TIMBER SUPERSTRUCTURES

3/7/2024

IL NBI Refresher Course 2024

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Item 59 - Timber Superstructures

Common Timber Superstructure Types:

- Solid sawn multi-beam bridges
- Glulam multi-beam bridges
- Trusses and covered bridges

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Item 59 - Timber Superstructures

Solid Sawn Lumber Beams

- This type of bridge has been around for thousands of years!
- Primary members consist of solid sawn or hewn timber
- Short spans on timber or masonry substructures
- Rarely used for vehicle bridges now

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Item 59 - Timber Superstructures

Glulam Beams

- This type of structure has been around since the 1970's
- Provides greater strength and allows longer spans
- High costs limits use

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Item 59 - Timber Superstructures

Truss / Arch / Covered

- Have been in use since at least the 1500's
- Primary members can consist of sawn timber or glulam
- Allows for longer spans
- High costs limits use

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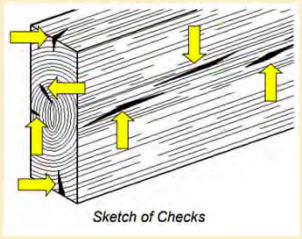
Item 59 - Timber Superstructures

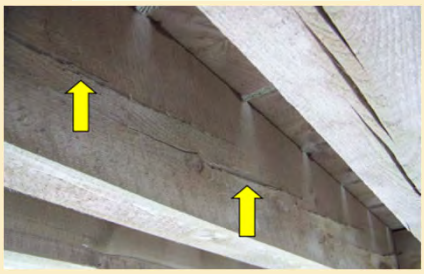
Timber Damage - Checks

- A separation of the wood fibers across or along the growth rings
- It does **not** extend completely thru the member
- Caused by the timber fibers drying/shrinking at different rates in the cross section
- Checking typically does not have a significant affect on beam capacity
- Severe checking should be documented

Pictures from Montana DOT Timber Bridge Inspection Guide



Sketch of Checks



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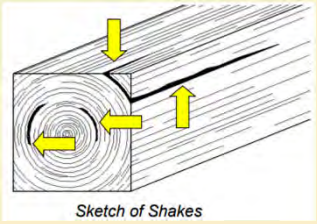
Item 59 - Timber Superstructures

Timber Damage - Shakes

- A separation or plane of weakness between growth rings usually caused by events before the wood is milled
- Shakes typically do not have a significant affect on beam capacity
- Severe, deep or long shakes should be documented

Pictures from Montana DOT Timber Bridge Inspection Guide



Sketch of Shakes

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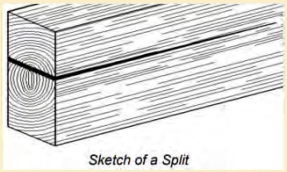
Timber Damage - Splits

- A check that extends completely thru a member
- It does not propagate thru the top or bottom of the member
- Often caused by seasoning of the wood
- Minor splits typically do not significantly affect the beam capacity of the member (< 20% of member length)

Pictures from Montana DOT Timber Bridge Inspection Guide



Sketch of a Split

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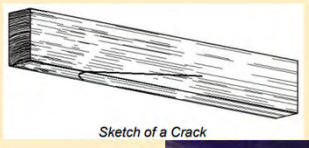
Item 59 - Timber Superstructures

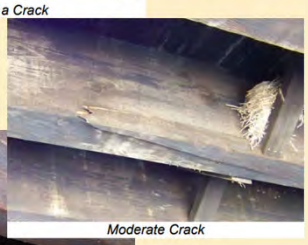
Timber Damage - Cracks

- A crack extends completely thru a member, typically starting in the tension portion and extending at an angle away from the tension face
- Often starts in high stress area at a stress riser such as a knot, impact damage or where a check follows the grain to the tension face surface
- Cracks affect the bending capacity of the beam & often lead to breaks
- Repair often required

Pictures from Montana DOT Timber Bridge Inspection Guide



Sketch of a Crack



Moderate Crack

Severe Crack

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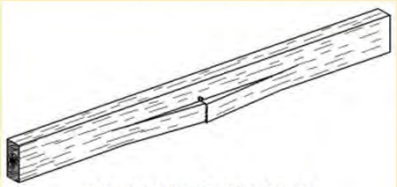
Timber Damage - Breaks

- Two Types: **Partial** & Complete
- Partial – loss of all strength in a portion of the member's cross section. Important to note the portion of the member that is still intact.
- Significantly reduces beam capacity – repair or replacement required

Pictures from Montana DOT Timber Bridge Inspection Guide



Sketch of a Partial Break

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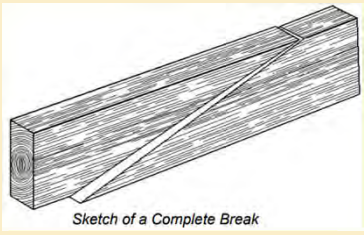
Item 59 - Timber Superstructures

Timber Damage - Breaks

- Two Types: Partial & **Complete**
- Complete – loss of all strength of a member, extends across the entire member
- Loss of beam capacity – repair or replacement required



Sketch of a Complete Break

Pictures from Montana DOT Timber Bridge Inspection Guide

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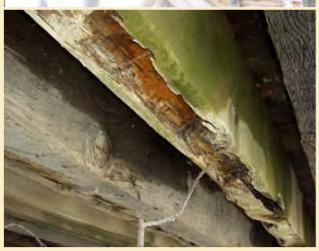
Item 59 - Timber Superstructures

Timber Damage – Decay & Crushing

- Deterioration typically caused by fungus, mold, bacteria & sunlight
- Causes loss of strength of member & often leads to crushing in compression areas
- Can be detected visually (external) or by sounding (internal)
- Determine and record extent of rot in member cross section when found



Pictures from Montana DOT Timber Bridge Inspection Guide

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Item 59 - Timber Superstructures

Key Indicators

- Cracks
- Decay
- Splitting
- Crushing
- Fire damage

Code	Description
8	VERY GOOD. May have only very minor defects in beams or stringers at non-critical locations.
7	GOOD. Minor insignificant decay, cracking, or splitting of beams or stringers.
6	SATISFACTORY. Some decay, cracking, or splitting of beams or stringers may be occurring near the main load carrying portions. Fire damage limited to surface scorching with no significant section loss.
5	FAIR. Moderate decay up to 10%, cracking, or splitting of beams or stringers but no significant effect in critical areas such as beam ends and mid-span. Fire damage limited to surface charring with minor section loss up to10%.

Item 59 - Timber Superstructures

Key Indicators

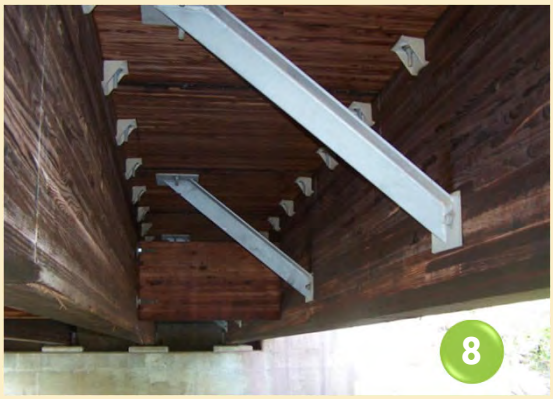
- Cracks
- Decay
- Splitting
- Crushing
- Fire damage

Code	Description
4	POOR. Extensive decay, cracking, splitting or crushing of beams or stringers, or fire damage with main load carrying portions affected. Section loss up to 30%.
3	SERIOUS. Severe decay, cracking, splitting or crushing of beams or stringers, or fire damage with major section loss up to 50% in critical load carrying portions of members. A further progression of problems noted for a condition rating of "4".
2	CRITICAL. Beam ends may be crushed or split with settlement of deck. Any further deterioration of problems noted for a condition rating of "3". Section loss over 50%, special feature inspection is required to allow bridge to remain open. The Bureau of Bridges and Structures shall be notified immediately.

Item 59 - Timber Superstructures

Very Good Condition

- Timber super and deck
- No significant defects noted
- Not the 1st inspection



VERY GOOD. May have only very minor defects in beams or stringers at non-critical locations.

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Item 59 - Timber Superstructures

Good Condition

- Sawn timber super and deck
- Minor checks in timber beams
- No section loss

GOOD. Minor insignificant decay, cracking, or splitting of beams or stringers.

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Item 59 - Timber Superstructures

Satisfactory Condition

- Sawn timber super and deck
- Some moderate splitting & checking
- Minor decay

SATISFACTORY. Some decay, cracking, or splitting of beams or stringers may be occurring near the main load carrying portions. Fire damage limited to surface scorching with no significant section loss.

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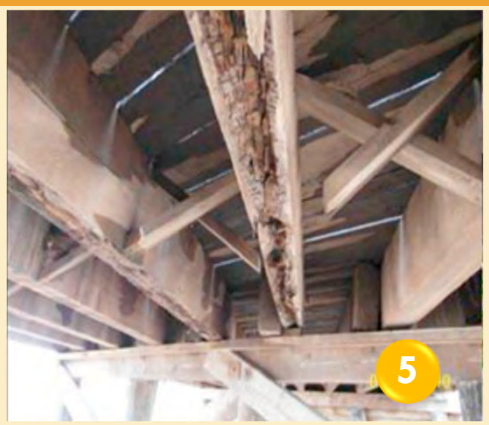
Item 59 - Timber Superstructures

Fair Condition

- Sawn timber super and deck
- Minor checks
- Moderate decay with 10% section loss



FAIR. Moderate decay up to 10%, cracking, or splitting of beams or stringers but no significant effect in critical areas such as beam ends and mid-span. Fire damage limited to surface charring with minor section loss up to10%.

