face



Slide No. 5-2-38
Schematic Slide
Blank tee beam defects sketch



Slide No. 5-2-39
Example Slide
Underside of tee beam bridge



Slide No. 5-2-40
Example Slide
Tee beam defect

E. CONCRETE TEE BEAM RECORDKEEPING EXAMPLE

See Slide 5-2-38

This is a reinforced concrete tee beam bridge.

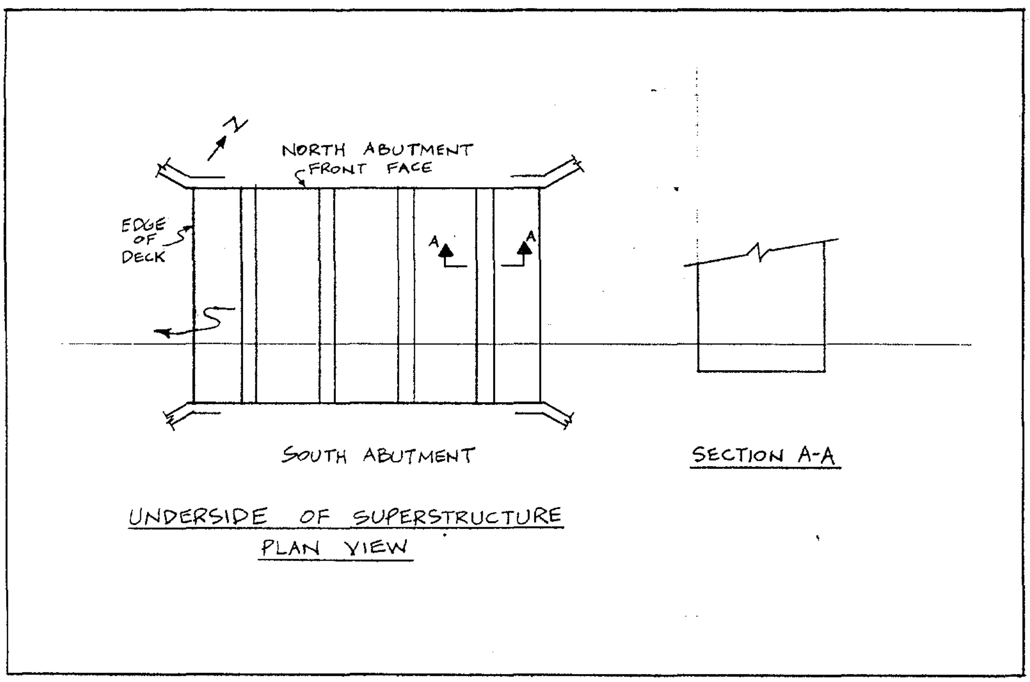
Defects observed:

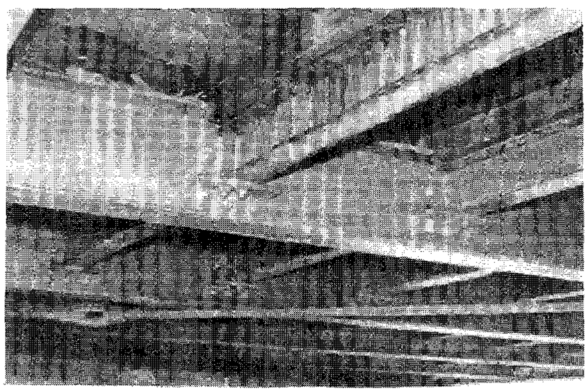
See Slide 5-2-39

- East fascia beam has a 10 inch diameter x 4 inches deep (250 x 100 mm) honeycombed area on the bottom surface of the stem located at a point 10 feet - 3 inches (3.1 m) from the north abutment. The bottom layer of tensile reinforcement, consisting of 4 - #8 bars spaced at 4 inches (100 mm), is exposed and has 1/16 inch (2 mm) section loss due to corrosion.

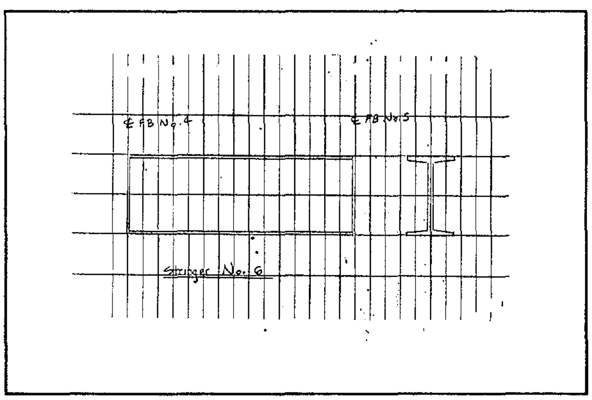
See Slide 5-2-40

Sketch:





Slide No. 5-2-42
Example Slide
Steel stringer defects



Slide No. 5-2-43
Schematic Slide
Blank stringer defects sketch

See Slide 5-2-42

F. STEEL STRINGER RECORDKEEPING EXAMPLE

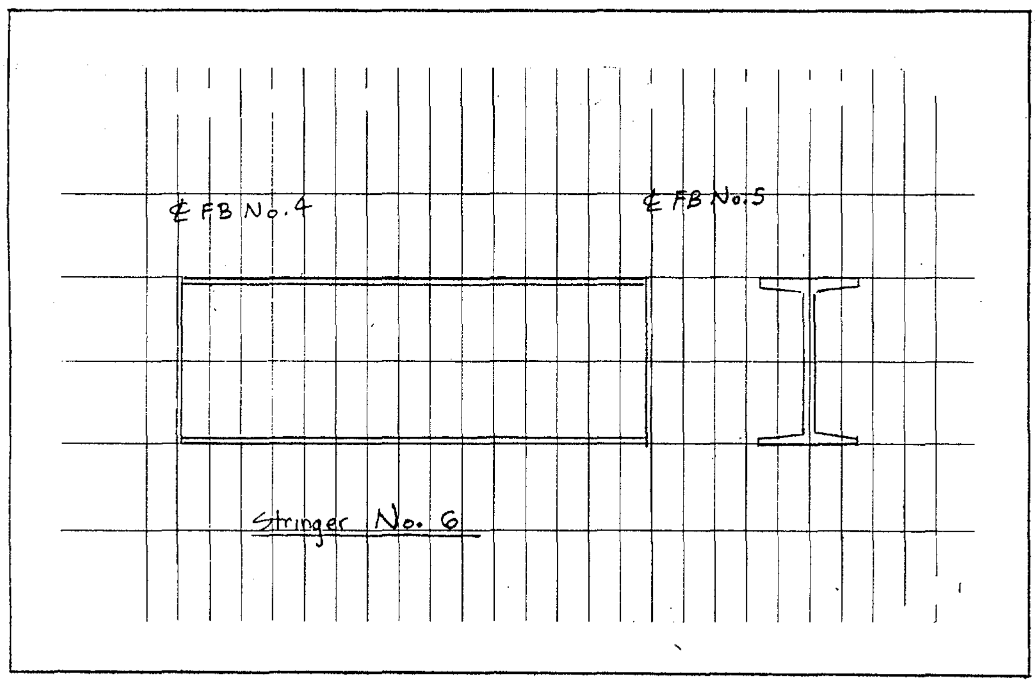
This is the underside of a steel truss bridge with rolled steel stringers and floorbeams.

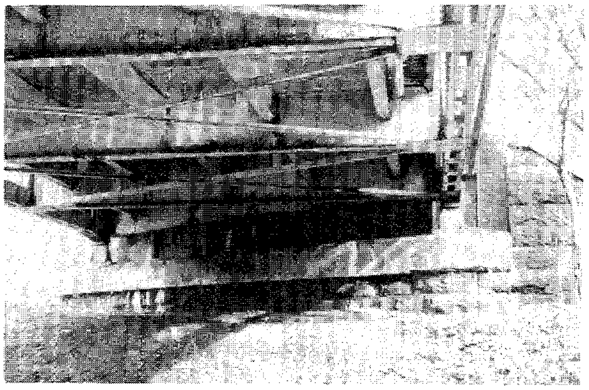
Defects observed:

- East side of Stringer No. 6 exhibits 1/16 inch (2 mm) section loss on the bottom of the top flange for 6 feet (1830 mm) from Floorbeam No. 4.
- East side of Stringer No. 6 has 1/8 inch (3 mm) section loss on the top side of the bottom flange starting 9 inches (230 mm) from Floorbeam No. 4 and extending for 4 feet -10 inches (1500 mm).

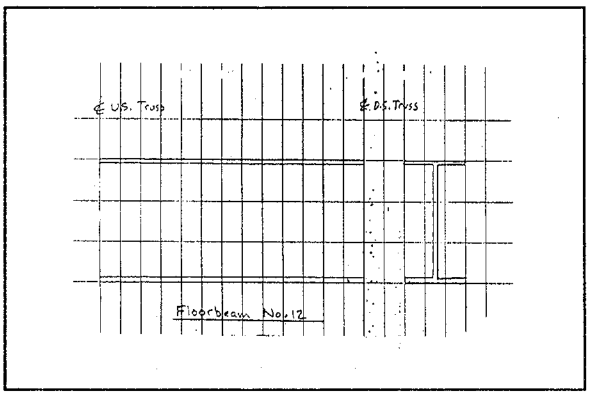
See Slide 5-2-43

Sketch:





Slide No. 5-2-45
Example Slide
Steel floorbeam defects



Slide No. 5-2-46
Schematic Slide
Blank floorbeam defects sketch

G. STEEL FLOORBEAM RECORDKEEPING EXAMPLE

See Slide 5-2-45

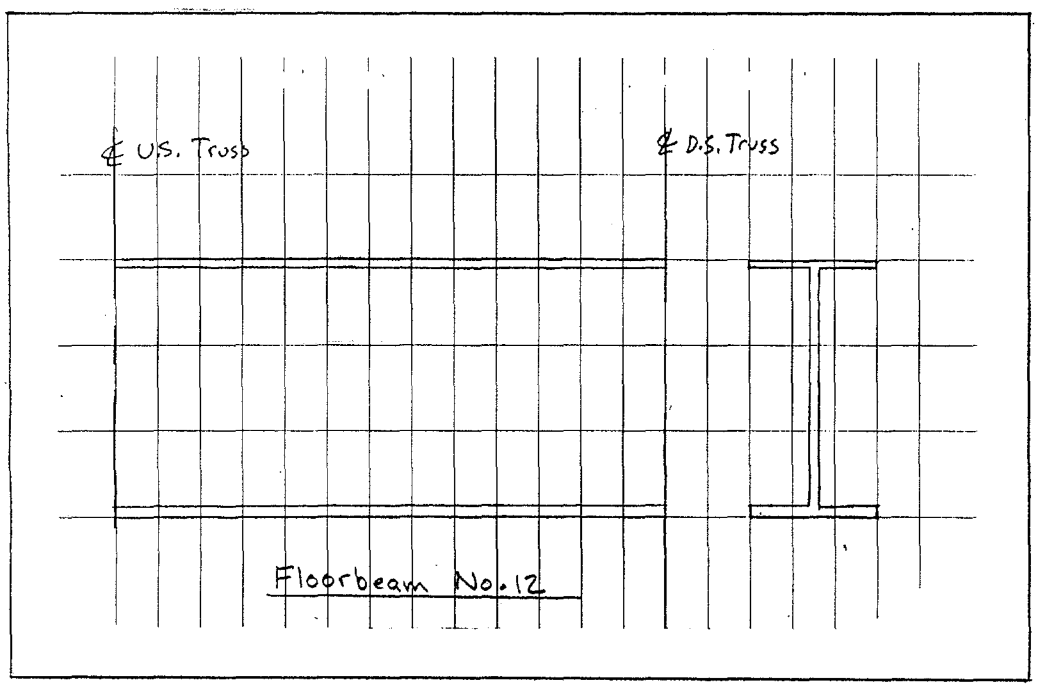
This is the underside of a steel truss bridge with rolled steel stringers and floorbeams.

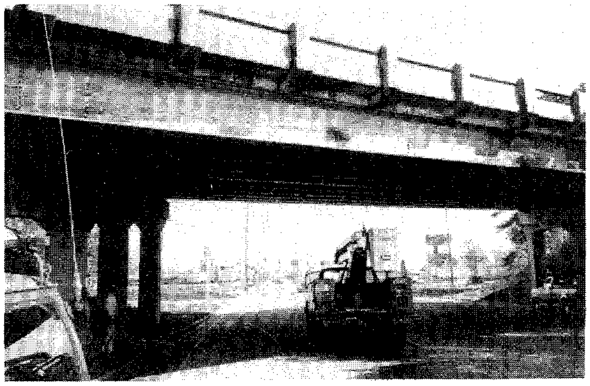
Defects observed:

- Floorbeam No. 12 has 1/16 inch (2 mm) section loss on the west side of the web below Stringer No. 4.
- Floorbeam No. 12 has 1/6 inch (2 mm) section loss on the top side of the bottom flange for a 7 foot (2100 mm) length starting 1 foot - 6 inches (460 mm) from the downstream truss.

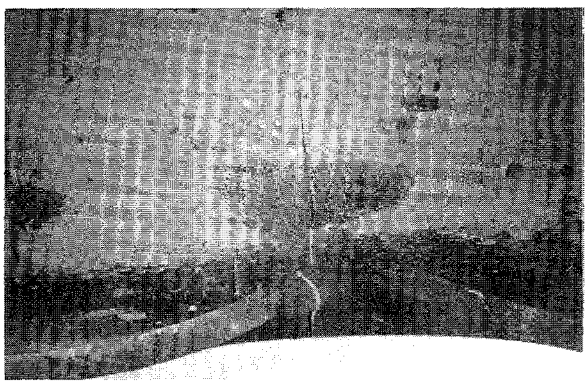
See Slide 5-2-46

Sketch:

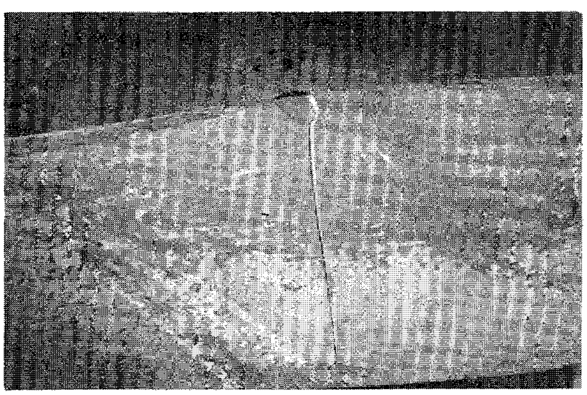




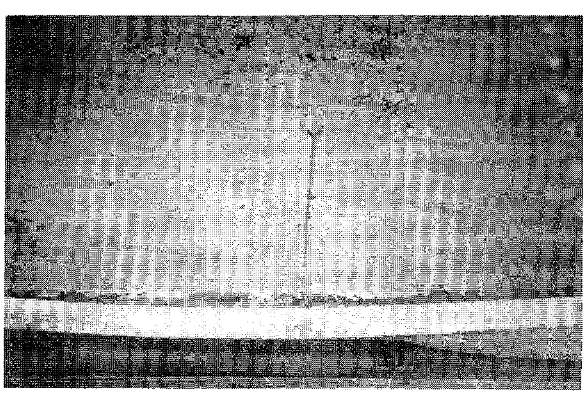
Slide No. 5-2-48
Example Slide
Bridge that suffered steel beam collision damage



Slide No. 5-2-49
Example Slide
Bent, cracked bottom flange (impact side)



Slide No. 5-2-50
Example Slide
Cracked bottom flange (bottom side)



Slide No. 5-2-51
Example Slide
Cracked web (side away from impact)

H. STEEL BEAM COLLISION DAMAGE/FATIGUE CRACKING RECORDKEEPING EXAMPLE

See Slide 5-2-48

This is the I-59 bridge over Beacon Street in Laurel, Mississippi. It is a rolled steel multi-beam bridge.

Defects observed:

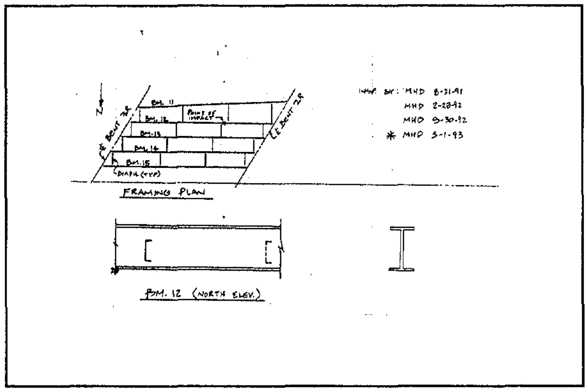
See Slide 5-2-49

- In August 1991, Beam No. 12, which is a W36 x 300 beam spanning 82 feet (25 m), suffered collision damage from a large garbage truck. The bottom flange was struck on the north side about 27 feet (8.2 m) from Bent No. 2R and was bent up about 3 1/2 inches (90 mm) maximum over a length of about 27 inches (700 mm). No cracks were noted.

See Slide 5-2-50

See Slide 5-2-51

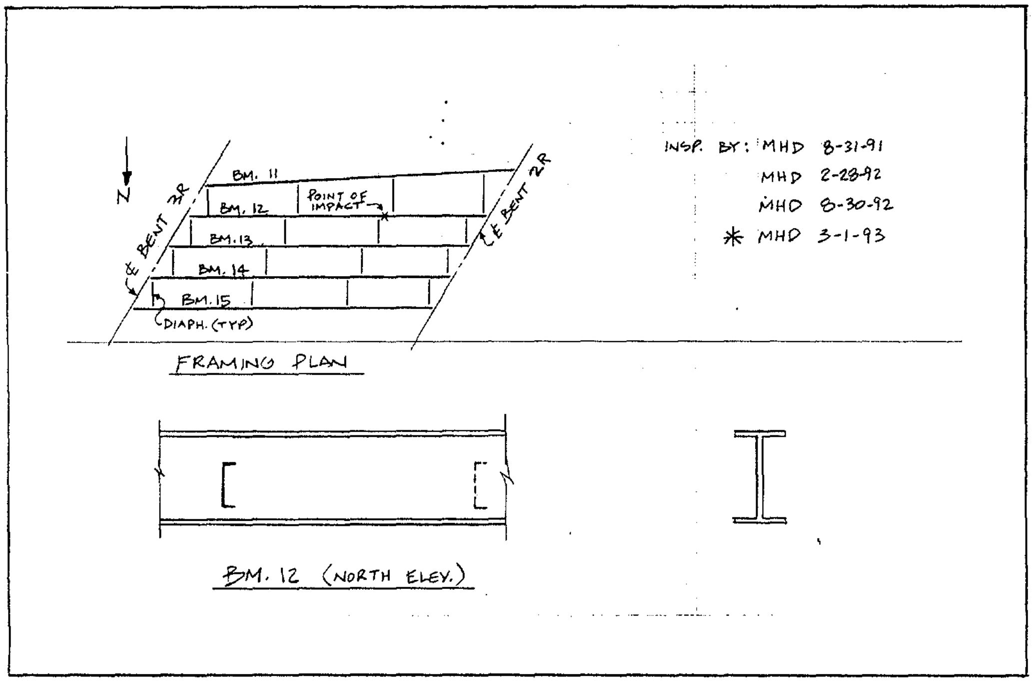
- In March 1993, a crack was discovered in the bottom flange and web. The crack width varied from 1/8 inch (3 mm) maximum at the bottom flange to zero at a point 9 inches (230 mm) up the web.

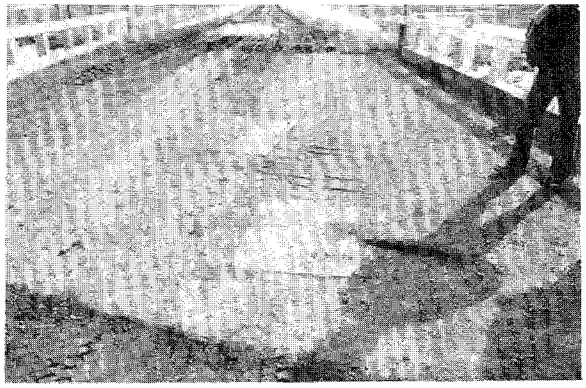


Slide No. 5-2-52
Schematic Slide
Blank steel beam collision damage sketch

See Slide 5-2-52

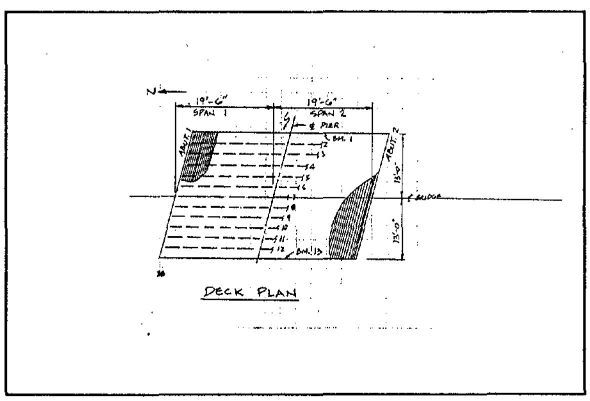
Sketch:





Slide No. 5-2-54
Example Slide
Timber deck condition (top side)

Slide No. 5-2-55
Example Slide
Timber deck localized failure (bottom side)



Slide No. 5-2-56
Schematic Slide
Blank deck defect sketch

I. TIMBER DECK RECORDKEEPING EXAMPLE

See Slide 5-2-54

This is a nailed laminated 2 inches x 4 inches (50 x 100 mm) timber deck on a two span timber multi-beam bridge near Helena, Montana.

Defects observed:

See Slide 5-2-55

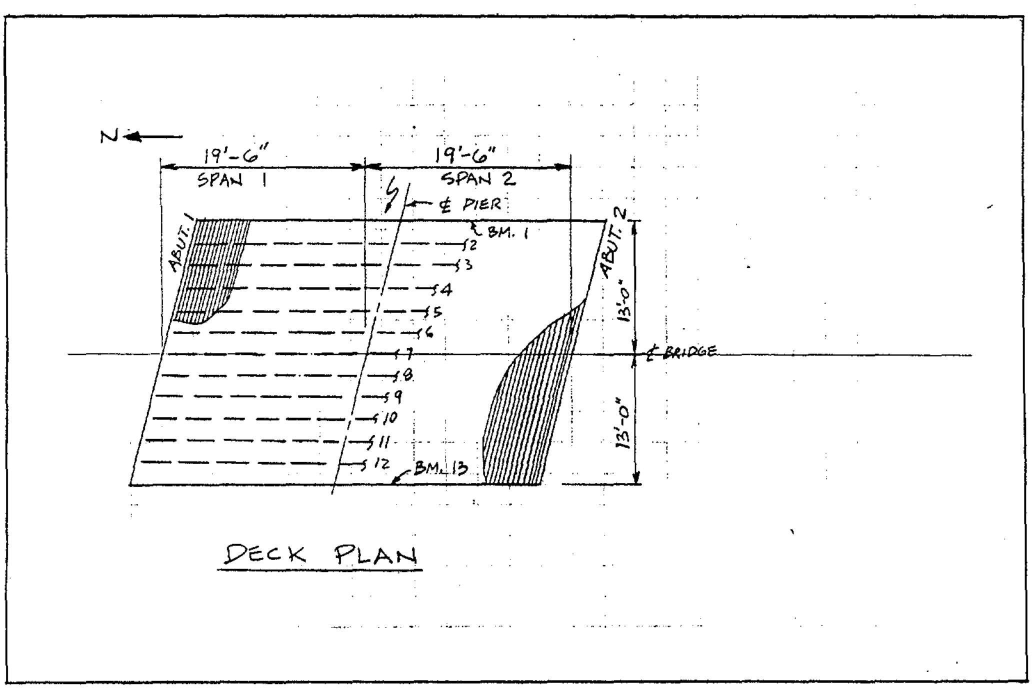
- Two 30 inches x 48 inches (760 x 1210 mm) steel patch plates cover two 24 inches x 30 inches (610 x 760 mm) localized deck failure areas in Span No. 1. The first one is located about 3 feet (915 mm) from Abutment No. 1, between Beam Nos. 8 and 9, and 8 feet - 6 inches (2600 mm) from Beam No. 13.

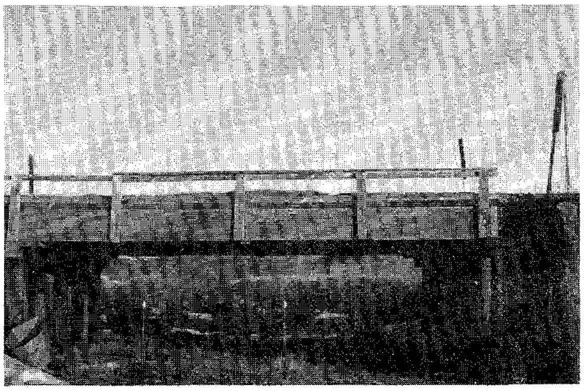
  The second one is located 10 feet (3050 mm) from Abutment No. 1, between Beam Nos. 6 and 7, and 10 feet - 7 inches (3230 mm) from Beam No. 1.

- Minor wear of the top side and minor decay on the bottom side is typical over most of the deck.

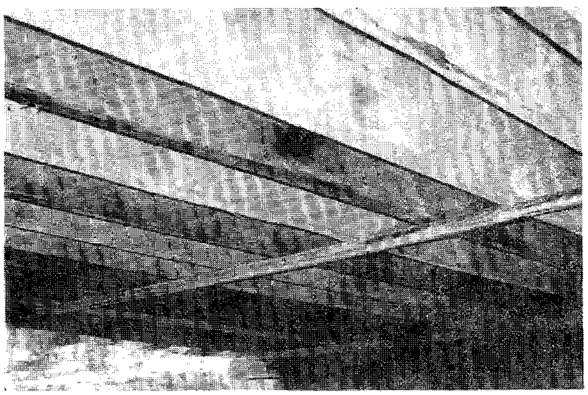
See Slide 5-2-56

Sketch:



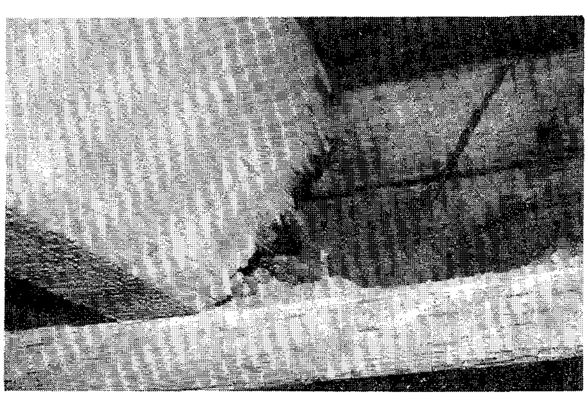


Slide No. 5-2-58
Example Slide
Timber multi-beam bridge



Slide No. 5-2-59
Example Slide
Typical underside view of superstructure

Slide No. 5-2-60
Example Slide
Beam No. 2



Slide No. 5-2-61
Example Slide
Beam No. 7 at West Abutment

J. TIMBER SUPERSTRUCTURE RECORDKEEPING EXAMPLE

See Slide 5-2-58

This is a solid sawn timber multi-beam bridge near Bismarck, North Dakota.

Defects observed:

See Slide 5-2-59

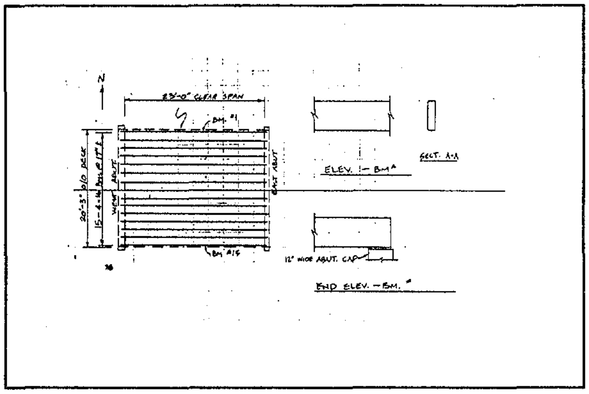
- The 4 inches x 16 inches (100 x 400 mm) timber beams exhibit staining and discoloration in many areas.

See Slide 5-2-60

- Beam No. 2 has a pocket of decay in the bottom of the beam at the point located about 15 feet (4.6 m) from the West Abutment. The pocket measures about 2 inches wide x 18 inches long x 4 inches deep (50 x 460 x 100 mm) into the beam.

See Slide 5-2-61

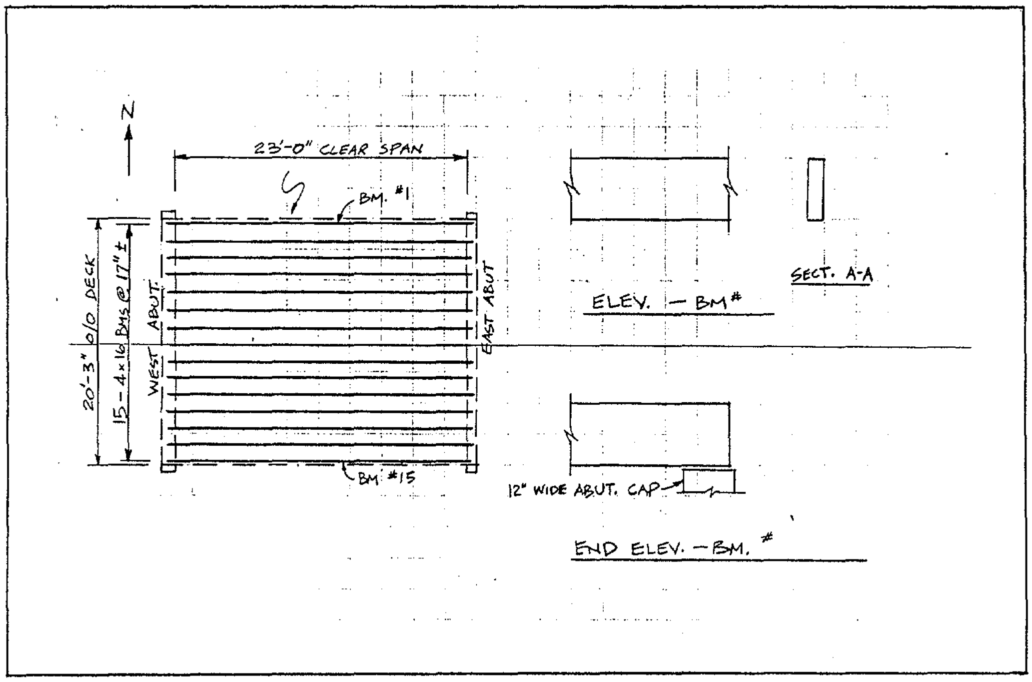
- Severe decay to the end of Beam No. 7 at the West Abutment has resulted in approximately 95% loss of bearing. At the West Abutment, the ends of Beam Nos. 3, 8, 12, and 14 also are decayed resulting in bearing losses of approximately 30%, 50%, 85%, and 10%, respectively.



Slide No. 5-2-62
Schematic Slide
Blank timber superstructure sketch

See Slide 5-2-62

Sketch:



SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

TOPIC 3: THE INSPECTION REPORT

LESSON PLAN

TOPIC DURATION	30 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 14 and Appendix B
GOAL	Understanding of the importance of an accurate, thorough bridge inspection report.
OBJECTIVE	To identify all the components that go into a good bridge inspection report and to emphasize the importance of bridge inspection reports.
PARTICIPATION	Participants will review the example inspection report in BITM 90, or an Agency supplied report, with the instructor.

I. GENERAL

A. PURPOSE OF BRIDGE INSPECTION REPORTING SYSTEM

1. **Existing Conditions** - To record the existing condition of a bridge for the safety of the traveling public.

2. **Planning** - To form the basis of quantifying the manpower, equipment, materials, and funds that are necessary to maintain the integrity of the structure.

B. REPORT CONTENTS

1. **The body of a complete bridge inspection report should contain the following parts:**

   - Introduction/Executive Summary
   - Location Map
   - Bridge Description
   - Bridge History
   - Inspection Procedures
   - Inspection Findings
   - Load Rating Summary
   - Conclusions and Recommendations

2. **The appendix of a complete inspection report should contain the following:**

   - Photographs
   - Plans and Sketches
   - S I & A Form
   - Load Capacity Analysis
   - Field Inspection Forms/Notes
   - Underwater Inspection Report
   - Material Testing Results

3. **Variations** - Whether or not all of these report components are needed depends largely upon the type and size of the structure.

C. CURSORY INSPECTIONS

1. **Cursory inspections** - are made many times for checking some specific item where a problem or change may be anticipated.

2. **Report** - Even though no changes are evident, a report should be made for every bridge inspection, even though it may only be a cursory inspection.

3. **Document** - It is important to document the condition of the structure at every inspection.

II. BODY OF REPORT

A. INTRODUCTION/EXECUTIVE SUMMARY

An in-depth report usually contains a one or two page summary at the beginning that describes the inspection and analysis findings in regard to the condition and the load capacity of the bridge, along with an overview of recommendations.

B. LOCATION MAP

Immediately following the Table of Contents, a map should be included with a scale large enough to positively locate the structure. The bridge should be clearly marked and labeled and the map should have a North arrow.

C. BRIDGE DESCRIPTION

The report should contain a detailed narrative that discusses the function and type(s) of deck, superstructure elements and substructure units and identifies the features carried and intersected by the bridge. A description should also be provided for:

- Number and length of spans
- Total Length
- Skew angle
- Roadway width
- Wearing surface
- Sidewalks
- Railing
- Traffic lanes
- Design live loading
- Clearances
- Alignment
- Waterway

D. BRIDGE HISTORY

The history of the bridge is from a structural standpoint and should be developed from information obtained from design, construction and rehab plans, previous inspection reports, maintenance records, discussions with local residents, and any other available source that offers pertinent information. Items to be included in the history narrative include:

- Year built
- Reconstruction year, if any
- Historical flood frequencies
- Maintenance measures and repairs
- Chronological record of conditions
- Reference drawings

E. INSPECTION PROCEDURES

This part of the report should describe exactly what actions were taken by the inspectors to perform the inspection. The following items should be included in the Inspection Procedures narrative, if they are used during the inspection:

- Inspection sequence (e.g. deck, superstructure, etc.)
- Access equipment (e.g. rigging, ladders, free climbing)
- Access vehicles (e.g. inspection cranes, bucket trucks)
- Traffic control operations (e.g. lane closures, flagmen)
- Special equipment (e.g. material testing, underwater inspection)
- Special inspection types and methods (coring, ultrasonic)
- Deviations from "hands-on" inspection of all areas
- Personnel (e.g. number of inspectors, boatmen)

F. INSPECTION FINDINGS

The inspection findings should summarize all documentation of defects and deficiencies performed during the inspection. The discussion should be both quantitative and qualitative, indicating the locations and the extent of the affected areas.

G. LOAD RATING SUMMARY

A summary of the load capacity stress analysis should be included in the report. The summary can be presented in either a narrative form or in a table or chart. Governing load ratings should be shown for both inventory and operating levels for all types of loadings used in the analysis. The governing member for each rating should be identified. The governing member is the one that has the lowest capacity for a given type of loading.

For example, in a Girder-Floorbeam-Stringer structure, Stringer #3 in Bay #5 may have the lowest capacity for carrying HS20 trucks, compared to all other stringers, floorbeams, or girders. The HS20 inventory and operating ratings for this stringer would be reported, and it would be identified as the governing member.

H. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations section of the report should summarize the following:

1. **Overall condition**
2. **Major deficiencies**
3. **Load carrying capacity**
4. **Recommendations for:**
   - further inspection
   - maintenance
   - repairs
   - painting
   - posting
   - replacing

This will require considerable judgement on the part of the inspector. However, if the inspector is in doubt about the proper recommendations, he should seek the advice of more experienced or more qualified personnel.

III. REPORT APPENDICES

A. PHOTOGRAPHS

Photographs should be mounted on sheets that are the same size as the report pages. Captions should be provided for each photo. The photos should be numbered so that they can be referred to in the body of the report. Sufficient photos should be provided to clearly show the conditions of the various elements and components.

B. PLANS AND SKETCHES

Drafting quality plans and sketches, sufficient to indicate the layout of the bridge should be included as an Appendix. Sketches should be used freely as needed to illustrate and clarify conditions of structural elements.

C. S.I. & A FORM

A complete SI&A form should be included in the Appendix. Entries should include the condition and appraisal ratings for the current inspection. If a previous report or printout is used for inventory data, items should be field checked for accuracy.

D. LOAD CAPACITY ANALYSIS

Stress analysis should be performed on the superstructure to determine the load capacity of the bridge. It should include investigation of all primary load carrying members of the superstructure. Such analysis is normally performed by engineers in the office, not by the inspector.

E. FIELD INSPECTION NOTES

The original notes taken by the inspectors in the field or photocopies thereof should be included in the Appendix section of the report. The original field notes are source documents and as such should be included in the structure file.

F. UNDERWATER INSPECTION REPORT

If an underwater inspection of the substructure has been performed, a separate report is usually prepared by the diver. If applicable, the diver's report should be included in the Appendix.

G. MATERIAL TESTING RESULTS

Sometimes material testing is performed on a structure in order to determine the strength and properties of an unknown or suspect material. The testing lab's report should also be included in the Appendix of the bridge inspection report.

IV. THE IMPORTANCE OF THE INSPECTION REPORT

A. SOURCE OF INFORMATION

A report is an extremely valuable document when completed properly. New inspection reports should be made each time a bridge is inspected. Reports and supplemental information must be accurate, clear, and thorough.

Well prepared report provides information on existing bridge conditions. It also becomes an excellent reference source for future inspections, comparative analyses, and bridge study projects.

The inspector should report all conditions, especially those that may be suspicious but unclear, in a clear and factual manner, avoiding speculation. More qualified personnel should be consulted in those situations where the inspector is unsure.

B. LEGAL DOCUMENT

A report is a legal record which may form an important element in some future litigation. Language used in reports should be clear and concise. The same phraseology should be used as much as possible to avoid ambiguity of meaning.

Information contained in reports is obtained from field investigations and is sometimes supplemented by reference to design drawings or as-built drawings. The source of the information should be clearly stated in the report.

The inspector should sign and date each report as he completes it.

- No undocumented alterations should be made to the report once it is completed.
- Some inspectors retain copies of their reports for their personal files in the interest of self-protection should any litigation come about.

V. INSPECTION REPORT OBJECTIVES

A. NEEDED ACTION

A report provides guidance for immediate follow-up inspections or other actions needed for the bridge. Critical areas of concern are identified in the report. The report may be used as the basis for possibly limiting the use of, or closing to traffic, any bridge which the inspection has revealed to be hazardous to public safety.

B. MAINTENANCE PLANNING

Inspection reports provide useful information on the needs and effectiveness of routine maintenance activities. Active preventive maintenance program is vital to the long-term structural integrity of the bridge.

A report enables bridge maintenance to be programmed more effectively, through early detection of structural defects or deficiencies, thus minimizing repair costs.

C. LOAD RATING ANALYSIS

If the inspection report determines that the defects or deficiencies may affect the load carrying capacity of the structure, a revised stress analysis must be made to ascertain the safe load capacity for the current condition of the structure.

Load restrictions may be placed on the structure so that its safe load capacity is not exceeded. The revised stress analysis then becomes part of the structure file.

D. BRIDGE MANAGEMENT

The inspection report is used by FHWA and the states to analyze the SI&A data as an aid in deciding how to allocate available funding.

Information from the inspection report is stored in a bridge management system, which provides an easily accessible system for maintaining and retrieving of bridge information that is useful in the planning and managing of the Nation's bridges.

VI. SUMMARY

IMPORTANCE OF BRIDGE INSPECTION REPORT

- Major source of information
- Legal document
- Determine action needed
- Maintenance planning
- Load rating analysis
- Bridge management

SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

TOPIC 4: REVIEW AGENCY INVENTORY ITEMS (OPTIONAL)

LESSON PLAN

TOPIC DURATION	90 minutes
PREREQUISITES	Session 5 - Topic 1
PARTICIPANT MATERIALS	Participant Notebook; BITM 90
GOAL	Understanding of the importance of proper bridge inspection reporting.

SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

TOPIC 5: THE PONTIS BRIDGE MANAGEMENT SYSTEM

LESSON PLAN

TOPIC DURATION	2 hours and 30 minutes
PRE-REQUISITES	None
PARTICIPANT MATERIALS	Participant's Notebook, Volume III Appendix, BITM 90
GOAL	An understanding of network bridge management and the thought process involved in the development and implementation of Pontis.
OBJECTIVE	To use the Pontis bridge management system as a means to assess, record and prioritize bridge needs on a network level.

The Pontis Bridge Management System Lecture Outline

I. Pontis Background

A. Introduction to Pontis
1. FHWA Videotape (11 minutes)

B. BMS Development
1. Status of the Nation's Bridge
2. The BMS Solution
3. Objectives of Pontis
4. The Pontis Approach

II. Major System Components

A. The Pontis Database
1. Terminology
2. Bridge Elements
3. Conventions
4. Environments
5. Condition States/Feasible Actions

B. Bridge Inspector Input
1. Maintenance Inspection VS Safety Inspection
2. Inspector Responsibilities and Duties
3. Standard Report Forms
4. Inspection Procedures

C. Optimization Models
1. MR&R
2. Improvement
3. Integrated Project Programming
4. Condition States and Physical Action
5. User Cost
6. Deterioration Prediction

III. Adoption of Pontis

IV. Summary

ISTEA - 1992
Inter model Surface Transportation Efficiency Act

BMS - 1995 Implementation
Bridge Management System

Slide No. 5-5-1
Title Slide

Parallel Achievements

1. Primary Requirements
   - General Procedures
   - Functional Needs

Slide No. 5-5-2
Title Slide

I. PONTIS BACKGROUND

A. INTRODUCTION TO PONTIS

With each passing day it is becoming increasingly more evident that needed funding for bridge maintenance , repair and rehabilitation (MR&R) far exceeds the available funding. Even with latest infusion of financial support provided by the Inter modal Surface Transportation Efficiency Act (ISTEA) of 1992, funding for bridge MR&R projects is difficult to obtain. This is due in part to the enormous demand from across the nation.

The ISTEA legislation now requires that each state have implemented a comprehensive bridge management system (BMS) by October 1995.

This deadline represented a remarkable challenge since few States have previously implemented a BMS which could be considered to meet the definition of a comprehensive BMS. In fact, prior to the late 1980's, there were no existing management systems adaptable to the management of bridge programs nor was there any clear, accepted definition of key bridge management principles or objectives. This gap was overcome by the following largely parallel achievements:

1. Primary Requirements

FHWA and California DOT working with specially formulated Technical Working Group (TWG), were able to establish the following primary requirements of a comprehensive BMS:

General Procedures

a. Identify and establish responsibility for data collection and management and for bridge decision making based on a comprehensive BMS.

b. Provide for: coordination of program and project level decisions; for coordination of bridge maintenance and improvement actions; and for a process of priority programming.

c. Ensure a clean method of communicating needs and programs to outside audiences.

Parallel Achievements

2. BMS Criteria
"AASHTO Guidelines for Bridge Management Systems (BMS)"

Slide No. 5-5-3
Title Slide

Parallel Achievements

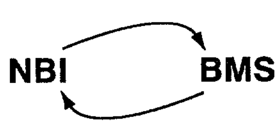
3. Pontis Software Development
   - FHWA - Caltrans - AASHTO
   - March 1994
   - AASHTOWare
4. Bridgit Software Development
   - NCHRP - TRB

Slide No. 5-5-4
Title Slide

Parallel Achievements

5. Agency BMS Development
   - New York
   - Pennsylvania
   - North Carolina
   - Alabama
   - Indiana

Slide No. 5-5-5
Title Slide



- Inventory Data
- Condition Appraisal
- Safety

Slide No. 5-5-6
Schematic Slide

Functional Needs

a. An automated data base of bridge inventory, condition data and a historical data file.

b. Deterioration models for projecting future condition of bridge elements with or without intervening actions.

c. Identification of feasible actions related costs; user costs associated with a deficient bridge condition; and budget and other key constraints.

d. Multiperiod optimization procedures and reporting capabilities.

2. **BMS Criteria**

AASHTO was able to define the criteria for a BMS and published the key document:

"AASHTO GUIDELINES FOR BRIDGE MANAGEMENT SYSTEMS (BMS)"

3. **Pontis Software Development**

The FHWA-Caltrans-AASHTO TWG developed the comprehensive BMS software called Pontis. Version 2.0, a public domain version of Pontis, was distributed in March of 1994. Future enhancements and distributions of Pontis versions will be done by AASHTO under the AASHTOWare software system.

4. **Bridgit Software Development**

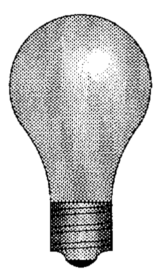
The National Cooperative Highway Research Program of the Transportation Research Board developed a BMS software called Bridgit.

5. **Agency BMS Development**

Several states including New York, Pennsylvania, North Carolina, Alabama and Indiana pioneered or continued development of their own comprehensive bridge management systems.

See Slide 5-5-6

It's important to note that bridge management systems are not a replacement for the entire NBI method of bridge inventory and appraisal.



Slide No. 5-5-7

Schematic Slide

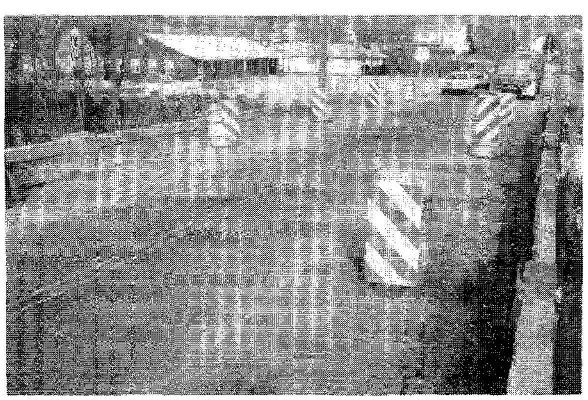
The common electric light bulb as an invention.

BMS Development
Basic Concerns

1. Problem
2. Solution
3. Objectives
4. Approach

Slide No. 5-5-8

Title Slide



Slide No. 5-5-9

Example Slide

Typical pre 1935 bridge.

The NBI and the NBIS came about as a response to the collapse of the Silver Bridge, with its primary objective being public safety relative to the nations bridges.

Bridge management systems, including Pontis, have come about because of a need for a management tool to help managers (not inspectors) effectively allocate limited funds for maintenance repair and rehabilitation (MR&R) of the nation's bridges.

The role of the inspector in a BMS is the same as with the NBI method, but with different procedures.

- Inspectors will continue to collect and update inventory data.
- Inspectors will continue to make condition appraisals.
- And last but not least, inspectors will continue to identify safety related deficiencies.

Since Pontis will be a widely used BMS, the following videotape provides an introduction to the Pontis bridge management system.

B. BMS DEVELOPMENT

See Slide 5-5-7

To quote Benjamin Franklin, "necessity is the mother of invention." So it is with bridge management systems. BMS developers had to address the following four (4) basic concerns or "needs":

- The problem with the nation's bridges
- The solution
- Objectives of the solution, and
- The proper approach

Each of these concerns will be discussed separately.

1. Status of the Nation's Bridges

See Slide 5-5-9

The United States has over 565,000 bridges. Approximately 70%, or about 400,000, of these bridges were built prior to 1935 and are now over 50 years old.

Increasing legal loads and traffic volumes, combined with the effects of weathering and de-icing chemicals have resulting in significant deficiencies in these structures.

Structurally Deficient
or
Functionally Obsolete

	Number of Bridges	Dollars Needed to Replace
1980	100,000	$25 Billion
1989	250,000	$52 Billion
1994	225,000	Over $52 Billion

Slide No. 5-5- 10
Title Slide

Network Optimization and Planning System

- Comprehensive
- Rigorous
- Flexible
- MR&R
- Improvements

Slide No. 5-5-11
Schematic Slide
Pontis Description

Pontis Developers

Cambridge Systematics, Inc.
Optima, Inc.
Caltrans

"Agency Customization"

Slide No. 5-5-12
Schematic Slide
Pontis Developers

Add to this a shortage of funding for routine and even critical maintenance and the overall result is that nearly 225,000 bridges are currently classified as structurally deficient or functionally obsolete and in need of rehabilitation or replacement.

This number has continued to rise every year in spite of the allocation of large sums of money through federal and state programs.

The cost to repair or replace all of our aging and deficient structures is far beyond what available funds can accommodate.

