INSPECTION OF STEEL GIRDER BRIDGES

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Introduction

Topics Covered in this Presentation:

- Bridge superstructure systems
- Defects in steel members
- Failure mechanics
- Fatigue
- Constrained Induced fracture (CIF)
- Inspection
- Inspection of Pin & Hanger

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Bridge Superstructure Systems

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Bridge Superstructure Systems

1. Rolled beams
   - Manufactured from one piece of steel
   - Webs are stocky, therefore no intermediate stiffeners.
   - Used as simple spans with span length from 9 to 15 m
2. Rolled beams with cover plates
   - Cover plates were added to increase the capacity
   - Cover plates were welded or riveted to the flanges
   - Welded cover plates created fatigue prone detail

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Bridge Superstructure Systems

Rolled Beam

Bridge Superstructure Systems

Rolled Beam with Cover Plates

Bridge Superstructure Systems

Steel Tub Girders

Bridge Superstructure Systems

3. Built-up Girders
   - Similar in appearance as rolled beams
   - Custom fabricated, not produced in rolling mills
   - Fabricated from thin plates, hence require stiffeners
   - Older built-up girders were riveted, newer are welded plates
   - Continuous girders can have spans over 150 m

Bridge Superstructure Systems

Built-up Girders

Bridge Superstructure Systems

4. Girders with Pin and Hanger
   - Analysis is simplified for a hinged structure
   - It moves drainage away from piers
   - Only one pin is required for rotation
   - For translation and rotation, two pins and hanger are provided

5. Steel Arches
   - Three types of arches: deck, through and tied
   - Arch spans range from 300 to 500 m

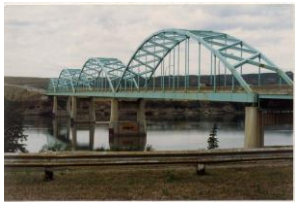
Bridge Superstructure Systems

Girder with Pin & Hanger

Bridge Superstructure Systems

Girder with Pin

Bridge Superstructure Systems



Steel Arch

Bridge Superstructure Systems

6. Suspension Bridges

7. Trusses
   - Through Truss
   - Pony Truss
   - Deck Truss

Bridge Superstructure Systems

Suspension Bridge

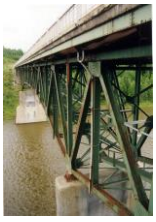
Bridge Superstructure Systems

Through Truss

Bridge Superstructure Systems

Pony Truss

Bridge Superstructure Systems



Deck Truss

Primary and Secondary Members

Primary Members for Bridge Systems 1 to 4

- Fabricated girders / Rolled beams
- Diaphragms for curved girders
- Pin and hanger

Secondary Members for Bridge Systems 1 to 4

- Diaphragms

Primary and Secondary Members

Primary Members for Bridge System 7

- Trusses (chords, web members)
- Floor beams
- Stringers

Secondary Members for Bridge System 7

- Bracing

Defects in Steel Members

Steel Damage and Deterioration

- Corrosion
  - Environmental corrosion
  - Stray current corrosion
  - Stress corrosion
- Cracking
  - Fatigue
  - Impact
  - Excessive loading
- Deformation
  - Excessive Loading
  - Impact
  - Heat Damage

Steel Damage and Deterioration

Corrosion

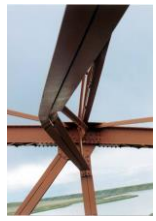
Steel Damage and Deterioration

Corrosion

Steel Damage and Deterioration

Fatigue Crack

Steel Damage and Deterioration



High Load
Impact Damage

Steel Damage and Deterioration

Impact Damage

Steel Damage and Deterioration

90% failure of
diagonal – wide load
impact damage

Steel Damage and Deterioration

Fire Damage

Steel Damage and Deterioration

Fire Damage

Steel Damage and Deterioration

Overload Damage

Fatigue & Fracture in Steel Members

Fatigue

- Tendency of a member to fail at a stress level below its yield stress when subjected to repeated loading

Fracture Critical Member (FCM)

- Member is in tension
- Member is non-redundant, its failure causes partial or total collapse of a structure

Failure Mechanics

Describing the process by which a member fails when subjected to fatigue.