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Item 59 - Timber Superstructures

Poor Condition

- Extensive Crack in timber beam
- 20% loss in cross section

POOR. Extensive decay, cracking, splitting or crushing of beams or stringers, or fire damage with main load carrying portions affected. Section loss up to 30%.

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Item 59 - Timber Superstructures

Serious Condition

- Sawn timber super and deck
- Fire damage
- Section loss at 35% in critical load carrying areas

SERIOUS. Severe decay, cracking, splitting or crushing of beams or stringers, or fire damage with major section loss up to 50% in critical load carrying portions of members. A further progression of problems noted for a condition rating of "4".

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Item 59 - Timber Superstructures

Critical Condition

- Sawn timber super and deck
- Decay & Partial Break of girder
- Section loss of 80% in critical load carrying area of single beam
- Multi girder cross section

CRITICAL. Beam ends may be crushed or split with settlement of deck. Any further deterioration of problems noted for a condition rating of "3". Section loss over 50%, special feature inspection is required to allow bridge to remain open. The Bureau of Bridges and Structures shall be notified immediately.

Discussion

PPC DECK BEAMS

3/7/2024

IL NBI Refresher Course 2024

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Item 59 - PPC Deck Beams

Precast Prestressed Concrete Deck Beams

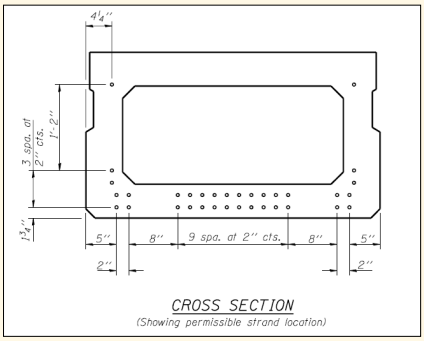
- Characteristics of PPC Deck Beams
- Effect of overlays type on rating codes
- Sounding and scaling beams during inspection
- Key Indicators for PPC Deck Beams
- Determining Condition Ratings using Key Indicators

2

Item 59 - PPC Deck Beams

Precast Prestressed Concrete Deck Beams

- **Introduced in the 1950's**
- **Advantages over non-prestressed concrete superstructures:**
  - **Eliminates need to form, pour and cure a deck**
  - **Shallow structural depth**
  - **Rapid construction**



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Item 59 - PPC Deck Beams

"**Flexible Wearing Surface**"

- **Deck (Item 58) and Super (Item 59) are rated and coded the same**
- **Generally consist of bituminous or oil & chip overlays**
- **Longitudinal Cracks in the overlay usually indicate cracked shear keyways**

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Item 59 - PPC Deck Beams

"Rigid Wearing Surface"

- **Thickness of Conc. overlay must be 4" or greater**
- **Concrete overlay must be reinforced**
- **Rate the overlay as the Deck (Item 58) and the beams as the Superstructure (Item 59)**

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Item 59 - PPC Deck Beams

Sounding

- **Use hammer sounding to detect delaminated areas**
- **Delaminations have a distinctive "hollow or clacking" sound**
- **Sound concrete has a solid "pinging" sound**
- **Remove loose & delaminated concrete if practical to reduce the deterioration rate**

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Item 59 - PPC Deck Beams

General Notes:

Prestressing strands, reinforcement bars or wire mesh should be considered ineffective in areas where concrete is deteriorated or unsound (delaminated) to the level of the strands, bars or mesh

Post construction repair patches are considered delaminated and the PS strands beneath are considered ineffective

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Item 59 - PPC Deck Beams

General Notes:

Shear keyway clamps are used at times to remediate differential beam movement

If the clamps are effectively causing the beams to work together and share LL, then they can be considered a good repair

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Item 59 - PPC Deck Beams

General Notes:

PPC Deck Beams - 1 of 2

- Moderate/severe leaching cracks full width of beam
- Sounding indicated not delaminated yet but soft/dull
- Keyways deteriorated
- Not a salted route
- Super was rated a 5 during last inspection
- Beams failed at 2 bridge locations!
- This bridge received multiple loadings from single axle grain wagon prior to failure

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Item 59 - PPC Deck Beams

General Notes:

PPC Deck Beams - 2 of 2

- Concrete crushed in top of beam, strands looked good
- Beam concrete cores showed strengths of 1.8, 2.8, 3.8 & 7.6ksi for 5.0ksi design strength
- Similar looking beam conditions have been found at other bridges
- Be sure to rate similar beams as if the cracked/leaching areas were delaminated!!

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Item 59 - PPC Deck Beams

General Notes:

Prestressing strands adjacent to longitudinal cracks shall be considered as ineffective

The “end quarters of span” do not include the beam ends (last 3’)

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Item 59 - PPC Deck Beams

General Notes:

Another Example

Prestressing strands adjacent to longitudinal cracks shall be considered as ineffective

Note keyway leaking full length of beam

The dimensions stated on the following pages relate to the width of the cross section of a beam

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Item 59 - PPC Deck Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Ineffective Keyways w/differential movement of beams

Code	Description
8	VERY GOOD. No notable problems.
7	GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Moderate cracking and leakage may be present in keyways, but no differential movement occurring between deck beams.
6	SATISFACTORY. Center half of span: No beams with prestressing strands, stirrup reinforcement or wire mesh bars exposed, no longitudinal cracking or spalling along the bottom of the beams. End quarters of span: No more than 2 strands or 3" of stirrup reinforcement bars or 3" of wire mesh exposed in the bottom of any beam. Larger widths of wire mesh may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½" cover), keyway cracking may be evident with wide spread leakage, but beams are still fully acting together.

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Item 59 - PPC Deck Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Ineffective Keyways w/differential movement of beams

Code	Description
5	FAIR. Center half of span: No more than 2 strands or 3" of stirrup reinforcement bars or 3" of wire mesh exposed in any beam, longitudinal cracking or spalling limited to one edge with no other defects exposing reinforcement, wire mesh or strands. End quarters of span: No more than 4 strands or 6" of stirrup reinforcement bars or 6" of wire mesh exposed in the bottom of any beam, no more than one longitudinal crack in any beam without any other defect. Beam ends (up to 3'): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of any beam bottom. Larger widths of wire mesh may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½" cover), keyway cracking with extensive leakage and evidence that beams are beginning to act independently of each other.

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Item 59 - PPC Deck Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Ineffective Keyways w/differential movement of beams

Code	Description
4	POOR. Center half of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅓ the width of any beam bottom, spalling or delamination of the top of the beams down to the top reinforcement, one longitudinal crack in the bottom of any beam. End quarters of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam. Beam ends (up to 3'): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of adjacent beam bottom with no exposed strands in the second layer of strands and sound concrete above the bottom layer. Larger width of wire mesh exposed and actively corroding due to inadequate concrete cover occurring during manufacturing (up to ½" cover), keyway has failed with groups of beams acting independently of others.

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Item 59 - PPC Deck Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Ineffective Keyways w/differential movement of beams

Code	Description
3	SERIOUS. Center half of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more that ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam, combinations of deterioration in condition rating "4". End quarters of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅔ the width of any beam bottom, combination of deterioration in condition rating "4". Beam ends (up to 3'): Prestressed strands, stirrup reinforcement bars or wire mesh exposed full width of adjacent beam bottom with exposed strands in the second layer of strands or unsound concrete above the bottom layer. Keyways have failed causing 3 or 4 beams to act independently from others.

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Item 59 - PPC Deck Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Ineffective Keyways w/differential movement of beams

Code	Description
2	CRITICAL. Similar to but more serious and extensive than what is described for a condition rating of "3", transverse cracks full width in the bottom of the beams, keyways have failed causing 1 or 2 beams to act independently from others. Structural elements that are judged to be in critical condition must receive special inspections in order for the structure to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.
1	"IMMINENT" FAILURE. Superstructure in "imminent failure" condition requiring bridge closure or temporary measures to allow structure to remain open.
0	FAILED. Superstructure that has failed and is beyond repair, requiring bridge closure.

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Item 59 - PPC Deck Beams

When does the condition rating of an individual deck beam effect that of the whole superstructure if the other beams are in better condition?

- *If one or more beams meets the condition rating requirements of a "4" or lower rating, this condition rating should be applied to the superstructure as a whole*
- *The condition rating of "4" POOR CONDITION was selected as this is the level where loss of Structural Load Capacity generally begins to occur*
- *An initial rating of "4" or below will trigger a Load Rating Inspection by IDOT*

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Item 59 - PPC Deck Beams

New Construction

No deficiencies

New Deck Beam – Allowed first inspection only

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Item 59 - PPC Deck Beams

Very Good Condition

- **No Deficiencies**
- **Not 1st inspection**

VERY GOOD. No notable problems.

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Item 59 - PPC Deck Beams

Good Condition

- Cracks in the RC overlay (0.02")
- No noticeable keyway leakage
- Rigid wearing surface would be rated as the Deck (Item 58)
- Deck would be rated "4" due to widespread map cracking.
- Item 59 is a "7"

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Moderate cracking and leakage may be present in keyways, but no differential movement occurring between deck beams.

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Item 59 - PPC Deck Beams

Good Condition

- Underside of the Superstructure in the previous slide
- Reflective cracking in the rigid WS may indicate cracked or failed keyways

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Moderate cracking and leakage may be present in keyways, but no differential movement occurring between deck beams.

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Item 59 - PPC Deck Beams

Good Condition

- Moderate keyway leakage with efflorescence
- Beams are still acting together

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Moderate cracking and leakage may be present in keyways, but no differential movement occurring between deck beams.