2. The BMS Solution

To curtail further deterioration and systematically address existing deficiencies in order of need, current policies had to change to incorporate a system of project selection that would derive the maximum benefit from the use of limited funds.

Formulation of such policies requires an owner's network-wide analysis that would evaluate the needs of each bridge in the context of overall network benefits, budgets and restrictions.

The Solution:

See Slide 5-5-11

Pontis (from the Latin word pons: bridge)

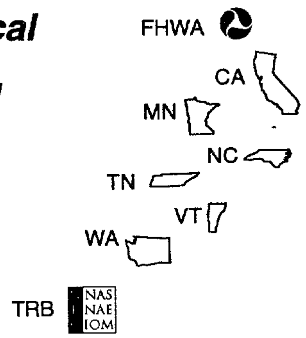
A comprehensive, rigorous and flexible network optimization and planning system to formulate network-wide maintenance, rehabilitation, replacement and improvement policies.

Pontis is a well thought out bridge management system ready for implementation.

See Slide 5-5-12

Developed jointly by Optima, Inc. and Cambridge Systematics, Inc., Pontis was first implemented in the state of California. The system has sufficient flexibility to allow customization to any agency or organization responsible for maintaining a network of bridges.

Technical Working Group



Slide No. 5-5-13
Schematic Slide
Technical Working Group

TWG Input:

- Bridge experience
- Bridge element list
- Condition states
- Remedial actions

Slide No. 5-5-14
Title Slide

Agency Objectives

Public Related:

- Safety
- Comfort & Convenience
- Emergency Routes
- Transport Routes
- Minimize Delays & $ Waste
- Prompt Repairs

Slide No. 5-5-15
Title Slide

Agency Objectives

Budget Related:

- Investment
- Allocation
- Maintenance
- Personnel Use
- Funding Use
- Long Term Cost

Slide No. 5-5-16
Title Slide

See Slide 5-5-13

This flexibility in the system was the result of developmental input by a Technical Working Group (TWG) comprised of representatives from the FHWA, the Transportation Research Board (TRB) and the following 6 states: CA, MN, NC, TN, VT and WA. The TWG provided guidance drawing on considerable experience in bridge management and engineering.

The TWG also developed the list of bridge elements which would be used to define a bridge, the possible condition of each element and a set of remedial actions for each condition.

3. Objectives of Pontis

Budgeting decisions for maintenance needs as well as corrective measures, future rehabilitations, improvements and possible replacements, will always be affected by the desire to meet various objectives. Pontis systematically addresses an agency's objectives and prescribes the actions necessary to maintain a defined standard.

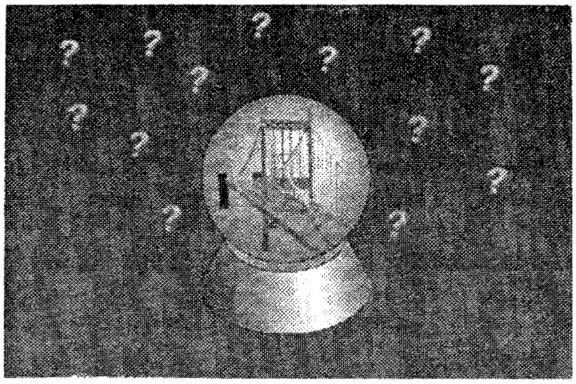
Common agency objectives include:

Public Related:

- High safety standards.
- Comfort and convenience.
- Efficient routes for emergency service.
- Economical routes for the transport of goods.
- Minimal user delays and tax dollar waste.
- Correcting deficiencies promptly.

Budget Related:

- Preserving the existing investment.
- Equitable allocation of resources.
- Effective preventative maintenance.
- Efficient utilization of engineering and maintenance personnel.
- Efficient utilization of funding.
- Minimization of long term costs.



Slide No. 5-5-17
Schematic Slide
Crystal ball predictions

Meeting Objectives → Making Decisions

Pontis → Decision Modeling

Slide No. 5-5-18
Title Slide

Pontis Objectives:

- MR&R Budget Requirements
- Level of Service Goals
- Optimize MR&R Policies
- Network Considerations
- Address Bridge Subsets
- Set Needs Priorities
- Coordinate Future Improvements

Slide No. 5-5-19
Title Slide

Pontis Objectives:

- Consider Needs vs. Type
- Improved Deterioration Estimates
- Cost - Benefit of Maintenance vs. Repair
- Cost - Benefit of Policy Decisions
- Policy Input
- Short and Long Term Planning
- Expert Judgement

Slide No. 5-5-20
Title Slide

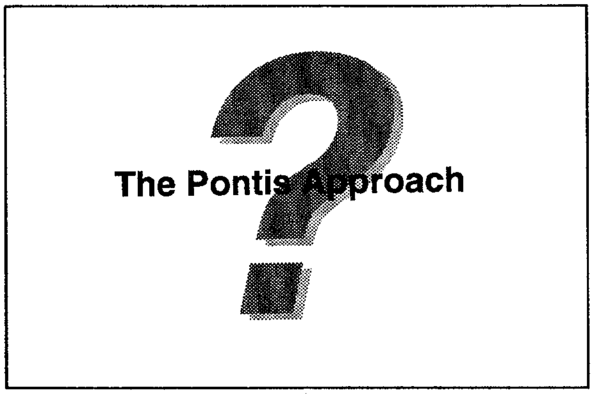
See Slide 5-5-17

Meeting these objectives is dependent on estimated future needs, and uncertain budgetary policies. Unfortunately, this input is based on hypothetical deterioration rates derived from existing condition histories. Not a very solid foundation.

Therefore to achieve the objectives, the Pontis program was formulated as a multi-objective, dynamic, decision model. This allows flexibility to input adjustments for actual conditions which may be different than those estimated, and to analyze the effects of various budget policies.

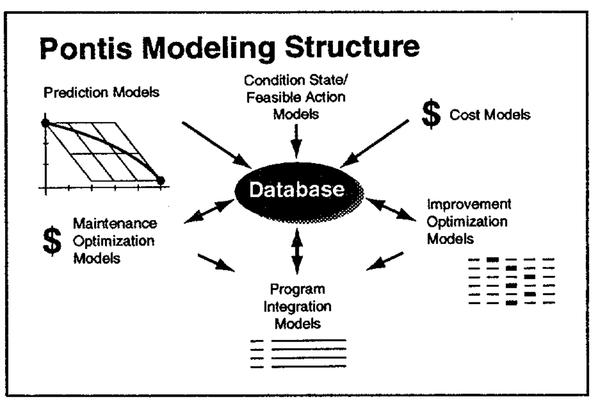
The objectives of the Pontis system are to achieve the following:

- Provide a systematic procedure for finding current MR&R budget requirements.
- Incorporate level-of-service goals.
- Optimize MR&R policies for each element and each condition.
- Bridge network consideration.
- Flexibility to address bridge subsets.
- Prioritize bridges in need of MR&R and improvement.
- Coordinate MR&R planning with future improvement decisions.
- Consider differing inspection and repair needs for various bridge types and components.
- Permit updates of estimated deterioration rates based on new data.
- Provide cost-benefit analysis of maintenance vs. repair.
- Provide cost-benefit analysis of policy recommendations.
- Accommodate state specific policies.
- Provide a basis for short and long term budget planning and resource allocation.
- Incorporate expert engineering judgment.

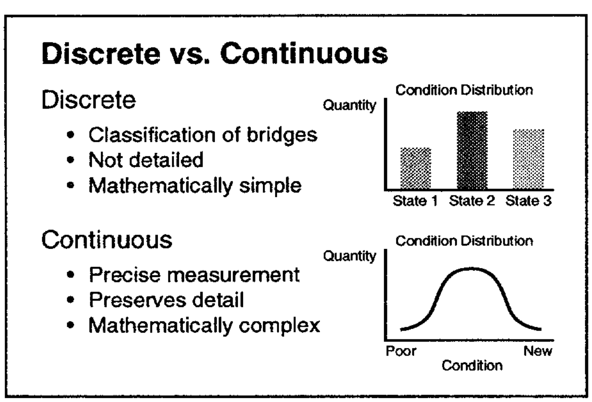


Slide No. 5-5-21
Title Slide

Slide No. 5-5-22
Example Slide
Plastic model of the new Dodge Viper RT 10 Coupe. Concept precedes production



Slide No. 5-5-23
Schematic Slide
Pontis mathematic modeling structure



Slide No. 5-5-24
Schematic Slide
Discrete vs. continuous

4. The Pontis Approach

By meeting the stated objectives, a comprehensive BMS such as Pontis will enable agencies to compare preventative versus corrective actions, and provide a systematic procedure for allocation of resources.

See Slide 5-5-22

How does Pontis do it? **Modeling**.

Modeling can be defined as building a mathematical representation of a physical product or concept.

See Slide 5-5-23

In Pontis, six (6) optimization models have been developed to meet the stated objectives. However, instead of each model operating on the entire database, they process specific groups of network information. Each group utilizes an independent sub-routine called a module to first summarize network conditions for optimization, and then to expand the outcome of the optimization for application to the entire database.

Features of the modeling approach include:

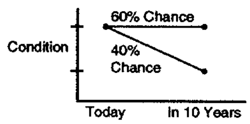
- Flexibility and generality to meet unforeseen future requirements and accommodate national adaptation.
- Problem formulation and solution methodologies independent of the number of bridges, to free the models from computational restrictions.
- Separation of MR&R from improvement and replacement. These functions are addressed separately but recommendations are coordinated based on network requirements.

See Slide 5-5-24

Probabilistic vs. Deterministic

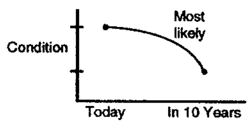
Probabilistic

- Measured uncertainty
- Multiple outcomes
- General strategies



Deterministic

- Ignored uncertainty
- Single outcome
- Specific action



Slide No. 5-5-25
Schematic Slide
Probabilistic vs. Deterministic

Slide No. 5-5-26
Schematic Slide
NBI database format is not used

NBI Database

- Major Components Only
- Numerical Condition Rating
- No Action Indication
- Not Suited for Optimization
- Subjective

Slide No. 5-5-27
Title Slide

Pontis Database

- All Bridge Elements
- Measurable Condition Parameters
- Condition State Identification
- Feasible Action Indication
- Objective

Slide No. 5-5-28
Title Slide

See Slide 5-5-25

- Dynamic optimization of MR&R to determine future consequences and cost of present-day actions.
- The ability to address uncertainties in deterioration patterns using a probabilistic deterioration model which "learns" from experience.

This makes network modeling principles practical for databases as large as 50,000 bridges.

See Slide 5-5-26

Currently state agencies maintain databases compiled over the years using the National Bridge Inventory NBI method. This data is typically used to assign condition ratings to bridge components and for report preparation. Funding allocations are made based on the condition ratings and MR&R and improvement needs are determined on an individual bridge basis.

The Pontis approach does not attempt to utilize information in existing NBI format databases for the following reasons:

- Only information about the major bridge components is stored.
- The information stored is a numerical rating with no indication of actions required.
- Numerical ratings do not enable cost / benefit analyses to be performed.
- Numerical ratings are applied subjectively and may obscure exceptions or represent an inspector's signal for action.

The Pontis approach to generating a database which overcomes these shortcomings and is compatible with the modeling operations is to:

- Define each bridge by its individual elements.
- Set measurable parameters for defining element condition.
- Assign a "condition state" for each element.
- Identify "feasible actions" for each "condition state".

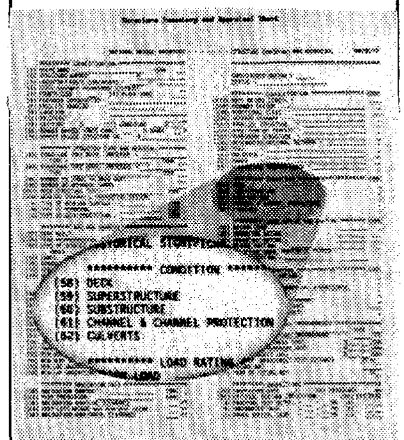
Generating a new array of bridge information for a Pontis database will take a significant commitment of time and resources. Therefore, in order to provide a transition for agencies adopting Pontis, the software is designed so that the system will operate using NBI data as a starting point. Pontis capabilities are rather constrained, however improvement will occur as a new database is gradually created.

Major System Components

- **The Pontis Database**
- Bridge Inspector Input
- Optimization Models

Slide No. 5-5-29
Title Slide

Slide No. 5-5-30
Schematic Slide
National Bridge Inventory
Structure Inventory and Appraisal
Sheet



Pontis Database Characteristics

- **Terminology**
- Bridge Elements
- Conventions
- Environments
- Condition States/Feasible Actions

Slide No. 5-5-31
Title Slide

II. MAJOR SYSTEM COMPONENTS

For discussion purposes, the Pontis bridge management system can be subdivided into three (3) major components.

- The Pontis database
- Bridge inspector input
- Optimization models

A. THE PONTIS DATABASE

See Slide 5-5-30

In order to obtain Federal funding, every state must collect a certain amount of bridge inventory and appraisal data for each bridge that is classified as "NBIS Bridge Length" (structure length over 20 feet). As a minimum, the state must produce a computer tape which reports information relative to the required items identified on the FHWA Structure Inventory and Appraisal sheet. This information has become the nucleus of expanded data bases which have been modified and manipulated by state agencies to meet a number of different objectives.

The missing objectives, of course, are the BMS objectives that permit network management.

Agency data bases typically have information not relative to a BMS but at the same time are lacking of items that BMS needs. In addition, agency data bases have varied formats and use a wide variety of software.

Pontis therefore, has its own standardized database but draws what information is useful from the agency database and from other sources.

To properly understand the Pontis database or to input data into it correctly, the following 5 characteristics must be learned.

Table 1A. Listing of Fields in the Pontis Database

Source (see key)	Short Name	Long Name	Units	Display Specs Width	Display Specs Dec	Display Specs Format	Format Type	Range or Selection	Index (8)	Segment	NBI Format/ Coding (if diff)	Description	Notes	Ref. Page
Supp	Transit	PubTrans Route		1	0	#	RegInt	0-1		1		Existance of public transit route over bridge		
Supp	Critical	Critical Facility		1	0	#	RegInt	0-1		1		Is bridge a critical travel facility		
TRAFFIC AND ACCIDENTS UNDER THE STRUCTURE														
NBI19U	BypassLenU	BypLength Under	(mi)	3	0	###	RegInt	0-254		1	N2.0	Detour length for route under bridge		40
NBI29U	ADTTotalU	ADT Under		6	0	######	LongInt	0-655340	A	0		Average daily traffic for route under bridge	5	40
NBI30U	ADTYearU	ADTYr Under		4	0	YYYY	RegInt	1980-2042		1		Year for average daily traffic under bridge		40
NBI109U	TruckPctU	TruckPct Under	(%)	2	0	##	RegInt	0-99		1		Average daily truck percent under bridge		40
Supp	BypassSpdU	BypSpeed Under	(mph)	2	0	##	RegInt	0-75		1		Average travel speed on bypass for rte under bridge		
Supp	SpeedU	Speed Under	(mph)	2	0	##	RegInt	0-75		1		Average travel speed on route under bridge		
Supp	AccidentsU	Accidents Under		6	2	###.##	FixPt	0-655.34		0		Annual average accidents under the structure		
APPRAISAL AND INSPECTION														
NBI36A	RailRating	Rail Rating		1		X	SelChar	01N		1		Bridge railing adequacy rating		
NBI36B	TransRating	Transition Rating		1		X	SelChar	01N		1		Approach to bridge rail transition adequacy rating		
NBI36C	ARailRating	Approach Rail		1		X	SelChar	01N		1		Approach guardrail adequacy rating		
NBI36D	AEndRating	Approach End		1		X	SelChar	01N		1		Approach guardrail end adequacy rating		
NBI58	DkRating	Deck Rating		1		X	SelChar	0-9N		0		Deck condition rating		
NBI59	SupRating	Superstr Rating		1		X	SelChar	0-9N		0		Superstructure condition rating		
NBI60	SubRating	Substruc Rating		1		X	SelChar	0-9N		0		Substructure condition rating		
NBI61	ChanRating	Channel Rating		1		X	SelChar	0-9N		1		Channel rating		
NBI62	CulvRating	Culvert Rating		1		X	SelChar	0-9N		1		Culvert rating		
NBI67	StrRating	Structural Rating		1		X	SelChar	0-9N		1		Structural Rating		
NBI68	DeckGeom	Deck Geometry		1		X	SelChar	0-9N		1	NBI Range 0-9	Deck geometry rating		

1. Terminology

The data base plays a crucial role in the organization of information provided to and derived from all Pontis models. Proper terminology is essential. Here are some Pontis terms and their definitions that should be committed to memory.

Backlog
The total cost of projects which are recommended, but could not be scheduled due to budget constraints.

Condition Data
All bridge data items which change as a result of deterioration, traffic, or maintenance.

Condition State
A particular classification of the condition of a bridge element. Applicable to a portion of, or the entire element.

DataBase
Individual bridge information files created and maintained by Pontis to support its analytical requirements.

DataBase Segment
One of the files making up a database, and containing a defined set of fields for all bridges in the database.

Data Field
The major division of a record, usually corresponding to a single item of data.

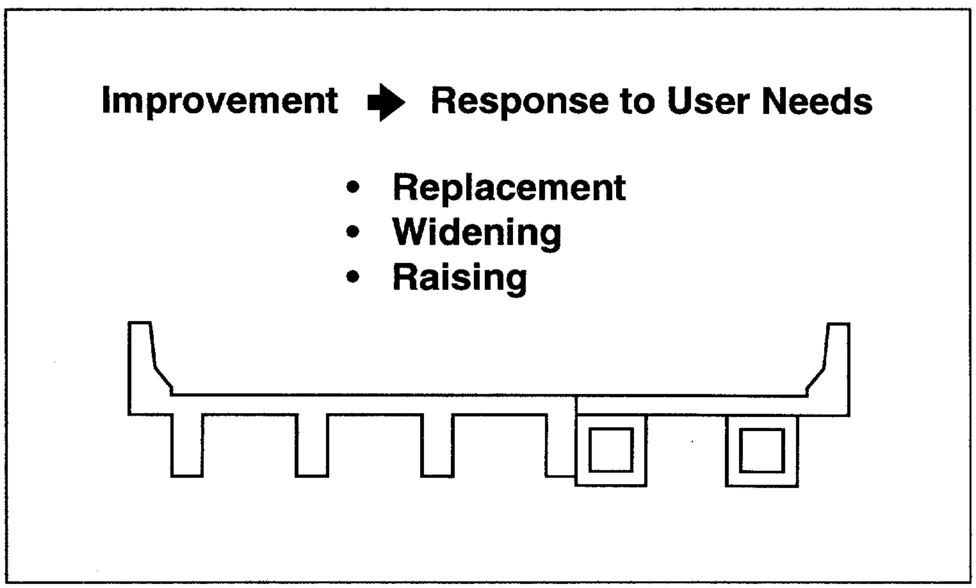
Data File
A collection of data managed as a single unit by the computer's operating system.

DN
Do Nothing. A policy in which no action is taken except for outline maintenance activities or incidental repairs which are not analyzed in Pontis.

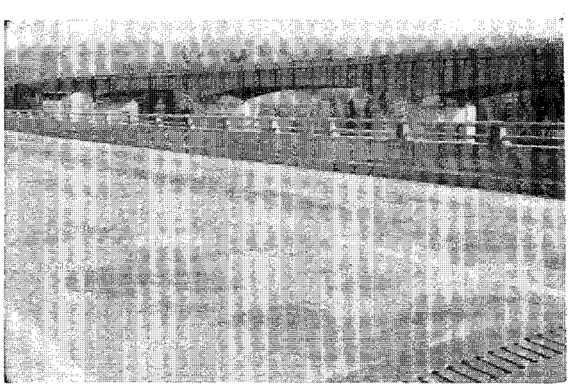
Do Something
A policy in which one of the defined Pontis MR&R feasible actions is performed at a given time.

Element
A single type of component or part of a bridge, characterized by the type of member and its material.

Example Photo
Typical steel box girder



Example Schematic
Improvement description



Example Photo
Typical concrete bridge deck as a
Pontis bridge member

Environment
The classification of a bridge element according to its exposure to the weather or operating practices that accelerate deterioration.

Feasible Action
A defined Pontis MR&R activity relative to an element's material composition and condition state.

Girder
A structural shape used as a main longitudinal beam type member. Girders can be rolled or extruded beam shapes or fabricated from smaller individual components of similar or dis-similar material.

Improvement
An action taken to increase the ability of the bridge to meet user demands.

Inventory
Individual bridge information files currently maintained by the States for the purpose of reporting on bridge characteristics and conditions to the FHWA.

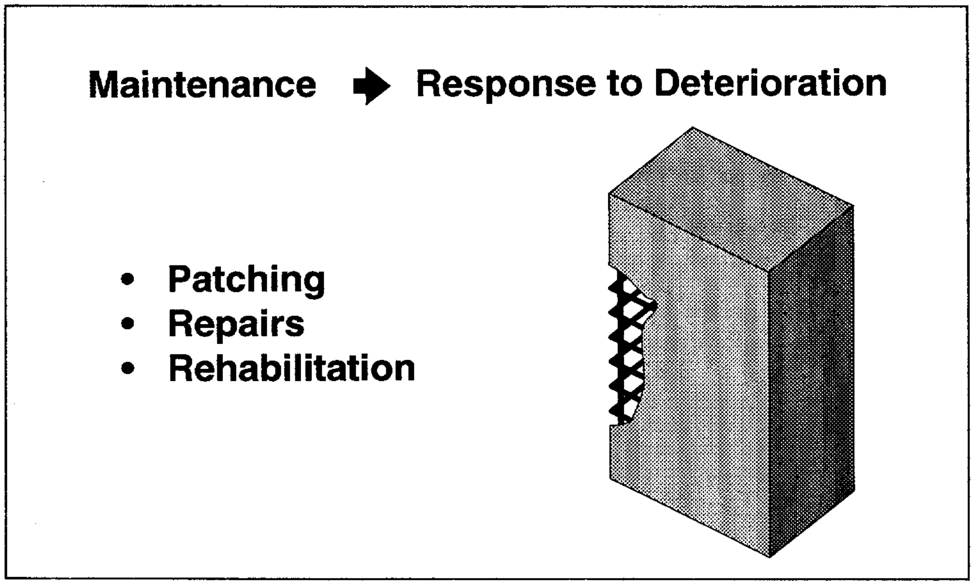
Inventory Data
All bridge data items which do not change as a result of deterioration, traffic, or maintenance.

Long Term
Conditions and actions which are predicted to occur at an undefined time in the future.

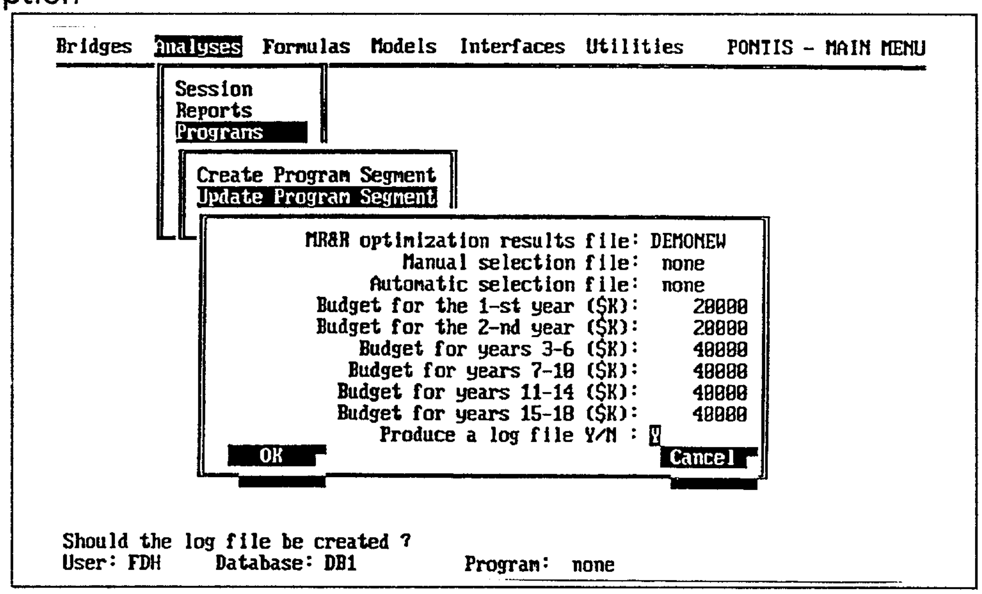
Master Database
The Pontis database which collects all data from the inventory and condition updates and is the authoritative source of the most up-to-date Pontis data.

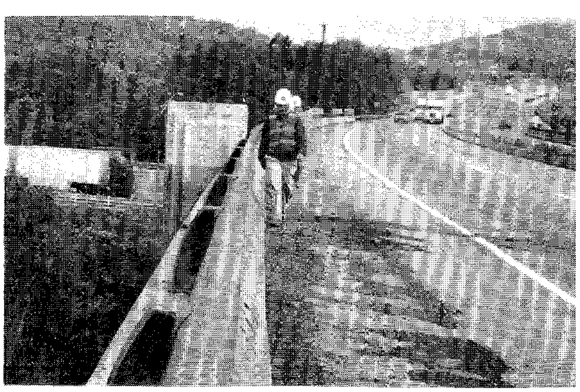
Member
A single type of component or part of a bridge, which has been distinguished from the parts because of its unique deterioration behavior, maintenance requirements, cost, or other factors important to network level analysis.

MR&R Benefit
The long term average biennial cost savings associated with taking a recommended action now rather than waiting years and taking the action that would be recommended then.



Example Schematic
Maintenance description





Example Schematic
Program segment

Example Photo
Deck water table in need of cleaning type maintenance

MR&R - Maintenance, Repair and Rehabilitation
All actions taken to offset the deterioration caused by traffic, weather, or any chemical or physical process.

NBI
The National Bridge Inventory

Needs
The total costs of optimal actions recommended for immediate implementation at a given time.

Network Level
An analysis or policy which applies to a whole set of bridges and does not distinguish among individual bridges.

Normalization
An automatic adjustment performed by Pontis to ensure that the transition probabilities out of every state sum to 100 percent.

Pipeline Project
A project whose implementation has already begun and for which any additional work must be scheduled immediately.

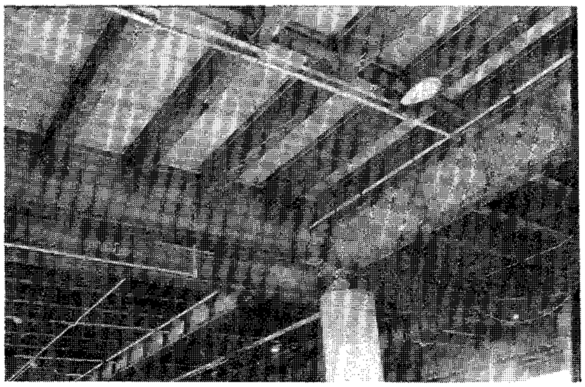
Program Segment
A segment of database containing a schedule of costs to be expended on each bridge.

Project Level
An analysis or action which applies to one single bridge or part thereof, and does not consider simultaneously the other bridges in the network.

Routine Maintenance
Cleaning of scuppers, sweeping of the deck, and other maintenance activities that are not budgeted in Pontis.

Short Name
A one word name which represents a database field in a formula file.

Smart Flag
A condition identifier associated with a specific load capacity or safety related defect on an element, which is not accounted for in that element's condition state descriptions.



Example Photo
Typical steel floor system comprised of floorbeams and "stringers"

Pontis Database Characteristics

- Terminology
- Bridge Elements
- Conventions
- Environments
- Condition States/Feasible Actions

Slide No. 5-5-32
Title Slide

Commonly Recognized

CoRe

Elements

Slide No. 5-5-33
Title Slide

CoRe Element Description

- Name
- Units
- Definitions
- Condition States
- Feasible Actions
- Relationship to NBI

Slide No. 5-5-34
Title Slide

Stringer
A longitudinal beam type member supported by floorbeams which in turn supports the deck of a bridge.

What If Analysis
A repetitive analysis where each iteration differs in some input variable. Often used for sensitivity analysis or adjusting policies to account for non-economic factors.

2. Bridge Elements

The selection and definition of structure elements is a central issue in preparing a bridge database for successful modeling. This applies to all BMS systems including the Pontis program. For this reason, the Technical Working Group established a proposed list of standard elements referred to as Commonly Recognized elements, called CoRe elements for short.

The intent is for all states to use the CoRe elements so that nationwide uniformity can be achieved.

There are five (5) reasons why the development of CoRe elements are essential.

- To share data between users. (i.e. cost, deterioration rates, actions)
- To provide consistent methods of tracking significant bridge condition data.
- To define certain limits of customization to Pontis.
- To identify bridge elements which influence federal apportionment.
- To provide a standard basis for conversion of CoRe element data to NBI.

A CoRe element description contains the following information:
- Element name
- Units of measure
- Element definition
- Condition state descriptions
- Feasible actions
- Relationship to NBI (if any)

In defining the CoRe elements, four (4) criteria had to be met.

- Members comprising an element must be made of the same material.

CoRe Element Categories

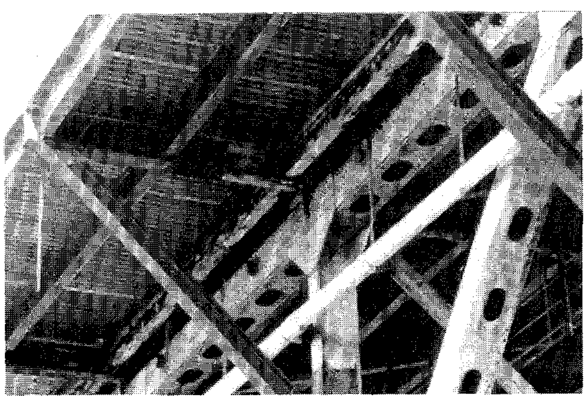
- Deck (10 series)
- Superstructure (100 series)
- Substructure (200 series)
- Other (300 series)

Slide No. 5-5-35
Title Slide

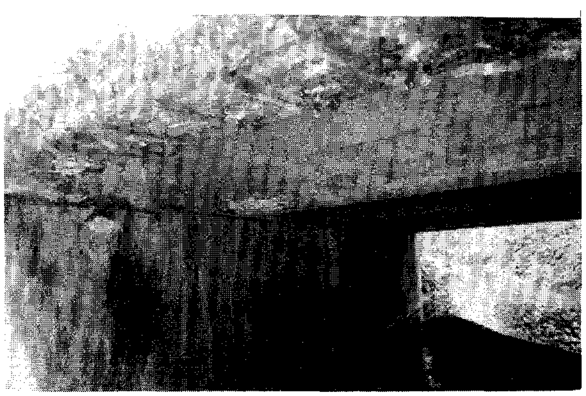
Sub-Elements

"agency defined"

Slide No. 5-5-36
Title Slide



Slide No. 5-5-37
Example Slide
Steel bridge paint systems



Slide No. 5-5-38
Example Slide
Fascia girder deterioration different than interior girders

- These members must have similar deterioration characteristics. (i.e. type and rate)
- The element must be measurable in units which are easily documented but meaningful at the network level.
- The description of the element's condition state must address only the primary type of deterioration and use standard engineering terminology.

A total of 95 recommended CoRe elements have been defined in the current Pontis User's Manual. These elements are sub-divided into four (4) categories.

- Deck Elements (10 Series)
- Superstructure Elements (100 Series)
- Substructure (200 series)
- Other Super/Sub Elements (300 Series)

Although each State can adopt a numbering scheme based on their preference, the FHWA is promoting these CoRe element categories and numbering as the government's recommended policy.

Although Pontis has the capability to consider 160 elements, a typical bridge does not include more than 6 to 8 elements.

Sub-Elements

If desired, an agency has the flexibility of defining additional elements called sub-elements. A sub-element is basically the same as its parent CoRe element except that its physical size, location, or exposure is different as determined by the agency.

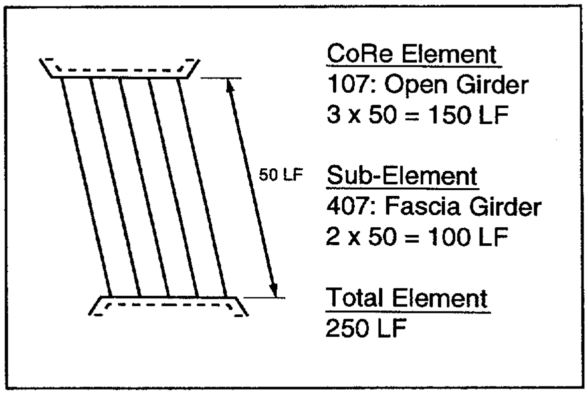
Sub-elements must meet the criteria established for CoRe elements because they are processed the same way by the Pontis program.

The recommended list of sub-elements that qualify include:

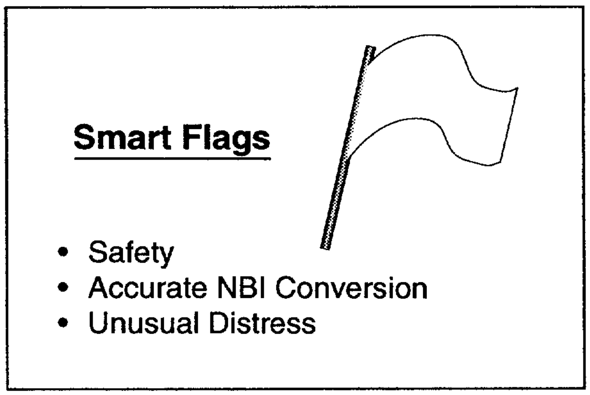
See Slide 5-5-37

See Slide 5-5-38

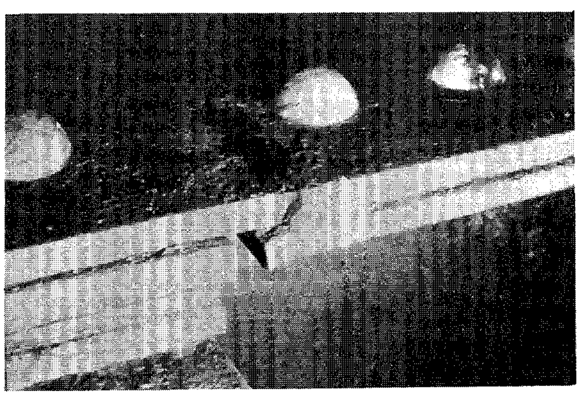
- All separate types of paint systems.
- Exterior or fascia girders if their deterioration rate is different.
- Beam ends beneath defective deck joints.
- Hinges(not pin & hanger assemblies)
- Various substrate repair categories for decks and slabs.
- Precast panel deck



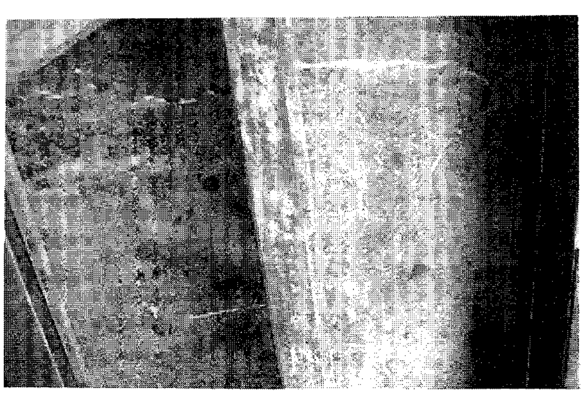
Slide No. 5-5-39
Schematic Slide
Sub-element example



Slide No. 5-5-40
Title Slide



Slide No. 5-5-41
Example Slide
Existing fatigue crack



Slide No. 5-5-42
Example Slide
Cracking in a concrete deck

On bridges where sub-elements are used, the corresponding CoRe element should NOT include quantities identified by the sub-element.

See Slide 5-5-39

Example: A steel multi-beam bridge may have the interior girders identified as an open girder CoRe element and the exterior girders listed as a sub-element. The quantity in each condition state for both elements would be added to give the total quantity of steel girder for the bridge.

A "roll-up" procedure is planned for generating the total CoRe element quantities by adding up all sub-elements and any part of the element identified as a CoRe element.

Non-CoRe Elements

A number of elements were considered for adoption as CoRe elements but were rejected based on the established criteria. States remain free to add non-CoRe elements to their own systems if desired.

Smart Flags

There is one last type of element used in Pontis that is called a smart flag.

A smart flag can be defined as a condition identifier associated with a specific load capacity or safety related defect on a CoRe element, which is not accounted for in that element's condition state descriptions.

Smart flags provide two important capabilities.

- First, they will enable a more accurate conversion to NBI.
- Second, they will permit States to track various unusual distress types.

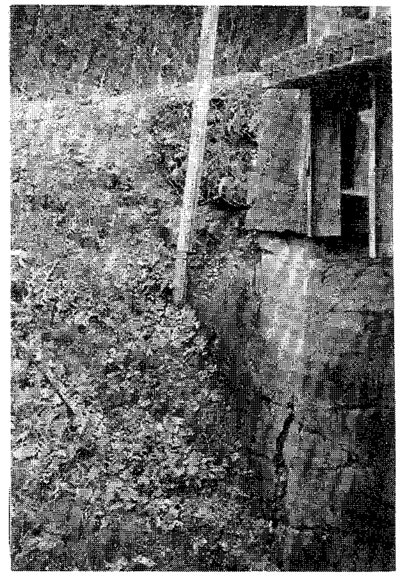
The following visual condition deficiencies qualify, and have been approved as smart flag elements:

See Slide 5-5-41

See Slide 5-5-42

- Steel - Fatigue (EA.) - Existing fatigue induced cracks.
- Pack Rust (EA.) - Rust packing between steel plates.
- Deck Cracking (EA.) - Existing structural or non-structural cracks.

Slide No. 5-5-43
Example Slide
Substructure rotation



Slide No. 5-5-44
Example Slide
Superstructure collision damage

Pontis Database Characteristics

- Terminology
- Bridge Elements
- **Conventions**
- Environments
- Condition States/Feasible Actions

Slide No. 5-5-45
Title Slide

Element Quantity Conventions Modified for Pontis:

- Deck Elements
- Girder Elements
- Truss Elements
- Substructure Elements

Slide No. 5-5-46
Title Slide

See Slide 5-5-43

- Soffit (EA.) - The underside of concrete decks and slabs
- Settlement (EA.) - Substructure settlement or rotation.
- Scour (EA.) - Scour holes and undermining at the bridge site.
- Traffic Impact (EA.) - Existing vehicular impact damage on an element. This flag is anticipated to be used for superstructure members.

See Slide 5-5-44

Because some of these types of deficiencies are considered in the NBI condition appraisal rating method but not in Pontis, approved Smart Flags can play a significant role in NBI conversion.

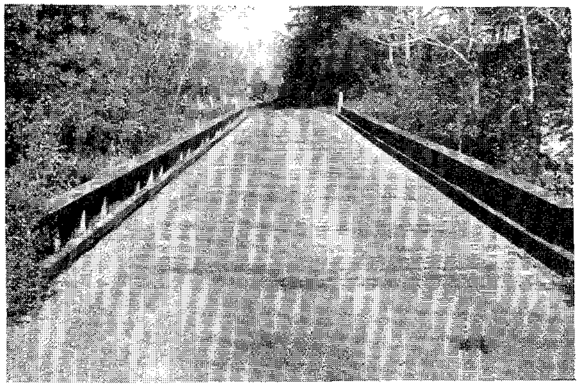
Sometimes referred to as "Special Elements", smart flags look and operate just like CoRe elements, however, they have no feasible actions or costs and are not included in MR&R decision making. The concept of smart flags is an option for States to use as a means to improve their bridge condition inventory.

3. Conventions

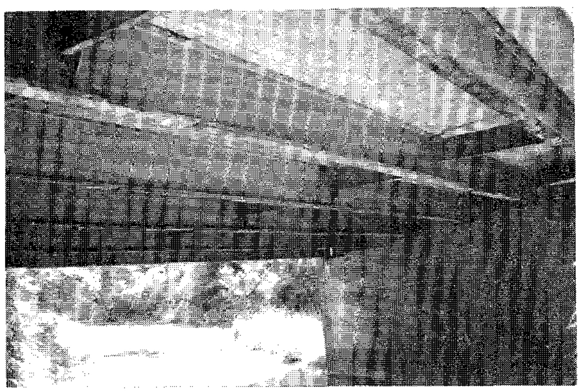
The term convention is usually associated with establishing a standard of orientation or measuring.(i.e., positive / negative, left / right, near/ far, etc.) In Pontis, general orientation conventions of the bridge site are the same as used with the NBI method. However, the Pontis conventions for identifying quantities of certain newly defined bridge elements are unique.

The CoRe elements affected by a modified convention for quantities include:

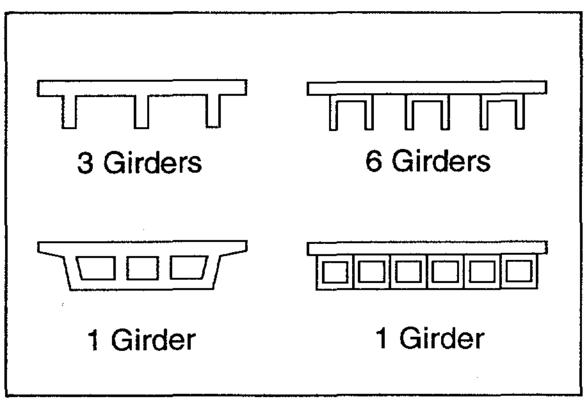
- Deck Elements
- Girder Elements



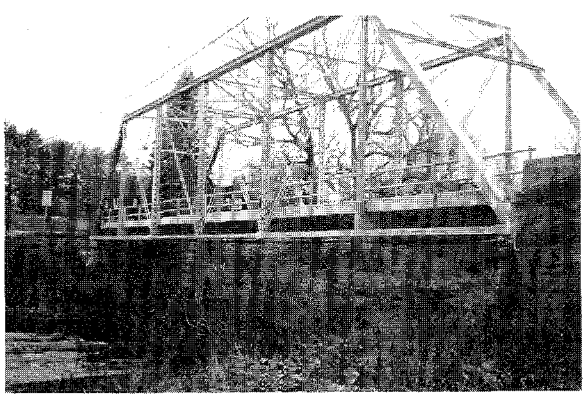
Slide No. 5-5-47
Example Slide
Typical timber deck



Slide No. 5-5-48
Example Slide
Steel girder element



Slide No. 5-5-49
Schematic Slide
Girder element quantities



Slide No. 5-5-50
Example Slide
Typical steel truss superstructure

- Truss Elements
- Arch Elements
- Substructure Elements

See Slide 5-5-47

Deck Elements: The units for reporting of deck and slab information is "each". For the identification of total deck area to be considered and the quantitative condition evaluation, only the area of the physical riding surface is considered. Smart flags for Deck Soffit (underside) and Deck Cracking are available for tracking structural problems and are also measured in units of "each".

Because the units for deck MR&R and improvement models are "sq. ft.", FHWA does encourage States to gather and track deck deterioration on a square foot basis and develop a conversion formula to identify the appropriate Pontis "each" code.

See Slide 5-5-48

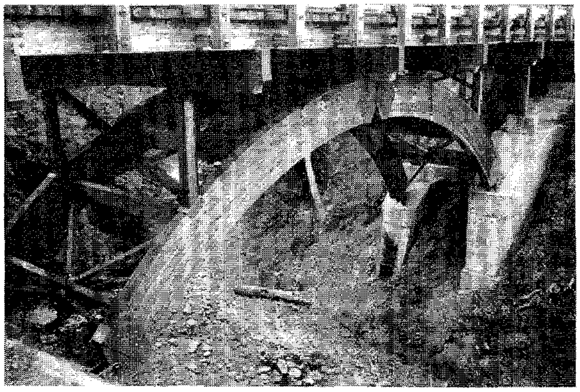
Girder Elements: The quantity measurement for girders is lineal feet. The quantity recorded is equal to the girder length multiplied by the "number of girders". In general the "number of girders" carried in the Pontis inventory for a bridge can be determined from the number of "pairs" of exterior girder faces visible during a field inspection.

See Slide 5-5-49

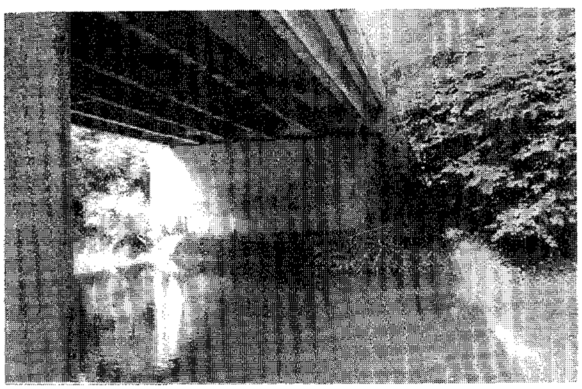
This method may produce a "number of girders" which conflicts with the actual number of structural members that make up the element. For the Pontis program, this is acceptable because the goal is to quantify the condition of the element rather than define its actual configuration of members.

See Slide 5-5-50

Truss Elements: The quantity measurement for a truss is also lineal feet. As usual there are at least two trusses which make up a truss bridge. All measurements of the truss are along the horizontal projection, including deterioration measurements. Therefore a total quantity for a truss element is typically the span length times the number of trusses. Because vertical and diagonal truss members project a measurement different than their actual length, a



Slide No. 5-5-51
Example Slide
Timber arch superstructure in Michigan



Slide No. 5-5-52
Example Slide
Typical concrete substructure arrangement

<u>Pontis Database Characteristics</u>

- Terminology
- Bridge Elements
- Conventions
- **Environments**
- Condition States/Feasible Actions

Slide No. 5-5-53
Title Slide

Pontis Environments

- Benign
- Low
- Moderate
- Severe

Slide No. 5-5-54
Title Slide

conservative minimum measurement of one panel length is used whenever deterioration must be quantified.

See Slide 5-5-51

Arch Elements: The quantity measurement for an arch is also in lineal feet. The convention used for arches is similar to that used for trusses.

See Slide 5-5-52

Substructure Elements: The units for abutments are lineal feet along the face of abutment. If so desired, sub-elements can be used to differentiate between full height and stub abutment configurations.

The units for pier caps and pier walls are also in lineal feet.

4. Environments

Another important piece of information in the Pontis database is the identification of an element's environment. The behavior of each element over time is governed by its environment and the random effects of traffic and age. To best model environmental effects, each element of a bridge is placed in one of the following environmental categories:

Benign - Environmental factors and operating practices are **not** likely to significantly change the condition of the element over time or their effects have been mitigated by past non-maintenance actions or the presence of highly effective protection systems.

Low - Environmental factors and operating practices do not adversely influence the condition of the element or their effects are substantially lessened by the application of effective protective systems.

Moderate - Environmental factors and operating practices are considered to be typical and any change in the condition of an element is likely to be normal.

Severe - Environmental factors and operating practices contribute to the rapid decline in the condition of an element. Protective systems are not in place or are ineffective.

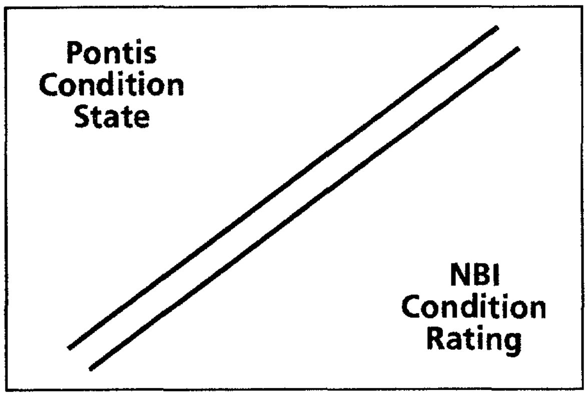
The environment category designated for a particular element can change if operating policies were to change.(e.g. the reduced use of road salt) However the designation cannot change as the result of maintenance actions or deterioration.

Pontis Database Characteristics

- Terminology
- Bridge Elements
- Conventions
- Environments
- **Condition States/Feasible Actions**

Slide No. 5-5-55

Title Slide



Slide No. 5-5-56

Schematic Slide

Condition state descriptions are similar to condition ratings

Condition State Descriptions

- 3 to 5 Categories
- Common Deterioration
- Corresponding Action

Slide No. 5-5-57

Title Slide

Important Points

- Discrete Steps of Deterioration
- Deterioration Distribution
- Total Element Description
- Statistical Profile
- Ease of Data Collection

Slide No. 5-5-58

Title Slide

5. Condition States / Feasible Actions

One of the most important data fields in the Pontis data base is the assigned condition state and its associated feasible action. As mentioned earlier, the condition states and feasible actions for the CoRe elements have already been defined.