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Types of Fractures in Steel Members

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Fatigue Failure Process

Fatigue failure process consists of three stages:

1. Crack initiation
2. Crack propagation
3. Fracture

Fatigue Crack Categories

- Details and Defects
- Out-of-plane Distortion

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Factors Affecting Fatigue Crack Initiation

(Details & Defects)

1. Plug welds
2. Tack welds
3. Material flaws
   - External flaws (Surface scabs)
   - Internal flaws (Non-metallic inclusions, Rolled in plate defects)
4. Weld flaws
   - Non-visible flaws (IP welds, Porosity, Slag inclusions)
   - Visible flaws (Undercut, Overlap)
5. Fabrication Flaws
   - Cutting of plates, Holes, Coping

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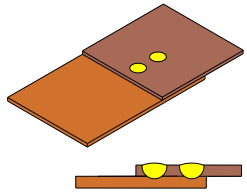
Factors Affecting Fatigue Crack Initiation
(Details & Defects)

6. Transportation & Erection Flaws
   - Nicks
   - Notches
   - Indentation

7. In-Service Flaws
   - Collision damage
   - Improper heat straightening
   - Torched or notched holes

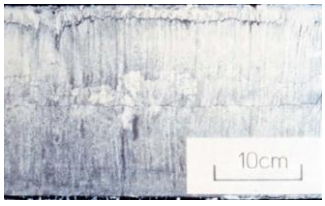
Plug Weld



Tack Weld

Material External Flaw

Material Internal Flaw



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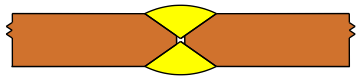
Incomplete Penetration Weld



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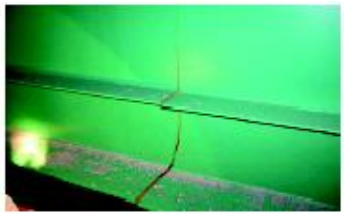
Incomplete Penetration Weld



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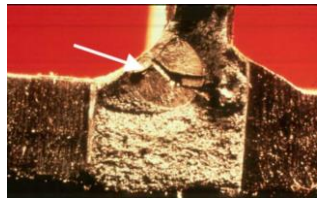
Weld Crack Due to Slag Inclusion



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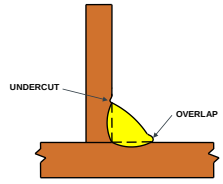
Fillet Weld Draws



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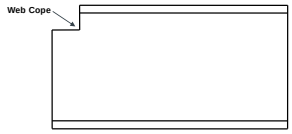
Improper Web Coping



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Correct Web Coping

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Torched Hole

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Torched Damage

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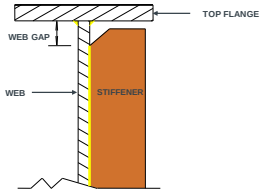
Factors Affecting Fatigue Crack Initiation

(Out-of-plane Distortion)



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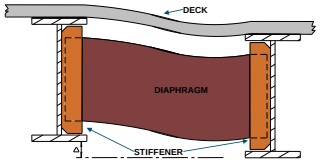
Girder Differential Deflection



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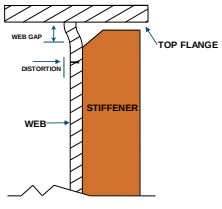
Girder Web Gap Distortion



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Girder Web Gap Distortion

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Factors Affecting Fatigue Crack Propagation

- Stress range
- Number of cycles
- Types of details
  - Flange cover plates
  - Transverse stiffeners
  - Bolted joints
  - Longitudinal stiffeners

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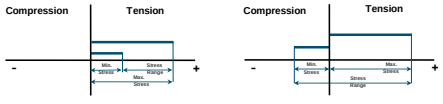
Stress Range



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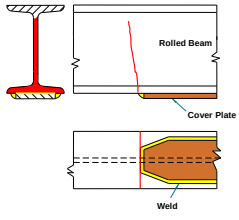
Flange Crack Growth Process



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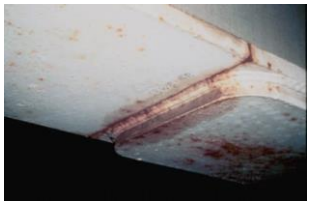
Through Crack at a Cover Plate



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Crack Propagation Into the Web

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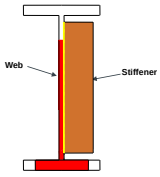
Crack Growth at Transverse Stiffener Welded to Web



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Constrained Induced Fracture (CIF)

- Fracture is not due to fatigue or number of cycles
- Occurs suddenly with no prior signs
- Fractures are at intersecting welds or at small gaps between intersecting welds
- Girder fracture at Hoan bridge Milwaukee was due to CIF