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Item 59 - PPC Deck Beams

Satisfactory Condition

- Keyway leakage
- Beams still acting together
- Inadequate concrete cover has exposed mesh on one beam
- Verify exposed wire is not a prestress strand

SATISFACTORY. Center half of span: No beams with prestressing strands, stirrup reinforcement or wire mesh bars exposed, no longitudinal cracking reinforcement or wire mesh bars exposed, no longitudinal cracking or spalling along the bottom of the beams. End quarters of span: No more than 2 strands or 3" of stirrup reinforcement bars or 3" of wire mesh exposed in the bottom of any beam. Larger widths of wire mesh may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½" cover), keyway cracking may be evident with wide spread leakage, but beams are still fully acting together.

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Item 59 - PPC Deck Beams

Fair Condition

- Spall up to 6” wide in the end quarter of the span with reinforcement exposed
- Spall with reinforcement exposed near the beam end

FAIR. Center half of span: No more than 2 strands or 3” of stirrup reinforcement bars or 3” of wire mesh exposed in any beam, longitudinal cracking or spalling limited to one edge with no other defects exposing reinforcement, wire mesh or strands. End quarters of span: No more than 4 strands or 6” of stirrup reinforcement bars or 6” of wire mesh exposed in the bottom of any beam, no more than one longitudinal crack in any beam without any other defect. Beam ends (up to 3’): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of any beam bottom. Larger widths of wire mesh may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½” cover), keyway cracking with extensive leakage and evidence that beams are beginning to act independently of each other.

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Item 59 - PPC Deck Beams

Fair Condition

- Spall full width on the beam end with reinforcement exposed
- No other defects

FAIR. Center half of span: No more than 2 strands or 3” of stirrup reinforcement bars or 3” of wire mesh exposed in any beam, longitudinal cracking or spalling limited to one edge with no other defects exposing reinforcement, wire mesh or strands. End quarters of span: No more than 4 strands or 6” of stirrup reinforcement bars or 6” of wire mesh exposed in the bottom of any beam, no more than one longitudinal crack in any beam without any other defect. Beam ends (up to 3’): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of any beam bottom. Larger widths of wire mesh may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½” cover), keyway cracking with extensive leakage and evidence that beams are beginning to act independently of each other.

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Item 59 - PPC Deck Beams

Poor Condition

- Spalls with reinforcement exposed
- Width is 8” of the 36” beam width (less than 1/3 of the beam width)
- Location of defect is near center half of span

POOR. Center half of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅓ the width of any beam bottom, spalling or delamination of the top of the beams down to the top reinforcement, one longitudinal crack in the bottom of any beam. End quarters of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam. Beam ends (up to 3'): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of adjacent beam bottom with no exposed strands in the second layer of strands and sound concrete above the bottom layer. Larger width of wire mesh exposed and actively corroding due to inadequate concrete cover occurring during manufacturing (up to ½” cover), keyway has failed with groups of beams acting independently of others.

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Item 59 - PPC Deck Beams

Poor Condition

- Spalls with reinforcement exposed
- Full width of adjacent beam ends

POOR. Center half of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅓ the width of any beam bottom, spalling or delamination of the top of the beams down to the top reinforcement, one longitudinal crack in the bottom of any beam. End quarters of span: Prestressed strands, stirrup reinforcement bars or wire mesh exposed for no more than ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam. Beam ends (up to 3'): Prestressed strands, stirrup reinforcement bars or wire mesh exposed up to full width of adjacent beam bottom with no exposed strands in the second layer of strands and sound concrete above the bottom layer. Larger width of wire mesh exposed and actively corroding due to inadequate concrete cover occurring during manufacturing (up to ½” cover), keyway has failed with groups of beams acting independently of others.

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Item 59 - PPC Deck Beams

Serious Condition

- Spalls or delaminations
- Width is 15” of 36” beam width (> 1/3 < ½ of width)
- Location of defect is in center half span

SERIOUS. Center half of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more that ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam, combinations of deterioration in condition rating “4”. End quarters of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅔ the width of any beam bottom, combination of deterioration in condition rating “4”. Beam ends (up to 3’): Prestressed strands, stirrup reinforcement bars or wire mesh exposed full width of adjacent beam bottom with exposed strands in the second layer of strands or unsound concrete above the bottom layer. Keyways have failed causing 3 or 4 beams to act independently from others.

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Item 59 - PPC Deck Beams

Serious Condition

- Spalls or delaminations
- Width is 14” (8” + 6”) of the 36” beam width (> 1/3 < ½ of width)
- Located in center half of span
- Keyway failure indicated by observed differential movement

SERIOUS. Center half of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more that ½ the width of any beam bottom, two longitudinal cracks in the bottom of any beam, combinations of deterioration in condition rating “4”. End quarters of span: Prestressing strands, stirrup reinforcement bars or wire mesh exposed for no more than ⅔ the width of any beam bottom, combination of deterioration in condition rating “4”. Beam ends (up to 3’): Prestressed strands, stirrup reinforcement bars or wire mesh exposed full width of adjacent beam bottom with exposed strands in the second layer of strands or unsound concrete above the bottom layer. Keyways have failed causing 3 or 4 beams to act independently from others.

KD-30

3/7/2024

30

Item 59 - PPC Deck Beams

Critical Condition

- Spalls or delaminations
- Combined width is 26” of the 36” beam width (> ½ of width)
- Several keyways have failed with observed differential movement

CRITICAL. Similar to but more serious and extensive than what is described for a condition rating of “3”, transverse cracks full width in the bottom of the beams, keyways have failed causing 1 or 2 beams to act independently from others. Structural elements that are judged to be in critical condition must receive special inspections in order for the structure to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.

KD-31

3/7/2024

31

Item 59 - PPC Deck Beams

- Example of beams acting independently due to keyway failure
- Bituminous overlay becomes dislodged by differential movement of beams

KD-32

32

Item 59 - PPC Deck Beams

Critical Condition

- Spalls or delaminations
- Width extends 34" across the 36" beam width (> ½ width)
- Exposed prestressed strands
- Keyway failure
- Notify BBS immediately

CRITICAL. Similar to but more serious and extensive than what is described for a condition rating of "3", transverse cracks full width in the bottom of the beams, keyways have failed causing 1 or 2 beams to act independently from others. Structural elements that are judged to be in critical condition must receive special inspections in order for the structure to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.

KD-33

3/7/2024

33

PPC I-BEAMS

3/7/2024

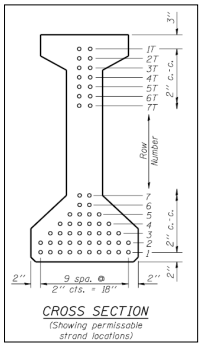
IL NBI Refresher Course 2024

1

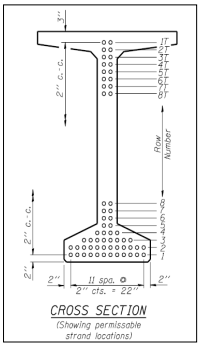
Item 59 – PPC I-Beams

Prestressed Concrete I-Beams

- Used since the 1950's
- "I" or "Bulb T" shape
- High Strength Concrete (5-10 ksi typically)
- Newer hybrid sections introduced by IDOT in 2015 with larger sections added in 2021
- Depth ranges from 35"- 90"



PPC I-Beam



PPC Bulb-T

KI-2

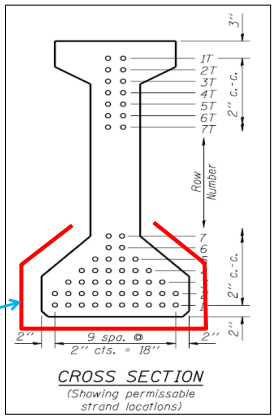
3/7/2024

2

Item 59 – PPC I-Beams

Prestressed Concrete I-Beam

- **The condition of the beam "PERIMETER" is used to help determine the condition rating**
- **It is the bottom flange length enclosing the prestressing strands**



KI-3

3/7/2024

3

Item 59 – PPC I-Beams

Sounding

- **Use hammer sounding to detect delaminated areas**
- **Delaminations have a distinctive "hollow or clacking" sound**
- **Sound concrete has a solid "pinging" sound**

KI-4

3/7/2024

4

Item 59 – PPC I-Beams

Delams, Spalls & Strikes

Look Around:

- Current & old deck drain locations
- Beneath transverse deck joints
- Adjacent to current or old longitudinal deck joints
- Above traffic lanes

KI-5

3/7/2024

5

Item 59 – PPC I-Beams

Shrinkage Cracks or Shear Cracks

For Shrinkage Cracks

Look Around:

- Beam ends
- Look for tight cracks starting from the beam ends
- Moderate amounts = 7 rating

KI-6

3/7/2024

6

Item 59 – PPC I-Beams

Shrinkage Cracks
or Shear Cracks

For Shear Cracks

Look Around:

- Beam end quarter or beam ends
- Look for tight cracks extending up at an angle in the beam
- Shear cracks = 3 rating

KI-7

3/7/2024

7

Item 59 – PPC I-Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Tight Shear Cracks in End Quarters

Code	Description
8	VERY GOOD. No notable problems.
7	GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Minor shrinkage or release cracks may be present. Minor map cracking at drains with sound concrete.
6	SATISFACTORY. Center half of span: No beams with prestressing strands, stirrup reinforcement exposed. End quarters of span: No more than 2 strands or 3" of stirrup reinforcement bars exposed in the bottom of any beam. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed up to ½ the perimeter of the bottom flange of any beam. Larger width of stirrups may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½ cover). Webs may be spalled with exposed stirrups and only surface rust.