See Slide 5-5-56

Assignment of condition states to a bridge element is the Pontis method of rating an element during a field inspection.

Each element identified for a given bridge, is rated by dividing it among 3 to 5 condition state designations with a corresponding feasible action.. Each condition state designation is defined based on the most common form of deterioration for that element as well as the anticipated MR&R activity required.

Several important points should be noted about condition states:

- They divide the continuous **process of deterioration** into a small number of discrete steps.
- Parts of a given element on a given bridge can be **distributed** among any or all of the possible condition states.
- The **entire element** being inspected is described because the individual quantities of the various condition states being designated always add up to the total quantity identified for a given element.
- The condition description of a bridge element is a **statistical profile** rather than a precise measurement. This is particularly important in Pontis because it allows bridge level information to be incorporated into the network level for decision making.

Major System Components

- The Pontis Database
- **Bridge Inspector Input**
- Optimization Models

Slide No. 5-5-59
Title Slide

Safety Inspection

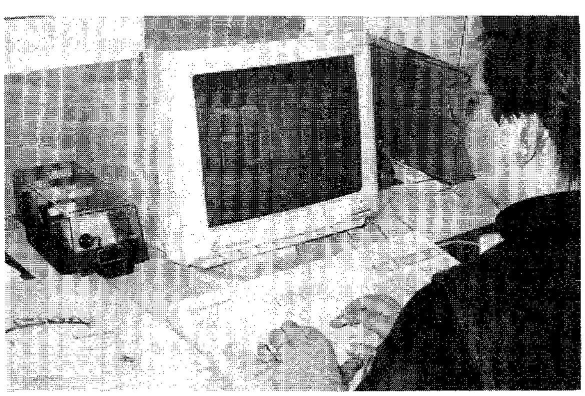
vs.

Maintenance Inspection

Slide No. 5-5-60
Title Slide

Documentation
is
Required

Slide No. 5-5-61
Title Slide



Slide No. 5-5-62
Example Slide
Inputting information into the Pontis program

- Also, since statistical profiles do not have to be very precise to get reliable network level conclusions, the field data collection for the condition description is **fairly quick** and requires **no elaborate measuring** equipment or procedures.

B. BRIDGE INSPECTOR INPUT

1. Safety Inspection vs. Maintenance Inspection

The majority of this course addresses the procedures associated with a **Safety Inspection**. Primary concerns include:

- What deterioration is damaging to a bridge member?
- Where to look for the deterioration?
- When is the deterioration detrimental to the structural capacity?

In exercising procedures to satisfy these concerns, the inspector must also carefully document his/her findings.

Finally, an assessment of the bridge components is made by assigning condition rating numbers. This assessment should be accompanied by repair and maintenance recommendations necessary to assure the continued "safe" operation of the structure.

A **Maintenance Inspection** on the other hand, satisfies Webster's definition for maintenance in that the inspector's goal is to identify recommended activities at the bridge site which are necessary to ensure the longevity of the structure. Main concerns include:

- Is deterioration present on the bridge members
- How much deterioration exists
- What activity is necessary to prevent further deterioration

Satisfying these concerns also requires **documentation** to quantify needed work.

See Slide 5-5-62

2. Inspector Responsibilities and Duties

Where does Pontis fit in?

The Pontis BMS is not designed to accommodate a particular type or style of inspection.

Pontis Inspection

≠

Safety Inspection

Slide No. 5-5-63

Title Slide

NBIS Inspector Responsibilities

- Maintain Public Safety
- Protect Public Investment
- Support the Inspection Program
- Produce Accurate Records
- Legal Responsibilities

Slide No. 5-5-64

Title Slide

NBI Condition Ratings

Replaced With

"New Duties"

Slide No. 5-5-65

Title Slide

Slide No. 5-5-66

Example Slide

Inspectors collecting inventory data in the office

Although Pontis programming functions primarily around MR&R activities, a field inspection for Pontis input is **not solely a Maintenance inspection**. This is because the condition state language for some elements considers an extent of deterioration which jeopardizes the "safety" of the structure.

However a field inspection for Pontis input only, is not specific enough to identify exact structural problems, and therefore it **does not satisfy the criteria for a Safety Inspection**.

Basic responsibilities of today's bridge inspector when performing Pontis BMS inspections remain the same as for the NBI inspections performed in the past.

There are five (5) basic responsibilities identified for a Safety Inspection as per NBIS.

- Maintain Public Safety
- Protect Public Investment
- Support the Inspection Program
- Produce Accurate Records
- Legal Responsibilities

The Pontis BMS program is not intended to replace the "inspection responsibilities" of the NBI method.

The Pontis BMS program does however replace the "component condition rating" procedure of the NBI method.

At this point, Pontis may sound like more paperwork for inspectors that are already overloaded. And in fact, collection of Pontis input data is a **new duty** for some inspectors, and an adjustment in record keeping for other inspectors.

See Slide 5-5-66

This new duty is identifying all of the individual elements used to define the bridge structure and reporting their condition states.

A significant amount of time will be saved, however.

By using Pontis, inspectors will no longer have to struggle with the task of subjectively assigning numbers to represent the condition of an entire bridge component.

Likewise inspectors will not have to prepare separate repair and maintenance recommendations.

02-0065- Page 1 of 3

ELEMENT DATA COLLECTION FORM Inspection Date Mon-Year

S DUNSMUIR UC Route: 0 0 5 Post mile: 0.69 01 Apr-2065

Element	Environment	Total Quant	Quantity by state 1	2	3	4	5
10	2	15350	463	0902	1041	4144	0
21	4	10716	109	4304	935	0422	4066
22	2	22	21	1	0	0	0
45	3	7376	1	6933	147	295	0
107	4	27644	1107	10781	5005	0016	1935
110	1	1042	20	1504	10	104	36
115	2	9094	2377	1079	3067	791	1700
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____
---	-	0	____	____	____	____	____

0-31

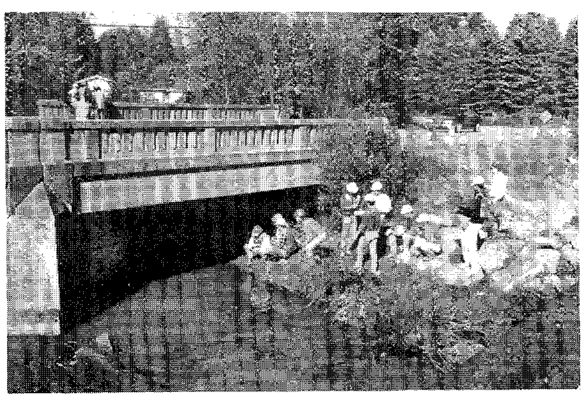
F1=Help Alt-Q-Quit Alt-S=Save/Display Esc=Cancel Alt-F=Find Alt-C=Comment

View: ELEMENTS Manual: none Auto: none Index: Bridge ID

User: PDT Database: CA1PCT Segment: none

Example Form

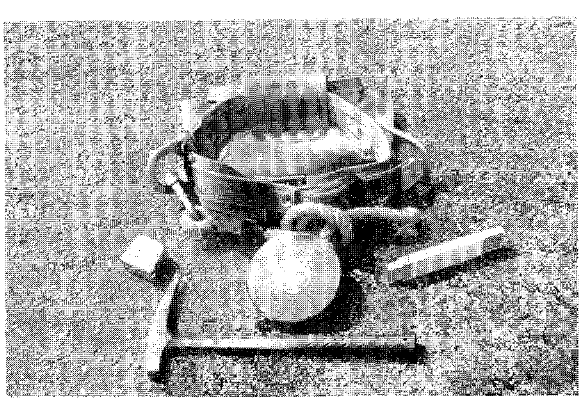
Element data collection form from the Pontis User's Manual



Slide No. 5-5-67

Example Slide

Typical NBIS inspection activity



Slide No. 5-5-68

Example Slide

Standard measuring tools

In addition, standard inspection report forms can be streamlined to focus on specific structural and safety related concerns rather than quantitative assessments for MR&R activities.

3. Standard Report Forms

The Pontis development effort did not include the design of a standard report form. However, a report form for the field will consist of a list of CoRe elements which make up the bridge, the quantity of that element, and space to identify the condition states which are applicable. The input required for Pontis is straight forward and well suited to collection on a tabular format.

On the opposite page is a sample format which an agency could use as a basis for their own customized **Pontis BMS Condition Report Form**.

See Slide 5-5-67

4. Inspection Procedures

As discussed, basic inspection procedures for an NBIS Safety Inspection must still be followed.

For the Pontis BMS program, the inspection procedure is not different but the documentation procedure is.

Upon reaching the bridge site, the inspector will have a Pontis BMS Condition Report Form that identifies all of the elements which make up the bridge.

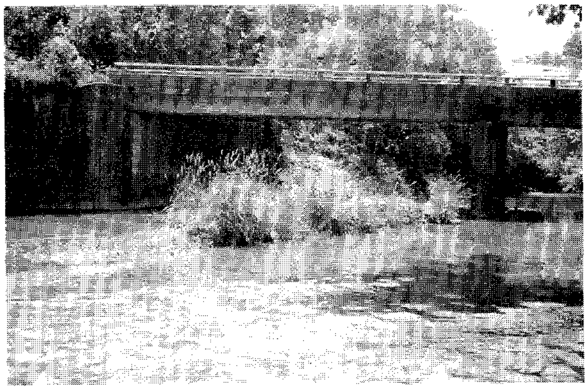
During routine inspection activity for each element, the inspector will assign a condition state based on prescribed condition state language for that particular element and the material from which it was made.

When completing the condition state input, special attention must be paid to quantifying various condition states which may exists within that element and the appropriate unit of measure.

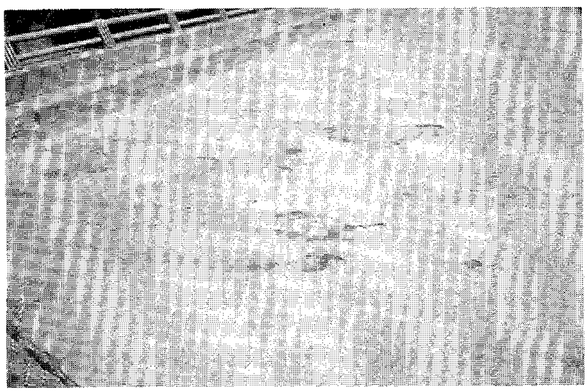
See Slide 5-5-68

The required level of effort to determine quantities of a condition state is just to provide an estimate. However, the more accurate the input, the more efficient Pontis will be. Therefore it is recommended that quantity measurements be made using **standard measuring devices** whenever possible.

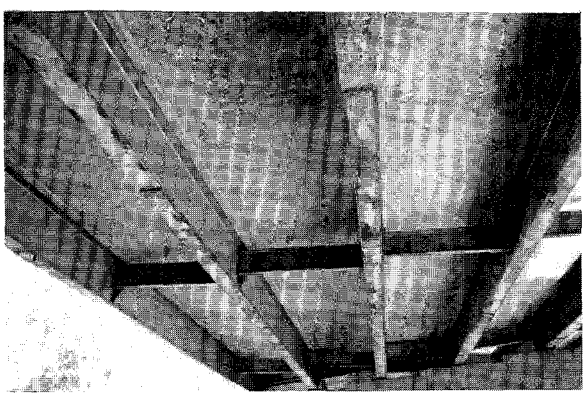
In some cases an inspector may have to identify a "Smart Flag" due to conditions not accounted for in the condition state language.



Slide No. 5-5-69
Example Slide
General elevation view of a steel multi-beam bridge



Slide No. 5-5-70
Example Slide
General view of the deck



Slide No. 5-5-71
Example Slide
General underside view of the superstructure

Slide No. 5-5-72
Example Slide
General view of the substructure

SESSION 5: BRIDGE INSPECTION REPORTING SYSTEM

TOPIC 5: THE PONTIS BRIDGE MANAGEMENT SYSTEM

PONTIS CONDITION REPORT EXAMPLE

NARRATIVE WITH QUANTITIES:

See Slide 5-5-69

- This is a two span rolled steel multi-beam bridge, with each span consisting of six beams. The two spans are supported by one pier and two abutments constructed of reinforced concrete, the bridge has a deck width of 24 ft. and structure length of 144 ft. This structure carries two lanes of traffic on Beaver Creek Road over the tributary to Beaver Creek.

CONDITION STATE SUMMARY:

See Slide 5-5-70

- The top of the deck has delaminated concrete and several spalls with exposed rebar. Approximately 13% of the deck surface is affected.
- The bridge railing is in good condition with no deficiencies.
- The expansion joints are clean and functional.
- The underside of the deck shows general areas of fine cracking with rust stains and efflorescence.
- Minor pitting to a depth of 1/16" and paint scaling is typical on all bottom flanges of the beams. Top flanges are in good condition with the exception of areas of the diaphragm connections. An area of approximately 6 inches on each side of the connection from top to bottom has 1/16" section loss.

See Slide 5-5-71

- Cover plate end welds at three locations exhibited 4" long HL cracks.
- The diaphragms are showing general pitting to 1/16" depth and scaled surface rust typical of all diaphragms.
- The bearings are in fair condition with a minor build-up of pigeon droppings around the base plates causing a failure of the paint system.

PONTIS
PONTIS

See Slide 5-5-72

- The far abutment has a full height vertical crack between Stringers No. 3 and No. 4. This crack varies in width from 1/16" to 1/8".
- The near abutment is in good condition, with no deficiencies.
- The pier is in good condition, with no deficiencies.
- The near abutment has lateral scour along front face for a length of 28' x 7' wide to a depth of 4'.
- The upstream end of pier has a build-up of sediments and debris measuring 40 ft. long x 7 ft. wide x 4 ft. high.

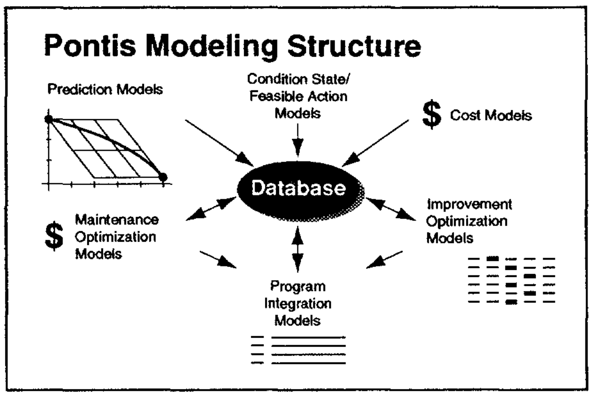
BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements (Deck/Super/Sub)							
12 Concrete Deck (Bare)	1 (3,456 SF)	EA				1	
107 Painted Steel Open Girder	864	LF				864	X
210 Reinforced Conc. Pier Wall	24	LF	24				X
215 Reinforced Conc. Abutment	52	LF	51	1			
Other CoRe Elements							
311 Movable Bearing	12	EA		12		X	X
313 Fixed Bearing	12	EA		12		X	X
330 Metal Bridge Railing	288	LF	288				X
Smart Flags							
356 Steel-Fatigue	1	EA		1		X	X
359 Soffit or Under Surface of Conc. Deck	1	EA				1	
361 Scour	1	EA		1		X	X

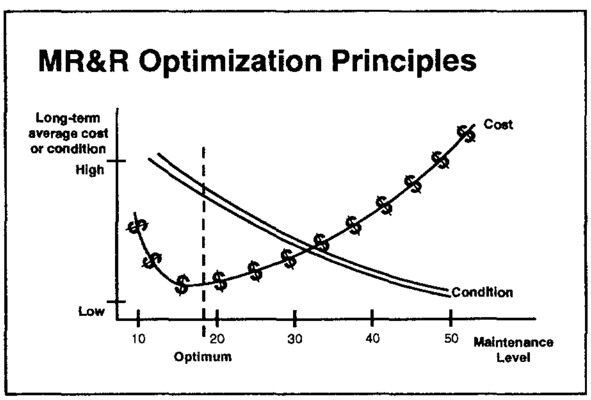
Major System Components

- The Pontis Database
- Bridge Inspector Input
- **Optimization Models**

Slide No. 5-5-73
Title Slide



Slide No. 5-5-74
Schematic Slide
Pontis modeling structure



Slide No. 5-5-75
Schematic Slide
MR&R optimization

Improvement Optimization

- User Cost Savings
- Level of Service

Slide No. 5-5-76
Title Slide

C. OPTIMIZATION MODELS

See Slide 5-5-74

The main feature of Pontis is its optimization capability. The schematic shown on the opposite page demonstrates the interrelationship among system components.

See Slide 5-5-75

1. MR&R Optimization

The objective of the MR&R optimization model is to find the long-term policy, for each element in each environment, which minimizes the long-term maintenance funding requirements while keeping the element out of risk of failure due to deterioration.

This means that Pontis will provide agencies the information they need to decide which short-term actions are most cost-effective for the long-term.

For any given agency, the MR&R optimization will recommend the best long-term policy(lowest-cost sustainable policy), and will also quantify the added cost of delaying the recommended policy.

2. Improvement Optimization

The objective of the improvement optimization model is to maximize the benefit gained , in terms of user cost savings, from any given level of investment.

Improvement action that could be considered include:

- Widening for improved deck geometry
- Raising for improved vertical clearance
- Seismic retrofit
- Scour mitigation
- Replacement

Improvement actions usually change the level of service, and once an action is taken, the physical characteristics remain the same and no new action needs to be considered until a future level of service makes it necessary.

Integrated Project Programming

- Scheduling
- Budget Constraints

Slide No. 5-5-77
Title Slide

Condition States and Physical Actions

- Element Definition
- Units
- Feasible Actions

Slide No. 5-5-78
Title Slide

User Costs (U)

$$U = A + O + T$$

where A = Accident $
O = Vehicle Operating $
T = Travel Time $

Slide No. 5-5-79
Title Slide

3. **Integrated Project Programming**

Both the MR&R model and the improvement model generate unconstrained needs and provide the information necessary to prioritize them. The Pontis programming module schedules the projects to conform to budget constraints.

It has the ability to recognize eligibility requirements and funding limitations, and it has the ability to simulate the possibility of future year projects and prioritize them.

4. **Condition States and Physical Action**

The definitions of elements and their units, condition states, and the set of feasible actions for each condition, constitute this model.

That is why the language of the condition state descriptions was carefully authored by the Technical Working Group to avoid ambiguities.

The number of condition states is typically five for each element, and for each condition state there are between one and three feasible actions.

Although Pontis has the capability to consider 160 elements, a typical bridge does not include more than 6 to 8 elements.

5. **User Cost**

In Pontis, annual benefits are measured as the savings in user costs that result from improving a bridge site versus maintaining the existing bridge.

Considerations include:

Accidents due to narrow deck widths
Detours due to load restrictions
Detours due to vertical clearance restrictions

Benefits are calculated as the sum of the savings in accident costs, vehicle operating costs, and travel time costs.

Example: Transition Probability Matrix

Concrete box girders, no action (probabilities in percent)

State this year	State 2 years later 1	2	3	4
1. No Deterioration	94	6	0	0
2. Minor cracks/spalls No exposed rebar	0	79	21	0
3. Rebar may be exposed Insignificant section loss	0	0	55	45
4. Advanced deterioration	0	0	0	100

Slide No. 5-5-80
Schematic Slide
Deterioration prediction

Adoption of Pontis

Slide No. 5-5-81
Title Slide

See Slide 5-5-80

6. Deterioration Prediction

This important model within Pontis estimates deterioration rates for each element and quantifies the uncertainties typical of such predictions.

The prediction model has the capability to learn from actual experience and to automatically update its prediction as more data becomes available.

The updating feature of the prediction model is one of the innovative aspects of Pontis which allows implementation of the program possible even when little information is available on how the various elements behave over time.

III. ADOPTION OF PONTIS

Pontis has been developed as a highly modular software system that is designed for Personal Computers.

The required PC hardware necessary to run the Pontis program is listed below.

Bare Minimum configuration (estimated cost $2,500)

PC clone with 80386 processor rated at 33 Megahertz
640K RAM
80387-33 math coprocessor
400 Megabyte hard disk with 15 ms access time
One floppy disk drive, preferably 3.5"
Color VGA monitor
Standard dot matrix printer

MS-DOS 5
Memory manager
Windows 3.1

Recommended configuration (estimated cost around $4,500)

PC clone with 80486 processor rated at 66 Megahertz
8 Megabytes RAM
600 Megabyte 7ms SCSI-II hard disk
Mouse
Two floppy disk drives, one 3.5", one 5.25"
Tape Backup Unit
14.4K Baud FAX/DATA Modem
Color VGA 15" monitor
Fast dot matrix printer or inexpensive laser printer

Major Steps

1. Customize Models
2. Customize Software
3. Agency Commitment
4. Learning Software

Slide No. 5-5-82

Title Slide

MS-DOS 5
Memory management software
DOS Shell Utility
Windows 3.1
Telecommunications software
File compression software

Notebook Configuration

Same as recommended configuration with the addition of disk compression software such as Stacker or SuperSoft to maximize disk space.

It is also transportable to mainframes, work stations and other platforms.

See Slide 5-5-82

In general there are four (4) major steps involved in adopting the Pontis BMS:

1. **Customizing the Models**

   All of the cost models, user cost formulas, deterioration probabilities, and page/screen layouts are treated as data and therefore can be customized. Decision models can be modified to reflect an agency's specific needs, policies and management requirements.

2. **Customizing the Software:**

   Adding database items, adjusting element condition descriptions and feasible actions, and other relatively minor customizations can be performed easily.

3. **Adopting the Pontis Rating System**

   Inspection procedures include identification of condition states for individual elements of a bridge in lieu of the current NBI method of assigning condition rating numbers.

   An agency must commit to describing each bridge on their inventory using the Pontis elements and conventions.

4. **Learning the Software**

   The PC-based version of Pontis is very simple to learn. All Pontis features are accessed from one set of pull-down menus.

Pontis Summary

- Network System
- Objective
- Flexible
- BMS Objectives
- What-If Analysis
- Management Tool

Slide No. 5-5-83

Bridge selections, sort orders, page/screen layouts, and models are easily combined in various ways to conduct routine and ad hoc tasks, including database updating, cost modeling, optimization and reporting

IV. SUMMARY

Pontis is an agency wide network optimization system to address the improvement and maintenance needs of all bridges.

Pontis replaces the current condition rating procedures which are based on subjective evaluation.

Pontis is flexible enough for implementation in various agencies.

Pontis integrates the objectives of public safety, user convenience, and preservation of investment, with budgetary and program policies.

Pontis compares preventative versus corrective maintenance policies.

Pontis provides a systematic procedure for determining the specific minimum funding requirements to remove backlogs and achieve goals.

Any Questions?

INSPECTION AND EVALUATION OF BRIDGE DECKS

SESSION 6: INSPECTION AND EVALUATION OF BRIDGE DECKS

TOPIC 1: DECKS

LESSON PLAN

TOPIC DURATION	90 minutes
PREREQUISITES	The ability to recognize various bridge deck types and understand their structural characteristics.
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 7
GOAL	Awareness of important inspection locations and procedures for common bridge decks.
OBJECTIVE	To be able to accurately evaluate the condition of a bridge deck and correctly apply the condition rating coding guidelines.

Timber Deck Defects

- Wear
- Check/Splits/Shakes
- Crushing
- Rot
- Fastener Damage
- Deformation
- Delamination

Slide No. 6-1-1

Narrative Slide

Concrete Deck Defects

- Wear
- Scaling
- Cracks
- Delamination and Spalls
- Contamination
- Honeycombing
- Reinforcement Corrosion
- Deformation

Slide No. 6-1-2

Narrative Slide

Steel Deck Defects

- Wear
- Corrosion
- Member Damage
- Fastener Damage
- Broken Welds

Slide No. 6-1-3

Narrative Slide

Causes of Defects

- Traffic
- Environmental
- Deicing agents
- Design/construction

Slide No. 6-1-4

Title Slide

D. OUTLET PIPES

See Slide 6-2-24

Outlet pipes must carry runoff away from the structure. The outlet pipe may only be a straight extension of the deck drain - this type should be long enough so the runoff is not discharged onto the structure.

The outlet pipe may also be a series of pipes, called downspouting. Check this type for split or disconnected pipes that may allow runoff to accelerate deterioration of the structure.

III. INSPECTION OF SAFETY FEATURES

A. SAFETY FEATURE EVALUATION

The inspection of bridge safety features involves evaluation of the bridge railing system on the bridge, the guardrail system leading from the bridge, the guardrail system leading from the approach roadway to the bridge end, and whether these two systems will likely function acceptably together to safely contain and redirect errant vehicles which may collide with them.

Evaluation of these features is divided into four elements under Item 36 in FHWA's Recording and Coding Guide. The inspector assigns a separate numerical rating each for the:

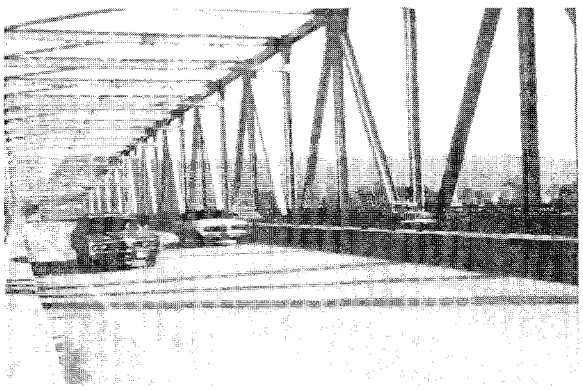
- Bridge railing system
- Guardrail transition to the bridge railing
- Approach guardrail system
- Approach guardrail end treatment

These ratings are to reflect whether each element does meet current safety criteria (1) or does not (0). Bridge owners, such as State highway departments or Federal agencies, usually establish the currently acceptable safety criteria to be used as a basis for safety feature evaluation.

Traffic

- Wear and Abrasion
- Impact Damage
- Overloads

Slide No. 6-1-5
Narrative Slide

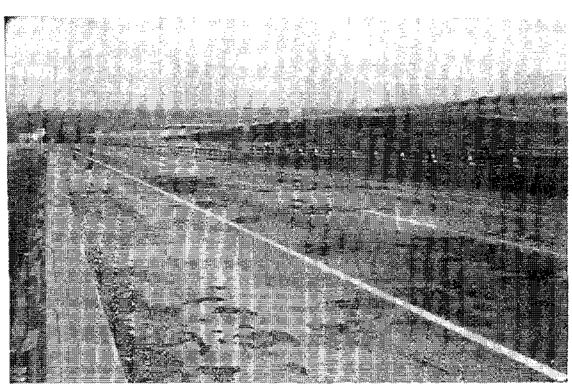


Slide No. 6-1-6
Example Slide
Traffic on a bridge

Environmental

- Sun and Wind
- Snow and Rain
- Freeze-Thaw Cycles
- Fungi and Parasites
- Seawater Spray

Slide No. 6-1-7
Narrative Slide



Slide No. 6-1-8
Example Slide
Freeze-thaw damage

See Slide 6-1-6

1. Traffic Induced

- Wear and abrasion (studded tires)
- Impact damage (snow plows, dropped cargo)
- Overloads

See Slide 6-1-8

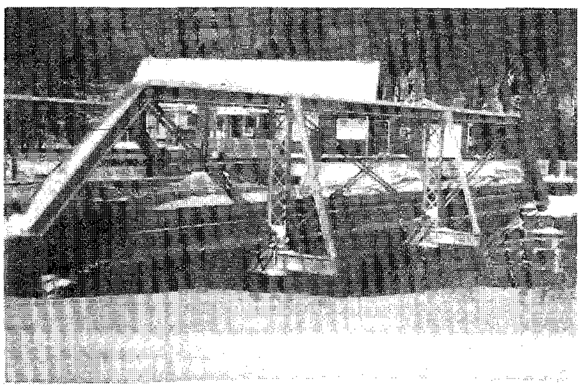
2. Environmental

- Weather elements such as the sun and wind
- Moisture from snow and rain
- Freeze-thaw cycles
- Presence of fungi and parasites
- Seawater spray

De-icing Agents

- Chlorides
- Sand Mix
- Gravel and Cinders

Slide No. 6-1-9
Narrative Slide

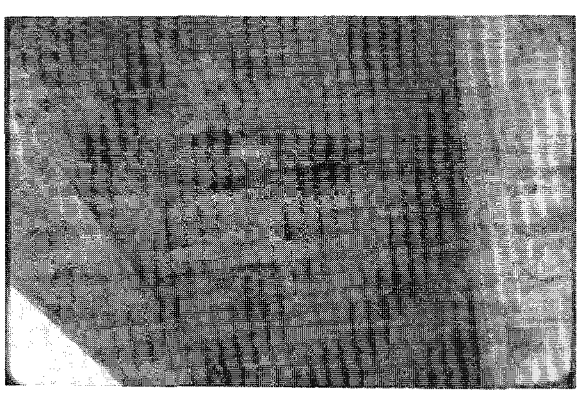


Slide No. 6-1-10
Example Slide
Snow removal and deicing operations

Design/Construction Deficiencies

- Improper Design Application
- Insufficient Rebar Cover
- Premature Form Removal
- Poor Concrete Mix
- Improper Vibration
- Improper Curing Techniques

Slide No. 6-1-11
Narrative Slide



Slide No. 6-1-12
Example Slide
Honeycomb

3. De-icing Agents

See Slide 6-1-10

- Chloride
- Sand mix
- Gravel and cinders

4. Design/Construction Deficiencies

Pre-service factors which create defects include:

See Slide 6-1-12

- Improper design application
- Insufficient reinforcement bar cover
- Premature form removal
- Poor concrete mix
- Improper vibration
- Improper curing techniques

Timber Decks

- Design Characteristics

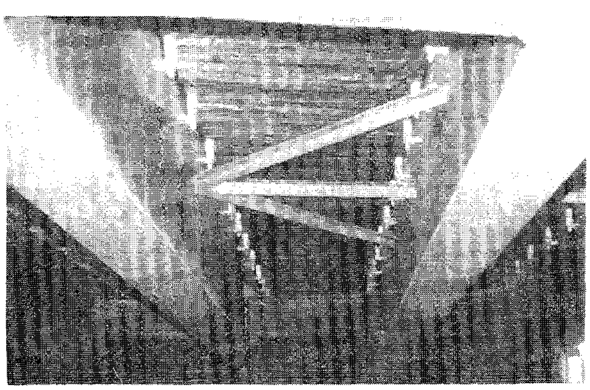
Slide No. 6-1-13
Title Slide

Timber Deck Types

- Plank Deck
- Nailed Laminated Deck
- Glued Laminated Deck
- Prestressed Laminated Deck/
Stressed Timber Deck

Slide No. 6-1-14
Narrative Slide

Slide No. 6-1-15
Example Slide
Plank deck



Slide No. 6-1-16
Example Slide
Underside view of timber deck fasteners

II. TIMBER DECKS

A. DESIGN CHARACTERISTICS

Timber decks are normally referred to as decking or timber flooring and the term is limited to the roadway portion which receives vehicular loads.

1. **Types** - the four basic types of timber decks are:

   - Plank deck
   - Nailed laminated deck
   - Glue laminated deck
   - Prestressed laminated deck/stressed timber deck

See Slide 6-1-15

2. **Placement** - Decking is usually placed across the bridge, perpendicular to the flow of traffic.

See Slide 6-1-16

3. **Attachment** - Decking is usually fastened to the floor system by nails, spikes or clip angles.

Slide No. 6-1-21
Example Slide
Areas exposed to traffic

Slide No. 6-1-22
Example Slide
Inspector probing timber deck with an ice pick (inspector is checking the timber at reflective cracks in the asphalt wearing surface)

Concrete Decks

- Design Characteristics

Slide No. 6-1-23
Title Slide

Concrete Deck Types

- Reinforced cast-in-place (CIP)
- Precast
- Prestressed Slabs
- Precast prestressed concrete deck panels with CIP topping

Slide No. 6-1-24
Narrative Slide

See Slide 6-1-21

- **Areas Exposed to Traffic** - Check these areas for wear, weathering, and impact damage.

2. **Inspection Procedures**

- **Visual** - All surfaces of the deck planks should receive a close visual examination. Suspect areas should be examined physically.

- **Sounding** - An inspection hammer should be used to initially evaluate the subsurface condition of the planks and tightness of the fasteners.

See Slide 6-1-22

- **Probing** - In suspect areas, performing a pick test or penetration test can reveal decayed planks.

  A pick test involves lifting a small sliver of wood with a pick or pocket knife and observing whether or not it splinters or breaks abruptly.

  Sound wood splinters, decayed wood breaks abruptly.

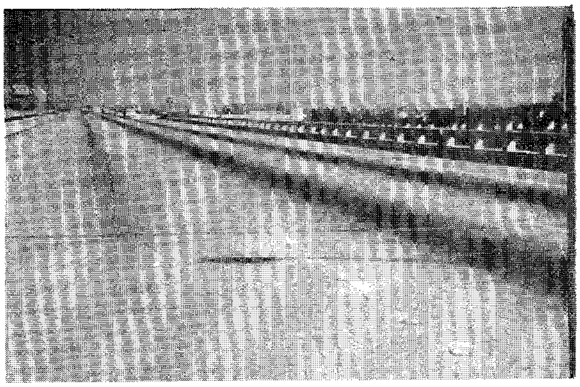
III. CONCRETE DECKS

A. DESIGN CHARACTERISTICS

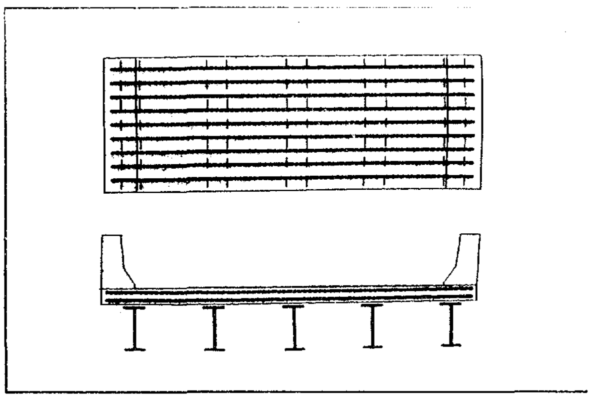
The most common bridge deck material is concrete.

1. **Types** - There are four common types of concrete decks:

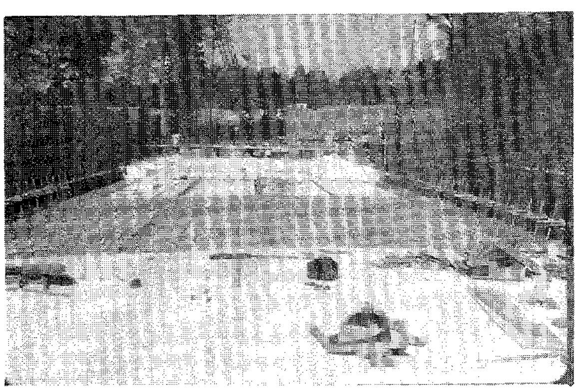
- Reinforced cast-in-place (CIP)
- Precast slabs
- Prestressed slabs
- Precast prestressed concrete deck panels with CIP topping



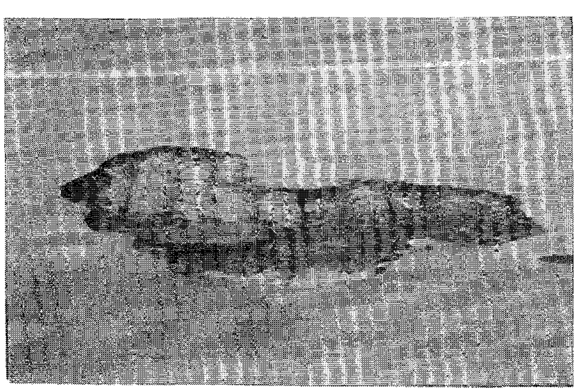
Slide No. 6-1-25
Example Slide
Typical reinforced cast-in-place deck



Slide No. 6-1-26
Schematic Slide
Primary reinforcing steel
perpendicular to traffic



Slide No. 6-1-27
Example Slide
Primary reinforcing steel
perpendicular to traffic



Slide No. 6-1-28
Example Slide
Pothole showing primary reinforcing
steel perpendicular to traffic

See Slide 6-1-25

The most common type of concrete deck is the reinforced cast-in-place deck.

2. **Steel Reinforcement** - The inspector must be able to determine the direction of the primary or tension reinforcement to properly evaluate any cracks in the deck.

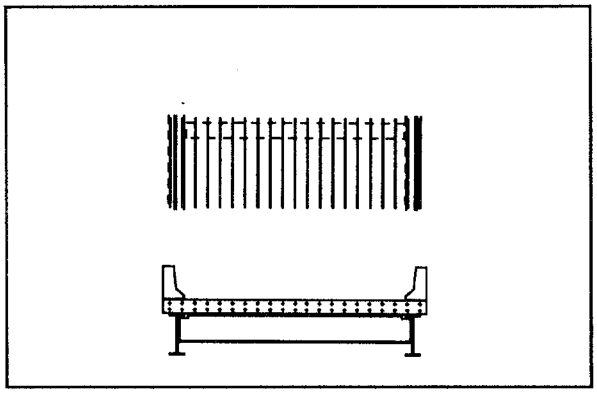
Primary reinforcement is placed perpendicular to the deck's support points. The points of support vary from bridge to bridge. For example:

See Slide 6-1-26

See Slide 6-1-27

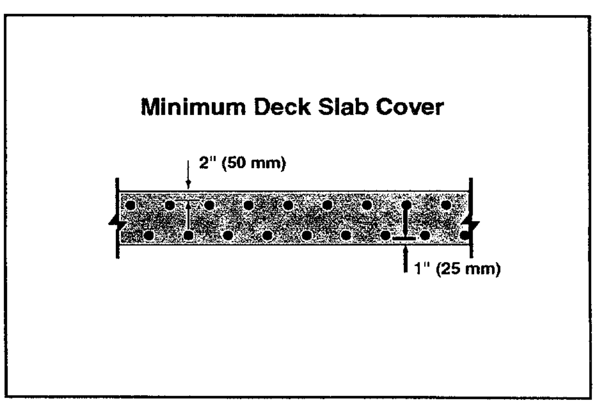
See Slide 6-1-28

- The deck support points on a multi-beam bridge are parallel to the direction of traffic, therefore, the primary steel is perpendicular to traffic flow. This is also the case for floorbeam and stringer type floor systems.



Slide No. 6-1-29
Schematic Slide
Primary reinforcing steel parallel to traffic

Slide No. 6-1-31
Example Slide
Deck reinforcing with the same bar size and spacing in both directions on precast panels with cast-in-place topping



Slide No. 6-1-32
Schematic Slide
Reinforcement bar cover

See Slide 6-1-29

- The deck support points on a floorbeam only type floor system are perpendicular to the direction of traffic. Therefore, the primary steel is parallel to the traffic flow.

See Slide 6-1-31

- Primary reinforcement is generally a larger bar size than the temperature and shrinkage steel. However, to improve design and construction efficiencies, some concrete decks may be reinforced with the same bar size and spacing in both directions in both the top and bottom rebar mats .

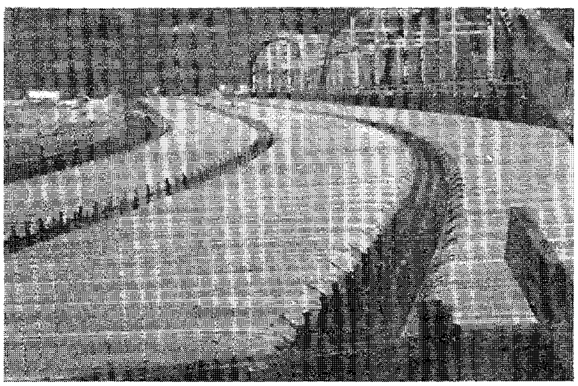
See Slide 6-1-32

Reinforcement cover for top and bottom rebars is generally 2 inches (50 mm) minimum for top reinforcement and 1 inch (25 mm) minimum for bottom reinforcement.

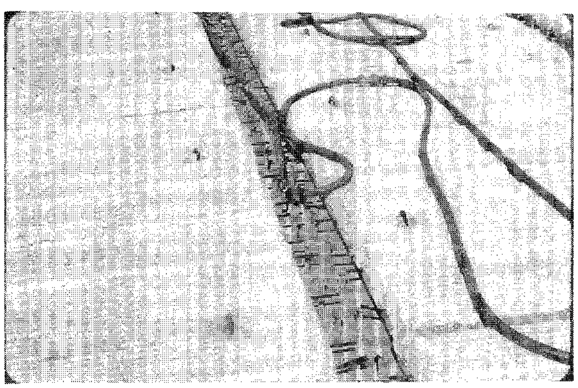
Composite Action

A deck designed to contribute to the overall structure capacity of the superstructure through composite action.

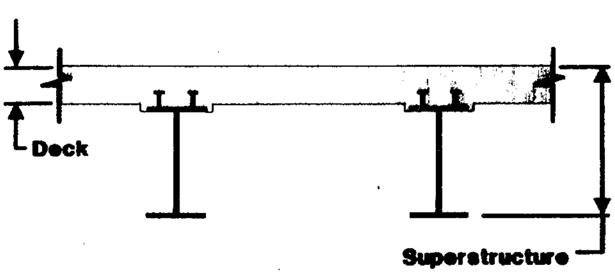
Slide No. 6-1-33
Narrative Slide



Slide No. 6-1-34
Example Slide
Shear connectors welded to the top flange (stay-in-place forms also shown)



Slide No. 6-1-35
Example Slide
Precast deck panels with lifting lugs evident and top beam flange exposed



Composite Steel Stringer

Slide No. 6-1-36
Schematic Slide
Composite action

3. **Composite Action** - Composite action is defined as dissimilar materials joined together so they structurally behave as one material.

- A composite bridge deck structure is one in which the deck acts together structurally with the beams to resist the span loads. To be classified as composite design, the deck material must be different from the superstructure and be strong enough to contribute significantly to the overall strength of the section.

See Slide 6-1-34

- The most common combinations are cast-in-place (CIP) concrete on steel and CIP concrete on prestressed concrete. Composite action is provided by shear connectors such as studs, spirals, channels, or stirrups that are attached to the beams and are embedded in a concrete deck providing a mechanical structural connection or interlock with the CIP deck.

See Slide 6-1-35

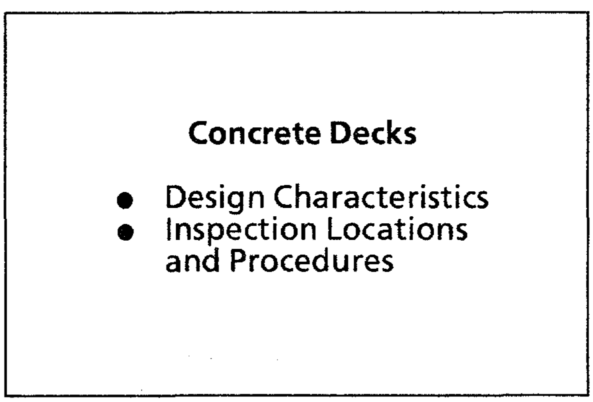
- A precast deck can also provide composite action as the shear connectors engage the upper cast-in-place portion as it is cast.

See Slide 6-1-36

- Composite concrete decks contribute to the superstructure capacity in addition to distributing wheel loads. Composite action is achieved only after the concrete deck has hardened.

- A non-composite deck does not contribute to the structural capacity of the superstructure.

Slide No. 6-1-37
Example Slide
Asphalt wearing surface on a concrete deck



Slide No. 6-1-38
Title Slide

4. Wearing Surfaces

See Slide 6-1-37

Most concrete decks have a 1/2 inch (13 mm) integral wearing surface.

When the wearing surface has deteriorated to the extent that rideability is affected, it is repaired with an overlay.

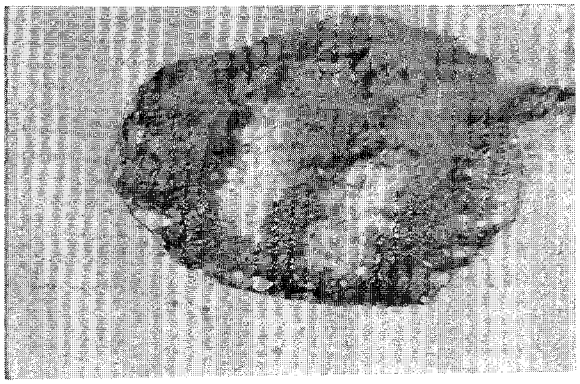
The most common overlay material is asphalt. There are however various concrete overlays used, including:

- Low slump dense concrete (LSDC)
- Latex modified concrete (LMC)
- Polymer modified concrete (PMC)

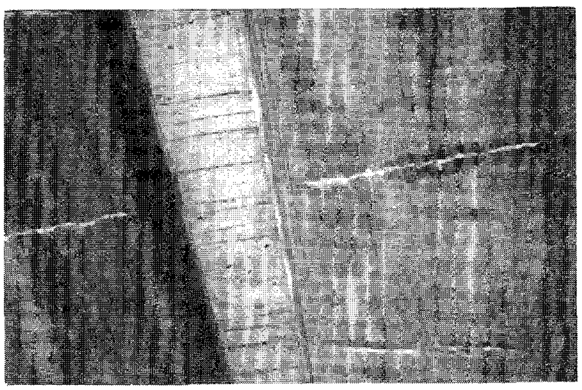
Depending on the condition of the deck, a waterproof membrane may be used between the deck and the new wearing surface.

Membranes are intended to seal the deck to prevent moisture and chloride intrusion from the roadway surface.

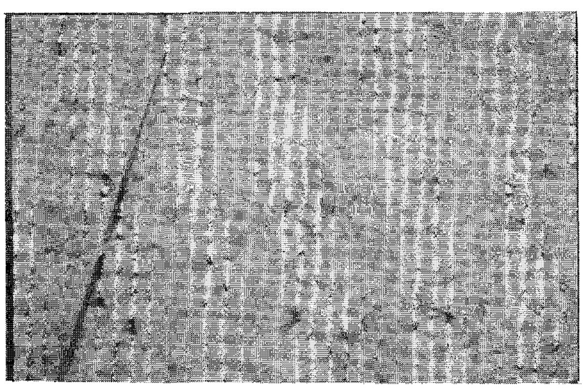
B. INSPECTION LOCATIONS AND PROCEDURES



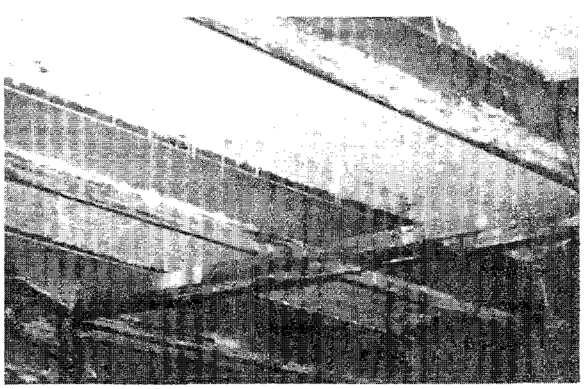
Slide No. 6-1-39
Example Slide
Pothole



Slide No. 6-1-40
Example Slide
Underside view of transverse deck cracks



Slide No. 6-1-41
Example Slide
Scaling



Slide No. 6-1-42
Example Slide
Chloride contamination

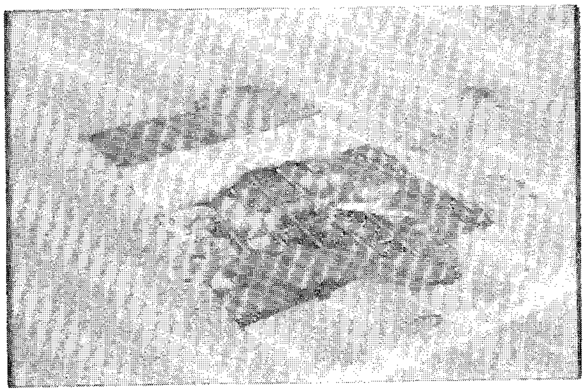
See Slide 6-1-39

See Slide 6-1-40

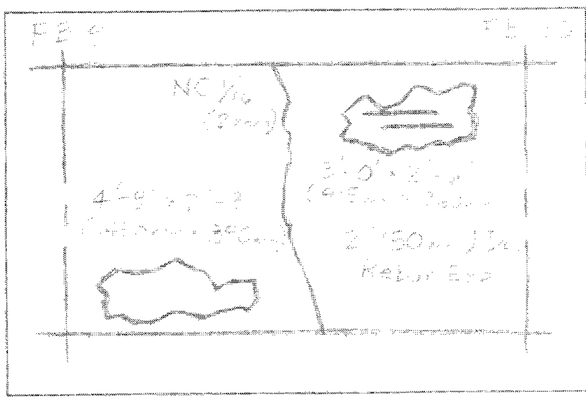
See Slide 6-1-41

See Slide 6-1-42

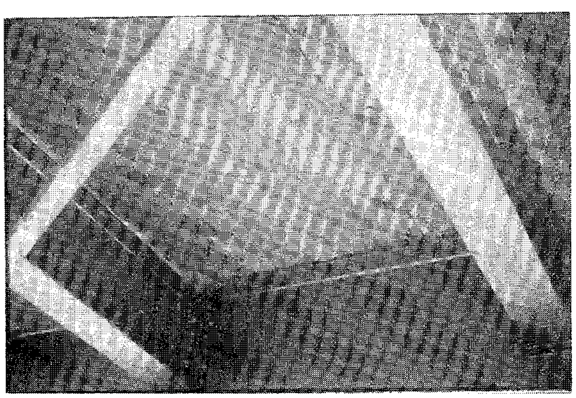
Concrete decks should be inspected top and bottom for cracking, scaling, spalling, corroded reinforcement, chloride contamination, delamination, and full or partial depth failures.