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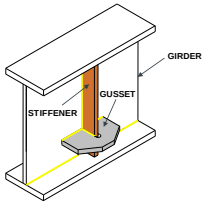
Constraint Induced Fracture (CIF)



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Constraint Induced Fracture (CIF)

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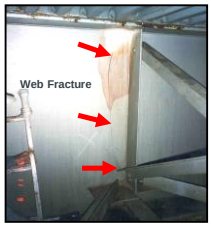
Constraint Induced Fracture (CIF)



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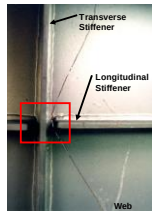
Constraint Induced Fracture (CIF)



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Inspection of Steel Members

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Inspection Procedures & Locations

Procedures

- Visual
  - Hands-on inspection
- Physical
  - Removal of dirt, paint etc.
- Identification
  - Fatigue crack may be identified by the development of rust stains
- Advanced Inspection Techniques

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Inspection Procedures & Locations

Locations

- Bearing areas
- Shear zones
- Flexure zones
- Fatigue prone details
- Out-of-plane distortion
- Constraint induced fracture detail
- Secondary members
- Areas that trap water and debris
- Areas exposed to traffic

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Corroded Shear Zone & Diaphragm

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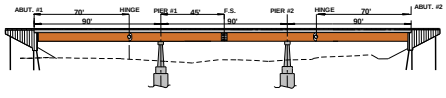
What to do if a Crack is Detected?

- Determine significance of crack on load carrying capacity
- Evaluate cause of cracking
- Show sketches with details of size and location
- Drill hole at the tip to arrest the growth
- Check with dye penetrant
- Take good photographs showing all the details

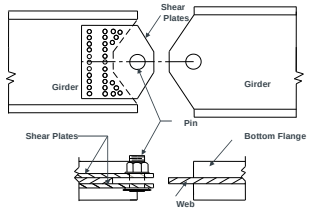
Note: Cracks perpendicular to primary stresses are very serious
Cracks parallel to primary stresses are less serious

Inspection of Pin and Hanger

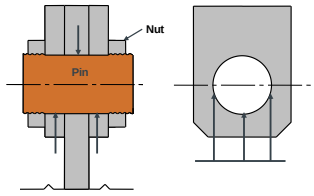
Pin Location



Pin Detail



Design Stresses in Pin



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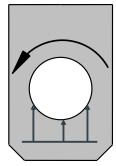
Actual Stresses in Pin



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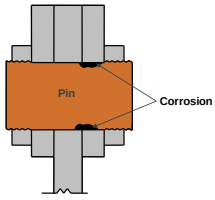
High Stress in Pin Due to Corrosion



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High Stress in Pin Due to Corrosion

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Hanger Location

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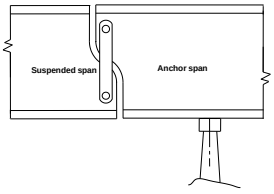
Hanger Details



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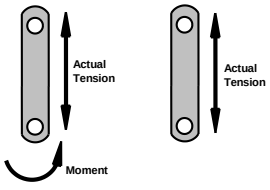
Stresses in Hanger



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Deterioration of Pin & Hanger

Pin

- Frozen
- Corroded
- Cracks in welded shear plates

Hanger

- Twisted or bent
- Ceased
- Cracks in edges

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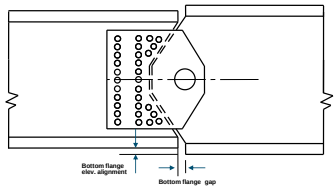
Inspection of Pins

Procedure

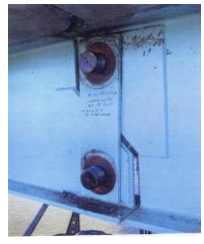
- Determine if pins are functioning
- Visual inspection not very effective
- Ultrasonic inspection is required
- Remove nuts if possible

Pin Measurements



Preparation for Inspection

Removal of Nuts



U/T Inspection

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Inspection of Hangers

Procedure

- Report any corrosion
- Hanger plate is as critical as pin.
- Examine edges
- Check hangers for bowing, out of plane bending

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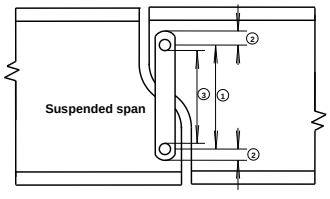
Measurements in Pin & Hanger



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Questions?

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