KI-8

3/7/2024

8

Item 59 – PPC I-Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Tight Shear Cracks in End Quarters

Code	Description
5	FAIR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 1/4 the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 1/3 the perimeter of the bottom flange of any beam. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed from ½ to full perimeter of the bottom flange of any beam. Larger areas of stirrup may be exposed due to inadequate concrete cover that occurs during manufacturing (up to ½ cover). Webs may be spalled with exposed stirrups minor section loss.

Item 59 – PPC I-Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Tight Shear Cracks in End Quarters

Code	Description
4	POOR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 2/3 the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Webs are spalled with exposed stirrups with up to 30% section loss at ends of beams.

Item 59 – PPC I-Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Tight Shear Cracks in End Quarters

Code	Description
3	SERIOUS. Center half of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. End quarters of span: Prestressing strands, stirrup reinforcement bars exposed for the full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Hairline transverse cracks in bottom of beams or hairline vertical/diagonal shear cracks in beam webs may be developing.

KI-11

3/7/2024

11

Item 59 – PPC I-Beams

Key Indicators

- Cracks
- Delams & Spalls
- Exposed Reinf & Strands
- Tight Shear Cracks in End Quarters

Code	Description
2	CRITICAL. Similar to but more serious and extensive than what is described for a condition rating of "3". Structural elements that are judged to be in critical condition must receive special inspections in order for the structure to remain open to traffic. Measurable shear or transverse cracks. The Bureau of Bridges and Structures shall be notified immediately.

KI-12

3/7/2024

12

Item 59 – PPC I-Beams

New Construction

- No defects
- First inspection

New PPC I-Beam – Allowed first inspection only

KI-13

3/7/2024

13

Item 59 – PPC I-Beams

Very Good

- No deficiencies
- Second inspection

VERY GOOD. No notable problems.

KI-14

3/7/2024

14

Item 59 – PPC I-Beams

Good

Minor shrinkage cracks present in beams

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Minor shrinkage or release cracks may be present. Minor map cracking at drains with sound concrete.

KI-15

3/7/2024

15

Item 59 – PPC I-Beams

Satisfactory

Three strands exposed at the end of the beam

SATISFACTORY. Center half of span: No beams with prestressing strands, stirrup reinforcement exposed. End quarters of span: No more than 2 strands or 3" of stirrup reinforcement bars exposed in the bottom of any beam. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed up to ½ the perimeter of the bottom flange of any beam. Larger width of stirrups may be exposed due to inadequate concrete cover occurring during manufacturing (up to ½ cover). Webs may be spalled with exposed stirrups and only surface rust.

KI-16

3/7/2024

16

Item 59 – PPC I-Beams

Two strands of reinforcement bars exposed in the bottom of beam

No beams with reinforcement exposed at center span

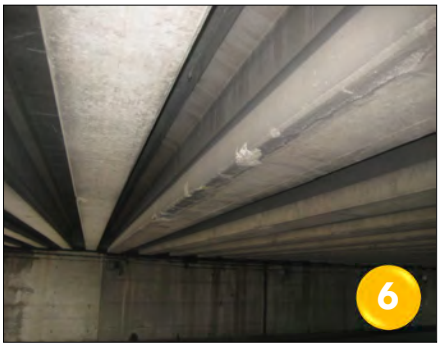
Item 59 – PPC I-Beams

Fair

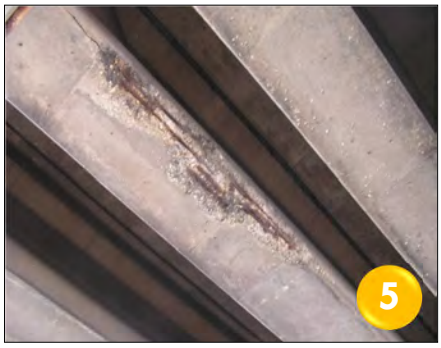
Reinforcement bars exposed for 30% of perimeter of bottom flange in end quarter of span

FAIR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 1/4 the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 1/3 the perimeter of the bottom flange of any beam. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed from ½ to full perimeter of the bottom flange of any beam. Larger areas of stirrup may be exposed due to inadequate concrete cover that occurs during manufacturing (up to ½ cover). Webs may be spalled with exposed stirrups minor section loss.

Item 59 – PPC I-Beams



No beams with reinforcement exposed at center span



Spall with 4 exposed strands in the end quarter

KI-19

3/7/2024

19

Item 59 – PPC I-Beams

Poor

Reinforcement bars exposed for more than 55% of perimeter of bottom flange in end quarter

POOR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 2/3 the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Webs are spalled with exposed stirrups with up to 30% section loss at ends of beams.

KI-20

3/7/2024

20

Item 59 – PPC I-Beams

Serious

Strands exposed for full perimeter of bottom flange in center half of span

SERIOUS. Center half of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. End quarters of span: Prestressing strands, stirrup reinforcement bars exposed for the full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Hairline transverse cracks in bottom of beams or hairline vertical/diagonal shear cracks in beam webs may be developing

KI-21

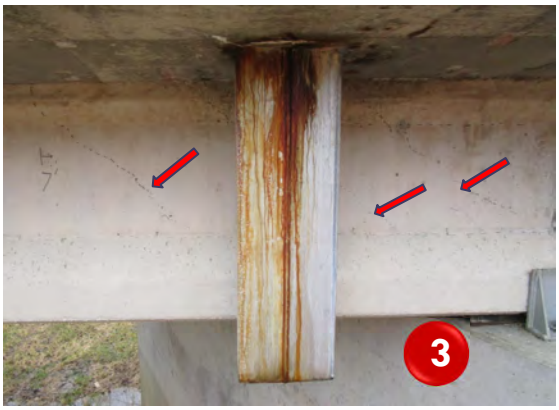
3/7/2024

21

Item 59 – PPC I-Beams

Serious

Tight diagonal shear cracks in beam web at the beam end quarter & beam end.



SERIOUS. Center half of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. End quarters of span: Prestressing strands, stirrup reinforcement bars exposed for the full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Hairline transverse cracks in bottom of beams or hairline vertical/diagonal shear cracks in beam webs may be developing

KI-22

3/7/2024

22

Item 59 – PPC I-Beams

Critical

- Prestressing strands exposed over full perimeter
- Open shear cracks
- Damage in middle half of beam

CRITICAL. Similar to but more serious and extensive than what is described for a condition rating of "3". Structural elements that are judged to be in critical condition must receive special inspections in order for the structure to remain open to traffic. Measurable shear or transverse cracks. The Bureau of Bridges and Structures shall be notified immediately.

KI-23

3/7/2024

23

Item 59 – PPC I-Beams

Imminent Failure

- Exterior beam has failed
- Strands exposed for full perimeter of bottom flange at center span

IMMINENT FAILURE. Condition requiring bridge closure or temporary measures to allow structure to remain open

KI-24

3/7/2024

24

REVIEW

KI-25

25

Item 59 – PPC I-Beams

KI-1: How would you rate this Superstructure?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. N

Minor shrinkage cracks present

KI-26

3/7/2024

26

Item 59 – PPC I-Beams

Good

Minor shrinkage cracks present

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Minor shrinkage or release cracks may be present. Minor map cracking at drains with sound concrete.

KI-27

3/7/2024

27

Item 59 – PPC I-Beams

KI-2: How would you rate this Superstructure?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. N

Reinforcement bars exposed for 22% of the perimeter of the bottom flange in the center half. The web is spalled with minor section loss to the stirrups.

KI-28

3/7/2024

28

Item 59 – PPC I-Beams

Fair

Reinforcement bars exposed for 22% of perimeter of bottom flange in center half.

The web is spalled with minor section loss to stirrups.

FAIR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than ¼ of the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 1/3 the perimeter of the bottom flange of any beam. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed from ½ to full perimeter of the bottom flange of any beam. Larger areas of stirrup may be exposed due to inadequate concrete cover that occurs during manufacturing (up to ½ cover). Webs may be spalled with exposed stirrups minor section loss.

KI-29

3/7/2024

29

Item 59 – PPC I-Beams

KI-3: How would you rate this Superstructure?

1. **1**
2. **2**
3. **3**
4. **4**
5. **5**
6. **6**
7. **7**
8. **8**
9. **9**
10. **N**

Tight diagonal cracks are found in the beam webs near the beam ends.

KI-30

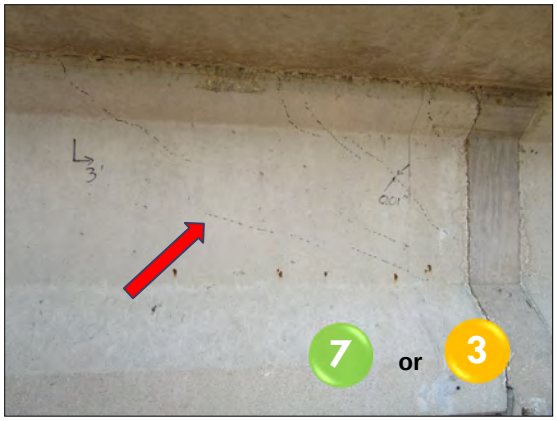
3/7/2024

30

Item 59 – PPC I-Beams

Serious

Tight diagonal cracks are found in the beam webs near the beam ends and exiting in the end of the beam.



SERIOUS. Center half of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. End quarters of span: Prestressing strands, stirrup reinforcement bars exposed for the full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Hairline transverse cracks in bottom of beams or hairline vertical/diagonal shear cracks in beam webs may be developing

KI-31

3/7/2024

31

Item 59 – PPC I-Beams

KI-4: How would you rate this Superstructure?