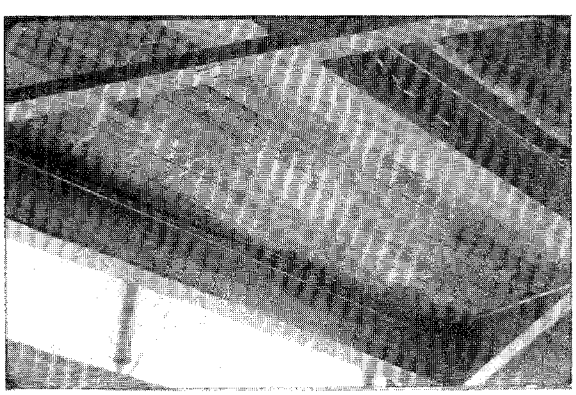
Slide No. 6-1-43
Example Slide
Progressive deterioration



Slide No. 6-1-44
Schematic Slide
Deck inspection notes



Slide No. 6-1-45
Example Slide
Bearing area (check the contact points of the deck with the floor system)



Slide No. 6-1-46
Example Slide
Cracks

See Slide 6-1-43

In all instances it is helpful if the inspector has available the previous inspection report so that the progression of any deterioration can be noted. This provides a more meaningful inspection.

See Slide 6-1-44

As always, the description, location and extent of deterioration should be documented in the inspection report.

1. Inspection Locations

See Slide 6-1-45

- **Bearing and Shear Areas** - Check the areas where the concrete deck is supported for spalls, and crushing.

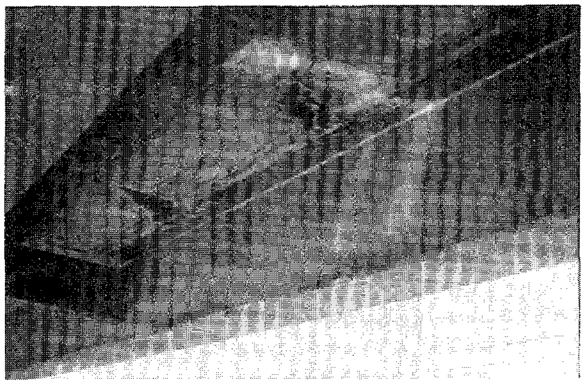
  Check shear key joints between precast deck panels for cracks and other signs of independent action.

- **Tension Areas** - On the top of the slab, check over the supports for flexure cracks.

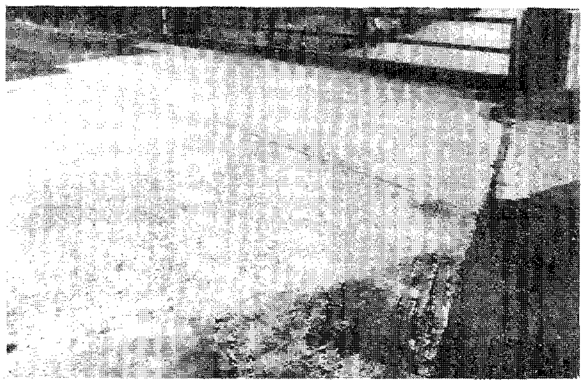
See Slide 6-1-46

  On the bottom of the slab, check between the supports for flexure cracks.

  Check the top and bottom of the slab for transverse flexure cracks in negative moment regions of the superstructure.

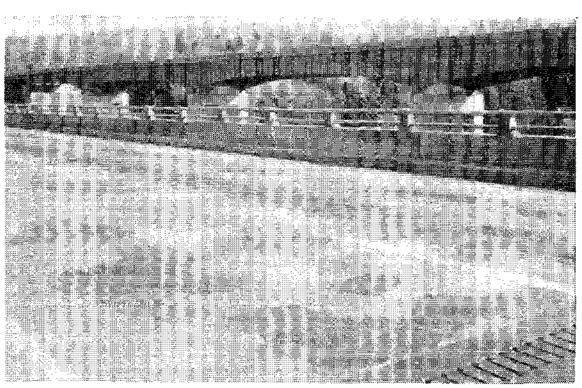


Slide No. 6-1-47
Example Slide
Area exposed to deck drain opening



Slide No. 6-1-48
Example Slide
Area exposed to traffic

Slide No. 6-1-49
Example Slide
Deteriorated stay-in-place form



Slide No. 6-1-50
Example Slide
Obvious defects observed during a visual inspection

See Slide 6-1-47

- **Areas exposed to drainage** - Check these areas for general deterioration of the concrete.

See Slide 6-1-48

- **Areas exposed to traffic** - This is the entire top side of the deck. The deck may show wear, scaling, delaminations, and spalls.

See Slide 6-1-49

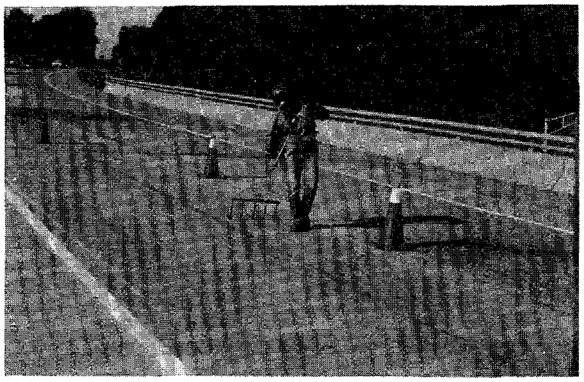
- **Stay-in-Place Forms** - These forms can hide damage. Deterioration and corrosion of the forms generally indicate that the concrete deck is contaminated.

- **Tie Rod Ends** - Check anchorage zones of precast slab tie rods for deteriorating grout pockets or loose lock off devices.

2. Inspection Procedures

See Slide 6-1-50

- **Visual** - The deck inspection is primarily a visual task, looking for cracks, spalls, and other defects.



Slide No. 6-1-51
Inspector using a chain drag

See Slide 6-1-51

- **Physical** - Hammers and chain drags can be used to detect areas of delamination. A delaminated area will have a distinctive hollow sound (as compared to sound concrete) when tapped with a hammer or revealed with a chain drag.

  A hammer hitting sound concrete will result in a solid "pinging" type sound. Delaminated concrete will produce a dull, fragile, thumping sound.

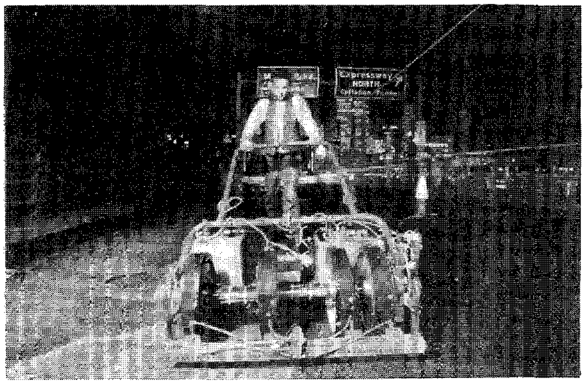
  Beating a deck with a hammer can be tedious operation. In most cases a chain drag is used. A chain drag is made of several sections of chain attached to pipe that has a handle attached to it. The inspector drags this across a deck and makes note of the pinging or thumping sounds. A chain drag can usually cover about a 3 foot (915 mm) section of deck at a time.

- **Advanced Techniques**

  Many of the problems associated with concrete bridge decks are caused by corrosion of the rebar. When the deterioration of a concrete deck progresses to the point of needing rehabilitated, an in-depth inspection of the deck is required to determine the extent, cause, and possible solution to the problem. Several techniques and methods are available.

  Delamination Detection Machinery is based on sonic responses. A portable electronic instrument known as a Delamtect consists of three components: a tapping device, a sonic receiver, and a signal interpreter. The instrument is moved across the deck as acoustic signals are passed through the deck. An electronically generated plan of the deck then indicates the delaminated areas.

  Half Cell Potentials are used to evaluate the corrosion activity of reinforcing steel embedded in concrete. Half cell electrical potentials of reinforcing steel are measured by moving an electrode about the concrete surface. Measured potential values indicate corrosion activity. Higher potential measurements indicate corrosion activity. The potential survey can be used to determine core sample locations.



Slide No. 6-1-52
Example Slide
Inspector using an automated concrete evaluation system

Steel Decks

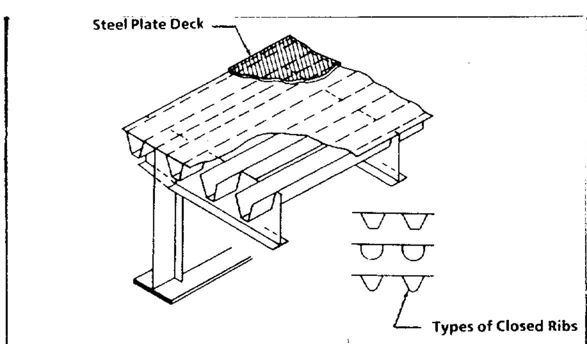
- Design Characteristics

Slide No. 6-1-53
Title Slide

Steel Deck

- Orthotropic
- Buckle Plate Deck
- Corrugated Flooring
- Grid

Slide No. 6-1-54
Narrative Slide



Orthotropic Bridge Deck

Slide No. 6-1-55
Schematic Slide
Orthotropic bridge deck

See Slide 6-1-52

Pulse Velocity techniques are used to evaluate relative quality of concrete and estimate compressive strength. The pulses pass through the concrete and the transit time is then measured. The pulse velocity is then interpreted to evaluate the quality of the concrete and to estimate in-place concrete compressive strength.

Core samples can be removed for laboratory analysis. In addition to standard strength tests, cores can be used for full petrographic analysis. Petrographics can provide water/cement ratio, type of aggregates, the air void system and the causes of deterioration (including chloride contamination).

IV. STEEL DECKS

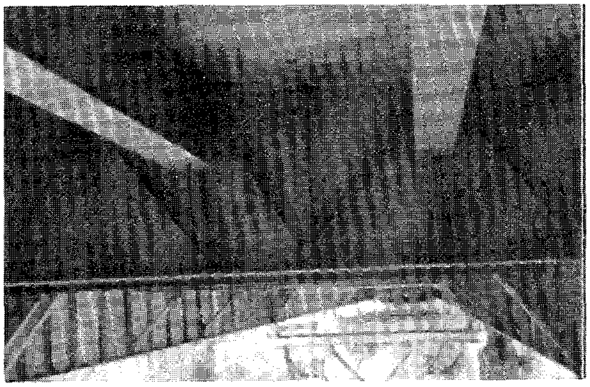
A. DESIGN CHARACTERISTICS

1. **Types** - There are four common types of steel decks:

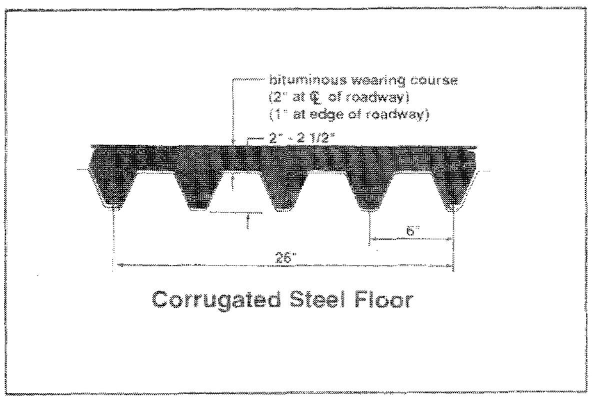
- Orthotropic
- Buckle Plate Deck
- Corrugated Flooring
- Grid

See Slide 6-1-55

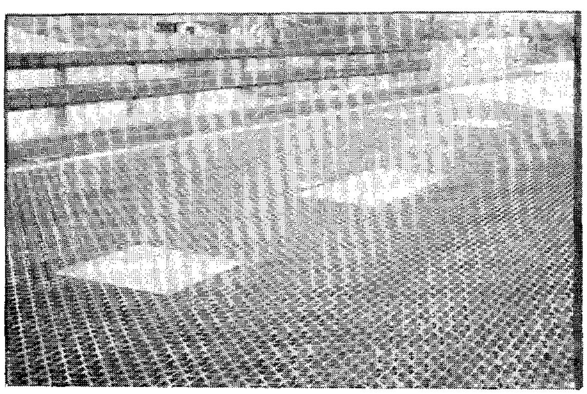
Orthotropic decks are occasionally used on large bridges and behave as part of the superstructure.



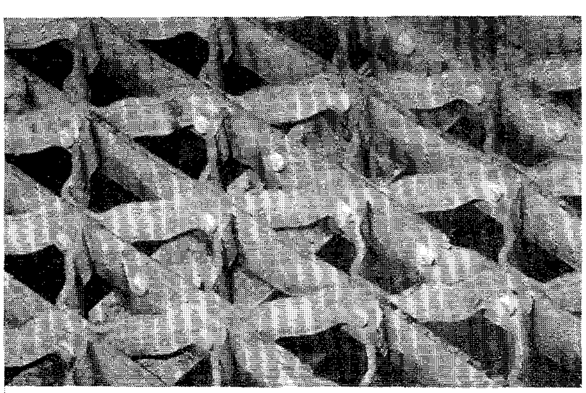
Slide No. 6-1-56
Example Slide
Underside view of buckleplate deck



Slide No. 6-1-56A
Schematic Slide
Sectional view of corrugated steel floor



Slide No. 6-1-57
Example Slide
Steel grid deck



Slide No. 6-1-58
Example Slide
Riveted steel grid deck

See Slide 6-1-56

Buckle plates which double as the structural deck and a deck form are obsolete and no longer used today.

See Slide 6-1-56A

Corrugated metal flooring is a structural deck that also doubles as the deck form in that it supports either concrete, asphalt or gravel. Corrugations are smaller than S.I.P. forms, but the steel is thicker, ranging from 0.1 inch (2.5 mm) to 0.18 inch (4.5 mm).

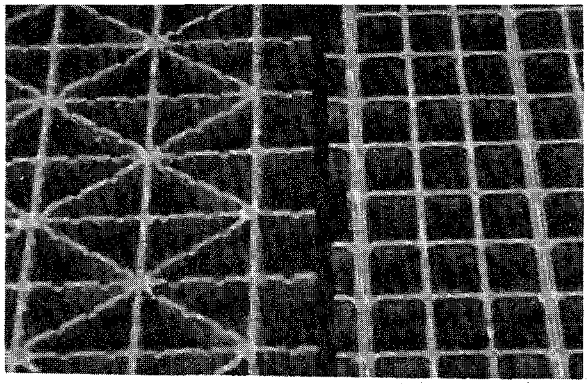
A corrugated metal flooring and grid decks are used because of their light weight and high strength.

See Slide 6-1-57

The most common steel deck is the steel grid deck.

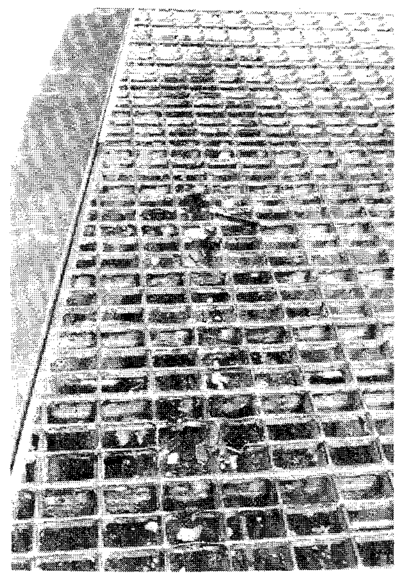
See Slide 6-1-58

- older, steel grids were manufactured using riveted construction



Slide No. 6-1-59
Example Slide
Various patterns of welded steel grid decks

Slide No. 6-1-60
Example Slide
Corroded steel grid deck

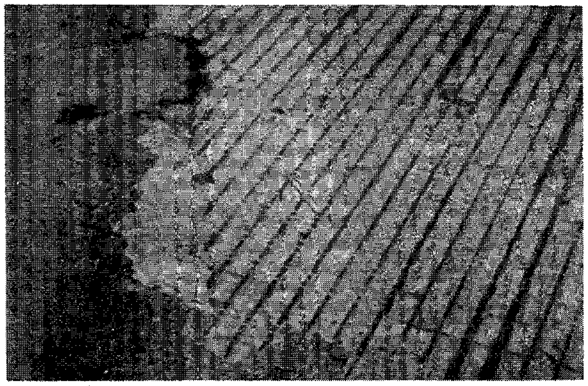


See Slide 6-1-59

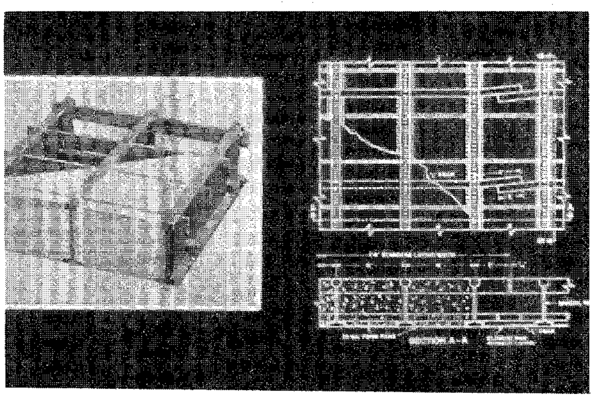
- as welding replaced rivets, steel grids were manufactured with various patterns.

See Slide 6-1-60

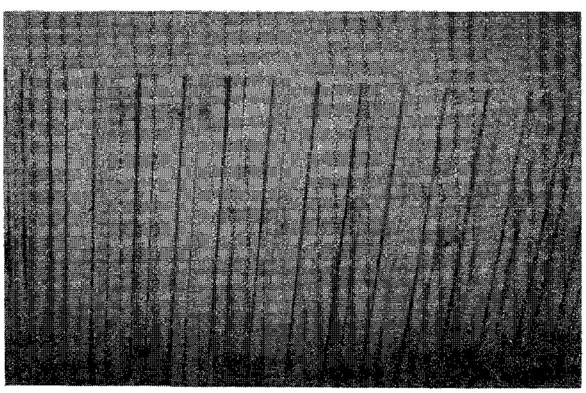
Steel grid decks today are commonly welded units and may be open or filled with concrete. Open decks are vulnerable to corrosion since they are constantly exposed to weather, debris, and traffic.



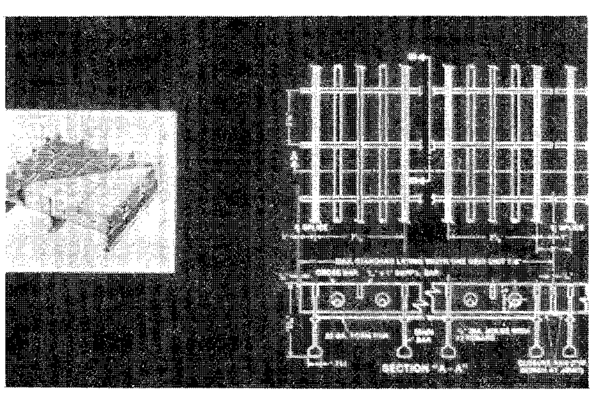
Slide No. 6-1-61
Example Slide
Concrete filled grid deck



Slide No. 6-1-62
Schematic Slide
Concrete filled grid deck



Slide No. 6-1-63
Example Slide
Underside view of a concrete filled grid deck



Slide No. 6-1-64
Schematic Slide
Half-filled concrete grid deck

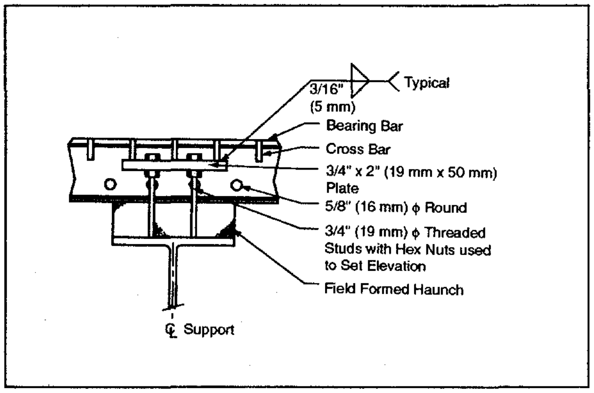
See Slide 6-1-61

See Slide 6-1-62

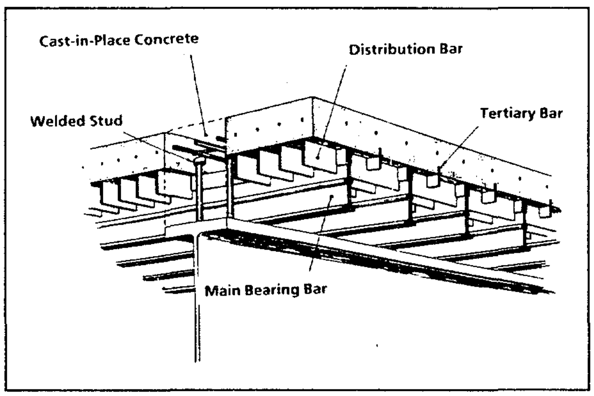
See Slide 6-1-63

See Slide 6-1-64

Concrete filled decks offer protection for the floor system against water, dirt, debris and deicing chemicals that usually pass directly though open grid decks. They can be full depth or half-filled.



Slide No. 6-1-65
Schematic Slide
Exodermic composite deck cross-section



Slide No. 6-1-66
Schematic Slide
Exodermic composite profile

See Slide 6-1-65

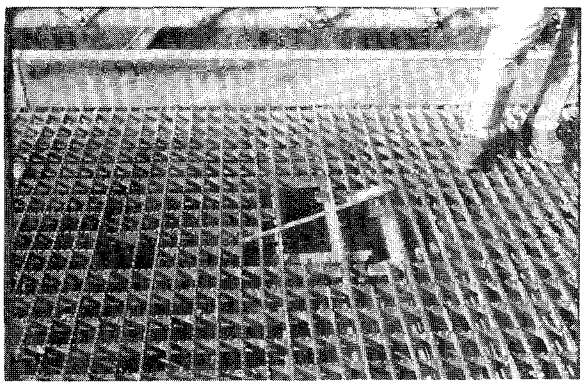
See Slide 6-1-66

3. **Composite Action** - Steel decks are usually non-composite. A new type of composite steel grid deck is known as an Exodermic deck.

Steel Decks

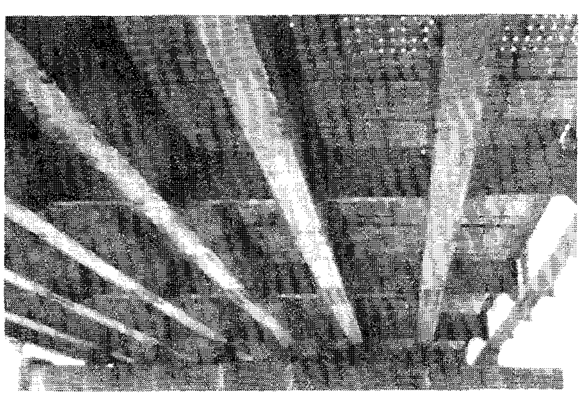
- Design Characteristics
- Inspection Locations and Procedures

Slide No. 6-1-67
Title Slide



Slide No. 6-1-68
Example Slide
Broken members

Slide No. 6-1-69
Example Slide
Section loss



Slide No. 6-1-70
Example Slide
Bearing areas

B. INSPECTION LOCATIONS AND PROCEDURES

See Slide 6-1-68

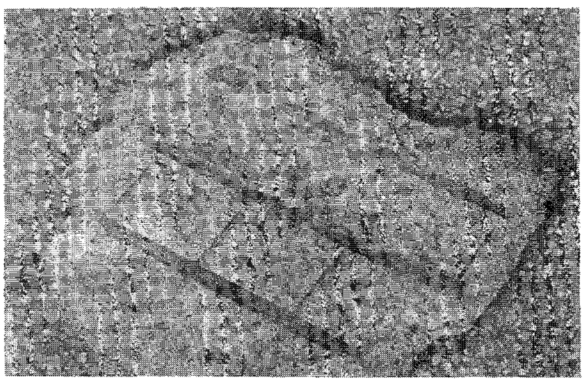
See Slide 6-1-69

Steel decks should be visually inspected for broken welds, failed fasteners, broken grids, and section loss.

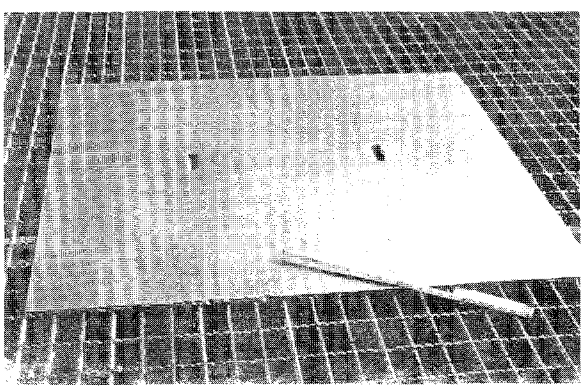
1. Inspection Locations

See Slide 6-1-70

- **Bearing Areas** - Check for cracked welds or broken fasteners which connect the steel deck to the supporting floor system.



Slide No. 6-1-71
Example Slide
Filled grid deck with an asphalt wearing surface



Slide No. 6-1-72
Example Slide
Repair plate

Summary

- Timber Decks
- Concrete Decks
- Steel Decks

Slide No. 6-1-73
Title Slide

- **Tension Areas** - On steel grid decks, check positive and negative moment regions of the primary bearing bars. Look for damage such as broken, cracked, or missing bars.

  On corrugated flooring, check between the support points for section loss due to corrosion.

- **Areas exposed to drainage** - Check areas where drainage can lead to corrosion.

See Slide 6-1-71

- **Areas exposed to traffic** - Steel grid decks should be checked for slipperiness, particularly when wet. On filled grid decks, an asphalt wearing surface may be applied.

2. **Inspection Procedures**

- **Broken Connections** - Listen for rattles as traffic passes over the deck.

- **Section Loss** - In areas where corrosion is evident, all scale should be removed with an inspection hammer in order to evaluate the amount of remaining material.

See Slide 6-1-72

- **Repairs** - Document the location and condition of any repair plates.

V. SUMMARY

A. **TIMBER DECKS**

B. **CONCRETE DECKS**

C. **STEEL DECKS**

SESSION 6: INSPECTION AND EVALUATION OF BRIDGE DECKS

TOPIC 2: JOINTS, DRAINAGE, AND SAFETY FEATURES

LESSON PLAN

TOPIC DURATION: 60 minutes

PREREQUISITES: Must have knowledge of the types and function of deck joints, drainage systems, and safety features.

PARTICIPANT MATERIALS: Participant Notebook, BITM 90 - Chapter 7

GOAL: Understanding of the purpose and function of deck joints, drainage systems and safety features as well as the importance of proper inspection.

OBJECTIVE: To be able to correctly evaluate the serviceability of deck joints, drainage systems, and safety features.

REFERENCES:

1. National Cooperative Highway Research Program Synthesis of Highway Practice 141 - Bridge Deck Joints
2. National Cooperative Highway Research Program Synthesis of Highway Practice 67 - Bridge Drainage Systems
3. AASHTO Roadside Design Guide, 1989
4. AASHTO Guide Specification for Bridge Railings, 1989
5. National Cooperative Highway Research Program Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features, 1993
6. AASHTO Standard Specifications for Highway Bridges, 15th Edition

Inspection of Deck Joints

Slide No. 6-2-1
Title Slide

Deck Joint Problems

- Debris
- Alignment
- Damage
- Overlays
- Supports

Slide No. 6-2-2
Narrative Slide

Deck Joint Problems

- Debris

Slide No. 6-2-3
Narrative Slide

Slide No. 6-2-4
Example Slide
Debris lodged in a sliding plate joint

I. INSPECTION OF DECK JOINTS

The deck joints must allow for the expansion and contraction of the bridge superstructure. The inspector must be aware of and record conditions that keep the deck joint from functioning properly.

There is not a separate item to code for the serviceability of deck joints. In fact, deck joint conditions are not to be considered in rating the structure. It is good practice, however, to thoroughly inspect the deck joints since they can indicate problems elsewhere on the structure.

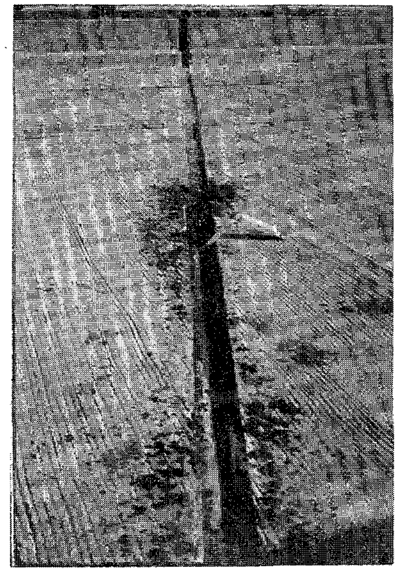
Problems with deck joints that the inspector should be aware of include:

A. DEBRIS

See Slide 6-2-4

1. **Debris Accumulation** - Debris lodged in the joint may prevent normal expansion and contraction, causing cracking in either the deck or the backwall or both.

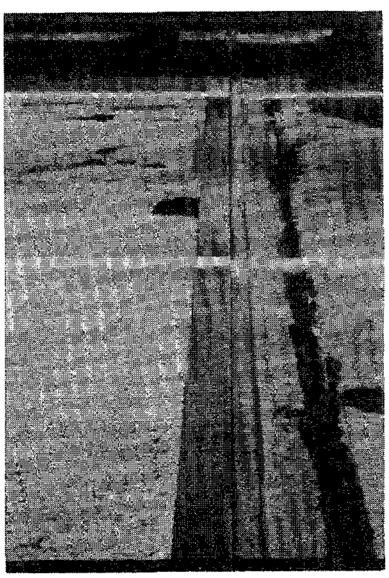
Slide No. 6-2-5
Example Slide
Dirt in a compression seal joint



Deck Joint Problems

- Debris
- Alignment

Slide No. 6-2-6
Narrative Slide



Slide No. 6-2-7
Example Slide
Straight joint opening

Slide No. 6-2-8
Example Slide
Vertical displacement at a joint

2. **Finger plate joint alignment** - The individual fingers of the finger plate joint should be aligned properly. The individual fingers should mesh together and be in the same plane as the deck surface.

3. **Proper opening** - Record the temperature and the measured opening. Both the air temperature and the superstructure temperature should be recorded. If you are going to be at the same bridge all day record the temperatures and openings at the coldest and warmest times of the day. What is important is that the relative movements are consistent.

C. DAMAGE

See Slide 6-2-10

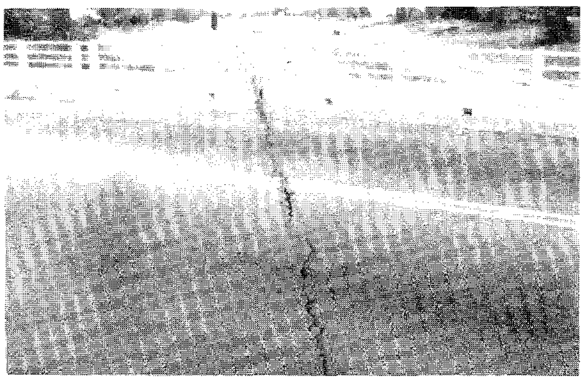
See Slide 6-2-11

1. **Damage to seals** - Snow plows, traffic, and debris have all taken their toll on seals. The seal might be torn, pulled out of the anchorage, even gone.

Deck Joint Problems

- Debris
- Alignment
- Damage
- Overlays

Slide No. 6-2-12
Narrative Slide



Slide No. 6-2-13
Example Slide
Asphalt wearing surface over an expansion joint

Deck Joint Problems

- Debris
- Alignment
- Damage
- Overlays
- Supports

Slide No. 6-2-14
Narrative Slide

Slide No. 6-2-15
Example Slide
Support system under finger plate joint

D. OVERLAYS

See Slide 6-2-13

1. **Indiscriminate overlays** - New pavement on the bridge - Many times, especially on smaller, local structures, a new wearing surface will be added with little or no regard for the joints.

   Transverse cracks in the overlay become the only evidence of the joint while joint function may be severely impaired.

E. SUPPORTS

See Slide 6-2-15

1. **Joint supports** - Where larger expansions are accommodated, the joint will have transverse beams supporting portions of the joint. The supports should be carefully inspected for proper function and for corrosion..

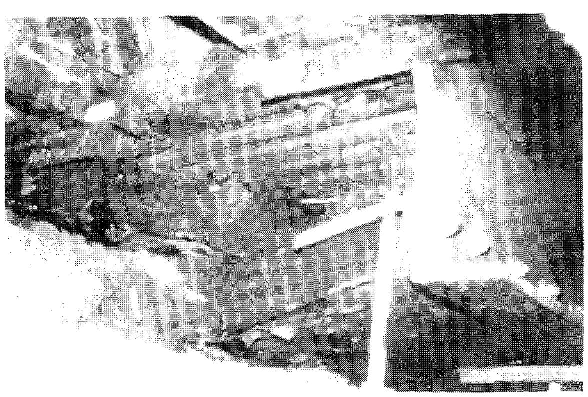
Inspection of Drainage Systems

Slide No. 6-2-16
Title Slide

Drainage Systems

- Troughs

Slide No. 6-2-17
Narrative Slide



Slide No. 6-2-18
Example Slide
Drainage trough with debris buildup

II. INSPECTION OF DRAINAGE SYSTEMS

A properly functioning drainage system removes water, and all hazards associated with it, from a structure. There is no serviceability coding for drainage systems. However, the inspection of the drainage system is important because its failure can ultimately lead to both structural and safety problems.

A. DRAINAGE TROUGHS

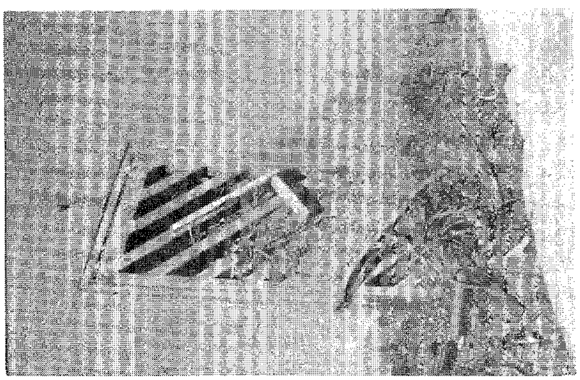
See Slide 6-2-18

Drainage troughs under joint should be carefully examined. A buildup of debris can accelerate the deterioration of the trough and allow water to drain onto structural components. It is essential that the trough be examined for any holes. Any evidence that indicates the trough is overflowing should be mentioned. Water staining of structural elements under a trough with no physical damage would be an example.

Drainage Systems

- Troughs
- Grates

Slide No. 6-2-19
Narrative Slide

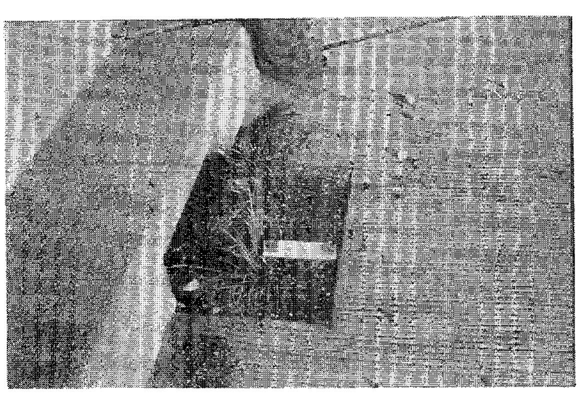


Slide No. 6-2-20
Example Slide
Typical inlet grate with debris accumulation

Drainage Systems

- Troughs
- Grates
- Deck drains and Inlets

Slide No. 6-2-21
Narrative Slide



Slide No. 6-2-22
Example Slide
"Flower Pot"

B. GRATES

See Slide 6-2-20

Grates should be clear and free to allow deck runoff to enter. If the grate is deteriorated, broken, or missing it presents a safety hazard.

C. DECK DRAINS AND INLETS

See Slide 6-2-22

Deck drains and inlets must be of adequate size and spacing to carry the runoff away from the structure safely. Remember, runoff conditions can change as a bridge ages - caused by area development.

Clogged deck drains lead to accelerated deck deterioration and the safety hazard of standing water in the travel lanes.

Drainage Systems

- Troughs
- Grates
- Deck drains and Inlets
- Outlet Pipes

Slide No. 6-2-23
Narrative Slide

Slide No. 6-2-24
Example Slide
Broken downspout

Inspection of Safety Features

Slide No. 6-2-25
Title Slide

Safety Features

- Bridge railing system
- Guardrail transition
- Approach guardrail
- End treatment

Slide No. 6-2-26
Narrative Slide

D. OUTLET PIPES

See Slide 6-2-24

Outlet pipes must carry runoff away from the structure. The outlet pipe may only be a straight extension of the deck drain - this type should be long enough so the runoff is not discharged onto the structure.

The outlet pipe may also be a series of pipes, called downspouting. Check this type for split or disconnected pipes that may allow runoff to accelerate deterioration of the structure.

III. INSPECTION OF SAFETY FEATURES

A. SAFETY FEATURE EVALUATION

The inspection of bridge safety features involves evaluation of the bridge railing system on the bridge, the guardrail system leading from the bridge, the guardrail system leading from the approach roadway to the bridge end, and whether these two systems will likely function acceptably together to safely contain and redirect errant vehicles which may collide with them.

Evaluation of these features is divided into four elements under Item 36 in FHWA's Recording and Coding Guide. The inspector assigns a separate numerical rating each for the:

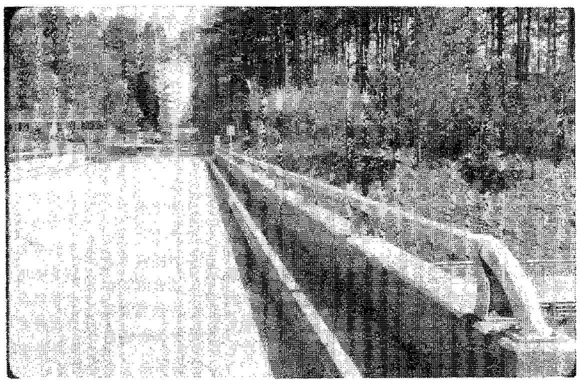
- Bridge railing system
- Guardrail transition to the bridge railing
- Approach guardrail system
- Approach guardrail end treatment

These ratings are to reflect whether each element does meet current safety criteria (1) or does not (0). Bridge owners, such as State highway departments or Federal agencies, usually establish the currently acceptable safety criteria to be used as a basis for safety feature evaluation.

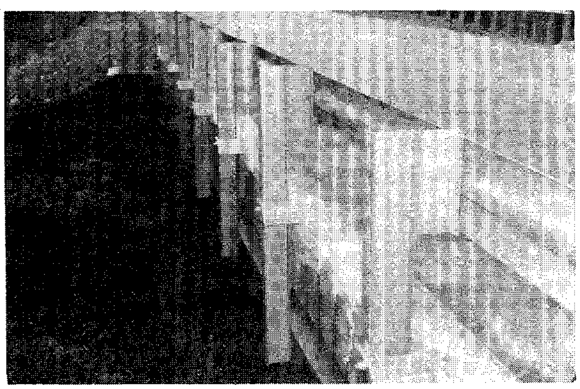
Safety Features

- Bridge rail

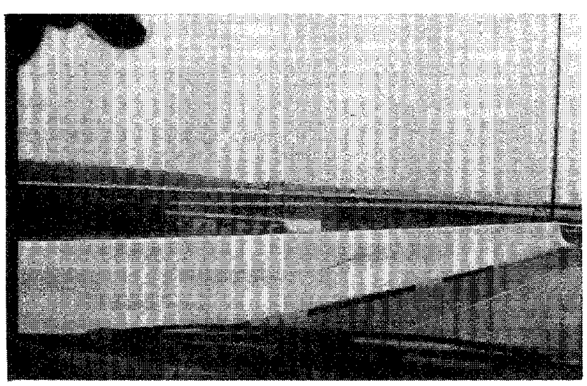
Slide No. 6-2-27
Narrative Slide



Slide No. 6-2-28
Example Slide
Concrete parapet with tubular steel rail on top



Slide No. 6-2-29
Example Slide
Galvanized W-shaped rail on steel posts



Slide No. 6-2-30
Example Slide
New Jersey Barrier

1. Bridge Railing Systems

The primary function of a bridge railing is to keep an errant vehicle from driving off the edge of the bridge. Many rails could conceivably do this, but the safety of the driver and redirection of the vehicle must be taken into account.

Both AASHTO and the FHWA have set minimum criteria for acceptable bridge railing. A bridge railing must smoothly redirect an impacting vehicle in such a manner that the vehicle does not overturn and the railing does not permit vehicle penetration.

Criteria that must be considered during the inspection of the bridge railing are the height, material, strength, geometric features, and the likelihood of acceptable crash test performance.

Many state agencies have developed acceptance guidelines for bridge railings in their states.

The inspector should be familiar with agency guidelines for his/her state.

Bridge railing designs have evolved over the years and exists in many forms. Examples include:

See Slide 6-2-28

- Concrete parapet with tubular steel rail

  This installation includes a safety walk or curb in front of the railing, which is a design feature no longer considered acceptable for good safety performance.

See Slide 6-2-29

- Galvanized W-shape rail on steel posts

  Though comon on many low-volume road bridges, this system is also a non-conforming design.

See Slide 6-2-30

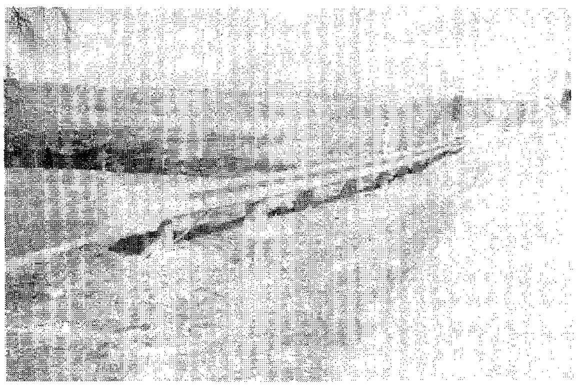
- New Jersey or "safety-shape" barrier

  This is a widely used and successfully crash-tested bridge railing which meets both AASHTO and FHWA performance requirements.

Safety Features

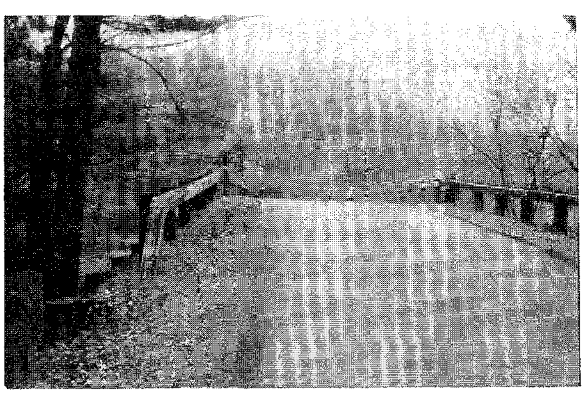
- Bridge railing
- Approach guardrail

Slide No. 6-2-31
Narrative Slide



Slide No. 6-2-31A
Example Slide
Approach guardrail system

Slide No. 6-2-33
Example Slide
Cable and steel posts



Slide No. 6-2-34
Example Slide
Timber approach rail

2. Approach Guardrail System

See Slide 6-2-31A

The approach guardrail system is the first rail that a motorist should encounter near a bridge. It is intended to shield motorists from the hazards of the bridge site. It must have adequate length and structural qualities to safely contain and redirect an impacting vehicle within tolerable deceleration limits. Redirection should be smooth, without snagging, and should minimize any tendency for vehicle roll over or subsequent secondary collision with other vehicles.

Just like bridge railing, the height, material, strength, and geometric features of the approach guardrail system must be considered during the inspection.

Again, agency standards should be applied when determining acceptability. AASHTO has determined acceptable guardrail systems on the basis of full scale crash test performance.

Approach railing systems exist in many forms.

- The galvanized W-beam guardrail on heavy steel or timber posts is a very common semi-flexible barrier system which meets AASHTO criteria for use as a longitudinal roadside barrier. It must be anchored at both ends and it has a design deflection distance of approximately four feet for the normal 6'3" post spacing.

See Slide 6-2-33

- Cable-type guardrail systems have also been successfully tested for roadside use but their design deflection distance is too great (11 feet) to permit safe use on bridge approaches. This example is an older installation which does not conform to any current criteria for roadside applications.

See Slide 6-2-34

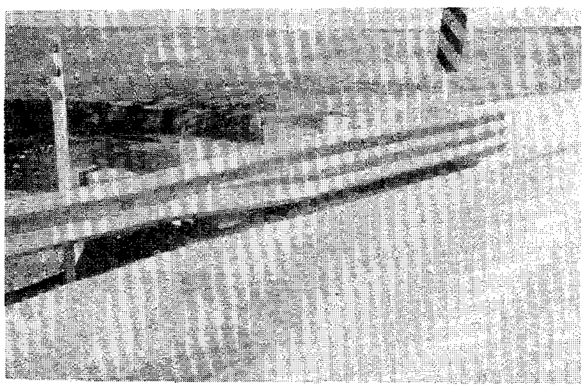
- Most timber guardrail systems do not conform with current AASHTO or FHWA criteria for safety performance.

There are also some bridge rail/guardrail installations where a single railing system has been used on both the approaches and across the bridge. Where these have been successfully tested, they can be considered acceptable.

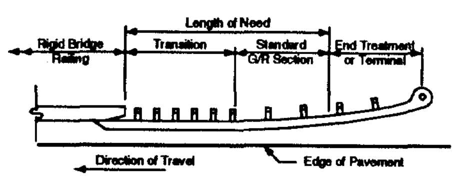
Safety Features

- Bridge railing
- Approach guardrail
- Transitions

Slide No. 6-2-35
Narrative Slide

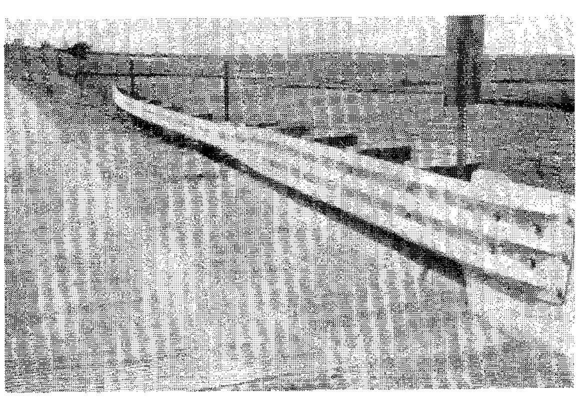


Slide No. 6-2-35A
Example Slide
Guardrail transition



Approach Guardrail System

Slide No. 6-2-35B
Schematic Slide
Approach guardrail system



Slide No. 6-2-35C
Example Slide
Thrie beam rail transition

3. Transitions

See Slide 6-2-35A

An approach guardrail system should not only serve to screen the hazard at a bridge, e.g., a stream or separated grades, but it should also screen the fixed object hazard of the rigid bridge rail endpost itself. This second function requires that a stiffened transition be constructed within the approach guardrail system at its anchorage with the bridge railing system.