1. **1**
2. **2**
3. **3**
4. **4**
5. **5**
6. **6**
7. **7**
8. **8**
9. **9**
10. **N**

Reinforcement bars exposed for 58% of the perimeter of the bottom flange at center half of span

KI-32

3/7/2024

32

Item 59 – PPC I-Beams

Poor

Reinforcement bars exposed for 58% of perimeter of bottom flange at center span

POOR. Center half of span: Prestressed strands or stirrup reinforcement bars exposed for no more than 2/3 the perimeter of the bottom flange of any beam. End quarters of span: Prestressed strands or stirrup reinforcement bars exposed up to full perimeter of the bottom flange of any beam. No strands are exposed inside the exterior perimeter of strands. Beam ends (up to 3'): Prestressed strands or stirrup reinforcement bars exposed full perimeter of the bottom flange of any beam with some strands exposed inside the exterior perimeter of strands. Webs are spalled with exposed stirrups with up to 30% section loss at ends of beams.

KI-33

3/7/2024

33

Item 59 – PPC I-Beams

KI-5: How would you rate this Superstructure?

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8
9. 9
10. N

Shrinkage Cracks with no reinforcement exposed

KI-34

3/7/2024

34

Item 59 – PPC I-Beams

Good

Shrinkage cracks with no reinforcement exposed

GOOD. No beams with prestressing strands, stirrup reinforcement bars or wire mesh exposed. Minor shrinkage or release cracks may be present. Minor map cracking at drains with sound concrete.

KI-35

3/7/2024

35

Discussion

KI-36

3/7/2024

36

STEEL SUPERSTRUCTURES

3/7/2024

IL NBI Refresher Course 2024

1

Item 59 - Steel Superstructures

- Types of Steel Structures and Unique Details
- Common Missed Deficiencies
- Section Remaining vs. Section Loss
- Condition Ratings

2

Item 59 - Steel Superstructures

Types of Steel Superstructures

Rolled I-Beams

- Various standard sizes:
  - 18” – 36” depths common in bridges (3” increments)
  - 40” & 44” also available
- May have bearing stiffeners
- Common in short to mid span steel bridges

3

Item 59 - Steel Superstructures

Types of Steel Superstructures

Welded Girders (I-shape)

- Made of plates welded together
- Width and thickness of flanges and webs can be varied
- Usually have bearing stiffeners
- Depth of web typically greater than 36”

4

Item 59 - Steel Superstructures

Types of Steel Superstructures

Riveted Girder (I-shape)

- Made up of plates and angles riveted together
- Width and thickness of flanges and webs can be varied
- Usually have bearing stiffeners
- Often have intermediate stiffeners

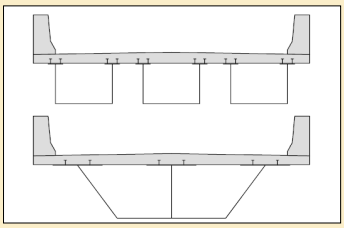
5

Item 59 - Steel Superstructures

Types of Steel Superstructures

Steel Box Girders

- Rectangular or trapezoidal cross section
- Commonly used for curved bridges
- Fracture Critical Inspection should include both inside and outside of box
- Confined Space Procedures?



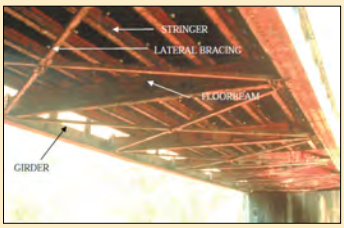
6

Item 59 - Steel Superstructures

Types of Steel Superstructures

Steel Two-Girder System

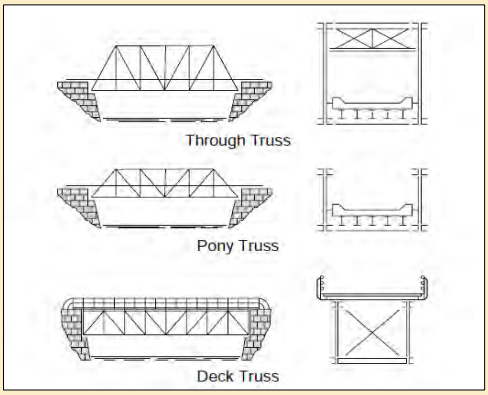
- May be riveted or welded
- Floor system may consist of floorbeams and stringers
- Through Girders fall in this category
- They are Fracture Critical (FC) Members or Nonredundant Steel Tension Members (NSTM)



Item 59 - Steel Superstructures

Types of Steel Superstructures

- **Steel Trusses**
  - Used since the early 1800's
  - Structure made of triangles
  - Two parallel trusses
  - Trusses are the main load-carrying members
- **Three Main Types**
  - Through
  - Pony
  - Deck



Item 59 - Steel Superstructures

Types of Steel Superstructures

Steel Arches

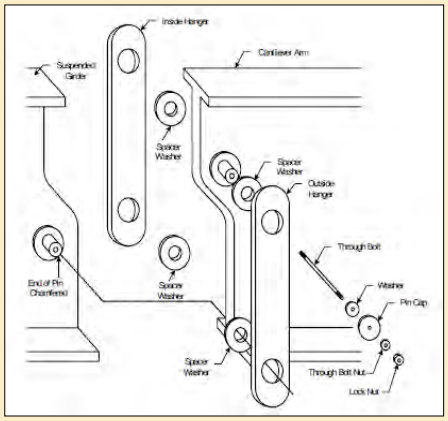
- Constructed since the late 1800's
- 3 Types
  - Deck
  - Through
  - Tied
- Tension chord, hangers & floor beams – typ. FC/NSTM

Item 59 - Steel Superstructures

Unusual Details

Pin and Hanger

- Used on Multi-span bridges prior to 1970
- Moves expansion joints away from abutments and piers
- Simplified analysis
- No longer used in design



Item 59 - Steel Superstructures

Unusual Details

Pin Connection

Single pin used without hanger bars to allow rotation only

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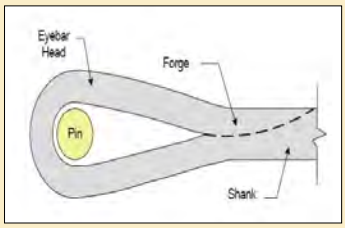
Item 59 - Steel Superstructures

Unusual Details

Steel Eyebars

- Eyebars are tension only members that require pins for end connections.
- Found on older truss bridges or suspension chain bridges



12

Item 59 - Steel Superstructures

Common Missed Deficiencies

- Section loss at beam ends below transverse deck joints
- Look for heavy section loss in webs and in the bearing area
- For **ratings ≤ 3** due to web section loss at the bearing area PM's are responsible for **installing/recommending wood blocking** between flanges to resist web crushing (July 2017)

Item 59 - Steel Superstructures

Common Missed Deficiencies

- Section loss along the bottom of the web and
- Section loss along the top of the bottom flange
- Section loss around diaphragm connections

Item 59 - Steel Superstructures

Common Missed Deficiencies

Defects Hidden by Pack Rust

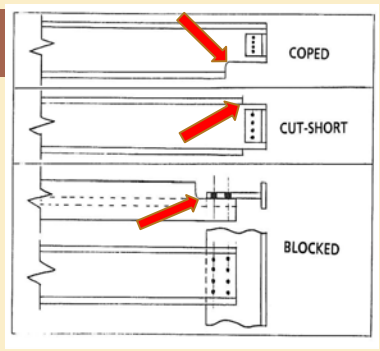
- Superstructure rating had just been lowered from a 5 to a 4
- The condition of the floor stringers was not considered in the rating
- Actual super rating was a 1 !!

Item 59 - Steel Superstructures

Common Missed Deficiencies

Cracks at Coped or Dapped Ends

- Connection may have been designed as a pinned
- The web may be carrying moment due to stiffness resulting from the depth of the connection
- Section loss can increase potential for cracks

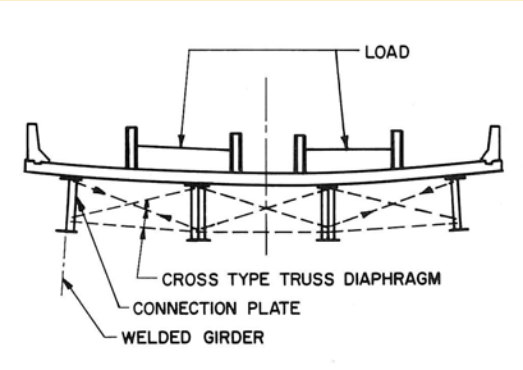


Item 59 - Steel Superstructures

Common Missed Deficiencies

Cracks at Connections

Cracks can occur at rigid connections of transverse members to thin webs due to out-of-plane bending



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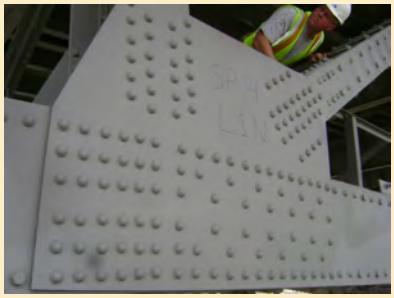
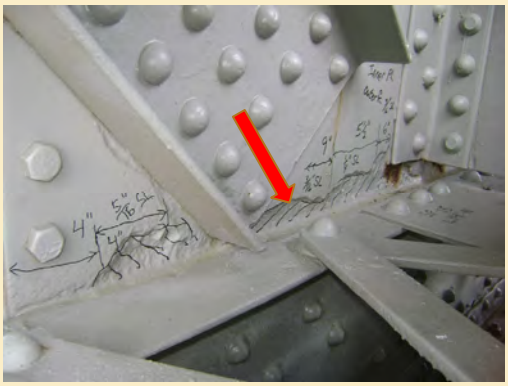
Item 59 - Steel Superstructures

Common Missed Deficiencies

Section loss in truss members and gusset plates at connections





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Item 59 - Steel Superstructures

Section Loss Measurements

- Steel Section Loss is measured as a % loss in the area of the original undamaged cross section of the **critical portion of a member**
- IDOT looks at Section Loss in 3 separate zones for a typical flexural steel member:
  - Flexure zone
  - Shear zone
  - Bearing zone
- Pure Tension or Compression members are typically evaluated over the full section area
- See the IDOT BB&S Website for a webinar on Calculating Steel SL

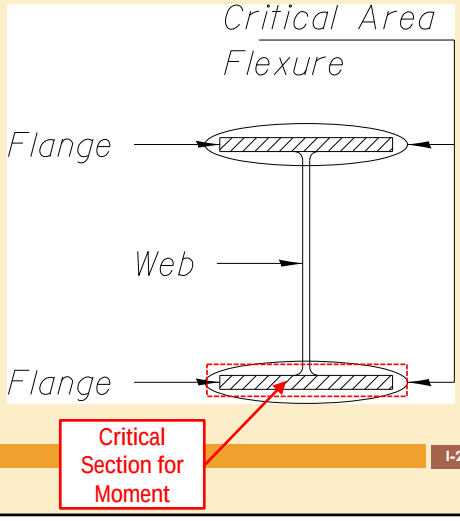
19

Item 59 - Steel Superstructures

Section Loss Measurements

FLEXURE ZONE:

- Section Loss is typically measured as the % loss in the area of either **one** of the flange cross sections
- A hole in a member is not necessarily 100% section loss
- Any web SL is not included in the % calculation for comparison to the SIP criteria



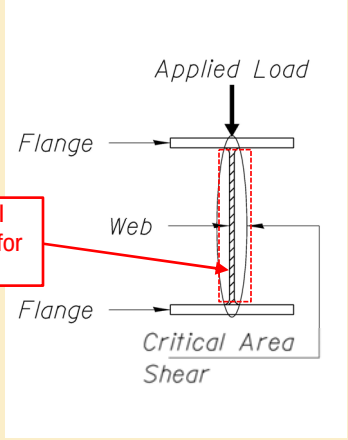
20

Item 59 - Steel Superstructures

Section Loss Measurements

SHEAR ZONE:

- Section Loss is typically measured as the % loss in the area of the total web cross section
- A hole in a member is not necessarily 100% section loss
- Any flange SL is not included in the % calculation for comparison to the SIP criteria



I-21

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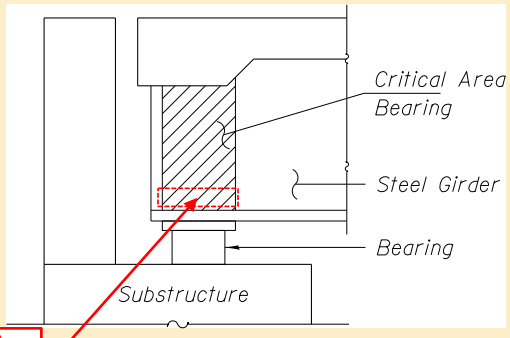
Item 59 - Steel Superstructures

Section Loss Measurements

BEARING ZONE:

- Section Loss is typically measured as the % loss in the area of the web cross section located directly above the bearing
- A hole in a member is not necessarily 100% section loss



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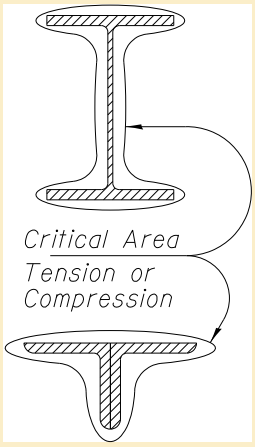
Item 59 - Steel Superstructures

Section Loss Measurements

TENSION & COMPRESSION MEMBERS:

- Section Loss is typically measured as the % loss in the total area of the member cross section
- A hole in a member is not necessarily 100% section loss



23

Item 59 - Steel Superstructures

Key Indicators

- **Section Loss**
- **Cracks**

Code	Description
N	Culvert.
9	New superstructure.
8	VERY GOOD. No visible rust.
7	GOOD. Some rust may be present but without any section loss.
6	SATISFACTORY. Initial section loss (minor pitting, scaling, or flaking) up to 2% section loss.
5	FAIR. Initial section loss up to 10% in critical areas, fatigue or out-of-plane bending cracks may be present in secondary members, arrested fatigue cracks may be present in primary members, hinges may be showing minor corrosion problems, anchor bolt(s) may be missing.

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Item 59 - Steel Superstructures

Key Indicators

- Section Loss
- Cracks

Code	Description
4	POOR. Section loss up to 30% in critical area, fatigue or out-of-plane bending cracks may be present in primary members, previously arrested fatigue cracks propagating beyond arresting holes in primary members, fatigue cracks in secondary members throughout the bridge, anchor bolts or pintles broken on rocker bearings with an offset of ½" or more between the rocker and the bearing or sole plates.
3	SERIOUS. Advanced section loss up to 50%, extensive perpendicular to stress fatigue or out of plane bending cracks in primary members.
2	CRITICAL. Severe section loss over 50% requires special inspections, temporary supports or repairs may be required to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.
1	Superstructure in "imminent failure" condition requiring bridge closure or temporary measures to allow structure to remain open.
0	Superstructure that has failed and is beyond repair, requiring bridge closure.

Item 59 - Steel Superstructures

New Construction

No deficiencies

New superstructure – Allowed first inspection only

Item 59 - Steel Superstructures

Very Good Condition

- No deficiencies
- Not new construction
- Note: Weathering Steel

VERY GOOD. No “excessive” rust.

Item 59 - Steel Superstructures

Good Condition

- Minor rust on the bottom flanges
- No section loss

GOOD. Some rust may be present but without any section loss.

Item 59 - Steel Superstructures

Good Condition

- Minor rust on bottom flange
- No section loss

GOOD. Some rust may be present but without any section loss.

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Item 59 - Steel Superstructures

Satisfactory Condition

- Initial section loss in non-critical area of bottom flange
- Rust stains on web resulting from rust on secondary member

SATISFACTORY. Initial section loss (minor pitting, scaling, or flaking) up to 2% section loss.

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Item 59 - Steel Superstructures

Satisfactory Condition

- Section loss on flanges of diaphragm (secondary member)
- No section loss on girder web

SATISFACTORY. Initial section loss (minor pitting, scaling, or flaking) up to 2% section loss.

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Item 59 - Steel Superstructures

Fair Condition

- Minor cracks
- Arrester holes have been drilled in web to prevent further progression of cracks

FAIR. Initial section loss up to 10% in critical areas, fatigue or out-of-plane bending cracks may be present in secondary members, arrested fatigue cracks may be present in primary members, hinges may be showing minor corrosion problems, anchor bolt(s) may be missing.

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Item 59 - Steel Superstructures

Fair Condition

8% section loss at bottom flange and on web of girder

FAIR. Initial section loss up to 10% in critical areas, fatigue or out-of-plane bending cracks may be present in secondary members, arrested fatigue cracks may be present in primary members, hinges may be showing minor corrosion problems, anchor bolt(s) may be missing.

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Item 59 - Steel Superstructures

Fair Condition

7% Section loss along the lateral edge bracing

FAIR. Initial section loss up to 10% in critical areas, fatigue or out-of-plane bending cracks may be present in secondary members, arrested fatigue cracks may be present in primary members, hinges may be showing minor corrosion problems, anchor bolt(s) may be missing.

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Item 59 - Steel Superstructures

Poor Condition

25% section loss in the web of the girder

POOR. Section loss up to 30% in critical area, fatigue or out-of-plane bending cracks may be present in primary members, previously arrested fatigue cracks propagating beyond arresting holes in primary members, fatigue cracks in secondary members throughout the bridge, anchor bolts or pintles broken on rocker bearings with an offset of ½" or more between the rocker and the bearing or sole plates.

Item 59 - Steel Superstructures

Poor Condition

- 25% section loss in web
- Hole at cope

POOR. Section loss up to 30% in critical area, fatigue or out-of-plane bending cracks may be present in primary members, previously arrested fatigue cracks propagating beyond arresting holes in primary members, fatigue cracks in secondary members throughout the bridge, anchor bolts or pintles broken on rocker bearings with an offset of ½" or more between the rocker and the bearing or sole plates.

Item 59 - Steel Superstructures

Poor Condition

- Cracked intermittent welds along edge of cover plate
- (cover plate area = 28% of bottom flange)

POOR. Section loss up to 30% in critical area, fatigue or out-of-plane bending cracks may be present in primary members, previously arrested fatigue cracks propagating beyond arresting holes in primary members, fatigue cracks in secondary members throughout the bridge, anchor bolts or pintles broken on rocker bearings with an offset of ½" or more between the rocker and the bearing or sole plates.

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Item 59 - Steel Superstructures

Serious Condition

- Cracks in web along bottom flange
- Arrested crack perpendicular to stress in web
- 15% section loss in lower portion of web

SERIOUS. Advanced section loss up to 50%, extensive perpendicular to stress fatigue or out of plane bending cracks in primary members.