See Slide 6-2-35B

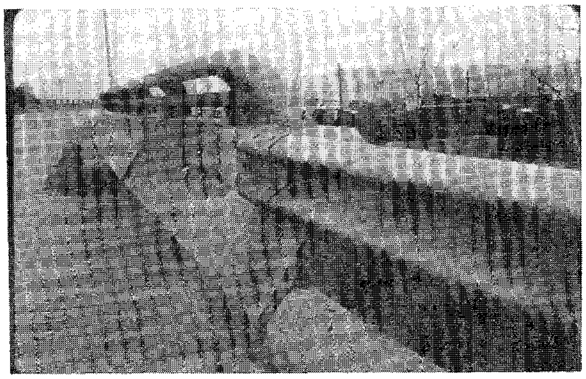
This transition should provide enough increase in stiffness and strength of the more flexible approach railing system, i.e., reduce its design deflection sufficiently so that impacting vehicles (1) are not suddenly decelerating by the rigid bridge endpost and (2) are safely redirected without pocketing, snagging or overturning.

Transition stiffening is usually accomplished through use of:

- decreased post spacing
- increased post size
- embedment of posts in concrete bases
- increased rail thickness, using a thicker gage rail element or by nesting two layers

See Slide 6-2-35C

Vehicle snagging is discouraged by providing an increased rail surface projection with either a broader rail face, e.g., thrie beam, or a rub rail being placed beneath the primary rail, to minimize both guardrail post and bridge endpost exposure as potential snag points.

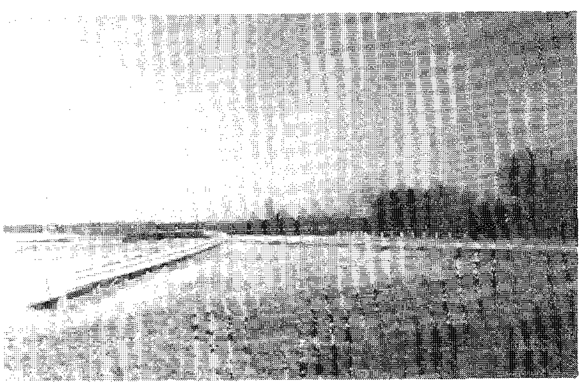


Slide No. 6-2-39
Example Slide
W-shaped guardrail securely attached to a concrete parapet

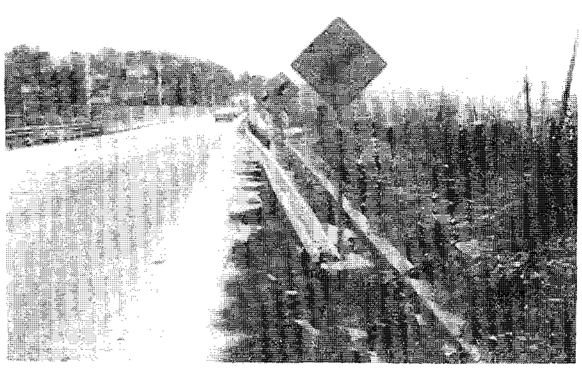
Safety Features

- Bridge railing
- Approach guardrail
- Transitions
- End treatments

Slide No. 6-2-40
Narrative Slide



Slide No. 6-2-41
Example Slide
Flared approach guardrail



Slide No. 6-2-43
Example Slide
Buried end of a straight approach guardrail

See Slide 6-2-39

Older transitions usually have some of the essential features but are often lacking in some. There may be guardrail anchorage to the bridge but insufficient stiffening, or perhaps some degree of stiffening but insufficient concealment of potential snag points such as the front corner of the bridge endpost or exposed guardrail posts.

4. End Treatments

As noted previously, one of the important functions of an approach guardrail system is to protect motorists from collision with the fixed object hazard of the rigid bridge rail endpost. As a consequence of adding the approach guardrail system to do this, a new fixed object hazard is created -- the exposed end of the approach guardrail.

Thus, an effective "end treatment" is needed at this point of barrier introduction in order to prevent either excessive deceleration, vehicle impalement, or vehicle rollover should there be an impact with the guardrail end. Several methods of end treatment have been employed:

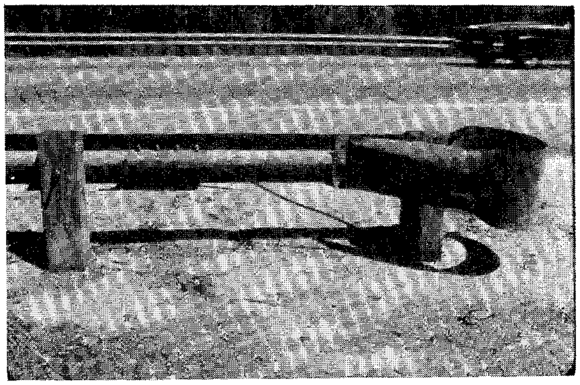
See Slide 6-2-41

- Flaring the guardrail end to reduce the likelihood of a vehicular impact. This is only effective if there is a substantial flare from the edge of travelled way.

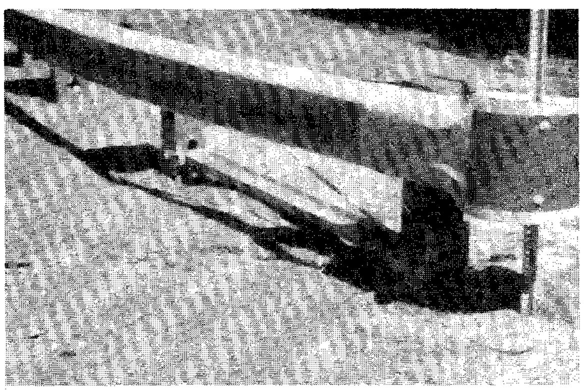
See Slide 6-2-43

- Burying the guardrail end. This has been used with and without flaring. If the guardrail end is turned down for burying, it has frequently produced rollover accidents and is not now considered an acceptable end treatment.

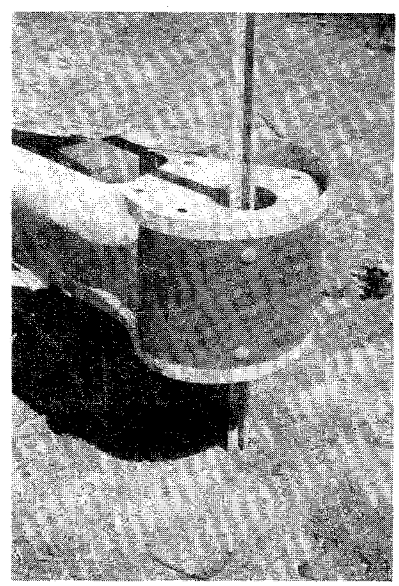
  If the end is concealed by flaring without turning down, and then burying at full height in a cut slope, the method has proven effective at preventing end impacts.



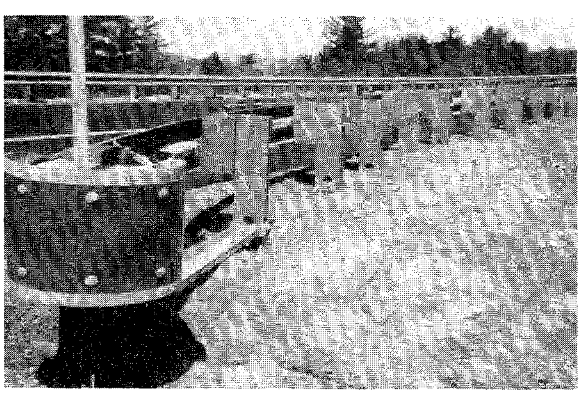
Slide No. 6-2-44
Example Slide
Breakaway end treatment



Slide No. 6-2-44A
Example Slide
MELT end treatment



Slide No. 6-2-44B
Example Slide
MELT - approach end



Slide No. 6-2-44C
Example Slide
MELT - note strut between end posts

- Use of one of several "breakaway" treatments where the guardrail end is modified to permit safe penetration through the system for end impacts, yet effective redirection of vehicles for impacts slightly downstream of the end treatment.

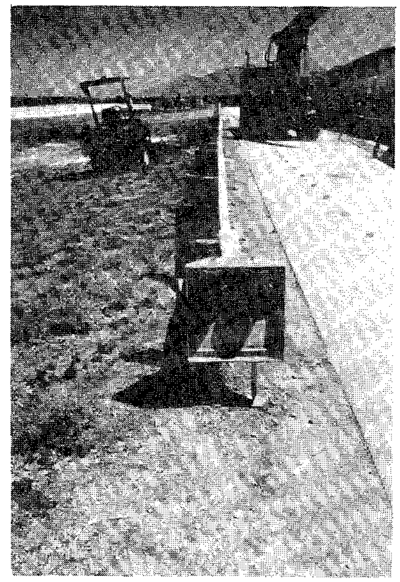
See Slide 6-2-44

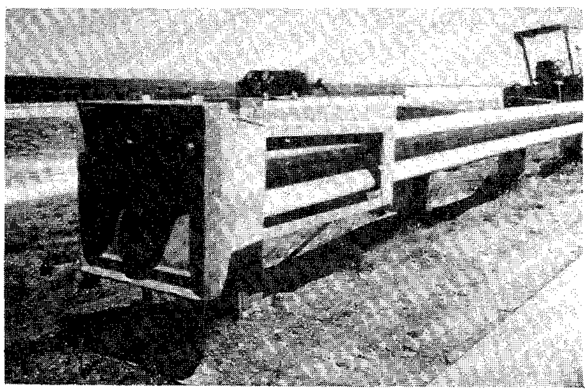
One of the most familiar and long-used breakaway end treatments is the BCT or breakaway cable terminal. This end treatment must also be flared to be safely effective. Flaring, along with blunting of the rail end serve to facilitate a "buckling" of the rail element rather than vehicle impalement. Two weakened timber posts are breakaway to minimize deceleration forces upon direct impact with either post. Cable anchorage of the rail is provided to assure adequate anchorage of the system for possible impacts downstream of the end treatment.

See Slide 6-2-44A
See Slide 6-2-44B
See Slide 6-2-44C

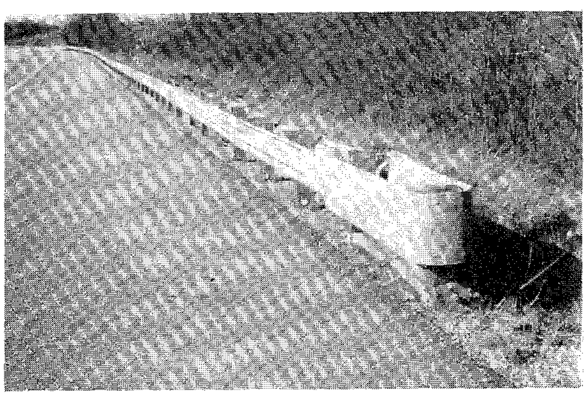
A newer version of the BCT called the MELT, for modified eccentric loader terminal, provides improved breakaway performance, especially for smaller vehicles. An eccentric loader and buffer stiffening are employed to assure deflection of the rail without impaling, and a load distributing strut between the first two breakaway timber posts enhances rail anchorage capability.

Slide No. 6-2-44D
Example Slide
Extruder terminal

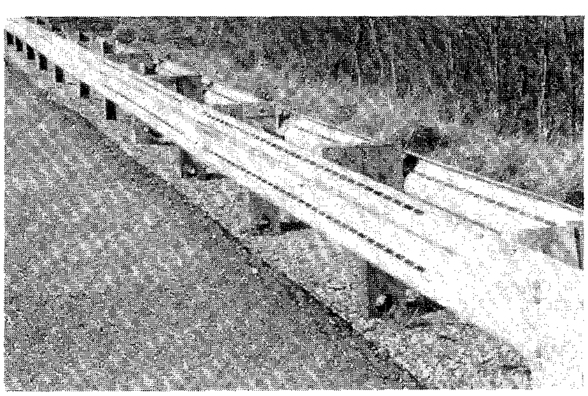




Slide No. 6-2-44E
Example Slide
Extruder terminal



Slide No. 6-2-44F
Example Slide
CAT - crash-cushion attenuating terminal



Slide No. 6-2-44G
Example Slide
CAT - note holes in W-beam

See Slide 6-2-44D

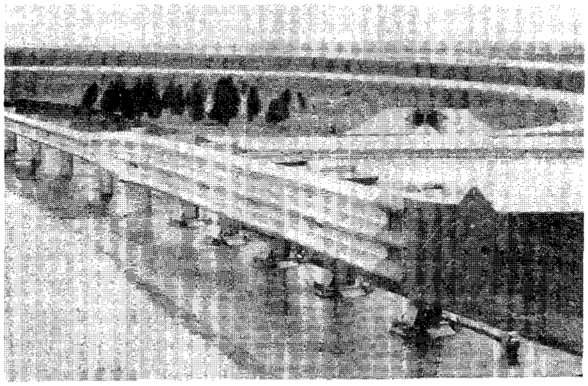
See Slide 6-2-44E

Other newer breakaway or energy-absorbing end treatments include the ET 2000 extruder terminal, a proven end treatment which, when impacted, slides down the rail causing diversion of the W-beam rail element through a flattening or extruding fitting. As the rail is threaded through and flattened out by the extruder, impact energy is expended. The flattened rail element is peeled back out of the way as vehicle energy is transferred and gradual deceleration occurs. This end treatment is designed for use without flaring.

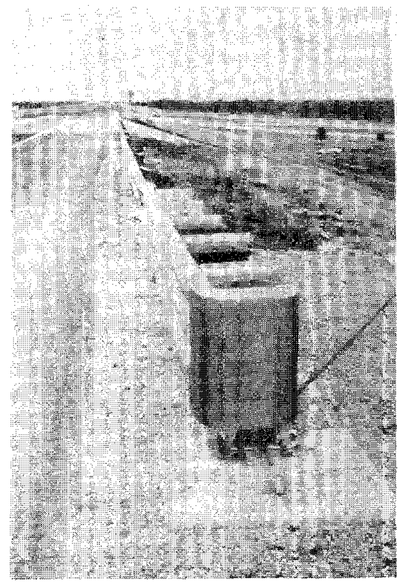
See Slide 6-2-44F

See Slide 6-2-44G

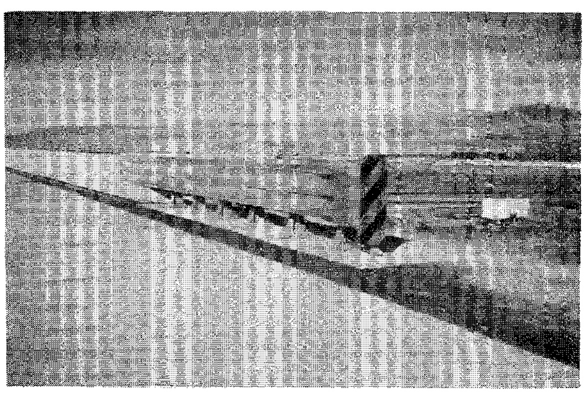
The CAT or crash-cushion attenuating terminal progressively collapses with perforated W-beam rails telescoping as the system safely decelerates an impacting vehicle. Crash energy is attenuated in the process. Breakaway timber posts are employed and the treatment does not have to be flared. This makes it a feasible end treatment for guardrail introduction when there is insufficient roadside space for flaring.



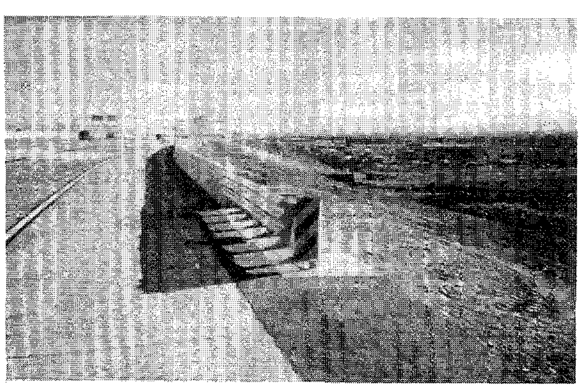
Slide No. 6-2-44H
Example Slide
SENTRE end treatment



Slide No. 6-2-44I
Example Slide
SENTRE end treatment



Slide No. 6-2-44J
Example Slide
TREND dual purpose end treatment



Slide No. 6-2-44K
Example Slide
TREND dual purpose end treatment

See Slide 6-2-44H

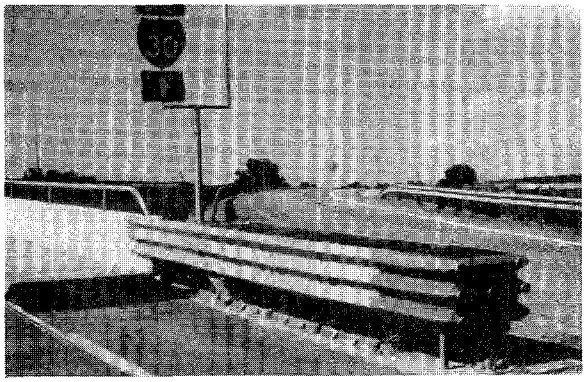
See Slide 6-2-44I

The SENTRE guardrail end treatment is another telescoping terminal which utilizes posts with slip bases for breakaway and sand-filled boxes to gradually decelerate and gently guide an impacting vehicle away from the fixed rail hazard. Al major components are reusable which makes the system more economical for locations where more frequent impacts are expected. Flaring is possible but not required.

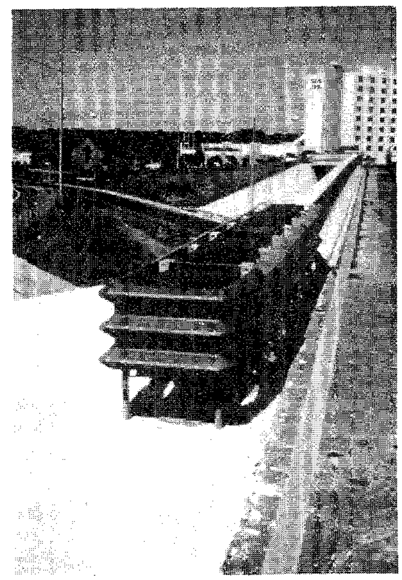
See Slide 6-2-44J

See Slide 6-2-44K

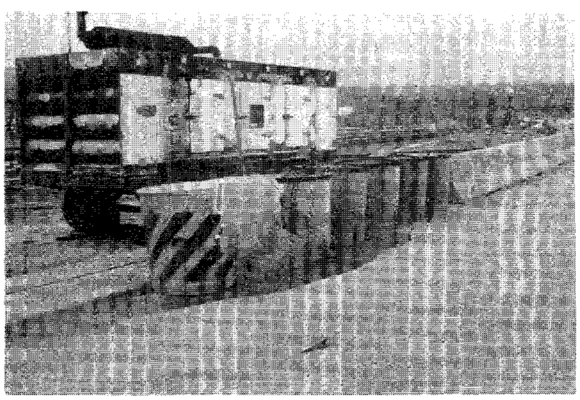
The TREND dual purpose end treatment has similar features with reusable telescoping rail panels, redirecting cable, breakaway slip base posts and replaceable sand-filled boxes, but the system is unique in that it is designed to also serve in a dual role as a transition connection to a rigid bridge railing. It is not designed to be flared.



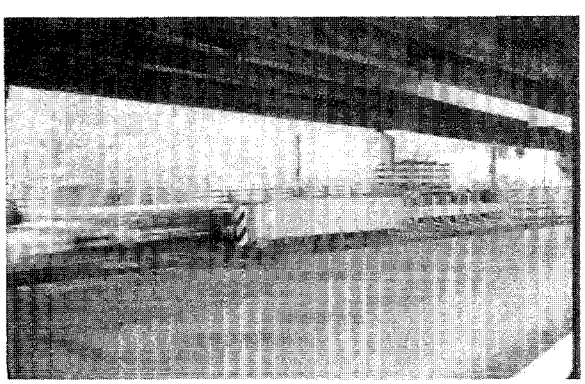
Slide No. 6-2-44L
Example Slide
G.R.E.A.T. crash attenuator



Slide No. 6-2-44M
Example Slide
G.R.E.A.T. installation



Slide No. 6-2-44N
Example Slide
Sand filled barrel crash attenuator



Slide No. 6-2-45
Example Slide
Guardrail end shielded with an impact attenuator

See Slide 6-2-44L

See Slide 6-2-44M

- A fourth method for railing end treatment is shielding of the barrier with an energy-absorbing or attenuating system which dissipates impact energy as an impacting vehicle is gradually brought to a stop before reaching a rigid bridge rial endpost. Though vehicle damage may be severe, deceleration is controlled within tolerable limits to minimize occupant injury.

See Slide 6-2-44N

A variety of impact attenuators have been used, including expendable sand-filled frangible containers which shatter and absorb energy during impacts.

See Slide 6-2-45

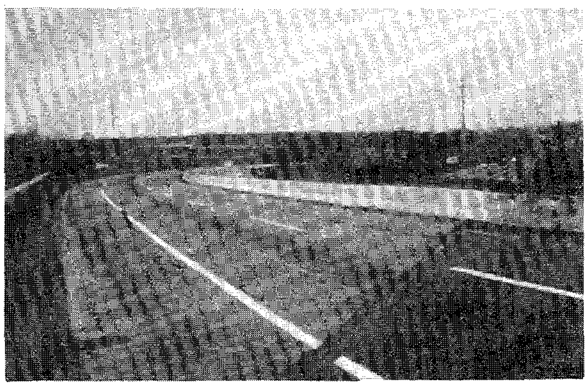
There are also more elaborate telescoping fender systems which redirect side impacts but also telescope and attenuate crash energy through crushing of replaceable foam-filled cartridges for direct impacts. Older versions absorbed energy through expulsion of water from water-filled tubes as the device collapsed. Most parts for these more elaborate devices are reusable, making them very suitable for bridge rail end locations where frequent impacts might be expected.

Safety Features

- Bridge railing
- Approach guardrail
- Transitions
- End treatments
- Median barriers

Slide No. 6-2-46

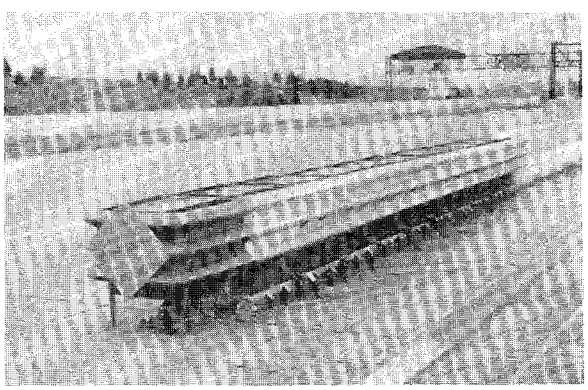
Narrative Slide



Slide No. 6-2-47

Example Slide

Concrete median barrier on a bridge



Slide No. 6-2-47A

Example Slide

G.R.E.A.T. protecting end of concrete safety shape median barrier

5. Median Barriers

See Slide 6-2-47

Median barriers are used to separate opposing traffic lanes when the average daily traffic of the road exceeds a specified amount. They are usually found on high speed, limited access highways.

See Slide 6-2-47A

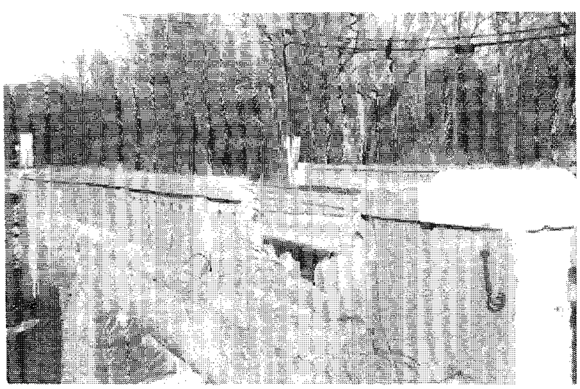
The most commonly used median barrier on bridges is the concrete safety shape median barrier. It is essentially a double sided parapet that meets the current criteria for the crash testing of bridge railing. A usual end treatment for this barrier is the addition of an impact attenuator.

Double-faced steel W-beam or thrie beam railing on standard heavy posts are also used for median barriers.

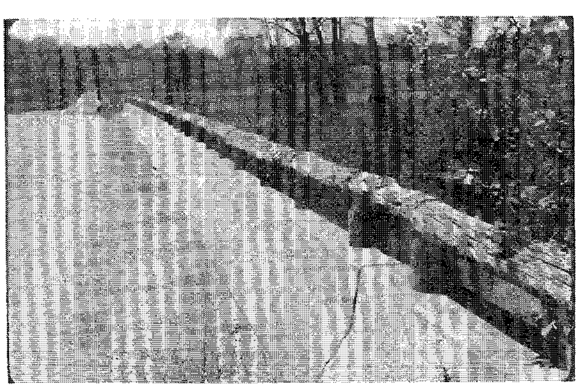
Inspection of Safety Features

Slide No. 6-2-49
Title Slide

Slide No. 6-2-50
Example Slide
Damaged steel post bridge railing



Slide No. 6-2-51
Example Slide
Damaged concrete bridge railing



Slide No. 6-2-52
Example Slide
Concrete parapet with timber railing

B. INSPECTION

Items to look for during inspection

1. Bridge Railing

See Slide 6-2-50

- Metal bridge railings should be firmly attached to deck and should be functional. Check especially for collision damage which might render these railings ineffective. Comparison of existing metal railing systems with approved crash-tested designs will establish their acceptability and crash worthiness.

See Slide 6-2-51

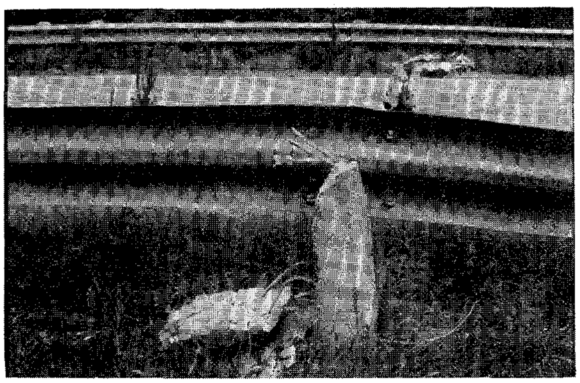
- Concrete bridge railing is generally cast-in-place and engages reinforcing bars to develop structural anchorage in the deck slab.

Again, check for deterioration and collision damage.

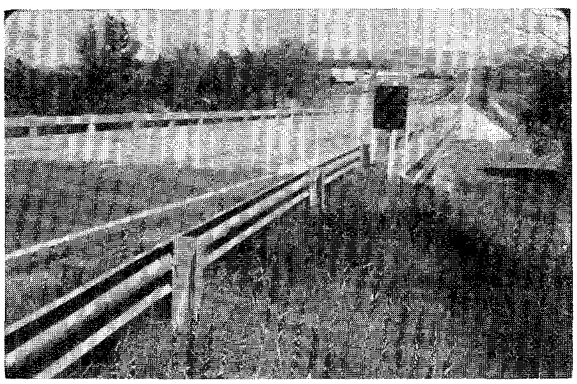
See Slide 6-2-52

A very commonly used bridge railing is the New Jersey parapet or safety shape.

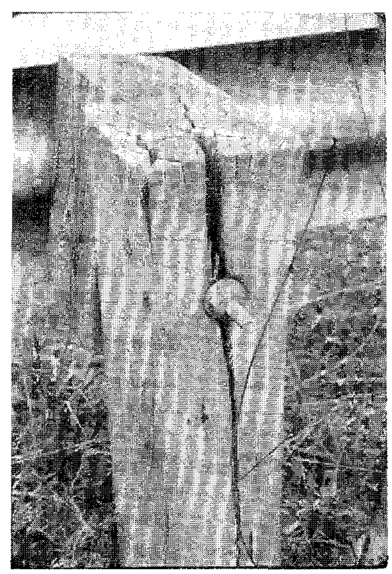
If add-on rails are other than decorative or for pedestrians, their structural adequacy can again be verified by comparison with successfully crash tested designs.



Slide No. 6-2-53
Example Slide
Approach guardrail collision damage



Slide No. 6-2-54
Example Slide
Approach guardrail with out-of-date excessive post-spacing



Slide No. 6-2-55
Example Slide
Deteriorated approach guardrail element

2. Approach Guardrail

- Make note of rail type and post spacing for comparison with approved designs.

See Slide 6-2-53

- Document any significant collision damage which is evident.

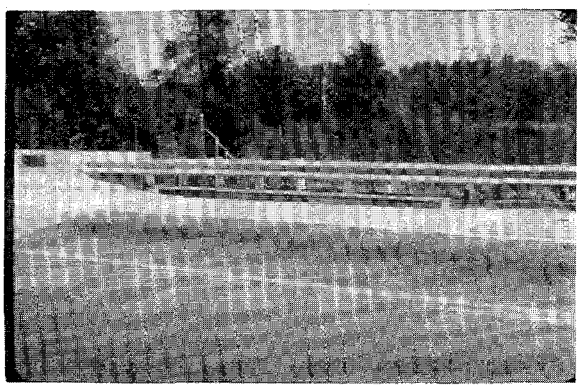
See Slide 6-2-54

- Verify acceptability of the guardrail system type by checking post spacing, post size and rail element type.

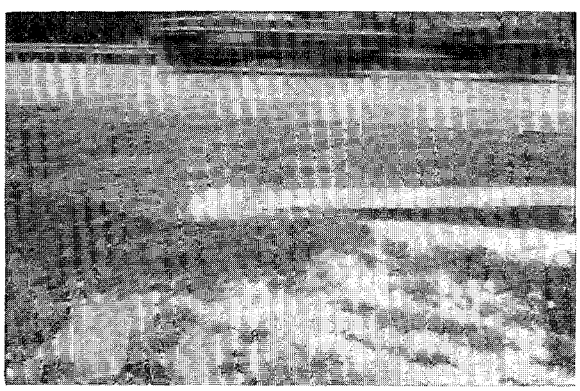
See Slide 6-2-55

- Note any deterioration of guardrail elements which could weaken the system.

Slide No. 6-2-56
Example Slide
Rigid connection of an approach guardrail transition



Slide No. 6-2-57
Example Slide
Reduced post-spacing of an approach guardrail transition



Slide No. 6-2-58
Example Slide
Approach guardrail end treatment

3. Transition

See Slide 6-2-56

See Slide 6-2-57

- Check the approach guardrail transition to the bridge railing.

  (1) for adequate structural anchorage to the bridge railing system.

  (2) for sufficient reduced post spacing to assure stiffening of the guardrail at the approach to the rigid bridge rail end.

  (3) for smooth transition details to minimize the possibility of "snagging" an impacting vehicle, causing excessive deceleration.

4. End Treatment

See Slide 6-2-58

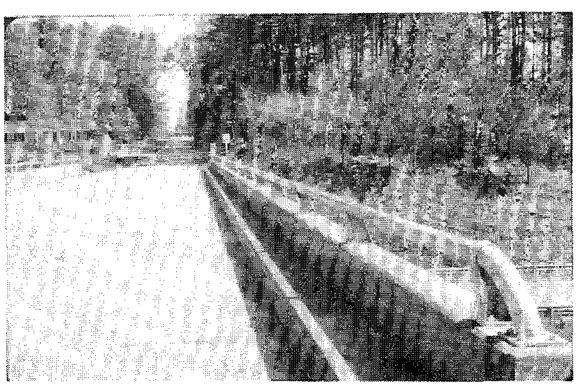
- Note the type, condition and suitability of any end treatment. Acceptable crash-tested end treatments are identified in the AASHTO roadside design guide, or with current FHWA issuances.

Evaluation of Safety Features

Slide No. 6-2-59
Example Slide
Title Slide

Serviceability

Slide No. 6-2-60
Title Slide



Slide No. 6-2-61
Example Slide
Concrete parapet with tubular steel rail on top

Slide No. 6-2-62
Example Slide
Galvanized W-shaped rail on steel posts

C. EVALUATION

1. Serviceability

We know what the various elements of the bridge rail system are and how they are supposed to function. Based on items from the inspection check list, we can make a determination of whether or not these elements work as they should.

Earlier, we showed slides of different bridge railings, approach guardrails, transitions, and end treatments. Let's take a closer look and see if they pass the minimum standard criteria established by AASHTO.

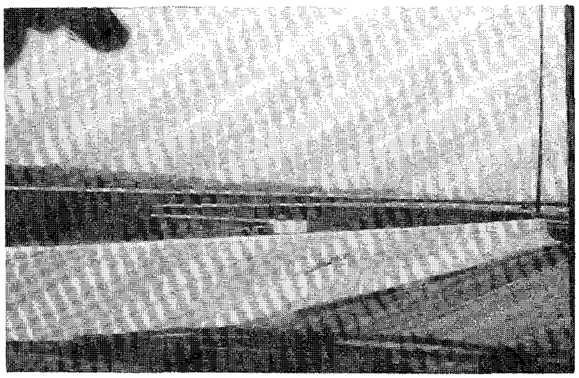
- **Bridge Rails**

See Slide 6-2-61

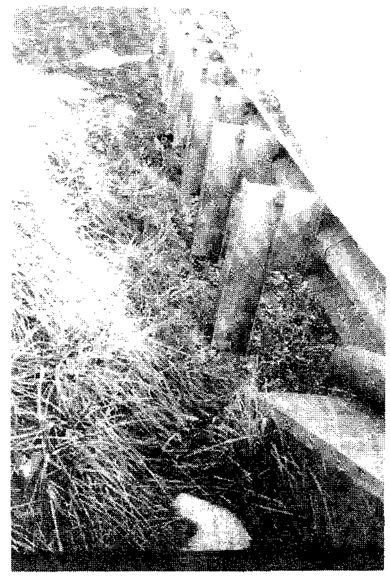
The overall height of this rail measures approximately 3 feet which does not meet minimum height criteria of 3 feet -6 inches for this type. It is not a successfully crash-tested system. The safety-walk in front of the railing is also not a currently acceptable treatment.

See Slide 6-2-62

This rail is the proper height. It is securely attached to the bridge deck. There is no rusting to affect its structural integrity. In spite of this, the rail still does not meet minimum criteria for geometric features. It does not pass current crash test requirements.

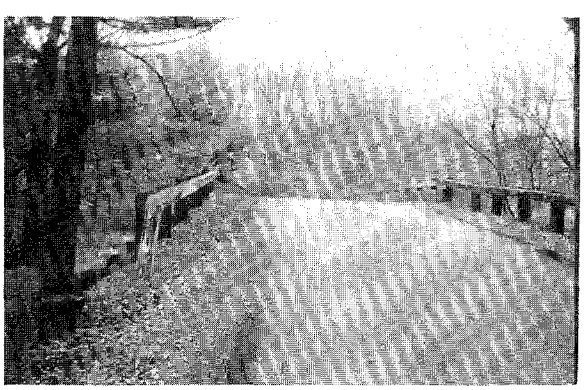


Slide No. 6-2-63
Example Slide
New Jersey Barrier



Slide No. 6-2-64
Example Slide
Galvanized W-shaped rail on steel posts

Slide No. 6-2-65
Example Slide
Cable and steel posts



Slide No. 6-2-66
Example Slide
Timber approach rail

See Slide 6-2-63

This bridge railing, the New Jersey concrete safety shape, is a reinforced concrete parapet with a sloped face and tapered curb. It is 32" tall. The concrete is solid with no spalling or hollow areas. Its primary reinforcing is 1/2 inch diameter rebars at 15 inches spacing. This bridge railing **does** meet minimum criteria.

See Slide 6-2-64

- **Approach Rails**

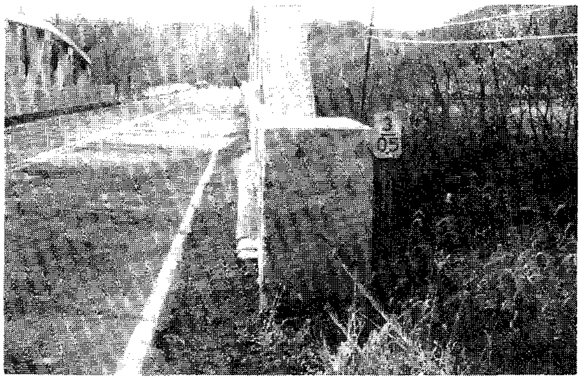
Although not acceptable as bridge rail, steel post W-beam rail is acceptable for an approach guardrail. Not only must the obvious items be checked, such as collision damage, loose bolts, etc., but post spacing should also be checked. The FHWA says this rail type should have a minimum post spacing of 6 feet -3 inches and a minimum height of 27 inches above grade to top of rail.

See Slide 6-2-65

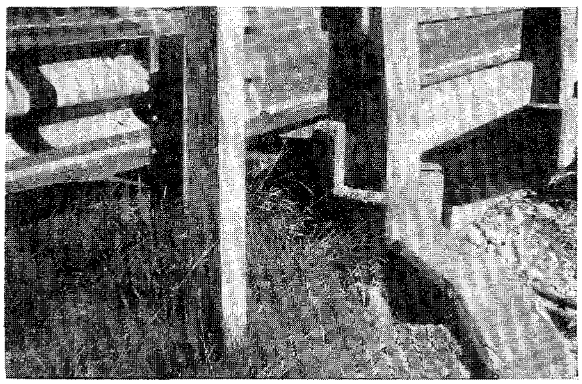
Post and cable systems do not meet minimum criteria for bridge approach guardrail systems because they allow both snagging and pocketing of a vehicle upon impact.

See Slide 6-2-66

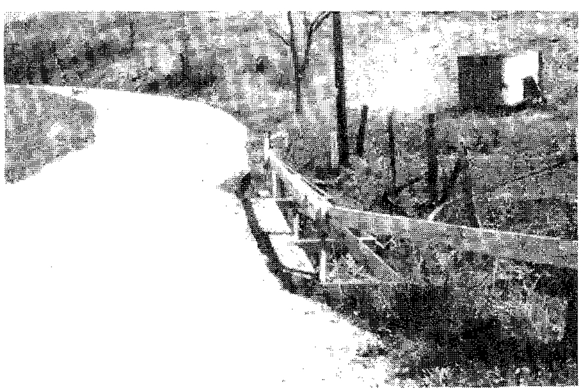
Timber approach guardrail does not meet minimum criteria for strength, continuity or performance.



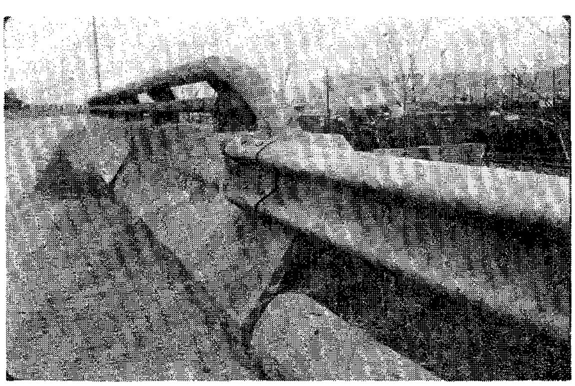
Slide No. 6-2-67
Example Slide
Cable and post transition



Slide No. 6-2-68
Example Slide
Galvanized W-shaped rail not connected to bridge rail



Slide No. 6-2-69
Example Slide
Timber approach guardrail attached to bridge railing



Slide No. 6-2-70
Example Slide
W-shaped guardrail securely attached to a New Jersey Barrier

See Slide 6-2-67

- **Transitions**

Cable connections to the bridge railing do not meet minimum criteria because they do not provide a smooth stiffened transition

See Slide 6-2-68

No transition is provided at all when the bridge railing and approach guardrail are not structurally connected.

See Slide 6-2-69

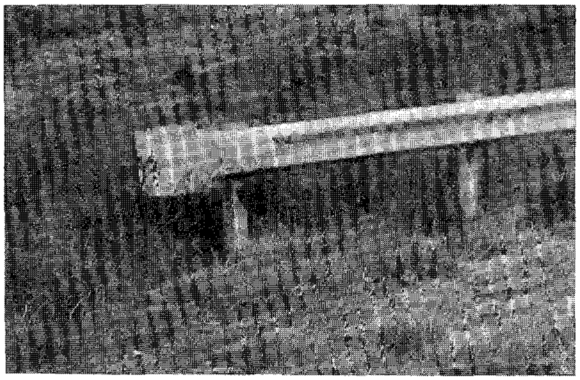
Timber approach rail attached to the bridge rail. This is not an acceptable transition.

Bridge railing and approach guardrail that do not in themselves meet minimum criteria will surely not have a transition that is adequate.

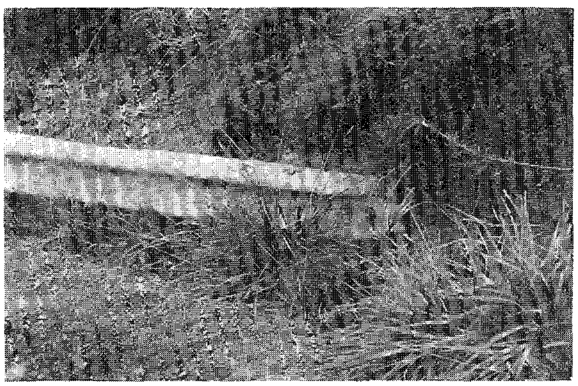
See Slide 6-2-70

W-beam rail securely attached to a concrete parapet. This is a good structural attachment.

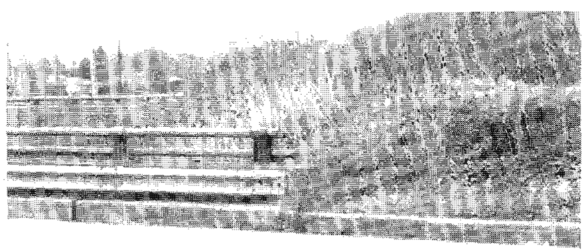
When W-beam guardrail is bolted to the face of concrete barriers and if post spacing has been reduced to 3 feet - 1 1/2 inches near the bridge, and the rail face exposure is widened with thrie beam or two levels of W-beam, the transition may be acceptable.



Slide No. 6-2-71
Example Slide
Boxing glove-type end treatment on a W-shaped guardrail



Slide No. 6-2-72
Example Slide
W-shaped guardrail end flared and buried into an embankment



Slide No. 6-2-73
Example Slide
Approach rail and end treatment on a divided highway

Appraisal Rating

Slide No. 6-2-74
Title Slide

- **End Treatments**

See Slide 6-2-71

This type of end treatment has sometimes been called a boxing glove. It is not an acceptable end treatment.

See Slide 6-2-72

The end of this guardrail has been flared and buried in an embankment. This is an acceptable end treatment if the rail is flared at full height and not turned down.

See Slide 6-2-73

There is no end treatment evident here. In fact there is no approach guardrail, either. Surprising as it may seem, this is acceptable. Why?

We are looking at the trailing end of a one way bridge. In these cases, guardrail is not required at all.

2. Appraisal Rating

After making the determination as to whether or not safety features at the site meet currently acceptable standards, the inspector assigns an appraisal code of either 1 or 0 for each element of Item 36 (page 17, FHWA Recording and Coding Guide):

36A - Bridge railing system
36B - Approach guardrail transition
36C - Approach guardrail system type
36D - Guardrail end treatment

Summary

- Deck Joints
- Drainage Systems
- Safety Features

Slide No. 6-2-75

Title Slide

IV. SUMMARY

A. DECK JOINTS

B. DRAINAGE SYSTEMS

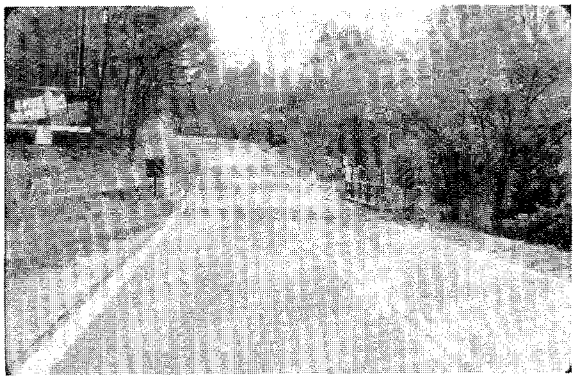
C. SAFETY FEATURES

SESSION 6: INSPECTION AND EVALUATION OF BRIDGE DECKS

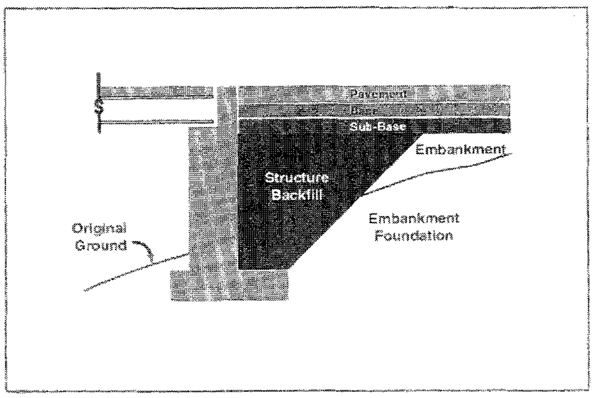
TOPIC 3: APPROACH ROADWAYS

LESSON PLAN

TOPIC DURATION	30 minutes
PARTICIPANT MATERIALS	Participant Notebook, BITM 90
GOAL	Understanding the purpose for the inspection of roadway approaches.
OBJECTIVE	To be able to apply the appraisal rating coding guidelines in the evaluation of approach roadway alignments.
REFERENCES	FHWA *Coding Guide*

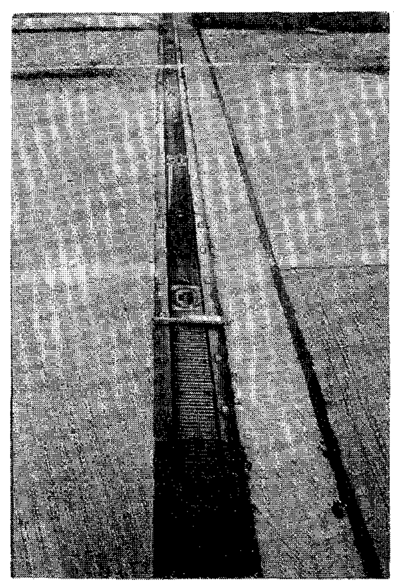


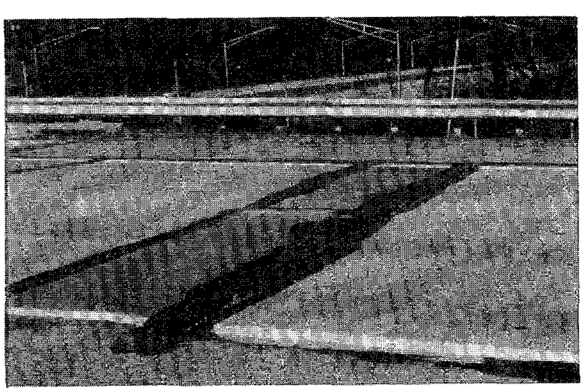
Slide No. 6-3-1
Example Slide
Typical approach roadway



Slide No. 6-3-2
Schematic Slide
Approach roadway elements

Slide No. 6-3-3
Example Slide
Joint between a concrete approach
slab and bridge backwall





Slide No. 6-3-4
Example Slide
Concrete approach slab pavement
relief joint

I. INTRODUCTION

See Slide 6-3-1

The primary function of the approach roadway is to provide a smooth transition between the roadway pavement and the bridge deck. The smoother the transition, the less the impact forces. Lower impact forces mean improved bridge safety and greater driver comfort.

II. INSPECTION OF APPROACH ROADWAYS

See Slide 6-3-2

A. ELEMENTS

There are four basic elements of the typical approach roadway:

- Pavement structure
- Subgrade
- Embankment
- Embankment foundation

1. Pavement Structure

The pavement structure varies with the type of approach.

For bituminous approaches the pavement structure would consist of:

- A bituminous wearing course
- A bituminous base material
- An aggregate subbase

For concrete approaches the pavement structure would consist of:

- An approach slab
- A relief joint
- An aggregate subbase material

See Slide 6-3-3

The approach slab is a concrete slab that actually rests on the abutment of the structure and bridges over the excavation for the abutment footing. The joint between the approach slab and backwall is typically sealed.