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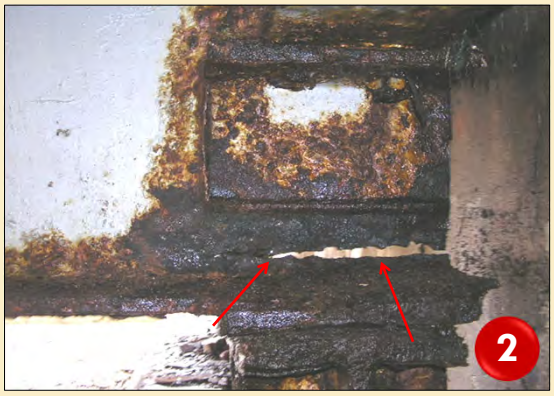
Item 59 - Steel Superstructures

Critical Condition

- 80% section loss above bearing
- Critical section for bearing at beam end is cut horizontally
- Critical section for shear near beam end is cut vertically



CRITICAL. Severe section loss over 50% requires special inspections, temporary supports or repairs may be required to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately. (install wood blocking)

Item 59 - Steel Superstructures

Critical Condition

- 50% section loss of web at mid-span
- 100% section loss of bottom flange at mid-span (completely disconnected from web)

CRITICAL. Severe section loss over 50% requires special inspections, temporary supports or repairs may be required to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.

Item 59 - Steel Superstructures

Critical Condition

Bottom flange cracked at bearing

CRITICAL. Severe section loss over 50% requires special inspections, temporary supports or repairs may be required to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately.

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Item 59 - Steel Superstructures

Critical Condition

- **Severe section loss throughout**
- **100% section loss above bearing**
- **Beam supported by bottom flange in flexure**

CRITICAL. Severe section loss over 50% requires special inspections, temporary supports or repairs may be required to remain open to traffic. The Bureau of Bridges and Structures shall be notified immediately. (install wood blocking)

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FATIGUE, FRACTURE & GUSSET PLATES

3/7/2024

IL NBI Refresher Course 2024

1

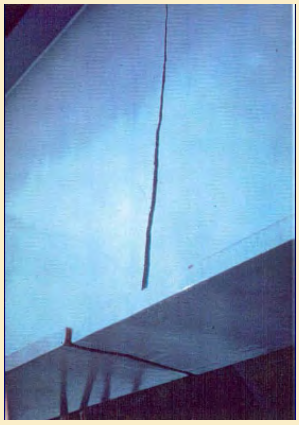
Fatigue, Fracture & Gusset Plates

Fatigue:

The tendency of a member to fail at a stress level below yield stress when subjected to cyclical loading.

Fracture:

The separation of a member into two parts.



Fractured Girder

2

Fatigue, Fracture & Gusset Plates

Fracture Critical Member (FC) or Nonredundant Steel Tension Member (NSTM):

1. Must be steel
2. Must be in tension or have a tension component
3. Failure would likely cause partial or complete collapse of the structure

Fatigue, Fracture & Gusset Plates

Redundancy:

- The structural condition where the number of supporting elements is greater than necessary for stability (alternate load paths exist)
- 3-Types of Structural Redundancy
  - Internal
  - Structural
  - Load Path

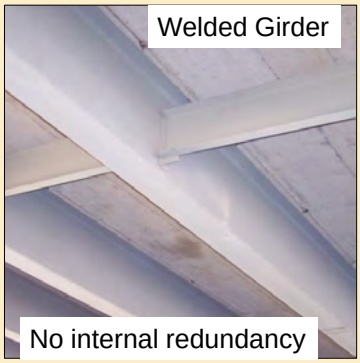
Fatigue, Fracture & Gusset Plates

Internal Redundancy – a member configuration containing 3 or more elements mechanically fastened together (by rivets or bolts) to form multiple independent load paths

Riveted Girder

Has internal redundancy

Welded Girder



No internal redundancy

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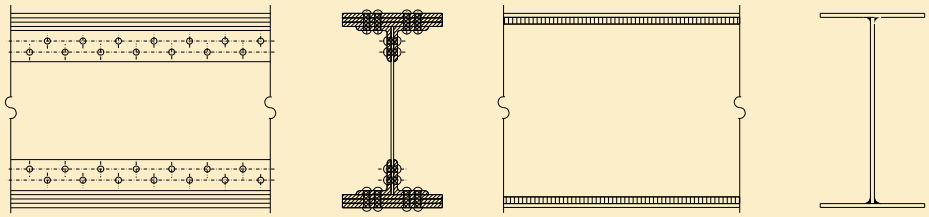
Fatigue, Fracture & Gusset Plates

Internal Redundancy



Riveted/Bolted Girder
Has internal redundancy

Welded Girder
No internal redundancy

I-6

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Fatigue, Fracture & Gusset Plates

Structural Redundancy – provides continuity of load path from span to span on interior spans of continuous structures

None

None

Spans 2 & 3

7

Fatigue, Fracture & Gusset Plates

Load Path Redundancy – having 3 or more main load carrying members between substructure units

Load Path Redundant

Not Load Path Redundant

8

Fatigue, Fracture & Gusset Plates

Non-Redundant Structures:

- **Do not have load path redundancy**
- Internal redundancy is disregarded
- Structural redundancy is disregarded

9

Fatigue, Fracture & Gusset Plates

FC/NSTM INSPECTION PROCEDURES:

- **Inspector background**
- **Equipment needs**
- **Where to look**
- **What to look for**
- **Nondestructive testing**

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Fatigue, Fracture & Gusset Plates

INSPECTOR BACKGROUND:

(*preferred* qualifications)

- Experienced steel inspector
- Has taken the NHI course on Fracture Critical Inspection Techniques for Steel Bridges (**required** as of 1/1/2024 for all TL/PM on FC/NSTM structures)
- Has an understanding of structural behavior and fatigue prone details
- Attention to detail
- Willingness to access hard to reach locations

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Fatigue, Fracture & Gusset Plates

Equipment Needs (Access Equip. – Arms Length Reach):

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Fatigue, Fracture & Gusset Plates

Equipment Needs (Damage Measurement):

- Tape measure
- Crack gauge
- UT thickness meter
- Hammer
- Wire brush
- Grinding wheel bit





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Fatigue, Fracture & Gusset Plates

Where to Look: (we will discuss each in detail)

- Areas vulnerable to corrosion
- Field, intersecting, plug (weld filled holes) & tack welds
- Sudden changes in cross section
- Stress risers (included in many of these)
- Locations with high displacement induced stress's
- Web stiffeners
- Coped sections
- Eyebars
- Pin and hanger assemblies

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Fatigue, Fracture & Gusset Plates

Where to Look - Areas Vulnerable to Corrosion:

Locations that trap and hold moisture & debris

- Beneath deck joints
- Near drains
- On flat surfaces
- Exposed surfaces of fascia beams
- Steel in contact with concrete
- At overlapping steel plates
- Corners on steel members

Loss of section due to corrosion causes a stress riser that may be susceptible to fatigue

Fatigue, Fracture & Gusset Plates

Where to Look – Field, Intersecting, plug(weld filled holes) & Tack Welds

- Field & intersecting welds are more susceptible to flaws
- Flawed welds cause increased strain
- Fatigue cracks can initiate more easily at these locations
- Field, intersecting, tack and plug welds
- Any weld <u>in a tension zone</u> on a FCM that is not part of the original design should be documented and inspected

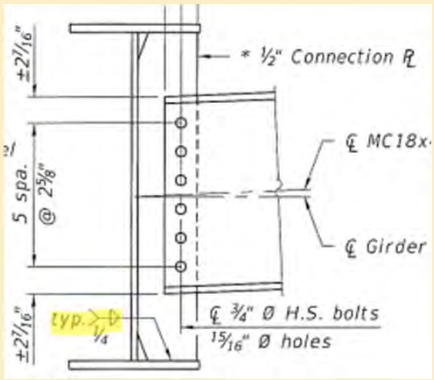
Fatigue, Fracture & Gusset Plates

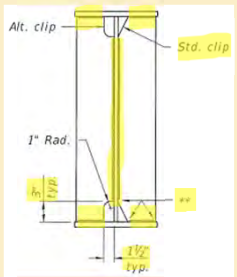
Where to Look – Sudden Change in Cross Section:

- Sudden changes in cross section cause stress increases
  - Cover plate terminations
  - Changes in plate size
- These are susceptible locations for fatigue cracks to initiate

Fatigue, Fracture & Gusset Plates

Where to Look – Transverse Web Stiffeners/Cross Frames





WELD LIMITS AND CLIP DETAILS

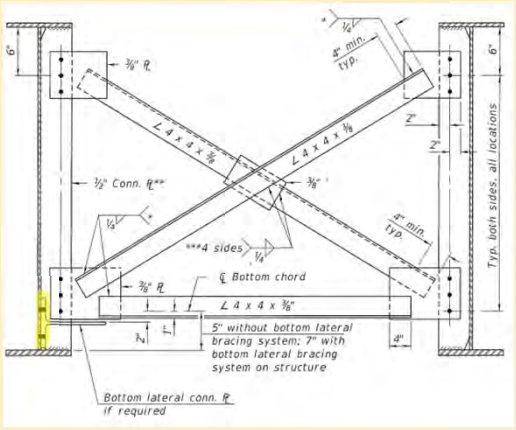
** Stop welds ¼" (±⅛") from edges as shown. Typical.