See Slide 6-3-4

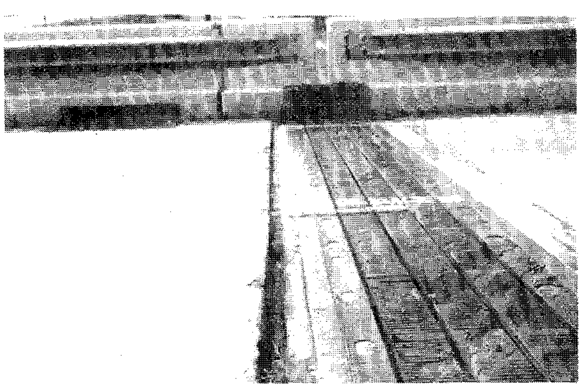
On concrete roadways, the pavement has a tendency to migrate toward the bridge. This presents a problem in that the approach slab is then pressed against the backwall. Since we do not want this additional loading on the abutment, a pavement relief joint is sometimes used to relieve the loading. A pavement relief joint utilizes a replacement asphalt strip which fails as the

Slide No. 6-3-5
Example Slide
Approach roadway embankment

Inspection Items

Slide No. 6-3-6
Title Slide

Slide No. 6-3-7
Example Slide
Settlement of the approach pavement



Slide No. 6-3-8
Example Slide
Heaving of the approach pavement

roadway pavement migrates. It is cheaper and easier to fix the asphalt relief joint than a concrete abutment or slab.

2. Subgrade

The subgrade is the prepared and compacted soil immediately below the pavement system.

3. Embankment

See Slide 6-3-5

The approach embankment is the fill material required to bring the existing ground line up to the proposed grade for the roadway subgrade.

4. Embankment Foundation

The embankment foundation is the material below the original ground surface which supports the embankment.

B. CONDITION INSPECTION ITEMS

1. Vertical Displacement

See Slide 6-3-7

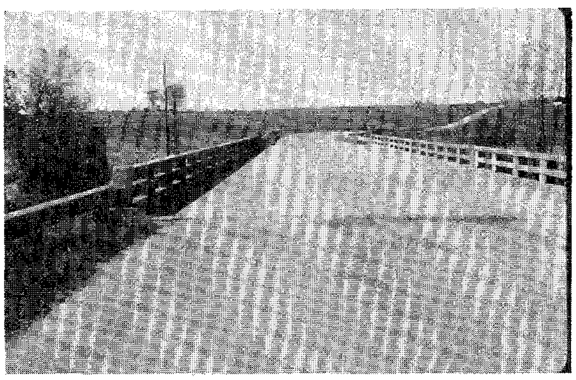
Settlement of the approach roadway is caused by a consolidation of the embankment material. This is especially a problem near the abutment where compaction efforts during construction are hampered.

See Slide 6-3-8

Heave of the approach slab can occur due to rotation of the abutment or an expansive reaction of backfill material (frost heave).

Any vertical displacement should be documented for evaluation of its cause.

Slide No. 6-3-9
Example Slide
Deteriorated approach roadway riding surface



Slide No. 6-3-10
Example Slide
Approach roadway riding surface in good condition

See Slide 6-3-9

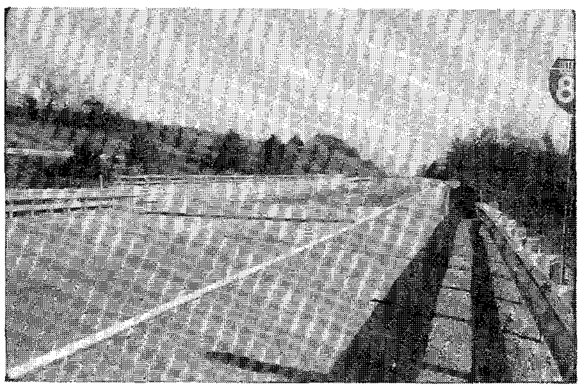
See Slide 6-3-10

2. Riding Surface

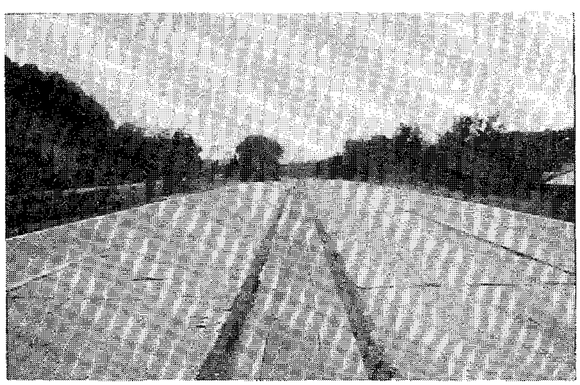
The riding surface should not compromise the quality of ride for a vehicle traveling at the posted speed limit.

It should be smooth, free of potholes and properly sloped for drainage.

Slide No. 6-3-11
Example Slide
Inspectors measuring an approach roadway width



Slide No. 6-3-12
Example Slide
Paved shoulder



Slide No. 6-3-13
Example Slide
Approach roadway with a mountable median

See Slide 6-3-11

3. Approach Roadway Width

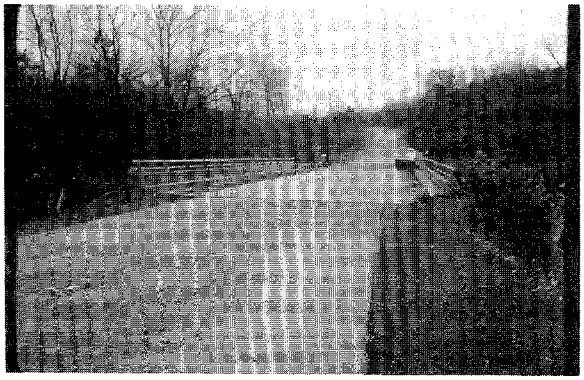
The approach roadway width is defined as the normal width of usable roadway approaching a structure. It includes shoulders which are structurally adequate for all weather and traffic conditions consistent with the facility being carried.

See Slide 6-3-12

In most cases, shoulders that meet this criteria will be paved.

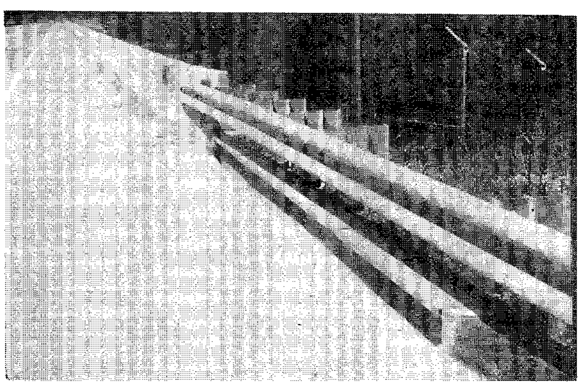
See Slide 6-3-13

The approach roadway width is coded in FHWA Item 32 to the nearest foot. In the case of a median, the value entered does not include the median width.



Slide No. 6-3-14
Example Slide
Typical dirt "shoulder" area

Slide No. 6-3-15
Example Slide
Typical embankment slope erosion



Slide No. 6-3-16
Example Slide
Approach roadway inlet

Approach Roadway Alignment

Slide No. 6-3-17
Title Slide

4. Shoulders, Slopes, Drainage

See Slide 6-3-14

Shoulders are constructed and normally maintained flush with the adjacent traffic lanes. Grass and dirt to the side of the traffic lanes do not qualify as shoulders.

See Slide 6-3-15

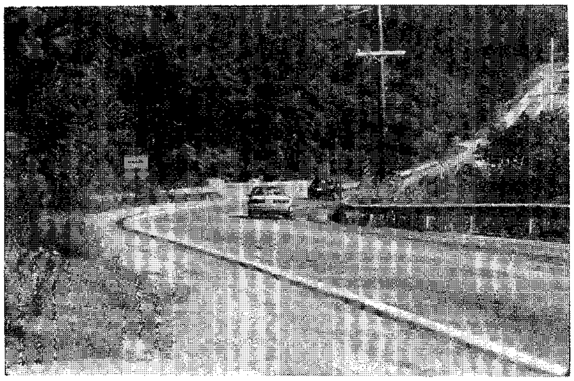
Embankment slopes should have adequate vegetation to prevent erosion.

See Slide 6-3-16

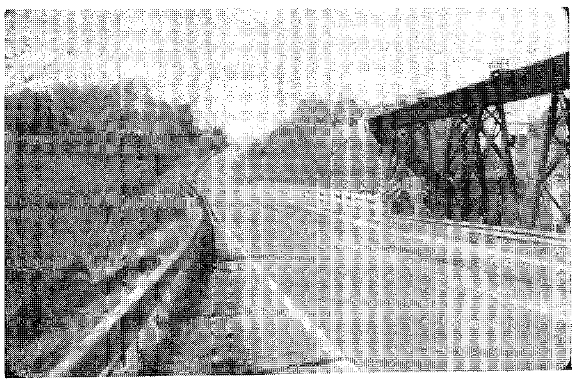
Roadway inlets located in the approach area should be in good condition and fully operational.

C. APPROACH ROADWAY ALIGNMENT APPRAISAL

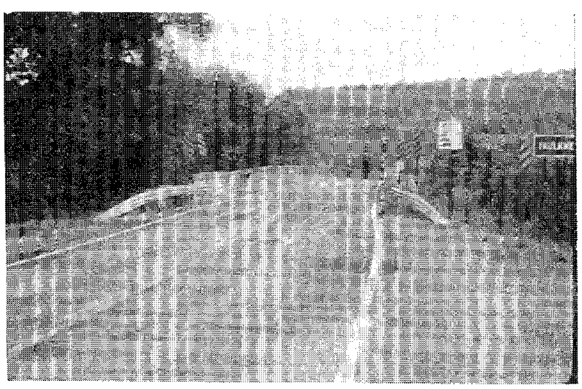
Approach roadway alignment is the only deck related item to receive an appraisal coding.



Slide No. 6-3-18
Example Slide
Typical curved approach roadway alignment



Slide No. 6-3-19
Example Slide
Straight approach roadway alignment



Slide No. 6-3-20
Example Slide
Approach roadway with reduced sight distance due to poor vertical alignment

Slide No. 6-3-21
Example Slide
Approach roadway with a hairpin turn alignment

See Slide 6-3-18

The evaluation of the approach roadway alignment is based on the need to decrease operating speed from the posted speed limit. Any decrease in speed must be due to the alignment of the approach and not due to the road itself or the bridge deck geometry. For example:

- You would not downgrade the approach because a serpentine road is posted for 30 miles per hour (50 km/h).

- You would not downgrade the approach because traffic must slow for a narrow bridge. Narrow bridges are accounted for with the Deck Geometry Appraisal Item.

- You would downgrade the approach if the driver of a vehicle must make a hairpin turn onto the structure.

- You would downgrade the approach if the alignment, vertical or horizontal, restricts sight distance such that a speed reduction is necessary.

The guidelines for FHWA Item 72, Appraisal of Approach Roadway Alignment, are as follows:

See Slide 6-3-19

- If no reduction in the operating speed of a vehicle is required compared to the highway, code Item 72 an "8"

See Slide 6-3-20

- If only a very minor reduction in the operating speed of a vehicle is required compared to the highway, code Item 72 a "6"

See Slide 6-3-21

- If a substantial reduction in the operating speed of a vehicle is required compared to the highway, code Item 72 a "3"

The remaining codes, between these general values should be applied at the inspector's discretion.

Summary

Slide No. 6-3-22
Title Slide

III. SUMMARY

SESSION 6: INSPECTION AND EVALUATION OF BRIDGE DECKS

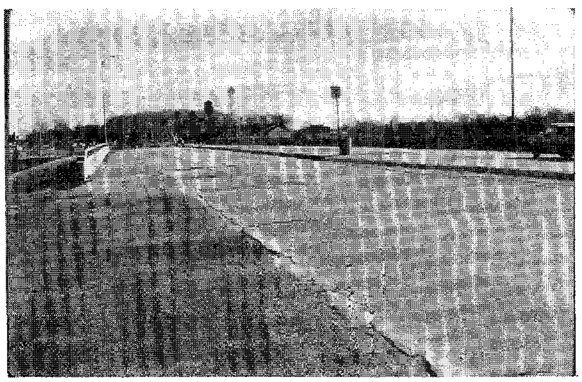
TOPIC 4: RATING EXERCISES

LESSON PLAN

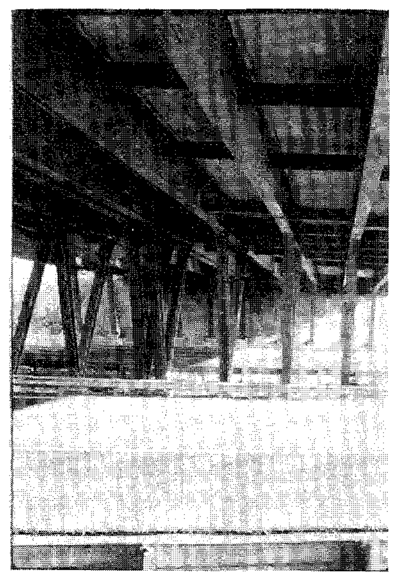
TOPIC DURATION	60 minutes
PREREQUISITES	Session 6, Topics 1-3
PARTICIPANT MATERIALS	Participant Notebook, BITM 90
GOAL	An understanding of the thought process involved in determining the condition coding for decks and the appraisal coding for approach roadway alignments.
OBJECTIVE	Be able to evaluate and determine the proper condition and appraisal codes for SI&A Item Nos. 58 and 72 using the guidelines presented in the training program and the FHWA *Coding Guide*.
PARTICIPATION	Each participant will be required to assign numerical ratings to the deck condition rating and approach roadway alignment appraisal rating based on a slide presentation and a narrative description of deficiencies. Participant ratings will be tallied and collectively compared to the correct rating assignment.

Concrete Decks

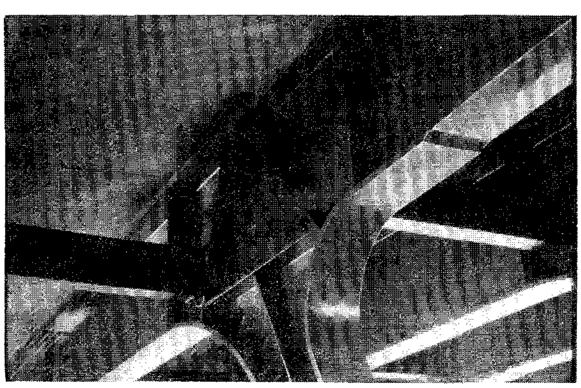
Slide No. 6-4-1
Title Slide



Slide No. 6-4-2
Example Slide
Approach and general view



Slide No. 6-4-3
Example Slide
General underside view



Slide No. 6-4-4
Example Slide
Typical underside close-up

I. CONCRETE DECKS

A. EXERCISE NO. 1

1. Examination

See Slide 6-4-2

The bridge is a steel rigid frame with a CIP concrete deck. This bridge was inspected in December 1987. The speed limit is 45 mph (65 km/h).

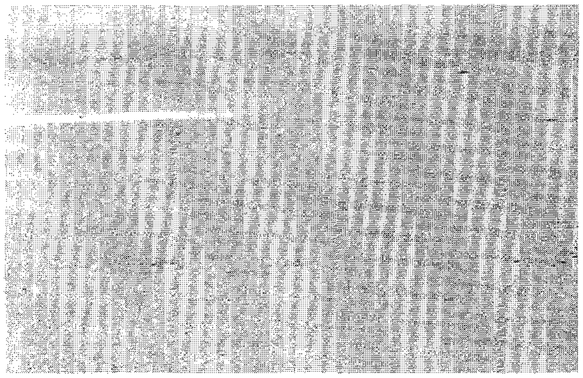
Although the approach pavement has some patches, the deck surface shows no cracks, delaminations, or spalls.

See Slide 6-4-3

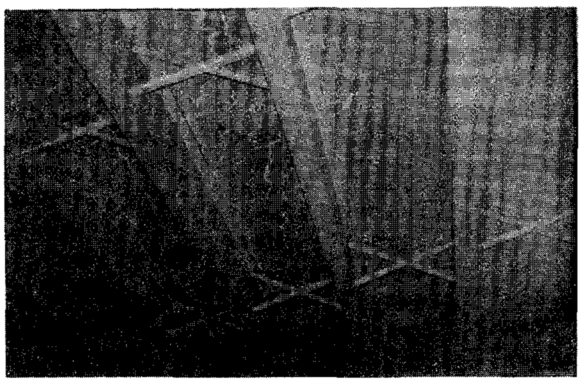
The underside view of the deck also shows no sign of any distress.

See Slide 6-4-4

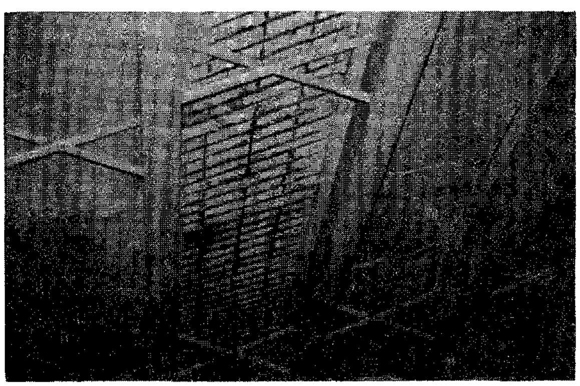
The lines in the concrete were caused by the plywood forms.



Slide No. 6-4-9
Example Slide
Longitudinal cracks in southbound lanes



Slide No. 6-4-10
Example Slide
Typical underside view with cracks and efflorescence



Slide No. 6-4-11
Example Slide
Large spall with exposed rebar

See Slide 6-4-9

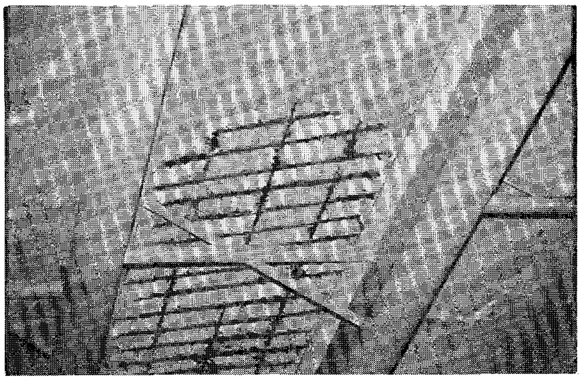
- Longitudinal cracks, hairline to 1/8 inch (3 mm) wide. Cracks were mostly found in the two southbound lanes.

See Slide 6-4-10

- Underside view showing the transverse and longitudinal cracks with efflorescence present.

See Slide 6-4-11

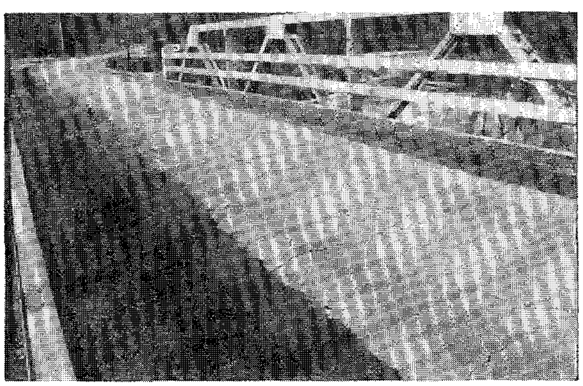
- One large spalled area was located under the median, near the south abutment. The spall measured 2 feet - 6 inches x 13 feet (760 mm x 3960 mm). There was minor section loss on the exposed reinforcement.



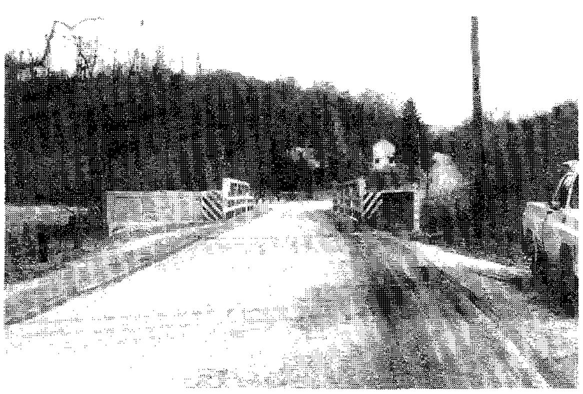
Slide No. 6-4-12
Example Slide
Underside spall and cracks

Rating Reasoning

Slide No. 6-4-13
Title Slide



Slide No. 6-4-14
Example Slide
General view of bridge



Slide No. 6-4-15
Example Slide
East approach

2. **Condition Rating Reasoning**

See Slide 6-4-13

3. **Approach Roadway Alignment**

C. **EXERCISE NO. 3**

1. **Examination**

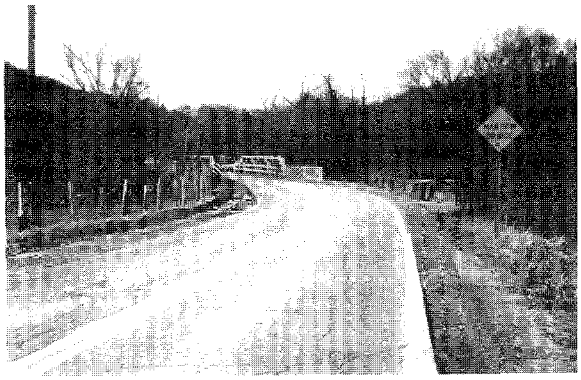
See Slide 6-4-14

This bridge is a single span steel pony truss. It has a CIP concrete deck with an asphalt wearing surface.

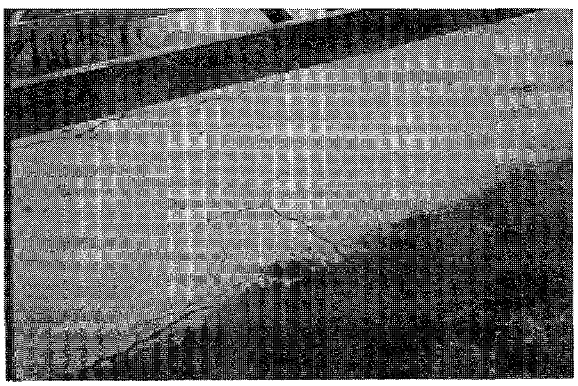
The bridge, which carries Route 588 over Brush Creek, was originally constructed in 1871 and completely reconstructed in 1929. The date of this inspection was January 1984. The posted speed limit is 35 MPH (55 km/h). The bridge can be safely traveled at approximately 30 MPH (50 km/h). The road is classified as a minor arterial and carries two-way traffic with an ADT of 450.

See Slide 6-4-15

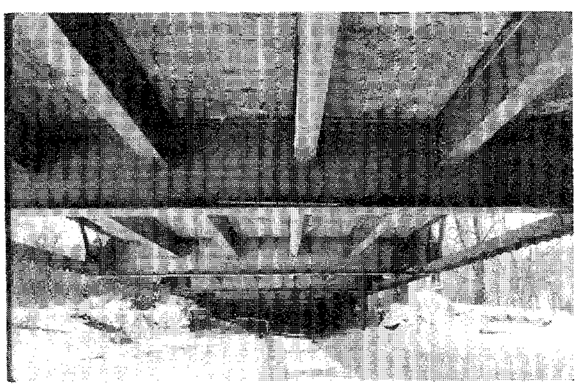
The east approach has a relatively straight alignment.



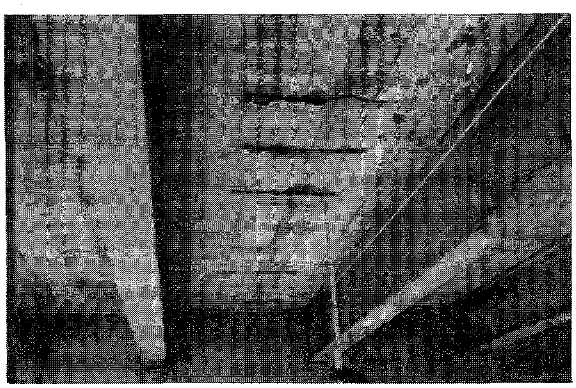
Slide No. 6-4-16
Example Slide
West approach



Slide No. 6-4-17
Example Slide
Close-up of deck wearing surface



Slide No. 6-4-18
Example Slide
Typical deck underside looking ahead



Slide No. 6-4-19
Example Slide
Underside of deck between interior stringers. Note exposed transverse rebar with minor section loss.

See Slide 6-4-16

The west approach includes an "S" curve.

Deficiencies include:

See Slide 6-4-17

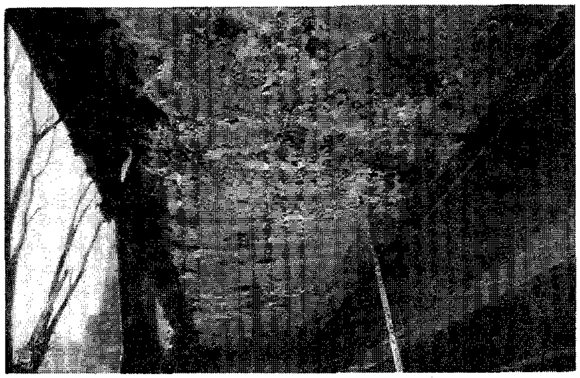
- Random cracking of the asphalt wearing surface over the entire span.. There are full width transverse cracks and longitudinal cracks at the wheel lines.

See Slide 6-4-18

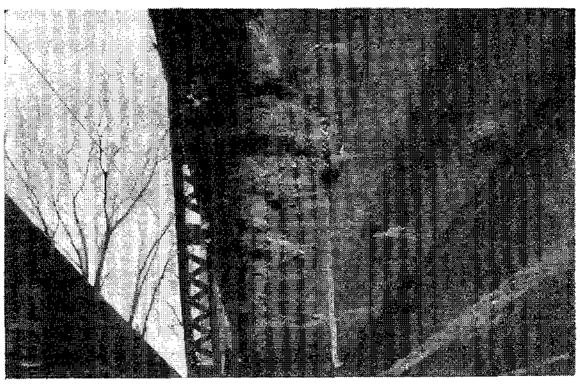
- The typical underside of the deck shows rust stains and road salt stains.

See Slide 6-4-19

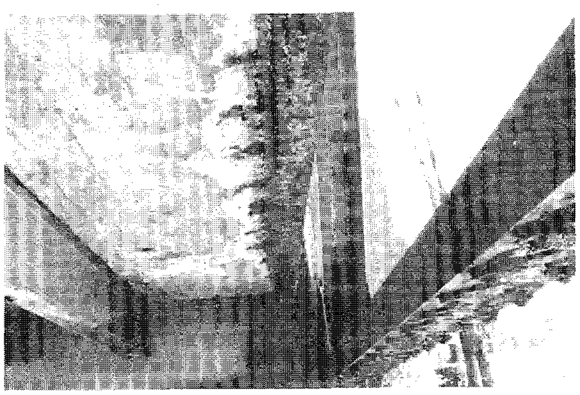
- There is some exposed transverse rebar with very minor section loss.



Slide No. 6-4-20
Example Slide
Underside of deck next to fascia beam
(typical condition)



Slide No. 6-4-21
Example Slide
Underside of deck - downstream side



Slide No. 6-4-22
Example Slide
Underside of deck - upstream view

See Slide 6-4-20

- The outside edges of the deck, along the fascia stringers, are typically contaminated with road salt, show rust stains, and have large areas of honeycombs.

See Slide 6-4-21

Typical view of the downstream side.

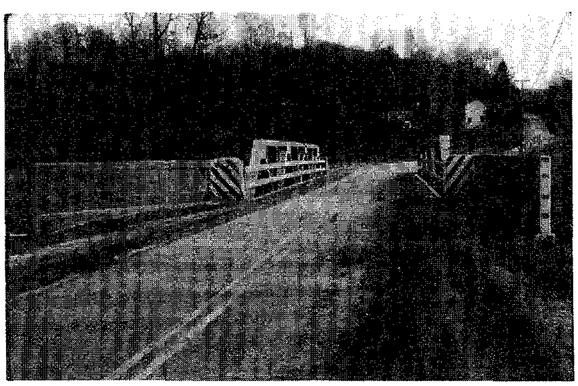
See Slide 6-4-22

Typical view of the upstream side.

Rating Reasoning

Slide No. 6-4-23
Title Slide

Slide No. 6-4-24
Example Slide
Close-up of honeycombs with rust stains and chloride contamination



Slide No. 6-4-25
Example Slide
Approach roadway alignment

II. TIMBER DECKS

A. EXERCISE NO. 1

1. Examination

See Slide 6-4-27

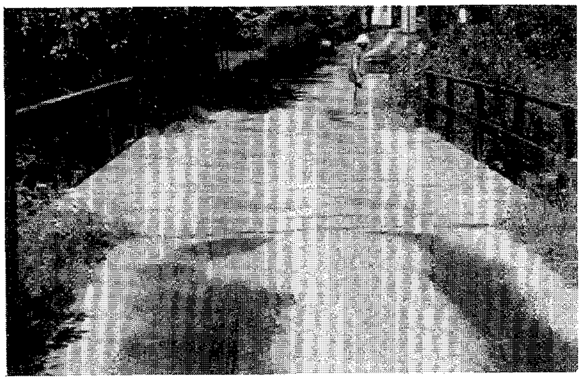
The bridge is a single span solid sawn timber multibeam with a timber plank deck. The bridge carries Hooks Road, posted 25 MPH (40 km/h), over Stoney Run. This bridge was inspected in September 1990.

See Slide 6-4-28

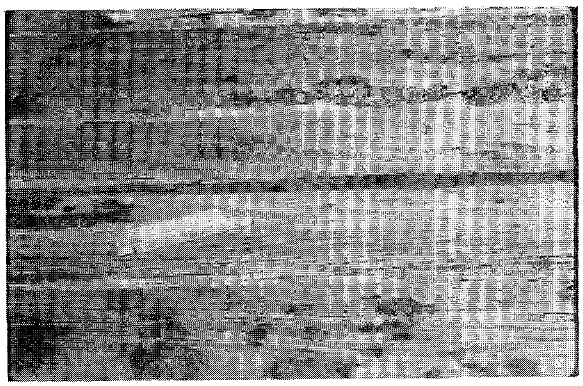
The west approach is relatively straight...

See Slide 6-4-29

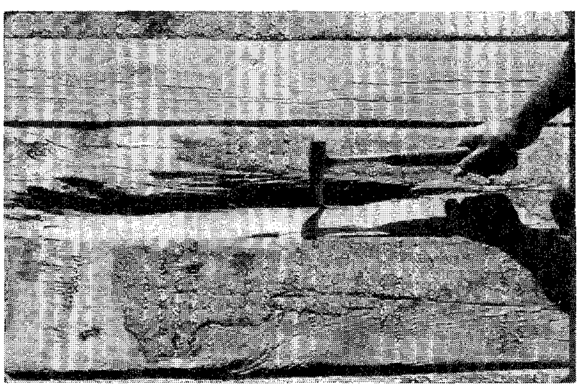
...while the east approach has a slight curve at the bridge.



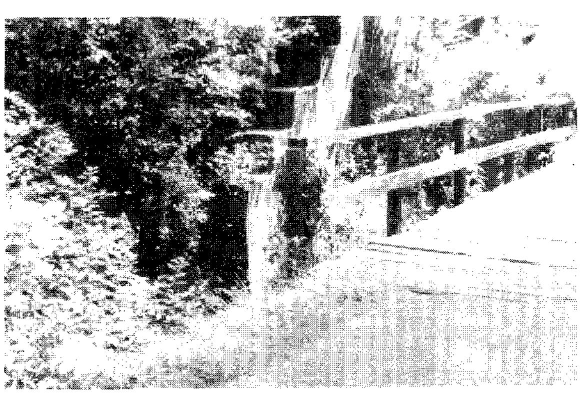
Slide No. 6-4-30
Example Slide
General view of deck



Slide No. 6-4-31
Example Slide
Typical close-up of deck planks



Slide No. 6-4-32
Example Slide
Partial failure of one plank



Slide No. 6-4-33
Example Slide
South edge of deck. Note the loose planks.

See Slide 6-4-30

General view of the deck.

Deficiencies include:

See Slide 6-4-31

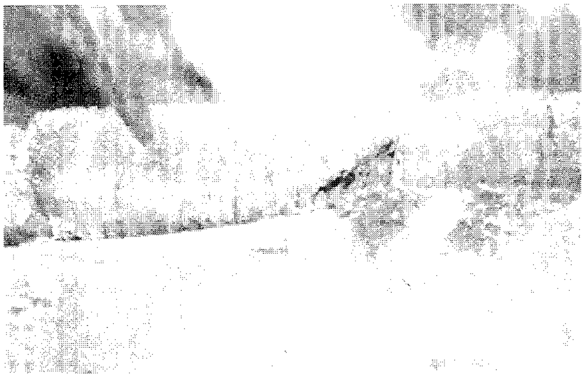
- The top side of the deck planks are weathered.

See Slide 6-4-32

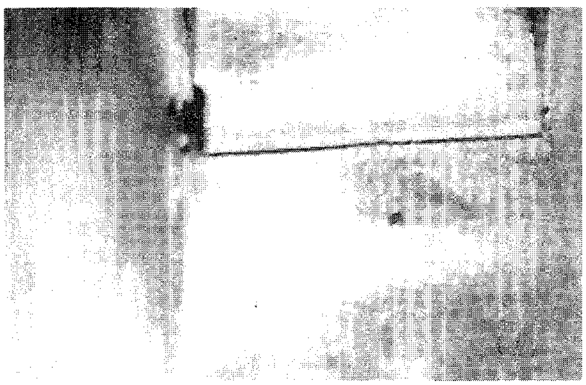
- There is one plank that has partially failed.

See Slide 6-4-33

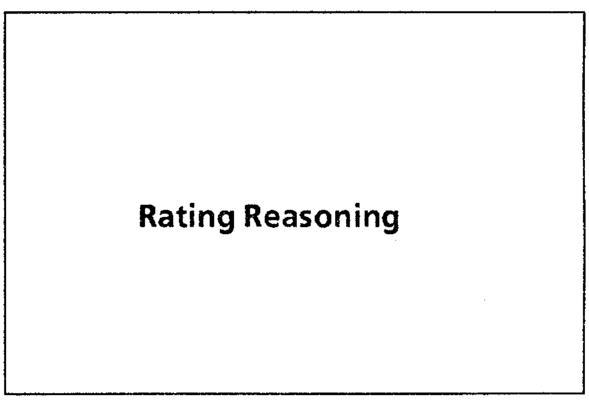
- Approximately one-third of the planks are loose at the connection to the fascia beams.



Slide No. 6-4-34
Example Slide
End view of loose planks. Note rotted condition.



Slide No. 6-4-35
Example Slide
Typical underside view of deck planks



Slide No. 6-4-36
Title Slide

See Slide 6-4-34

- The loose planks are also warped and rotted at the ends.

See Slide 6-4-35

- The underside of the planks are typically sound.

2. Condition Rating Reasoning

3. Approach Roadway Alignment

SESSION 6: BRIDGE DECKS — CASE 1

TOPIC 4: RATINGS (TIMBER DECKS)

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- The bridge is a single span solid sawn timber multibeam with a timber plank deck. The bridge deck is 18 ft. wide and spans 50 ft.

CONDITION STATE SUMMARY:

- The top side of all deck planks are weathered.
- There is one plank that has partially failed.
- Approximately one-third of the planks are loose at the connection to the fascia beams.
- The loose planks are also warped and rotted at the ends.
- The underside of the planks are typically sound.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements							
Other Elements							
Smart Flags							

SESSION 6: BRIDGE DECKS — CASE 1

TOPIC 4: RATINGS (CONCRETE DECKS)

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- The bridge is a steel rigid frame with a C.I.D. concrete deck. The bridge is 300 feet long and carries a four lane divided highway, 36 ft. curb to curb in each direction with a 4 ft. non-mountable median.

CONDITION STATE SUMMARY:

There are no deficiencies identified for this deck on top or bottom.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements							
Smart Flags							
							X
							X

SESSION 6: BRIDGE DECKS — CASE 2

TOPIC 4: RATINGS (CONCRETE DECKS)

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- The bridge is a single span rolled steel multibeam bridge. It has a CIP concrete deck. The bridge deck is approximately 62 feet wide and 30 feet long.

CONDITION STATE SUMMARY:

- Transverse cracks, hairline to 1/8 inch wide, were found in the surface of the two southbound lanes only.
- Longitudinal cracks, hairline to 1/8 inch wide, were also found in the surface of two southbound lanes.
- The underside of the southbound lanes exhibited transverse and longitudinal cracks with efflorescence present.
- One large spalled area was located under the median, near the south abutment. The spall measured 2 feet - 6 inches x 13 feet. There was minor section loss on the exposed reinforcement.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements							
Smart Flags							

PONTIS
PONTIS

SESSION 6: BRIDGE DECKS — CASE 3

TOPIC 4: RATINGS (CONCRETE DECKS)

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- This bridge is a single span steel pony truss. The bridge deck is 24 ft. wide and 50 ft. long, the deck was constructed of mild steel reinforcement with CIP concrete and an asphalt wearing surface.
- The bridge, which carries Route 588 over Brush Creek, was originally constructed in 1871 and completely reconstructed in 1929.

CONDITION STATE SUMMARY:

- The asphalt wearing surface has 1/16" to 1/8" random cracking over the entire span. There are full width transverse cracks and longitudinal cracks at the wheel lines.
- The underside of the deck shows rust stains and road salt stains typical throughout.
- There is some exposed transverse rebar with very minor section loss.
- The outside edges of the deck, along the fascia stringers, are typically contaminated with road salt, show rust stains, and have large areas of honeycombs.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements							
Smart Flags							

INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

TOPIC 1: INTRODUCTION

LESSON PLAN

TOPIC DURATION	30 minutes
PREREQUISITES	Participant must be familiar with the identification of timber bridge types and timber defects
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 8
GOAL	To be able to recognize the common types of timber bridges and common timber defects.
OBJECTIVE	To present examples of common timber superstructure types and to briefly review common timber defects.
PARTICIPATION	Participants may be asked to identify the types of timber superstructures and defects.
REFERENCES	1. U.S. Forest Service. *Timber Bridges - Design, Construction, Inspection, and Maintenance.* Washington, D.C.: United States Department of Agriculture, 1990.

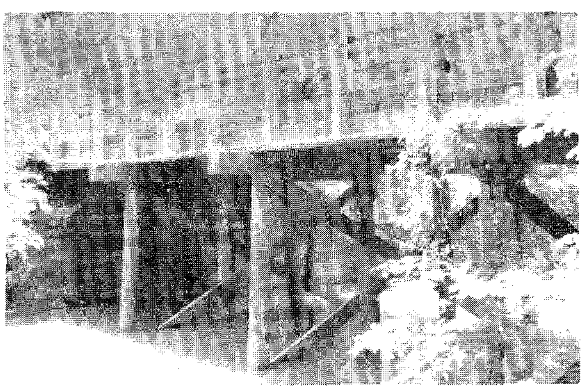
Construction Classification

- Solid Sawn
- Glued-Laminated (Glulam)

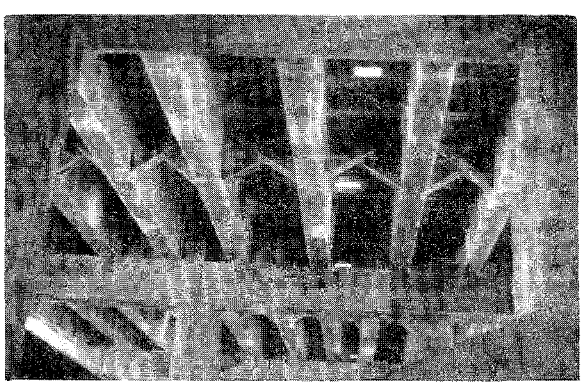
Slide No. 7-1-1
Title Slide

**Solid Sawn
Multi-beam Bridges**

Slide No. 7-1-2
Title Slide



Slide No. 7-1-3
Example Slide
Solid sawn multi-beam bridge
elevation view



Slide No. 7-1-4
Example Slide
Solid sawn multi-beam bridge
view of underside

I. INTRODUCTION

Timber bridges are gaining a new resurgence in popularity in the U.S.A., especially in the Northeast. In this session, we will review the various types of timber bridges that can be found here and some of the new types that may become commonplace in the next few years. We will also briefly review the defects common to timber bridges and review the condition rating guidelines with respect to their applicability to timber superstructures.

II. CONSTRUCTION CLASSIFICATION

A. SOLID SAWN

A solid sawn beam is simply a tree with its bark and branches removed and then sawn down to the desired size.

B. GLUED-LAMINATED (GLULAM)

Glulam members are made by gluing strips of wood together to form a structural member of the desired size.

- Strips may be 3/4 to 2 inches (19 to 51 mm) thick.
- Laminated sections allow for a higher utilization of the wood, since a lower grade of material can be used in areas where stresses are not extremely high.
- Size and length of a glulam member is not limited by the size or length of a tree.
- Many strength reducing characteristics of wood, such as knots and checks, can be controlled through laminating.

III. COMMON BRIDGE TYPES

See Slide 7-1-3

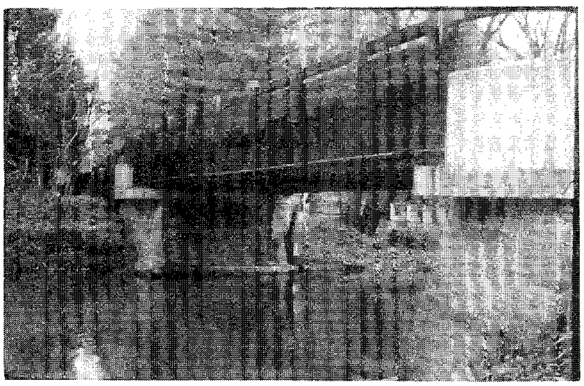
See Slide 7-1-4

A. SOLID SAWN MULTI-BEAM BRIDGES

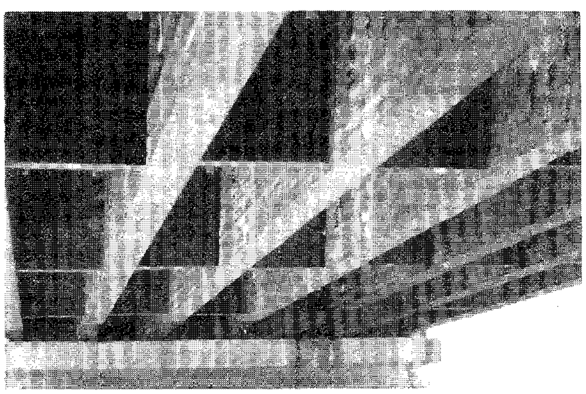
- Simply consist of multiple solid sawn beams

Glulam
Multi-beam Bridges

Slide No. 7-1-5
Title Slide



Slide No. 7-1-6
Example Slide
Glulam multi-beam bridge
elevation view



Slide No. 7-1-7
Example Slide
Glulam multi-beam bridge
view of underside

Truss Bridges

- Modern Timber Trusses
- Covered Bridges

Slide No. 7-1-8
Title Slide

B. GLUED-LAMINATED (GLULAM) BRIDGES

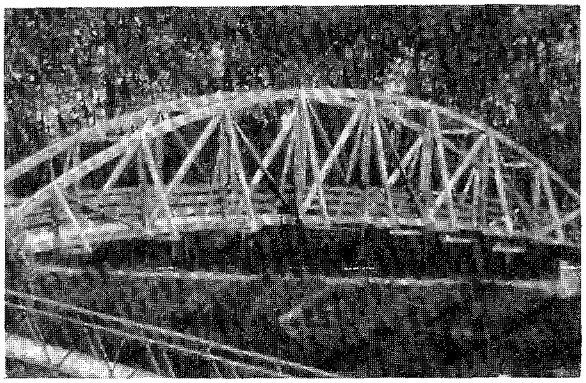
See Slide 7-1-6

- Simply consist of multiple glulam beams

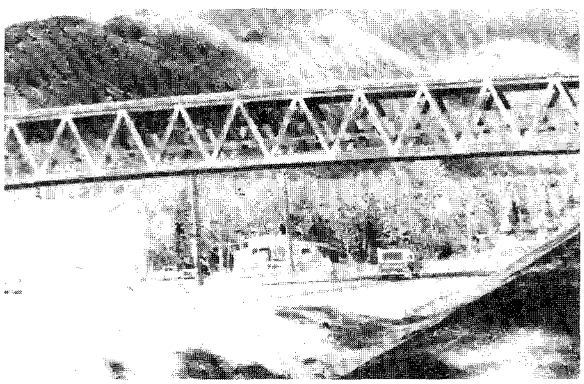
See Slide 7-1-7

C. TRUSSES AND COVERED BRIDGES

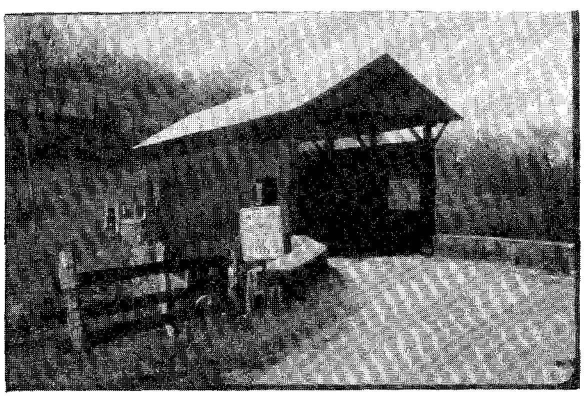
1. Modern Timber Trusses



Slide No. 7-1-9
Example Slide
Bowstring truss pedestrian bridge



Slide No. 7-1-10
Example Slide
Parallel chord truss pedestrian bridge
(Eagle River, Alaska)



Slide No. 7-1-11
Example Slide
Covered bridge
elevation view

Slide No. 7-1-12
Example Slide
Covered bridge
inside view showing truss

See Slide 7-1-9

See Slide 7-1-10

- Various truss types are used.

2. **Covered Bridges**

See Slide 7-1-11

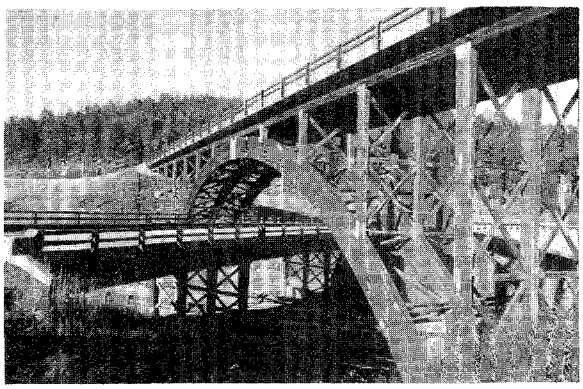
See Slide 7-1-12

- Essentially are truss bridges with covers

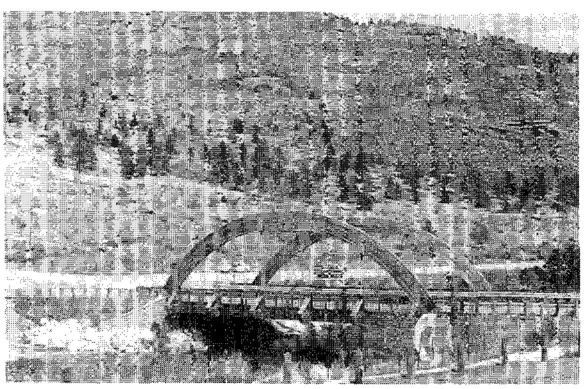
Arch Bridges

- Glulam Arches
- Covered Bridge Arches

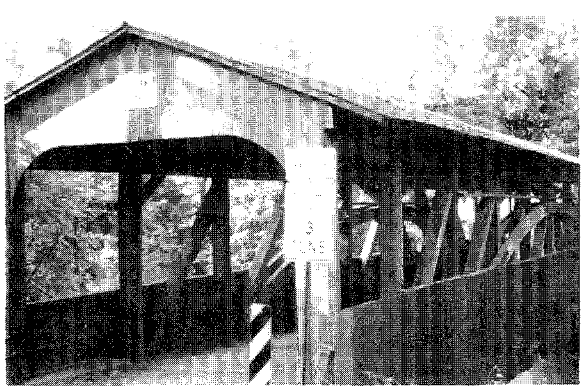
Slide No. 7-1-13
Title Slide



Slide No. 7-1-14
Example Slide
Glulam arch bridge over glulam multi-beam bridge (Keystone Wye interchange, South Dakota)



Slide No. 7-1-15
Example Slide
Glulam arch bridge (Colorado)



Slide No. 7-1-16
Example Slide
Covered bridge with Burr Arch-Trusses elevation view

D. OTHER TIMBER BRIDGES

1. Glulam Arches

- These bridges usually consist of two glulam three-hinged deck arches which support a glulam deck and floor system.

See Slide 7-1-15

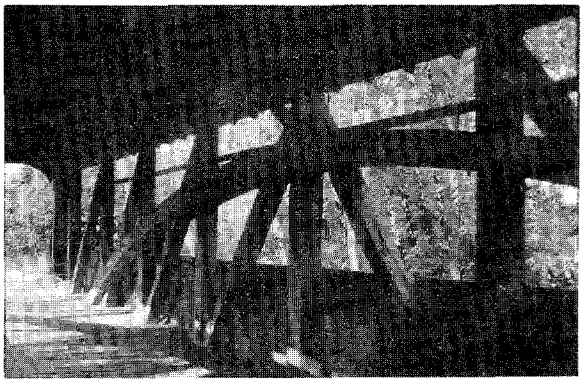
- Glulam arches are practical for spans up to about 300 feet (91 m).

- Although not as frequently used for highway structures, they are used many times for pedestrian overpasses and in locations such as parks where esthetics are a prime consideration.

2. Covered Bridge Arches

See Slide 7-1-16

- Timber arches were first used in covered bridges by Theodore Burr to strengthen the series of king-post trusses normally used in covered bridges. These became known as Burr arch-trusses.

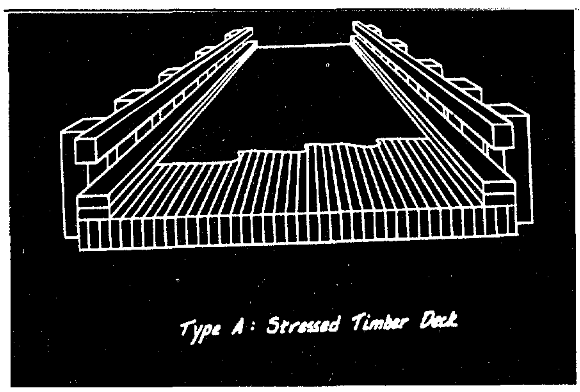


Slide No. 7-1-17
Example Slide
Covered bridge with Burr Arch-Trusses
inside view

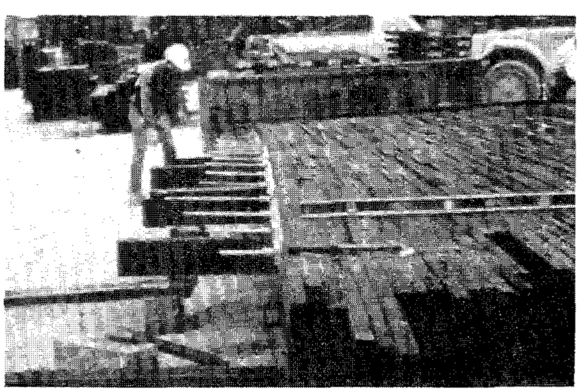
Stressed Timber Bridges

- Stressed Deck
- Stressed K-Frame
- Stressed T-Beam
- Stressed Box Beam

Slide No. 7-1-18
Title Slide



Slide No. 7-1-19
Schematic Slide
Stressed deck bridge
typical section
(Note: transverse stressing rods not
shown)



Slide No. 7-1-20
Example Slide
Stressed deck section being fabricated

See Slide 7-1-17

- Actually, the arch was the main supporting element and the king-posts made the arch stronger.

- Many of these structures still exist today.

3. **Stressed Deck Bridges**

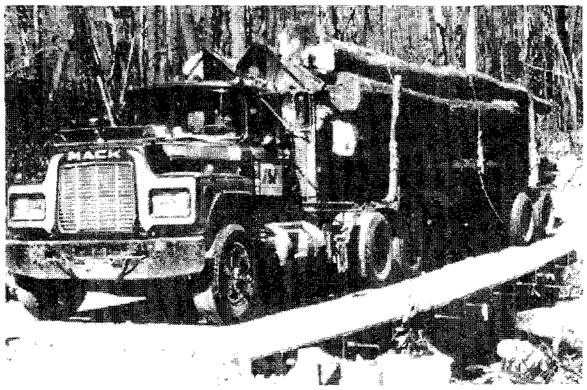
- First developed by the Ontario, Canada, Ministry of Transportation and Communications in 1976.

See Slide 7-1-19

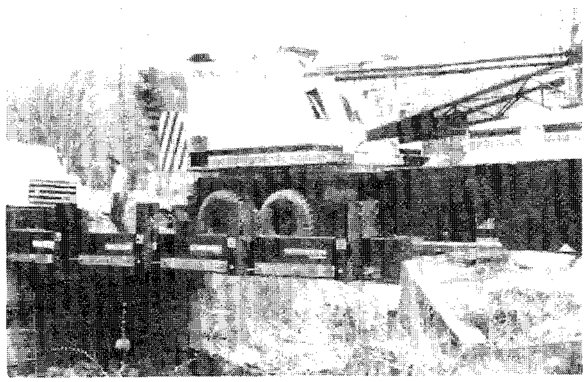
See Slide 7-1-20

- Consist of multiple laminations of solid sawn timber planks squeezed together by high strength steel rods passing through predrilled holes in the laminations. They have also been constructed using glulam laminations.

- The compression and frictional resistance within the timber laminations is the mechanism that makes this structural system work.

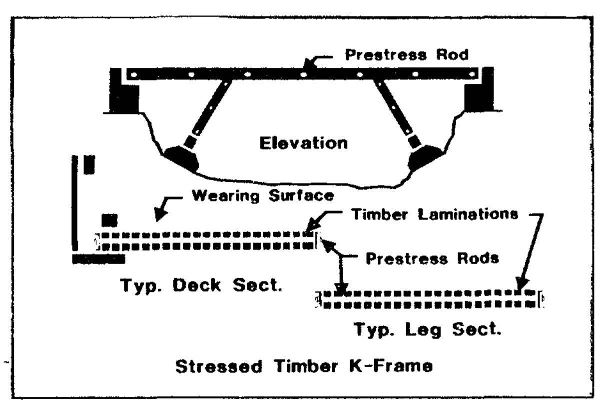


Slide No. 7-1-21
Example Slide
Stressed deck bridge carrying 90,000 lb. logging truck



Slide No. 7-1-22
Example Slide
Solid sawn stressed deck bridge (nearly completed)

Slide No. 7-1-23
Example Slide
Glulam stressed deck bridge



Slide No. 7-1-24
Schematic Slide
Stressed K-frame bridge

See Slide 7-1-21
See Slide 7-1-22
See Slide 7-1-23

- Solid sawn stressed decks can be used in simple spans up to about 50 feet (15 m) and are capable of carrying heavy loads. Glulam stressed decks have been used in spans up to about 63 feet (19 m).

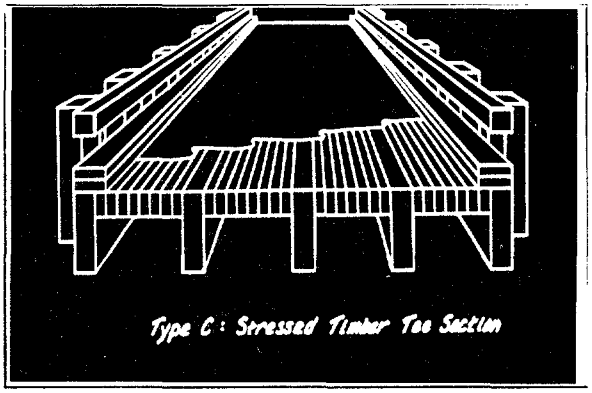
4. Stressed K-Frame Bridges

- Represents further development of the stressed deck bridge by the Canadians.

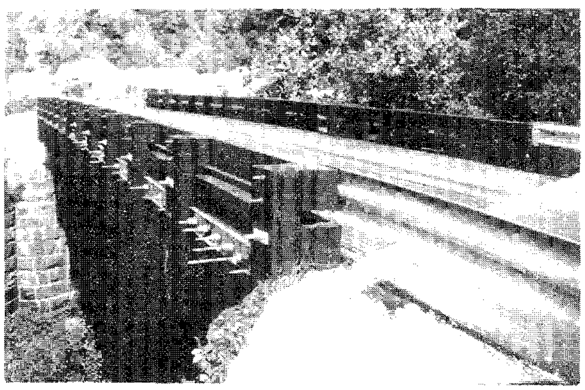
See Slide 7-1-24

- Consists of a three span bridge in which the stressed deck is supported at two intermediate points by stressed laminated timber legs/struts.

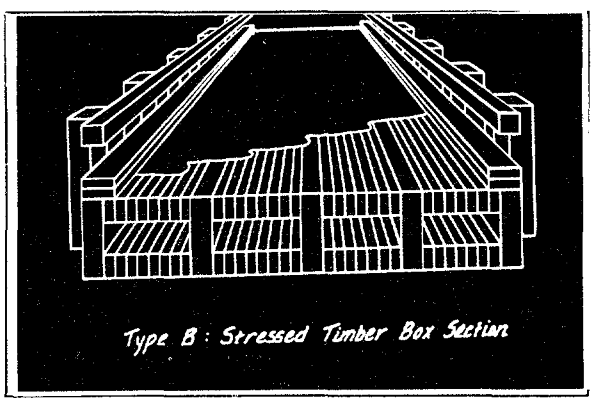
- This type has been used for a bridge with a total length of 43 feet (13 m), but it can easily be used for bridges with total lengths over 50 feet (15 m).



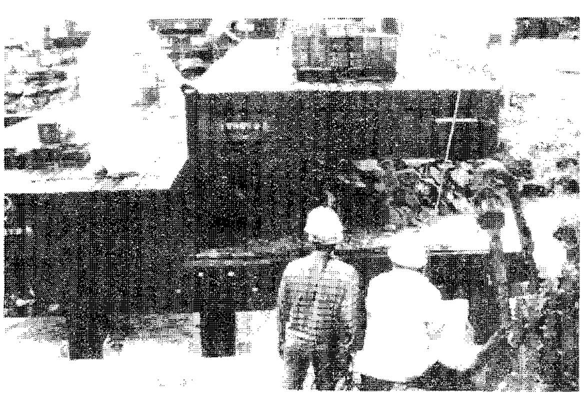
Slide No. 7-1-25
Schematic Slide
Stressed T-beam bridge
typical section
(Note: Transverse steel stressing rods not shown)



Slide No. 7-1-26
Example Slide
Stressed T-beam bridge
elevation view
(West Virginia)



Slide No. 7-1-27
Schematic Slide
Stressed box beam
typical section
(Note: Transverse steel stressing rods not shown)



Slide No. 7-1-28
Example Slide
Stressed timber box beam bridge
being erected

5. **Stressed T-Beam Bridges**

- This idea was developed at West Virginia University with the first structure of this type being built in 1988 near Charleston, West Virginia.

See Slide 7-1-25

- The bridge consists of a stressed deck and glulam (using laminated veneer lumber) beams. High strength steel rods are used to join the stressed deck and glulam beams together to form laminated timber T-beams.

See Slide 7-1-26

- This first structure is about 75 feet (23 m) long and has been performing well so far.

  - Deck - 1 1/2 inches x 9 inches (38 mm x 229 mm) red oak laminations
  - Stringers - seven beams 6 inches x 42 inches (152 mm x 1067 mm)
  - Stressing rods at 24 inches c/c (610 mm)
  - 2 inch (51 mm) asphalt wearing course

- Utilization of timber T-beams to achieve longer span lengths is likely in the future.

6. **Stressed Box Beam Bridges**

- Represents further development of stressed timber bridges by West Virginia University.

See Slide 7-1-27

- Consists of adjacent box beam panels formed by a stressed deck top flange and stressed deck bottom flange with glulam webs separating them. This type is also known as a cellular stressed deck.

See Slide 7-1-28

- Have been designed for span lengths up to 60 feet (18 m) although longer spans can no doubt be achieved.

Common Timber Defects

- Decay
- Parasite damage
- Chemical attack
- Fire damage
- Impact/collision damage
- Abrasion/wear
- Weathering/warping
- Overstress

Slide No. 7-1-29

Title Slide

IV. COMMON TIMBER DEFECTS

A. DECAY BY FUNGI

Rot is the most common defect affecting timber.

B. DAMAGE BY PARASITES

Damage caused by termites, carpenter ants, powder-post beetles, or marine borers, but not common on modern timber bridge superstructures.

C. DAMAGE FROM CHEMICAL ATTACK

Is not usually a problem with timber structures.

D. DAMAGE FROM FIRE

Does not occur very often but can be very destructive to timber structures, especially historic covered bridges.

E. DAMAGE FROM IMPACT/COLLISIONS

Occurs occasionally, usually to above deck portions of the structures.

F. DAMAGE FROM ABRASION/WEAR

Typically can be found on the top surface of timber decks or between mating parts at connections.

G. DAMAGE FROM WEATHERING/WARPING

May occur as the wood is exposed to alternating wet-dry exposure conditions.

H. DAMAGE FROM OVERSTRESS

May occur in bridge members that are subjected to much larger loads than they were designed to carry.

Common Timber Bridges Today

- Multi-Beam
- Trusses
- Arches

New Timber Bridges

- Stressed Deck
- Stressed K-Frame
- Stressed T-Beam
- Stressed Box Beam

Slide No. 7-1-30

Narrative Slide

V. SUMMARY

The bridge inspector needs to be cognizant of the various types of timber bridges as well as the defects that are common to them. Currently, the most common bridge types are solid sawn and glulam multi-beam bridges, timber truss bridges, covered bridges, and timber arch bridges. Stressed timber bridges will probably become more and more common. And, as the technology develops, other prototype timber bridges may become realities also.

SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

TOPIC 2: SOLID SAWN BEAMS

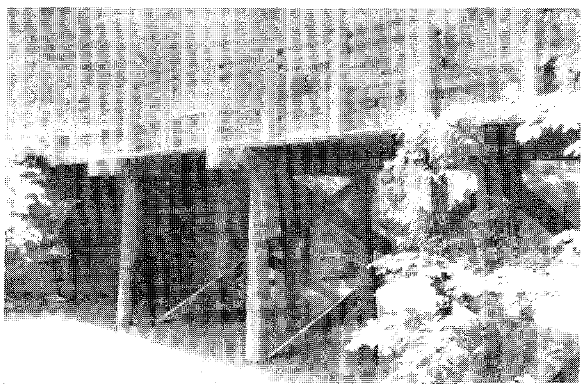
LESSON PLAN

TOPIC DURATION	30 minutes
PREREQUISITES	Participant should be familiar with the identification and components of a solid sawn multi-beam bridge and have an understanding of various timber defects.
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 8
GOAL	Recognition of the important areas for inspection of solid sawn multi-beam bridges and evaluation of any defects found.
OBJECTIVE	To introduce the location of significant inspection areas of solid sawn multi-beam bridges; the evaluation and rating of these bridges in regard to any defects found and properly document the defects.
PARTICIPATION	Participants will be asked to discuss their evaluation and rating of a solid sawn multi-beam bridge.
REFERENCES	1. U.S. Forest Service. *Timber Bridges - Design, Construction, Inspection, and Maintenance.* Washington, D.C.: United States Department of Agriculture, 1990.

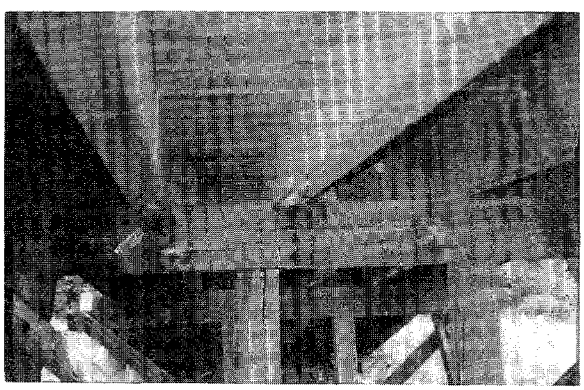
Solid Sawn Multi-beams

- Design Characteristics

Slide No. 7-2-1
Title Slide



Slide No. 7-2-2
Example Slide
Typical solid sawn timber multi-beam bridge - elevation view



Slide No. 7-2-3
Example Slide
Typical solid sawn timber multi-beam bridge - underside view

Slide No. 7-2-4
Example Slide
Typical solid sawn beam elevation view

I. DESIGN CHARACTERISTICS

A. GENERAL

See Slide 7-2-2

See Slide 7-2-3

1. **Description** - The solid sawn multi-beam bridge is the simplest type of timber bridge. It consists of multiple simply supported solid sawn beams spanning between the substructure units. The deck is typically comprised of transversely laid timber planks which are supported by the beams. Sometimes a bituminous wearing surface is placed on the deck planks to provide a less slippery riding surface for vehicles as well as a protective surface for the planks.

2. **Spans** - Typically are older, shorter span bridges spanning up to about 25 feet (8 m). Shorter spans are sometimes combined to form longer multiple span bridges/trestles.

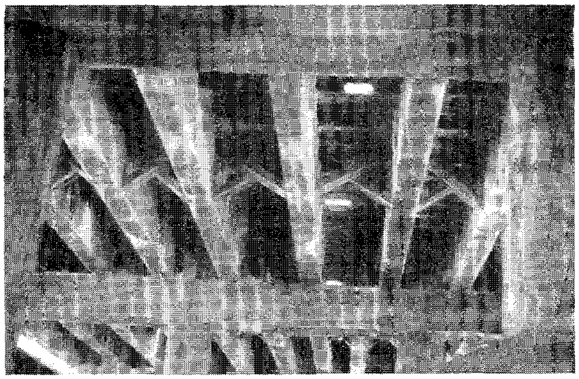
3. **Beam sizes** - typically range from about 6 inches x 12 inches (152 mm x 305 mm) to 8 inches x 16 inches (203 mm x 406 mm). They are usually spaced about 24 inches (610 mm) on center.

4. **Uses** - Usually found on local or out of the way roads. Many older timber trestles were built for railroads and trolley lines. Solid sawn timbers have become obsolete for most major bridge members due to the development of high quality glulam members.

B. PRIMARY MEMBERS

See Slide 7-2-4

- Beams

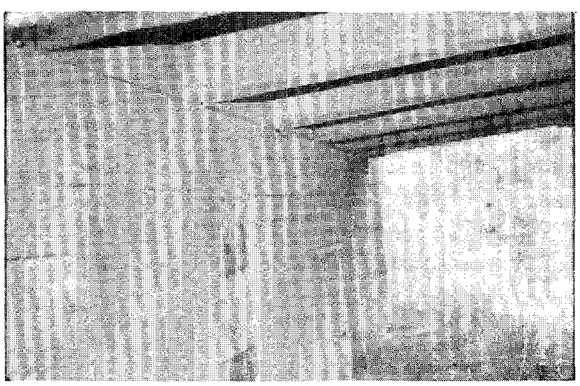


Slide no. 7-2-5
Example Slide
Typical timber diaphragm/bracing

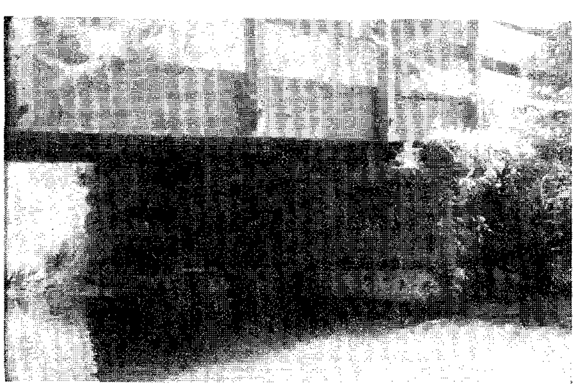
Solid Sawn Multi-beams

- Design Characteristics
- Inspection Locations and Procedures

Slide No. 7-2-6
Title Slide



Slide No. 7-2-7
Example Slide
Bearing area of typical solid sawn beam



Slide No. 7-2-8
Example Slide
Solid sawn multi-beam bridge elevation view of beam

C. SECONDARY MEMBERS

See Slide 7-2-5

- Diaphragms or cross bracing

  Usually, these bridges will have timber diaphragms or cross bracing between the beams at several locations along the span.

II. INSPECTION LOCATIONS AND PROCEDURES

A. BEARING AREAS

See Slide 7-2-7

- Check for crushing of the beams near the bearing seat.
- Check for decay and insect damage at the ends of the beams where dirt, debris and moisture tend to accumulate.
- Check the condition and operation of bearing devices, if any are present.

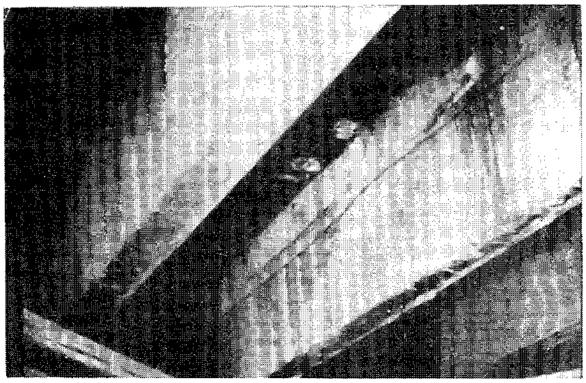
B. BEAMS

See Slide 7-2-8

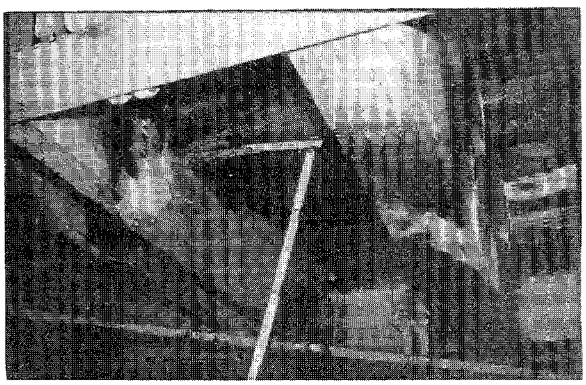
- Examine maximum shear and tension zones for signs of structural distress.

  Shear zone - ends of beam
  Tension zone - middle of beam, bottom half

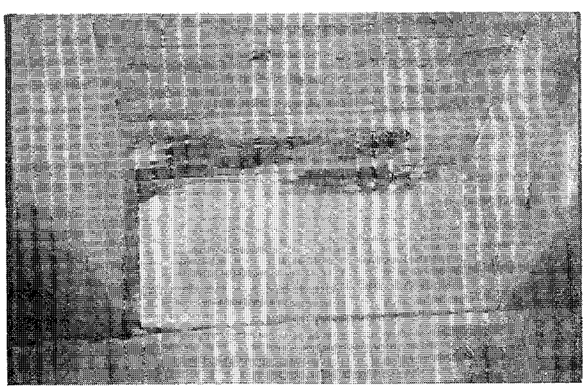
- Check for decay at the top of the beam where the deck planks are attached.
- Check for section loss, especially near mid-span and at the ends, due to decay or fire.



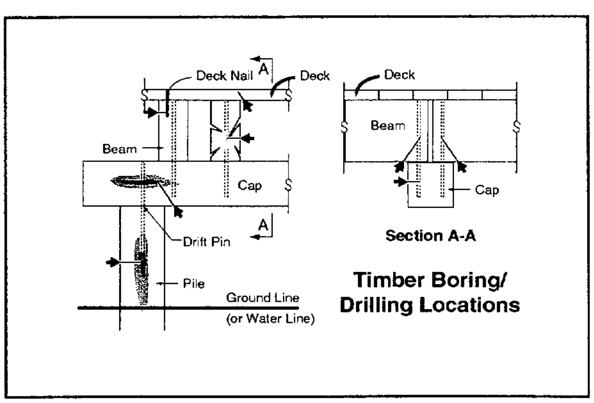
Slide No. 7-2-9
Example Slide
Horizontal shear crack in timber beam



Slide No. 7-2-10
Example Slide
Decay on timber beam



Slide No. 7-2-11
Example Slide
Typical timber end diaphragm



Slide No. 7-2-11A
Schematic Slide
Timber boring/drilling locations

See Slide 7-2-9

- Check for horizontal shear cracks near the ends of the beam. These cracks run horizontally along the length of the beam, at about mid-depth of the beam, and are due to overloading of the beam.

See Slide 7-2-10

- Check for signs of decay, chemical attack, or insect damage along the full length of the beam but especially where the beam is subjected to repeated wetting.

  Decay - may be evidenced by discolored wood, brown and white rot, the formation of fruiting bodies, "sunken" faces in the wood, or the soft punky texture of the wood.

  Chemical Attack - signs are similar to decay.

  Insect Infestation - can be seen by piles of sawdust (in the case of carpenter ants), small holes in the surface of the wood (powder-post beetles), or the presence of the insect itself (termites). Another indication is "hollow" sounding wood. In such cases, further probing and/or drilling should be performed on the suspect area.

- Check beams for excessive deflection or sagging.

- For an overhead structure, check for collision damage from vehicles passing below.

C. DIAPHRAGMS/BRACING

See Slide 7-2-11

- Check bracing members for decay, fire damage, etc.

- Examine connections of bracing to beams for tightness, cracked or split members, and corroded or missing fasteners.

D. FASTENERS/CONNECTORS

- Check all fasteners (nails, screws, bolts, deck clips) for corrosion.

- Also, check for loose or missing fasteners.

See Slide 7-2-11A

E. TIMBER BORING/DRILLING LOCATIONS

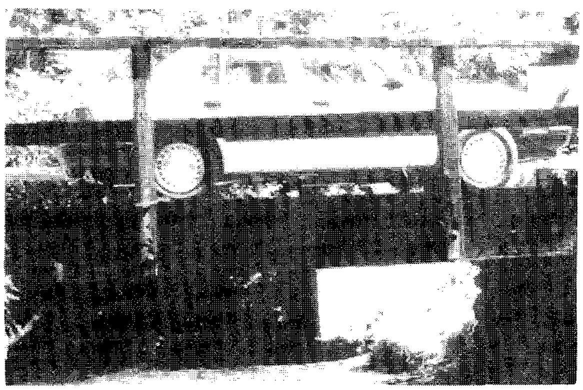
- Deck planks - in the bottom next to beam
- Beams - in sides near the deck and in the bottom over the bent cap
- Cap - under beams and over posts and piles
- Post/Pile - top under cap and bottom just above ground or water line

Solid Sawn Multi-beams

- Design Characteristics
- Inspection Locations and Procedures
- Application of Rating Guidelines

Slide No. 7-2-12

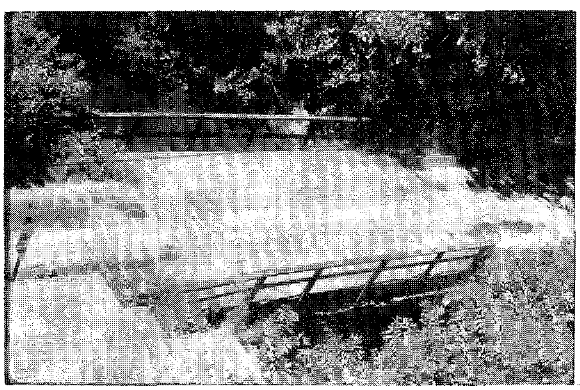
Narrative Slide



Slide No. 7-2-13

Example Slide

General elevation view



Slide No. 7-2-14

Example Slide

General plan view

III. APPLICATION OF RATING GUIDELINES

A. EXERCISE NO. 1

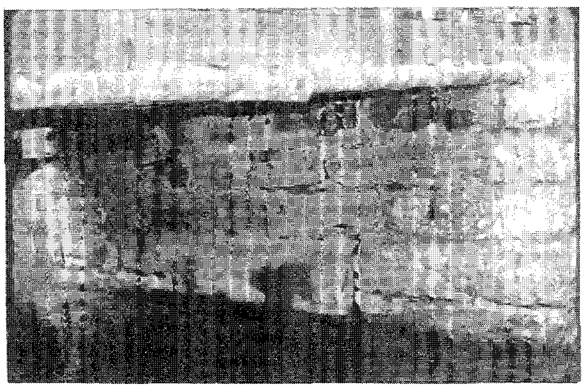
See Slide 7-2-13

1. Examination

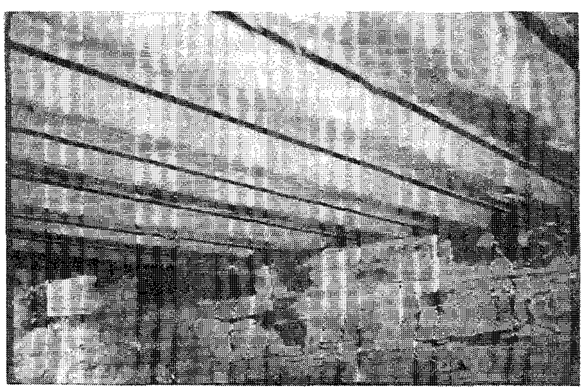
See Slide 7-2-14

This bridge is a single span solid sawn multi-beam bridge which carries Township Road T602 over Stony Run. It was last inspected in September, 1990.

Slide No. 7-2-15
Example Slide
Fascia beam elevation at abutment



Slide No. 7-2-16
Example Slide
Fascia beam elevation



Slide No. 7-2-17
Example Slide
Typical underside view of beams

Rating Reasoning

Slide No. 7-2-18
Title Slide

Deficiencies include:

See Slide 7-2-15

- Localized horizontal shear crack at one end of one fascia beam.

See Slide 7-2-16

- Surface checks on both fascia beams.

See Slide 7-2-17

- Scattered mold and stain on the beams. However, the beams have very little decay and have no section loss.

- No other defects were observed on the beams.

2. Rating Reasoning

SESSION 7: TIMBER SUPERSTRUCTURES — CASE 1

TOPIC 2: SOLID SAWN BEAMS

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- This bridge is a single span solid sawn multi-beam bridge which uses 7 timber beams to carry a 16 foot deck over a 26 foot span.

CONDITION STATE SUMMARY:

- A horizontal shear crack at one end of one fascia beam.
- Moderate sized surface checks on both fascia beams.
- Scattered molds and stains on the beams. However, the beams have very little decay and have no section loss.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States				
			1	2	3	4	5
CoRe Elements							
Other Elements							
Smart Flags							

SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

TOPIC 3: GLULAM BEAMS

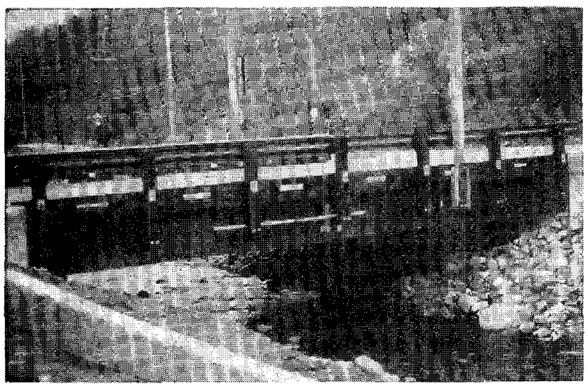
LESSON PLAN

TOPIC DURATION	30 minutes
PREREQUISITES	Participant should be familiar with the identification and components of a glulam multi-beam bridge and have an understanding of various timber defects.
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 8
GOAL	Recognition of the important areas for inspection of glulam multi-beam bridges and evaluation of any defects found.
OBJECTIVE	To introduce the location of significant inspection areas of glulam multi-beam bridge; to evaluate and rate these bridges with regard to any defects found and properly document the defects.
PARTICIPATION	Participants will be asked to discuss their evaluation and rating of a glulam multi-beam bridge.
REFERENCES	1. U.S. Forest Service. Timber Bridges - Design, Construction, Inspection, and Maintenance. Washington, D.C.: United States Department of Agriculture, 1990.

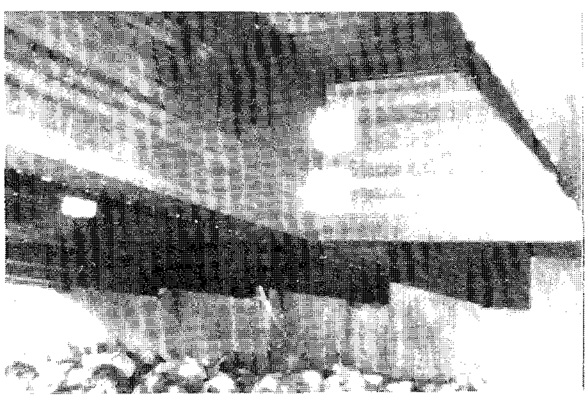
Glulam Multi-beams

- Design Characteristics

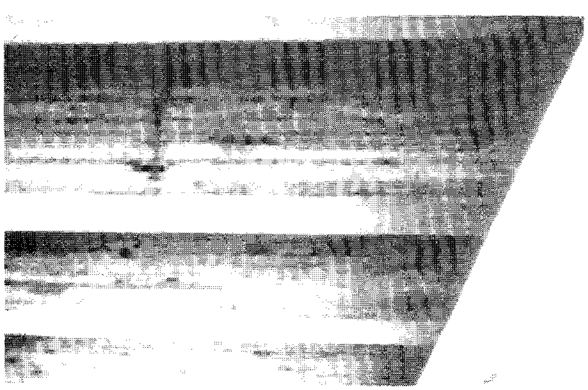
Slide No. 7-3-1
Title Slide



Slide No. 7-3-2
Example Slide
Typical glulam multi-beam bridge elevation view



Slide No. 7-3-3
Example Slide
Typical glulam multi-beam bridge underside view



Slide No. 7-3-4
Example Slide
Typical glulam beam elevation view

I. DESIGN CHARACTERISTICS

A. GENERAL

1. **Description** - The glulam multi-beam bridges are very similar to solid sawn multi-beam bridges but generally use larger members to span greater distances.

See Slide 7-3-2

See Slide 7-3-3

   Glulam multi-beam bridge consists of multiple simply supported glulam beams spanning between the substructure units. They usually support a deck consisting of glulam panels with a bituminous wearing surface.

2. **Spans** - These more modern multi-beam bridges can typically be used in spans up to 80 feet (24 m), although they have been used in spans up to 150 feet (46 m). These, too, can be used to form longer multiple span structures.

3. **Beam Sizes** - Beams usually range from about 6 3/4 inches x 24 inches (170 mm x 610 mm) to 12 1/4 inches x 60 inches (310 mm x 1525 mm) in size and are spaced 5 1/2 feet to 6 1/2 feet (1670 mm x 1980 mm) on center

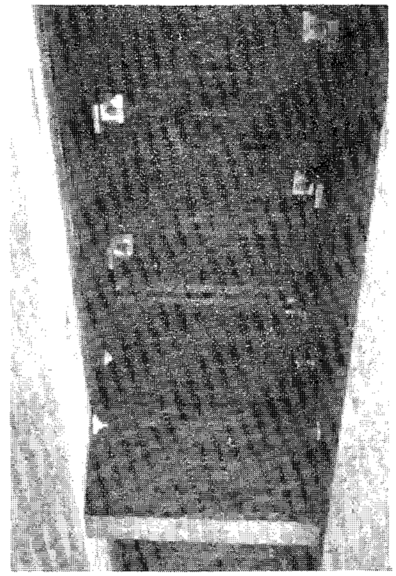
4. **Uses** - Can be found on local roads and secondary roads as well as in park settings.

See Slide 7-3-4

B. PRIMARY MEMBERS

- **Beams**

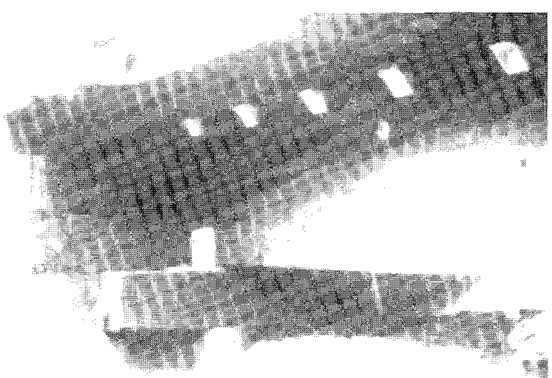
Slide No. 7-3-5
Example Slide
Typical glulam diaphragm



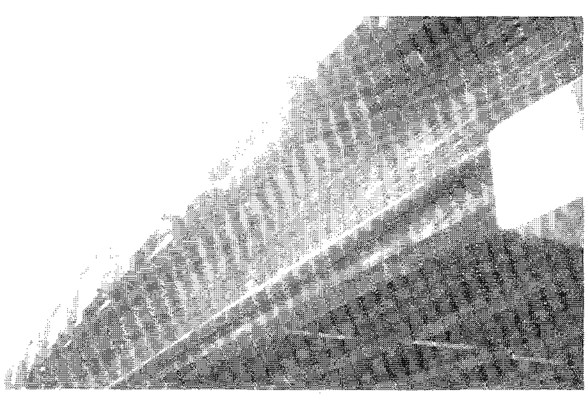
Glulam Multi-beams

- Design Characteristics
- Inspection Locations and Procedures

Slide No. 7-3-6
Title Slide



Slide No. 7-3-7
Example Slide
Bearing area of typical glulam beam



Slide No. 7-3-8
Example Slide
Glulam multi-beam bridge
elevation view of beam

C. SECONDARY MEMBERS

See Slide 7-3-5

- **Diaphragms/cross bracing**

  Due to the larger depth of the glulam beams, diaphragms/bracing should always be present. These may be constructed of either short glulam members (diaphragms) or from steel angles (cross bracing).

II. INSPECTION LOCATIONS AND PROCEDURES

Since these superstructures are very similar to solid sawn multi-beam superstructures, the inspection locations and procedures for glulam multi-beams are virtually the same as those for solid sawn multi-beams.

A. BEARING AREAS

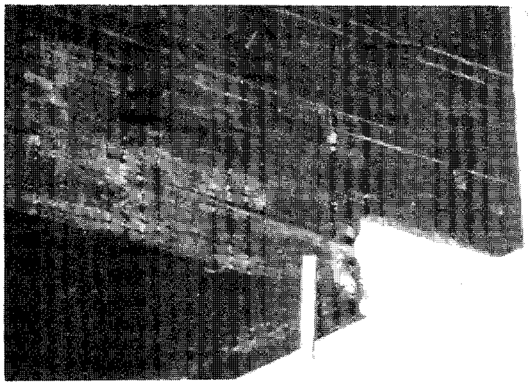
See Slide 7-3-7

- Check for crushing of beams.
- Check for decay and insect damage at the ends of the beams.
- Check condition of any bearing devices.

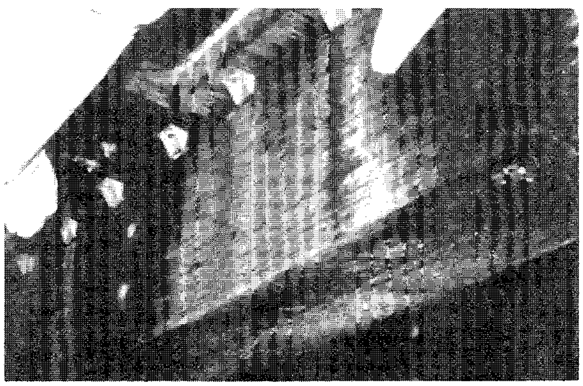
B. BEAMS

See Slide 7-3-8

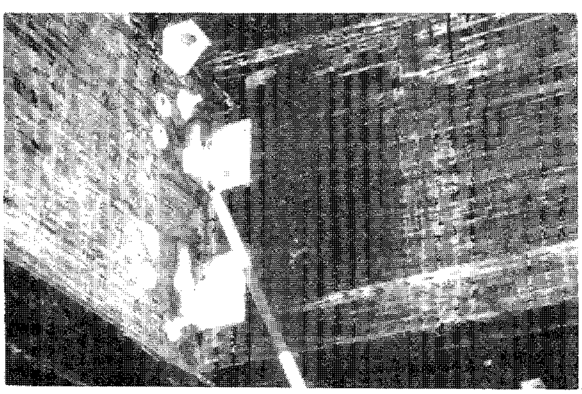
- Examine maximum shear zones (ends of beams) and tension zones (middle of beam, bottom half) for signs of structural distress.
- Check maximum stress areas (middle, ends) for section loss due to decay or fire.



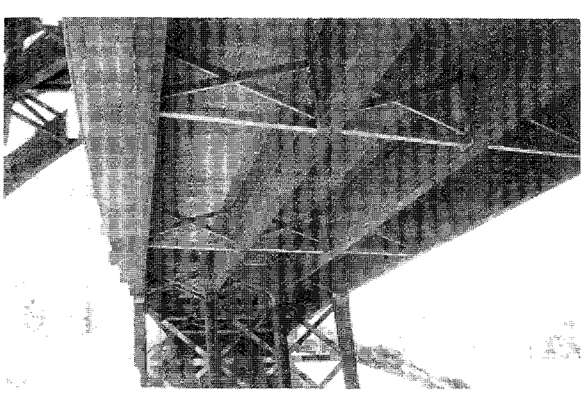
Slide No. 7-3-9
Example Slide
Close up of end of glulam bridge (showing laminations)



Slide No. 7-3-10
Example Slide
Decay on glulam beam



Slide No. 7-3-11
Example Slide
Typical diaphragm



Slide No. 7-3-11A
Example Slide
Glulam beams with numerous fastener locations (Keystone, South Dakota)

- Check for horizontal shear cracks and delaminations near the ends of the beams.

See Slide 7-3-9

Delamination - is a separation of the laminas due to either failure of the glue or at the bond between the glue and the lamina.

Most serious delaminations extend completely through the cross section of the member. This tends to make the member in that area act as two smaller members.

The closer delaminations are located to the center of the cross section, the more serious they are.

Delaminations directly through a connector are also undesirable.

See Slide 7-3-10

- Check for signs of decay, chemical attack, or insect damage along the full length of the member but especially where the beam is subjected to repeated wetting or prolonged exposure to moisture.
- Check for excessive deflection or sagging in the beams.
- Check beams in overhead structures for collision damage from vehicles passing below.

C. DIAPHRAGMS/BRACING

See Slide 7-3-11

- Check solid sawn or glulam diaphragms for decay, fire damage, insect damage, etc.
- Check steel cross bracing for corrosion and bowing or buckling.
- Examine connections for tightness, cracks/splits and corroded or missing fasteners.

Show Slide 7-3-11A

D. FASTENERS/CONNECTORS

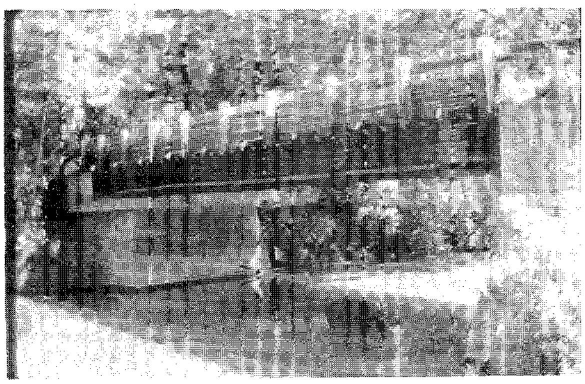
- Check all fasteners for corrosion, tightness, missing parts.

Glulam Multi-beams

- Design Characteristics
- Inspection Locations and Procedures
- Application of Rating Guidelines

Slide No. 7-3-12

Title Slide



Slide No. 7-3-13

Example Slide

General elevation view

Slide No. 7-3-14

Example Slide

Approach to bridge

III. APPLICATION OF RATING GUIDELINES

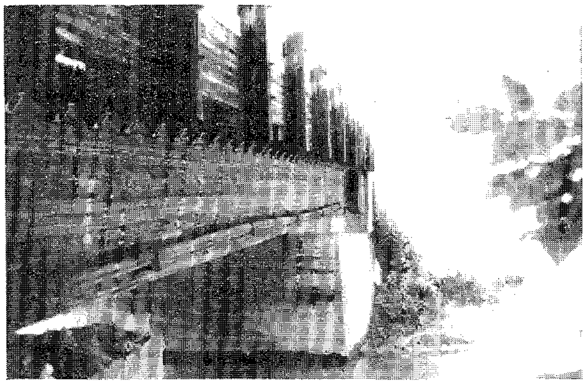
A. EXERCISE NO. 1

See Slide 7-3-13

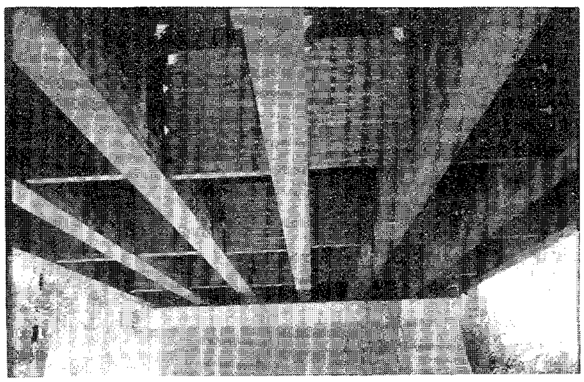
1. Examination

See Slide 7-3-14

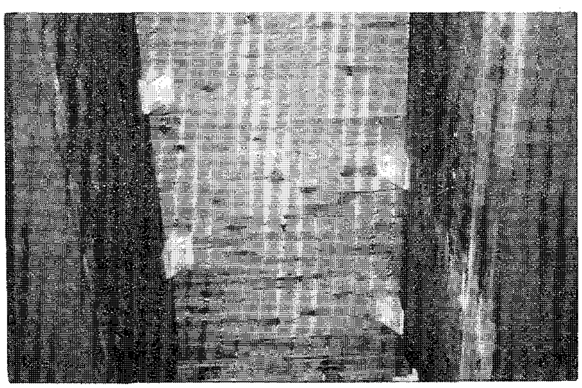
This bridge is a single span glulam multi-beam bridge which carries Township Road T372 over Slippery Rock Creek. The bridge was last inspected in September, 1990.



Slide No. 7-3-15
Example Slide
Typical fascia beam elevation



Slide No. 7-3-16
Example Slide
Typical underside view



Slide No. 7-3-17
Example Slide
Typical underside view of beams and deck (close-up)

Rating Reasoning

Slide No. 7-3-18
Title Slide

The areas inspected include:

See Slide 7-3-15

- Maximum shear zones at the beam ends, near the supports. No deficiencies were found.

See Slide 7-3-16

- Maximum flexure (bending moment) zones near mid-span of the beams. No deficiencies were observed except scattered water staining on the beams.

See Slide 7-3-17

- Close-up inspection of the stained areas indicated no decay had begun yet on the beams. Diaphragms were also found to be free of defects.

2. Rating Reasoning

SESSION 7: TIMBER SUPERSTRUCTURES — CASE 1

TOPIC 3: GLULAM BEAMS

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- This bridge is a single span glulam multi-beam bridge which uses 7 beams to carry a 26 foot wide deck for a 70 foot span.

CONDITION STATE SUMMARY:

- Maximum shear zones at the beam ends, near the supports. No deficiencies were found.
- Maximum flexure (bending moment) zones near mid-span of the beams. No deficiencies were observed except scattered water staining on the beams.
- Close-up inspection of the stained areas indicated no decay had begun yet on the beams. Diaphragms were also found to be free of defects.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States 1	2	3	4	5
CoRe Elements							
Other Elements							
Smart Flags							

SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

TOPIC 4: TRUSSES AND COVERED BRIDGES

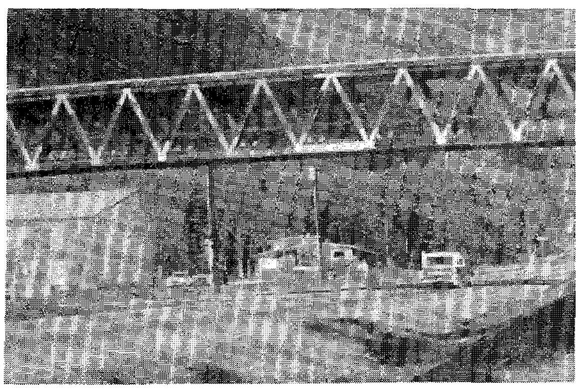
LESSON PLAN

TOPIC DURATION	30 minutes
PREREQUISITES	Participant should be familiar with the identification and components of a timber truss bridge and have an understanding of various timber defects.
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 8
GOAL	Recognition of the important areas for inspection of timber truss bridges and evaluation of any defects found.
OBJECTIVE	To introduce the location of significant inspection areas of timber truss bridges; the evaluation and rating of these bridges in regards to any defects found and properly document the defects.
PARTICIPATION	Participants will be asked to discuss their evaluation and rating of a timber truss bridge.
REFERENCES	1. U.S. Forest Service. Timber Bridges - Design, Construction, Inspection, and Maintenance. Washington, D.C.: United States Department of Agriculture, 1990.

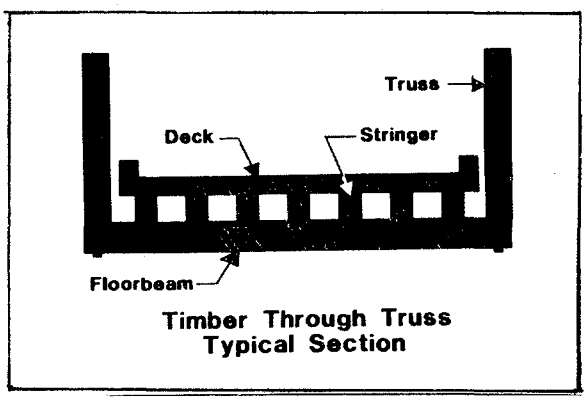
Timber Trusses

- Design Characteristics

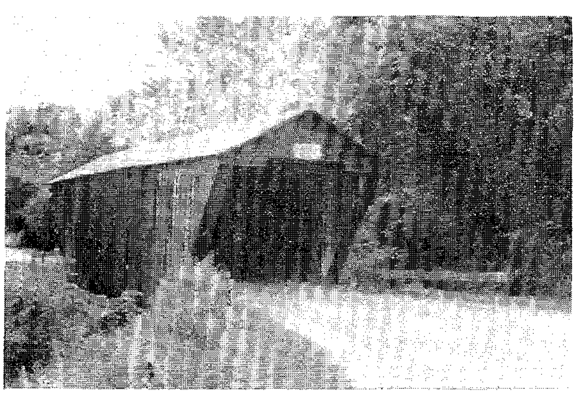
Slide No. 7-4-1
Title Slide



Slide No. 7-4-2
Example Slide
Timber truss pedestrian bridge
(Eagle River, Alaska)



Slide No. 7-4-3
Schematic Slide
Timber truss bridge typical section



Slide No. 7-4-4
Example Slide
Town lattice truss covered bridge

I. DESIGN CHARACTERISTICS

A. GENERAL

1. Modern Timber Trusses

See Slide 7-4-2

- Generally are used for spans that are not economically feasible for multi-beam bridges. Timber trusses are practical for spans that range from 150 to 250 feet (46 to 76 m).

- Trusses may be through type or they may be deck type.

- Two of the more popular truss configurations used are the bowstring truss and the parallel chord truss.

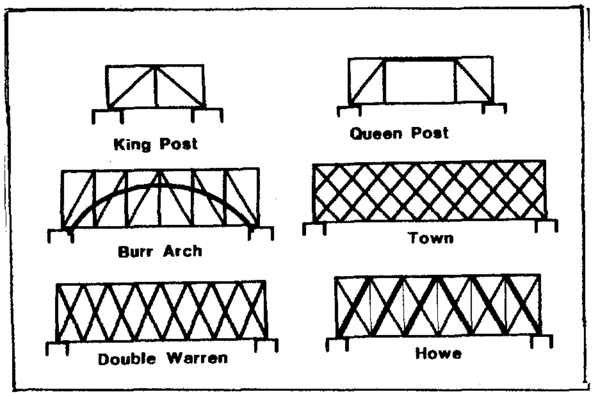
See Slide 7-4-3

- Trusses may be constructed of solid sawn members, glulam members, or both. Usually, the floor system consists of a timber deck supported by timber stringers and floorbeams, all of which are supported by the trusses.

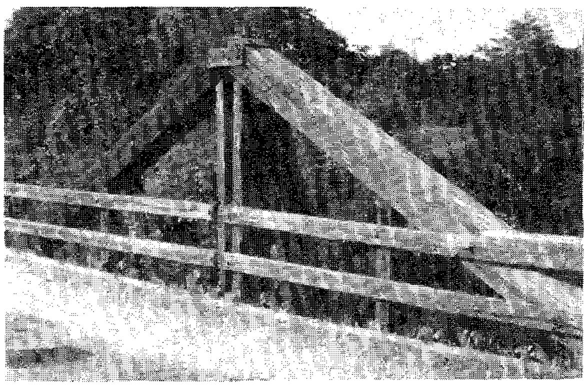
2. Covered Bridges

See Slide 7-4-4

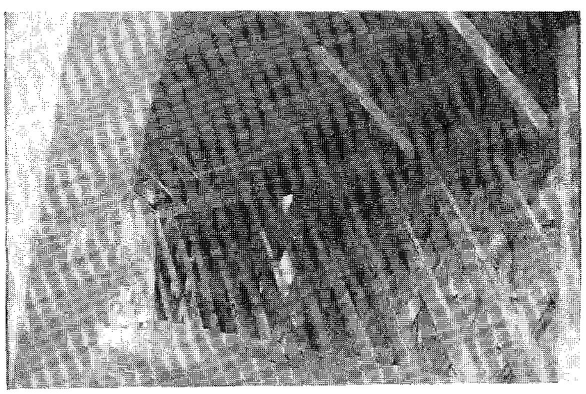
- Solid sawn timber trusses are the main supporting elements of these historic structures. Floor system consists of timber deck, stringers, and floorbeams.



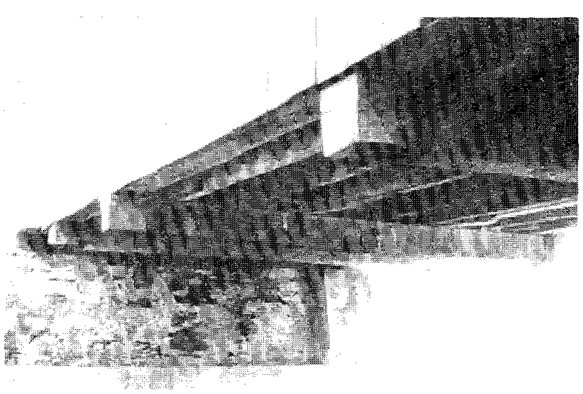
Slide no. 7-4-5
Schematic Slide
Common covered bridge trusses



Slide No. 7-4-6
Example Slide
King post truss



Slide No. 7-4-7
Example Slide
Covered bridge
inside view



Slide No. 7-4-8
Example Slide
Covered bridge
underside view

See Slide 7-4-5

- Typical truss types for covered bridges include the king-post, queen-post, Burr arch-truss, Town, Warren, and the Howe.

See Slide 7-4-6

- Span lengths of the remaining authentic covered bridges are generally in the range of 50 to 100 feet (15 to 30 m), although many are well over 100 feet (30 m) and some span over 200 feet (61 m).

- Generally found on rural, low volume roads and are usually owned by local municipalities although some are owned by states or private individuals. Some still carry highway traffic but many are open only to pedestrians.

- Covers on the bridges prevented decay of the trusses and undoubtedly are responsible for the longevity of these American artifacts.

- Authentic covered bridges were built during the 1800's and early 1900's, however, there are a number of new covered bridges being built today.

See Slide 7-4-7

B. PRIMARY MEMBERS

- Trusses
- Stringers
- Floorbeams

See Slide 7-4-8

C. SECONDARY MEMBERS

- Diaphragms/cross bracing - between stringers
- Lateral bracing - between trusses

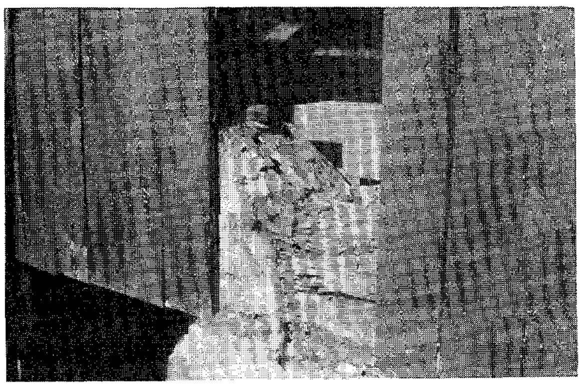
D. MISCELLANEOUS

- Covers (roof and sides) on covered bridges.

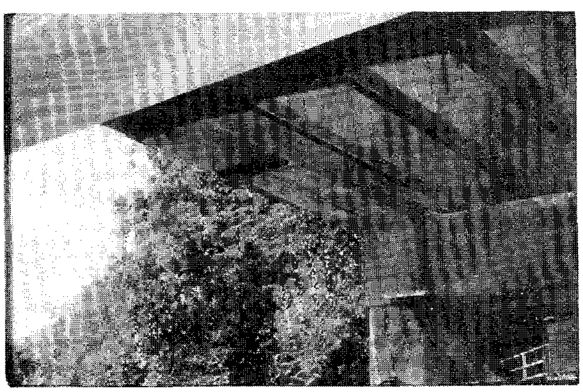
Timber Trusses

- Design Characteristics
- Inspection Locations and Procedures

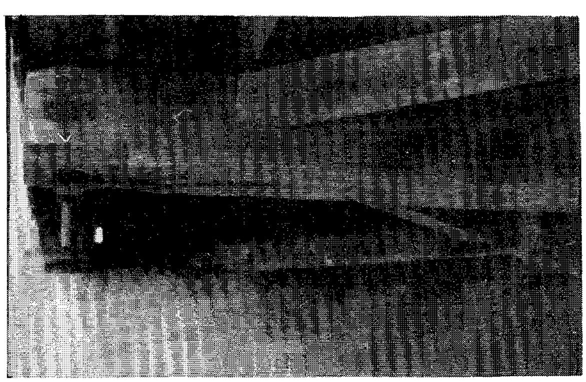
Slide No. 7-4-9
Title Slide



Slide No. 7-4-10
Example Slide
Bearing area of typical truss



Slide No. 7-4-11
Example Slide
Typical stringer



Slide No. 7-4-12
Example Slide
Typical floorbeam

II. INSPECTION LOCATIONS AND PROCEDURES

See Slide 7-4-10

A. BEARING AREAS

- Check for crushing of the bottom chord; also, at the ends of the stringers if they rest directly upon the abutment. Also, check for crushing in the stringers where they bear on the floorbeams.
- Check for decay and insect damage at the ends of the stringers, floorbeams and trusses.
- Check the condition of any bearing devices present under the ends of the trusses.

B. STRINGERS

See Slide 7-4-11

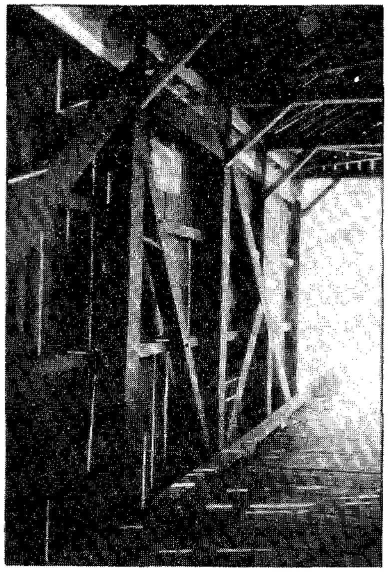
Should be inspected in a manner very similar to that used for multi-beam bridges:

- Examine the maximum shear zones (ends) and tension zones (middle) for signs of structural distress.
- Check entire stringer for signs of decay, fire damage, or chemical attack, paying particular attention to the areas that are subjected to repeated wetting or prolonged exposure to moisture.
- Check for excessive deflection or sagging.

See Slide 7-4-12

C. FLOORBEAMS

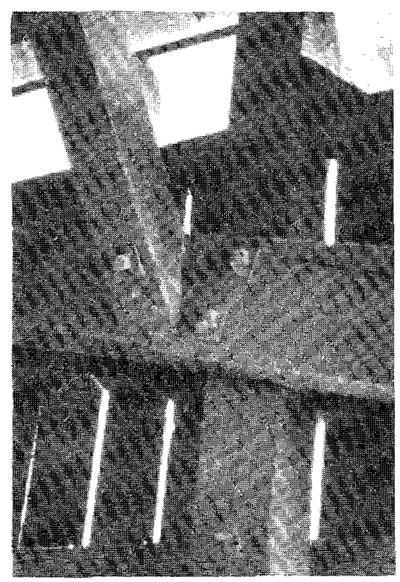
- Examine floorbeams for decay, fire damage, chemical attack, deflection, and structural distress similar to the stringers.
- Check the ends of the floorbeams where they are connected to the truss very closely for checks and splits, since these defects can seriously weaken the connection.



Slide No. 7-4-13
Example Slide
Inside elevation of typical truss

Slide No. 7-4-13A
Example Slide
Timber truss alignment

Slide No. 7-4-14
Example Slide
Close up of ends of truss members



Slide No. 7-4-15
Example Slide
Collision damage on truss

See Slide 7-4-13

D. TRUSSES

1. **Truss Members** - Examine the various truss members for decay, fire damage and insect damage as with all timber members. Pay close attention to the ends of the members at the connections where moisture can become trapped.

See Slide 7-4-13A

2. **Alignment** - Check both the vertical and horizontal alignment of the trusses to see if any permanent misalignment has occurred. Also, check for excessive live load deflection as traffic crosses the structure.

See Slide 7-4-14

3. **Checks and Splits** - Examine all of the members for checks and splits. Normally, checks are of relatively little importance unless they become water traps. However, depending upon the type of stress in the member, their presence may be significant.

   - At the ends of members stressed in compression parallel to the grain, such as top chords, checks and splits are relatively unimportant provided they have caused no slippage in the connections.
   - At the ends of members stressed in tension parallel to the grain, such as bottom chords, splits may be significant if they occur within the connector area.
   - For end splits in either tension or compression members with connector loads acting in a direction other than parallel to the grain, the splits may or may not be significant.
   - In any case, all splits and checks at the ends of members should be noted.

See Slide 7-4-15

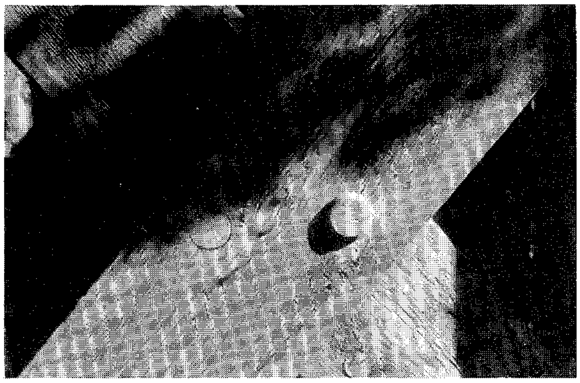
4. Examine through trusses for collision damage from vehicular impacts.

E. DIAPHRAGMS/CROSS BRACING

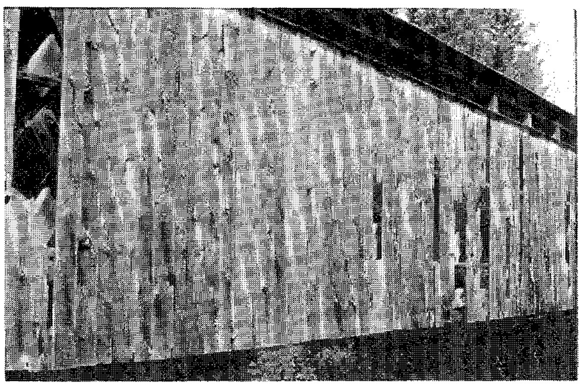
- If timber diaphragms are present between the stringer, check them for decay, chemical attack, and fire damage.
- Check connections to the stringers for tightness, checks/splits, and corroded or missing fasteners.

F. LATERAL BRACING

- Lateral bracing may be wood or metal (steel or wrought iron).
- Examine bracing for bowing or buckling.



Slide No. 7-4-16
Example Slide
Typical truss connection



Slide No. 7-4-17
Example Slide
Close-up of covered bridge cover

- Check timber bracing for decay, fire damage, chemical attack, etc.
- Check metal bracing for corrosion and section loss.
- Check bracing connections to trusses for tightness, deterioration, and missing fasteners.

See Slide 7-4-16

G. CONNECTIONS

- Check all connections for any signs of weakness or slippage.
- Check metal fasteners for corrosion, section loss, and missing fasteners.
- Check wooden peg type fasteners for decay, splits, etc.

H. COVERED BRIDGE COVERS

See Slide 7-4-17

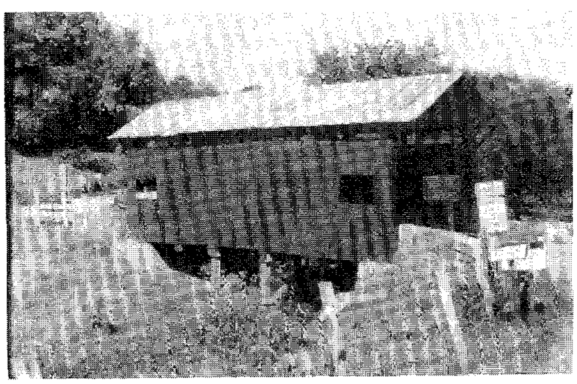
- Check roof for leaks (may be hard to do unless it's raining during the inspection).
- Check overall physical condition of the roof and side coverings, noting the condition of the siding and roof, paint, and fasteners.

Timber Trusses

- Design Characteristics
- Inspection Locations and Procedures
- Application of Rating Guidelines

Slide No. 7-4-18

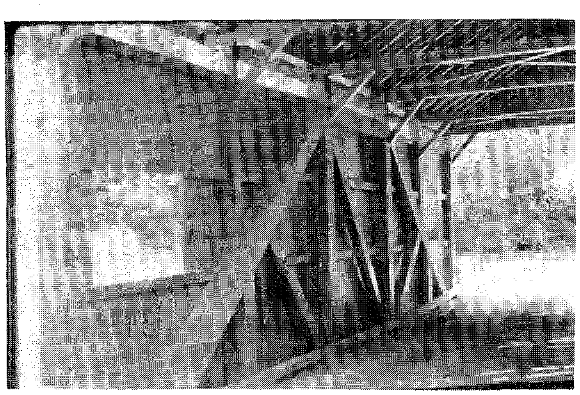
Title Slide



Slide No. 7-4-19

Example Slide

General elevation view



Slide No. 7-4-20

Example Slide

Typical truss elevation (inside)

III. APPLICATION OF RATING GUIDELINES

A. EXERCISE NO. 1

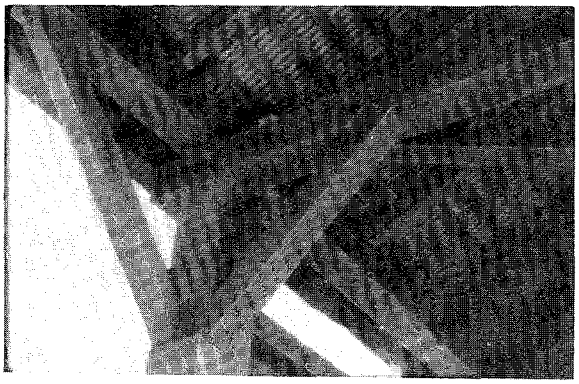
See Slide 7-4-19

See Slide 7-4-20

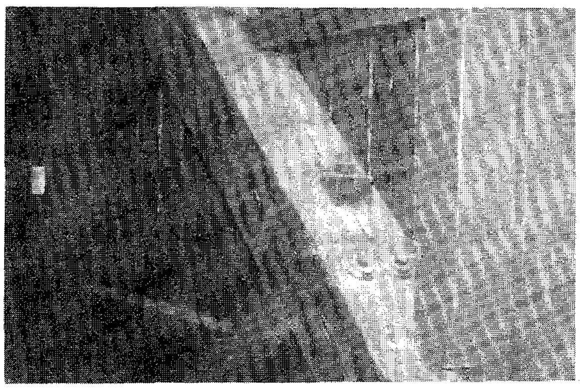
1. Examination

This structure is a simple span timber through truss constructed around 1898. It carries Township Road T301 over Two Mile Creek. The truss is the queen post type. It was last inspected in September, 1990.

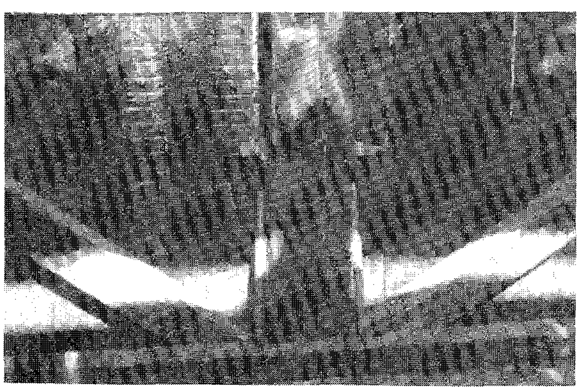
The timber bents supporting the bridge near the center of the span are temporary supports.



Slide No. 7-4-21
Example Slide
Typical bracing at top of truss



Slide No. 7-4-22
Example Slide
Typical end post of truss



Slide No. 7-4-23
Example Slide
Typical bottom chord panel point and floorbeam hanger rods

Deficiencies include:

See Slide 7-4-21

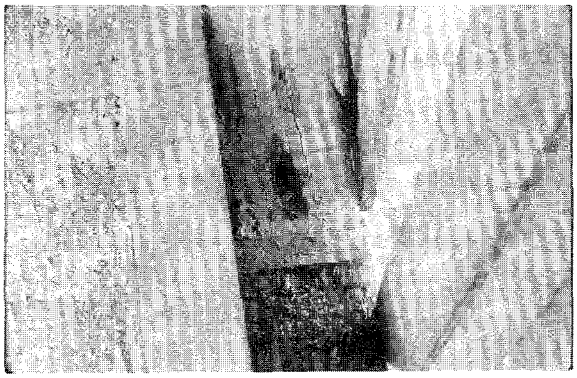
- The upper lateral bracing system was found to be in good condition only very minor defects.

See Slide 7-4-22

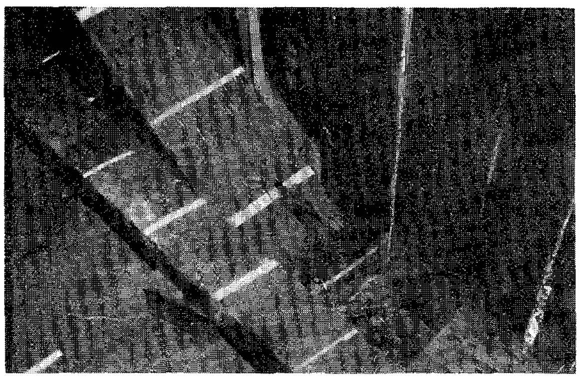
- The top chord and end post truss members were generally in good condition.

See Slide 7-4-23

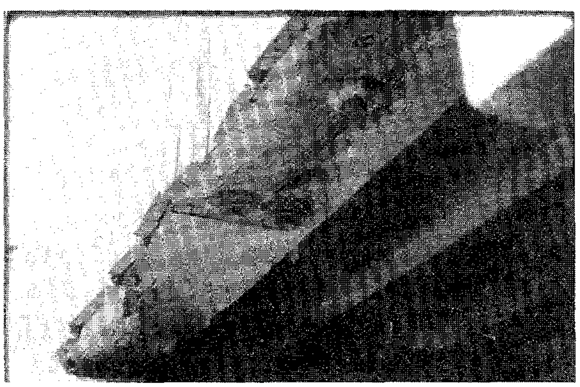
- The truss web members, connections, and floorbeam hanger connections were in relatively good condition due to the protection afforded by the bridge covering.



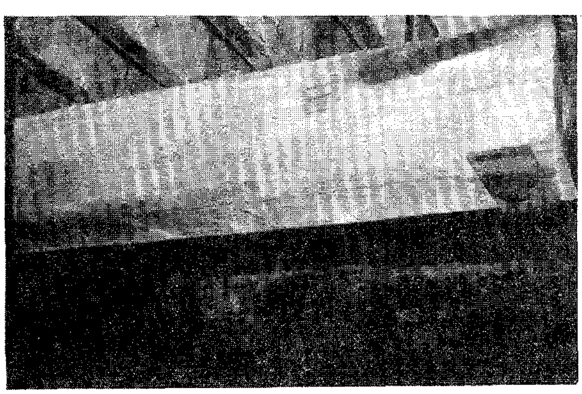
Slide No. 7-4-24
Example Slide
Bottom of one end post (bearing area)



Slide No. 7-4-25
Example Slide
Bottom of another end post (bearing area)



Slide No. 7-4-26
Example Slide
Typical underside of bottom chord



Slide No. 7-4-27
Example Slide
Typical floorbeam

See Slide 7-4-24

See Slide 7-4-25

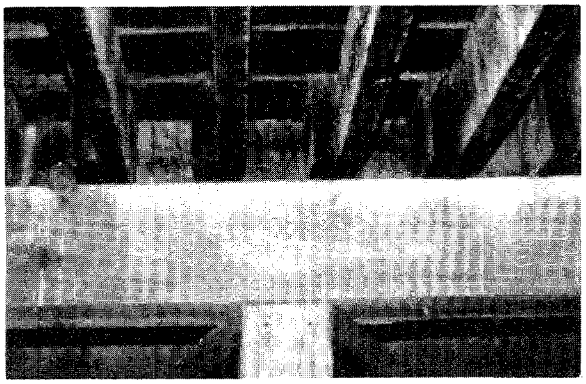
- The bottoms of the end posts and truss bearing areas were in poor condition with severe decay and minor crushing of the wood. This condition was typical at all four end posts. Structural capacity of the structure has been affected.

See Slide 7-4-26

- The underside of the bottom chord is fair as it typically exhibited some decay along its length, but particularly at the support where it meets the bottom of the end post.

See Slide 7-4-27

- Floorbeams typically were in fair condition with numerous surface checks.



Slide No. 7-4-28
Example Slide
Typical stringers

Rating Reasoning

Slide No. 7-4-29
Title Slide

See Slide 7-4-28

- Stringers were also fair with molds and stains common throughout. Also, some exhibited minor decay at the abutments.

2. **Rating Reasoning**

SESSION 7: TIMBER SUPERSTRUCTURES — CASE 1

TOPIC 4: TRUSSES AND COVERED BRIDGES

PONTIS RATING

NARRATIVE WITH QUANTITIES:

- This structure is a simple span timber queen post truss constructed around 1989. The bridge spans 40 ft. with a deck width of 14 ft. The floor system is made up of 6 floor beams, spaced at 8 ft., which support 8 lines of stringers.

CONDITION STATE SUMMARY:

- The upper lateral bracing system was found to be in good condition with only very minor defects.
- The top chord and end post truss members were generally in good condition.
- The truss web members, connections, and floorbeam hanger connections were in relatively good condition due to the protection afforded by the bridge covering.
- The bottoms of the end posts and truss bearing areas were in poor condition with severe decay and minor crushing of the wood. This condition was typical at all four end posts. Structural capacity of the structure has been affected.
- The underside of the bottom chord is fair as it typically exhibited some decay along its length, but particularly at the support where it meets the bottom of the end post.
- Floorbeams typically were in fair condition with numerous surface checks.
- Stringers were also fair with molds and stains common throughout. Also, five exhibited minor decay at the abutments.

BMS Condition Report:

Element	Total Quantity	Unit	Quantities in Condition States 1	2	3	4	5
CoRe Elements							

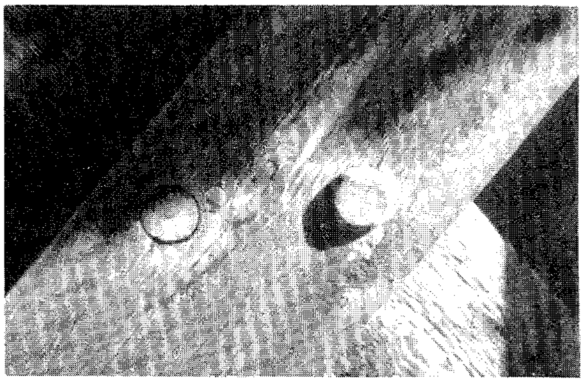
PONTIS PONTIS PONTIS

SESSION 7: INSPECTION AND EVALUATION OF COMMON TIMBER SUPERSTRUCTURES

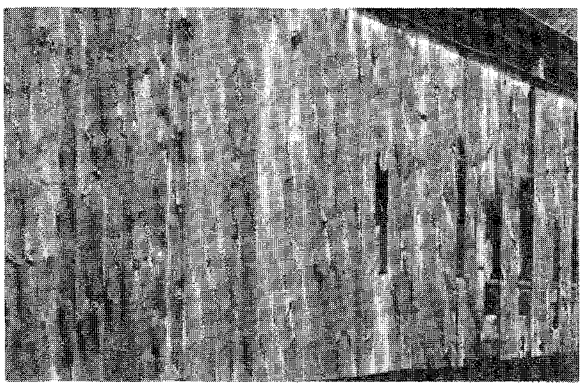
TOPIC 5: PROTECTIVE SYSTEMS FOR TIMBER BRIDGES

LESSON PLAN

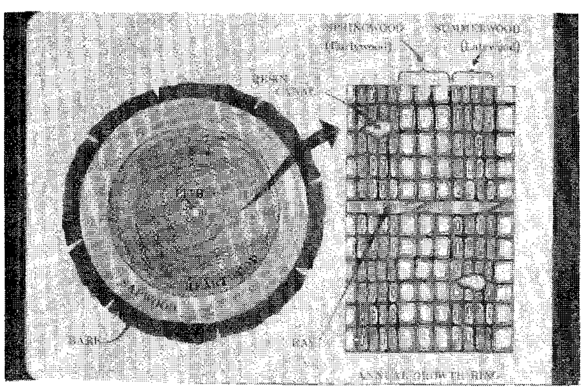
TOPIC DURATION	30 minutes
PREREQUISITES	Participants should be generally familiar with identification of timber bridge components.
PARTICIPANT MATERIALS	Participant Notebook, BITM 90 - Chapter 16
GOAL	Recognition of the important areas for inspection of timber bridge protective systems, methods of evaluation, and recognition of failure types.
OBJECTIVE	To be able to inspect protective systems used on timber bridge members. Evaluate these systems and types of failures.
REFERENCES	1. U.S. Forest Service. Timber Bridges - Design, Construction, Inspection, and Maintenance. Washington, D.C.: United States Department of Agriculture, 1990.



Slide No. 7-5-1
Example Slide
Solid timber bridge members sawn from the heartwood



Slide No. 7-5-2
Example Slide
Covered bridge covers provide protection from weathering



Slide No. 7-5-3
Schematic Slide
Anatomy of wood

Timber Deterioration

- Physical Agents: heat, abrasion, sunlight
- Biotic Agents: decay, fungi, bacteria, insects, marine borers

Slide No. 7-5-4
Narrative Slide
Causes of timber deterioration

I. INTRODUCTION

See Slide 7-5-1

See Slide 7-5-2

See Slide 7-5-3

Wood has been successfully used as a bridge material for thousands of years, but before the early 1900's most structures were built of untreated timber. Protection from decay and deterioration was afforded by using the heartwood of naturally durable species or by covering the structure to protect it from weathering. Although many bridges constructed of untreated timber performed well (some lasting longer than 100 years), the use of untreated timber declined as naturally resistant North American wood species became unavailable in the quantities and sizes necessary for bridge construction. Additionally, it became economically and functionally impractical to cover timber bridges for protection. In spite of the attractiveness of using naturally durable wood, modern timber bridges must be preservatively treated to obtain adequate performance.

A. STRUCTURE OF WOOD

- Wood is composed of cells, each surrounded by a cell wall.
- The cell walls, made largely of cellulose, provide the strength of wood.
- Wood grows faster in the springtime than in the summer. This causes the ring structure of wood.
- The spring or earlywood is less dense and more porous than the summer latewood.

B. CAUSES OF TIMBER DETERIORATION

Wood will last for centuries if kept dry. However, if it is used in an unprotected environment, it becomes susceptible to attack by living and nonliving agents capable of degrading the wood structure. Nonliving or physical agents, including heat, abrasion, ultraviolet light, and strong chemicals, generally act slowly to decrease wood strength. Although these physical agents may be significant in some applications, the greatest hazard to timber bridges results from living or biotic agents, such as decay fungi, bacteria, insects, and marine borers. These agents can cause serious damage to untreated wood in a relatively short period in a variety of environments.

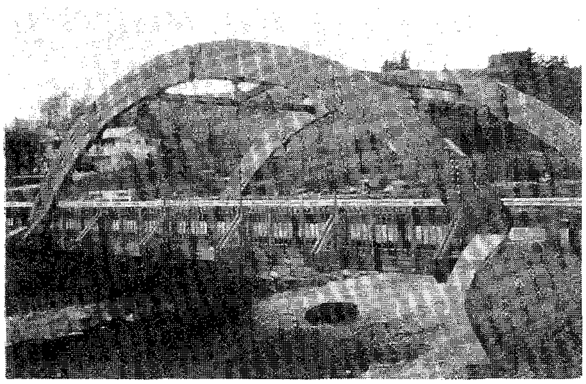
Factors Affecting Timber Deterioration

- Moisture
- Oxygen
- Favorable temperature
- Food source (wood)

Slide No. 7-5-5

Narrative Slide

Conditions for deterioration



Slide No. 7-5-5A

Example Slide

Glulam arch bridge that has been treated with preservative chemicals (Colorado)

Preventing Deterioration with Wood Preservatives

- Oil-type
- Waterborne

Slide No. 7-5-6

Narrative Slide

Types of wood preservatives

C. CONDITIONS FOR DETERIORATION

Most of the biotic agents that enter and decay untreated wood require four basic conditions for survival:

1. **Moisture levels in the wood above the fiber saturation point.**
2. **Oxygen**
3. **Favorable Temperature** (50-90°F) (10-32 °C)
4. **Food** (wood)

See Slide 7-5-5A

D. PREVENTING DETERIORATION

Although most biotic agents can be controlled by limiting moisture, oxygen, or temperature, it is often difficult or impractical to control these conditions. As a result, the most common method for controlling deterioration in adverse environments involves removing the food source by introducing toxic preservative chemicals into the wood cells using a pressure treatment process.

II. WOOD PRESERVATIVES

A. GENERAL

Wood preservatives are toxic chemicals that penetrate and remain in the wood structure. They should not be confused with protective coatings, such as paints or stains, which do nothing to kill or prevent the spread of biotic agents. A wood preservative must have the ability to penetrate the wood and persist in sufficient quantities for long periods. The degree of protection depends on the type of preservative used, the treatment process, the species of wood, and the environment to which the structure will be exposed. Applied correctly, wood preservatives can increase the life of timber structures by as much as five times or more.

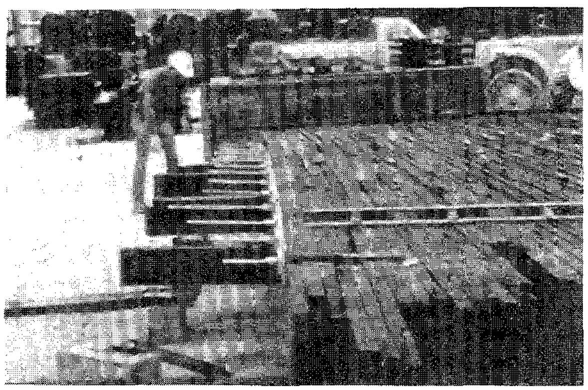
There are two broad classifications of wood preservatives:

1. **Oil-Type Preservatives**
2. **Waterborne Preservatives**

Oil-Type Preservatives

- Creosote
- Penta
- Copper naphthenate

Slide No. 7-5-7
Narrative Slide
Oil-type preservatives



Slide No. 7-5-8
Example Slide
Fabrication of a creosote treated stressed timber deck

B. OIL-TYPE PRESERVATIVES

For bridge applications, oil-type preservatives are used almost exclusively for treating such structural components as beams and decks. They provide good protection from decay and other deterioration, are noncorrosive, and generally afford good physical protection of the wood surface from the effects of weathering.

There are three oil-type preservatives used on bridges:

- Coal-tar creosote (creosote)
- Pentachlorophenol (penta)
- Copper Naphthenate

See Slide 7-5-8

1. **Creosote** - was first patented in 1831, it is a black or brownish oil consisting of a complex mixture of nearly 300 compounds.

   Creosote has a long record of satisfactory use as a wood preservative, with many case histories documenting more than 50 years of proven performance.

   Creosote has performed well in almost every environment except in areas where marine borer hazards are high because of attack by *Limnoria tripunctata* (this species of borer is capable of attacking creosoted wood in warmer marine saltwaters). Creosote provides the added advantages of protecting the wood from the effects of weathering and retarding the checking and splitting associated with changes in moisture content.

   At one time, creosote was the most commonly used wood preservative for timber products, but an increased desire for clean surfaces, coupled with complaints about handling creosoted wood, has led to a gradual decline in the percentage of wood treated with this chemical. Today, creosote is frequently used to treat bridge members.

2. **Penta** - first patented in 1935 is a highly effective wood preservative; however, it is not effective against marine borers.

3. **Copper Naphthenate** - originally developed in the 1940's, copper naphthenate is provided by complexing copper with naphthenic acid derived from petroleum.

Waterborne Preservatives

- CCA
- ACA
- ACZA

Slide No. 7-5-9

Narrative Slide

Waterborne preservatives

Its primary advantage is that it is considered an environmentally safe preservative and it not currently included on the EPA list of restricted-use pesticides.

C. WATERBORNE PRESERVATIVES

Waterborne preservatives include formulations of inorganic arsenical compounds in a water solution. These chemicals leave the wood surface relatively clean with a light green, grey-green, or brown color, depending on the type of chemical used. Unlike most oil-type preservatives, waterborne formulations usually do not cause skin irritations and are suitable for use where limited human or animal contact is likely. After drying, wood surfaces treated with these preservatives can also be painted or stained.

Waterborne preservatives are used most frequently for railings and floors on pedestrian sidewalks or other areas that may receive human contact. In some situations, they are also used to treat laminations for glulam before gluing. Waterborne preservatives are also very effective in treating piling for marine exposures where borer hazards are high.

Waterborne preservatives are not recommended for large glulam members because the wetting and drying process associated with treatment can cause dimensional changes as well as warping, splitting, or cracking of members. Additionally, they provide little resistance to weathering, which may result in more pronounced checking and splitting from moisture changes than would occur with oil-type preservatives.

Of the numerous types of waterborne preservatives, those most commonly used in bridges include:

1. **CCA** - chromated copper arsenate is generally used to treat southern pine, ponderosa pine, and red pine.

2. **ACA** - ammoniacal copper arsenate is the preferred waterborne preservative for difficult-to-treat species, such as Douglas-fir, because it penetrates the wood more effectively.

3. **ACZA** - ammoniacal copper zinc arsenate, also for difficult-to-treat species.

Methods of Applying Preservatives

- Nonpressure
- Pressure

Slide No. 7-5-10

Narrative Slide

Methods of applying preservatives

Nonpressure Methods

- Limited to field application and in-service treatments

Slide No. 7-5-11

Narrative Slide

Nonpressure methods

Pressure Methods

Vacuum and pressure are used to kill fungi growing in the wood and to provide adequate preservative

Slide No. 7-5-12

Narrative Slide

Pressure methods

Full-Cell Process

Coats the wood cell walls and fills the empty cell cavities

Slide No. 7-5-13

Narrative Slide

Full-cell process

III. METHODS OF APPLYING PRESERVATIVES

There are two common methods for applying preservative treatment to wood:

- Nonpressure methods
- Pressure methods

A. NONPRESSURE METHODS

Nonpressure methods include brushing, soaking, dipping, and the thermal process. With the exception of the thermal treatment of western red cedar and lodgepole pine, nonpressure processes are not used to any significant extent to initially treat wood used in bridge construction. Brushing and soaking are used to protect field cuts and bore holes made after pressure treatment.

B. PRESSURE METHODS

Wood used in bridges and other exposed environments is treated by using processes involving combinations of vacuum and pressure in a confined cylinder (retort) to deliver a specified amount of chemical into the wood.

The objectives of the pressure processes are to kill any fungi that may be growing in the wood and ensure that a sufficient amount of preservative is delivered to the proper depth in the wood. The two types of pressure processes are:

1. **Full-Cell Process** - In the full cell process, wood preservative coats the wood cell walls and, to various degrees, fills the empty cell cavities.

   The full-cell process produces the maximum solution retention for a given depth of penetration and is most often used for treatments with waterborne preservatives and for treating marine piling with creosote.

   With the exception of wood members in ground contact in areas of high decay hazard, the full-cell process is not recommended for timber bridge members treated with creosote or other oil-type preservatives. High retentions of oil-type preservative in cell cavities can result in excessive bleeding of preservatives on the wood surface.

Empty-Cell Process

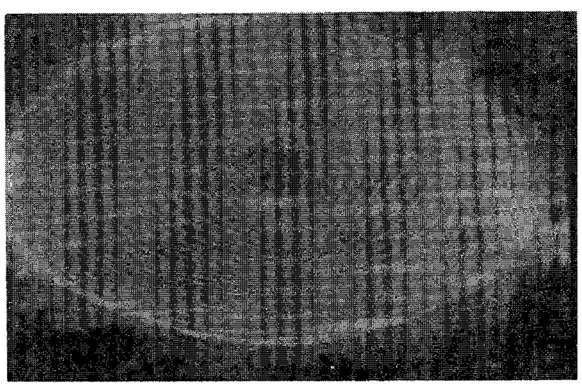
The cell walls are penetrated, but the cell cavities are empty of preservatives

Slide No. 7-5-14
Narrative Slide
Empty cell process

Material Preparation

Enhances penetration and retention of preservatives

Slide No. 7-5-15
Narrative Slide



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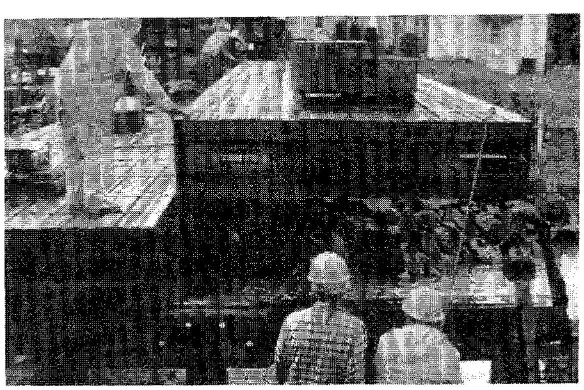
Example Slide
Log with bark still intact



Slide No. 7-5-17
Example Slide
Erection of a prefabricated section of a stressed timber box beam bridge

2. **Empty-Cell Process** - In the empty-cell processes, the cell walls also are penetrated, but the cell cavities are left relatively empty of preservative.

The empty-cell processes do not use the initial vacuum treatment employed in the full-cell process.

Empty-cell processes are used for oil-type treatment of sawn lumber, glulam, piling, and poles. The objective of the processes is to achieve deep penetration with a relatively low net retention. As a result, the potential for substantial surface bleeding of preservative is less than with a full-cell process. It is recommended that empty-cell processes be used for all bridge treatments involving oil-type preservatives, provided retention requirements can be met.

C. MATERIAL PREPARATION

There are a number of mechanical processes that can substantially improve preservative treatment by enhancing penetration and retention of preservatives, providing maximum protection. These processes include:

See Slide 7-5-16

1. **Debarking** - one of the first processing steps in preservative treatment involves removal of the bark. This zone contains cells that are extremely resistant to fluid flow and can leave untreated, decay-susceptible sapwood pockets near the wood surface.

See Slide 7-5-17

2. **Prefabrication** - one of the most damaging, yet common, practices in the construction of timber bridges is field fabrication of treated wood (for example, attaching connectors or other wood members). Preservative treatment creates an envelope of protection around the wood. Any field fabrication involving cutting or drilling after treatment breaks this envelope, exposing untreated wood to attack by decay fungi and insects. All timber members should be fabricated before preservative treatment.

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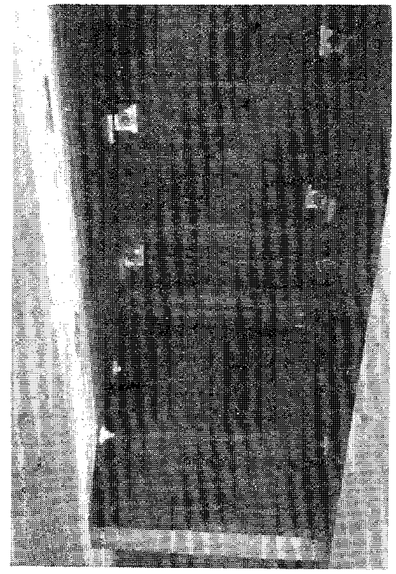
Example Slide

Closeup of incising marks



Material Preparation

- Debarking
- Prefabrication
- Incising
- Radial Drilling
- Through Boring
- Kerfing
- Conditioning

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Narrative Slide

Material preparation processes

See Slide 7-5-18

3. **Incising** - the sapwood of most species is easily penetrated by liquids, but adequate penetration of species containing mostly heartwood can pose much difficulty. Because fluids move more easily through end-grain, one approach to improving the preservative penetration of these species is to increase the amount of cross-sectional area exposed to the fluid. This can be accomplished by cutting or boring a series of slits or holes into the wood. This practice, called incising, is required for the adequate treatment of many wood species and results in a deeper, more uniform treatment.

   Incising is most commonly performed by pressing teeth into the wood surface to a predetermined depth, generally 1/4 to 3/4 inch (6 mm to 19 mm).

   When large, glued-laminated members exceed the size capacity of incising equipment, individual laminations should be edge incised before gluing, or the entire member manually incised after gluing.

4. **Radial Drilling** - In some applications, incising can be replaced by radial drilling. In this process, a series of small-diameter holes are drilled into the sapwood to the desired depth of treatment in high-decay-hazard areas. It also may be used for the treatment of piling but is not commonly used for sawn lumber or glued-laminated timber.

5. **Through-Boring** - This process involves drilling a series of angled holes through the wood approximately 4 feet above and below the theoretical groundline. Through-boring can result in nearly complete preservative penetration.

6. **Kerfing** - Most large wood members cannot be fully dried before preservative treatment. As a result, the wood continues to dry in service, resulting in splitting and checking from shrinkage. These cracks penetrate beyond the preservative-treated shell of the wood member, providing avenues of entry for decay organisms. One method for limiting check development is to saw a narrow, longitudinal kerf to the center of the wood before preservative treatment. The kerf serves to allow some movement and relieve stresses from dimensional changes (shrinkage) that would otherwise cause the wood member to check. Although not commonly used in bridge applications, kerfing seems to work equally well in round or sawn timbers. While kerfing may reduce wood strength, the presence of a deep split has the same effect and, with kerfing, the location of the split can be controlled to minimize strength effects.

In-Service Treatments

- Surface treatments
- Fumigants

Slide No. 7-5-20
Narrative Slide
In-service treatments

7. **Pretreatment Conditioning** - Conditioning is the process used to reduce the moisture content of wood before preservative treatment. Although there are many methods of conditioning, the four most common methods are:

- Air drying - 6 months to 3 years
- Kiln drying - 110° to 180°F (43 °C to 82 °C)
- Steaming - heated to temperatures up to 245°F (118 °C) for several hours
- Boulton drying - heating the wood in oil under vacuum for 24 to 48 hours

IV. IN-SERVICE TREATMENT

In-service treating involves the application of preservative chemicals to prevent or arrest decay in existing structures. A large number of timber bridges have been treated in-service, extending service life by as much as 20 years or more.

Two types of treatment are common:

- Surface treatments
- Fumigants

A. SURFACE TREATMENTS

Surface treatments are applied to existing bridge members to protect newly exposed, untreated wood from decay or to supplement the initial treatment some years after installation. This type of treatment is most effective when applied before decay begins and is commonly used for treating checks, splits, delaminations, mechanical damage, or areas that were field-fabricated during construction. The ease of application and effectiveness of surface treatments as toxic barriers make them useful in preventive maintenance; however, the shallow penetration limits their effectiveness against established internal decay.

Conventional liquid wood preservatives are applied by brushing, squirting, or spray-flooding the wood surface. Creosote heated to 150° to 200°F (66 °C to 93 °C) is probably the most commonly used preservative, but penta and copper naphthenate are also used.

Summary

- Wood Preservatives
- Methods of Applying Preservatives
- In-Service Treatment

Slide No. 7-5-21

Title Slide

It is recommended that surface treatments used for bridge applications be systematically reapplied at intervals of 3 to 5 years to ensure adequate protection from decay.

B. FUMIGANTS

Fumigants are specialized preservative chemicals in liquid or solid form that are placed in prebored holes to arrest internal decay. Over a period of time, the fumigants volatilize into toxic gases that move through the wood, eliminating decay fungi and insects. Fumigants can diffuse in the direction of the wood grain for 8 feet (2440 mm) or more from the point of application in vertical members, such as piles. In horizontal members, the distance of movement is approximately 2 to 4 feet (610 to 1220 mm) from the point of application. Immediately after placing the chemicals, the hole is plugged with a tight-fitting, treated-wood dowel.

Fumigants will eventually diffuse out of the wood, allowing decay fungi to recolonize. Retreatment can be made at periodic intervals in the same holes used for the initial treatment. It is recommended that a 10-year treatment cycle be used with a regular inspection program at 5-year intervals.

V. SUMMARY

A. WOOD PRESERVATIVES

B. METHODS OF APPLYING PRESERVATIVES

C. IN-SERVICE TREATMENT