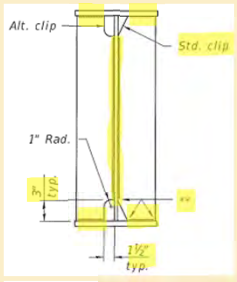
- Stiffener is full height of web
- Ample corner clips
- Welded to web & Flanges
- Welds do not touch

GOOD Diaphragm connection details to WF girders

Fatigue, Fracture & Gusset Plates

Where to Look – Transverse Web Stiffeners/Cross Frames





WELD LIMITS AND CLIP DETAILS

** Stop welds ¼" (±⅛") from edges as shown. Typical.

- Stiffener is full height of web
- Ample corner clips
- Welded to web & Flanges
- Welds do not touch
- Lateral Brace conn is bolted

GOOD Cross Frame connection details to PL girders

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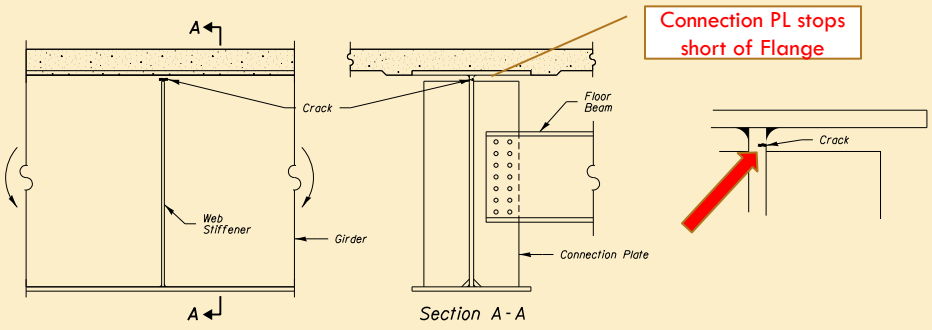
Fatigue, Fracture & Gusset Plates

Where to Look – Transverse Web Stiffeners/Cross Frames



POOR Cross Frame connection details to girders

20

Fatigue, Fracture & Gusset Plates

Where to Look – Cross Frames

POOR Cross Frame connection details – look at ends of plates in tension zones of girders

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Fatigue, Fracture & Gusset Plates

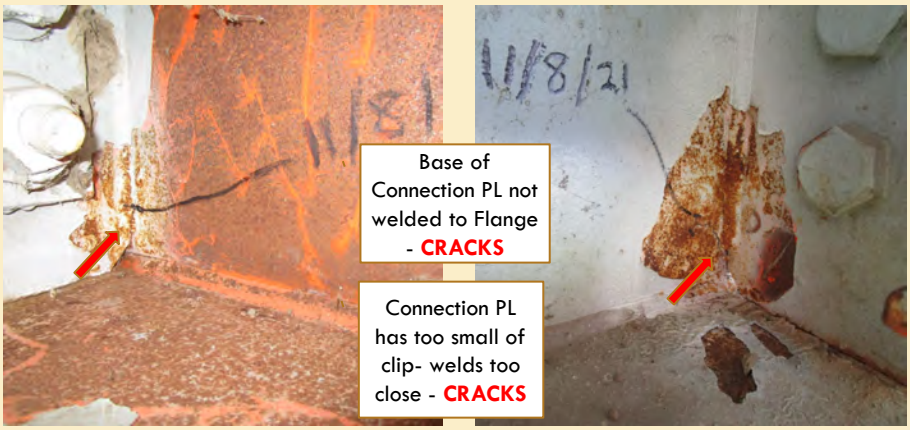
Where to Look – Transverse Web Stiffeners/Cross Frames

POOR Web Stiffener connection details – look at ends of plates in tension zones of girders

22

Fatigue, Fracture & Gusset Plates

Where to Look – Cross Frames & Diaphragms

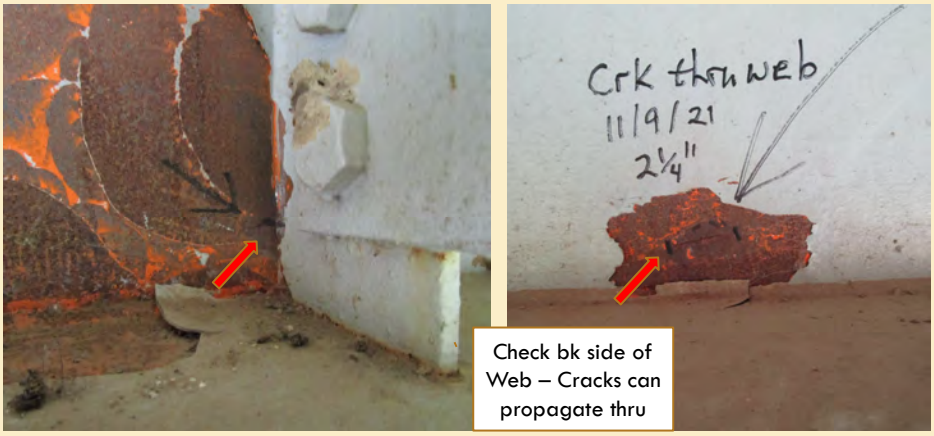


POOR Cross Frame/Diaphragm connection details – cracks at ends of PL in tension zones

23

Fatigue, Fracture & Gusset Plates

Where to Look – Cross Frames & Diaphragms

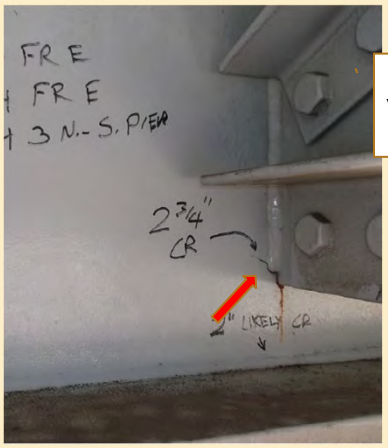


POOR Cross Frame/Diaphragm connection PL details – cracks at ends of PL in tension zones

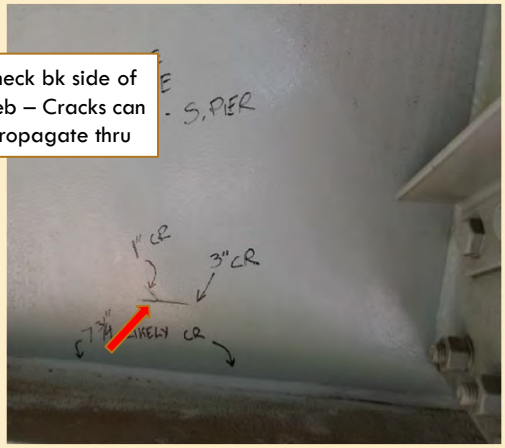
24

Fatigue, Fracture & Gusset Plates

Where to Look – Cross Frames & Diaphragms



Check bk side of Web – Cracks can propagate thru



POOR Cross Frame/Diaphragm connection PL details – cracks at ends of PL in tension zones

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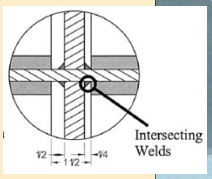
Fatigue, Fracture & Gusset Plates

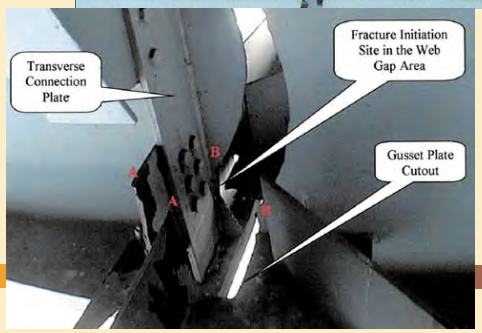
Fatigue Prone Details

Highly-Restrained Connections

"Hoan" like details

- Intersecting welds at stiffeners and connection plates without corner clips
- Transverse members rigidly connected to girder webs without attachment to flanges





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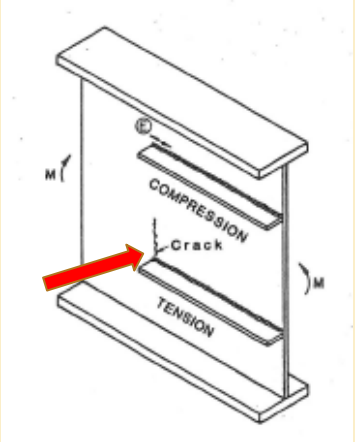
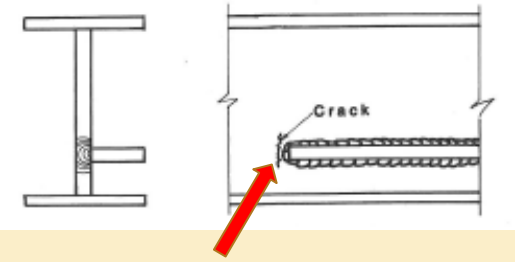
Fatigue, Fracture & Gusset Plates

Where to Look – Longitudinal Web Stiffeners:





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Fatigue, Fracture & Gusset Plates

Where to Look – Eyebars:

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Fatigue, Fracture & Gusset Plates

Recent Case: I-40 over Mississippi R. at Memphis

- **May 2021, fracture of lower truss cord discovered during inspection**
- **Interstate closed due to severity**
- **Crack may have been present for a few years!**
- **Inspector from previous inspection cycles fired. Claimed it was a difficult to reach location.**

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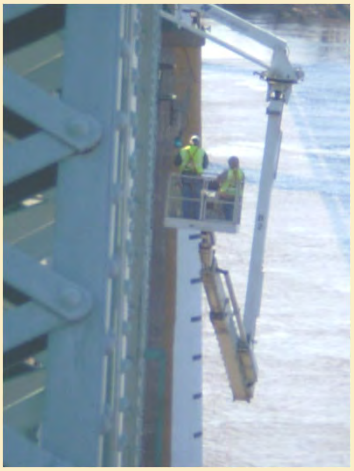
Fatigue, Fracture & Gusset Plates

What to Look For:

- Section Loss
- Poor Weld Details
- Crack Identification
- Evaluating the Crack



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Fatigue, Fracture & Gusset Plates

Nondestructive Testing Methods:

- **Ultrasonic Testing** – Method uses high frequency sound waves to measure material thickness. Surface must be relatively smooth and clean. Effective in finding surface & subsurface defects.
- **Magnetic Particle Test** – Method uses a magnetic field with iron particles to locate defects. Can be difficult to use in the field. Effective in finding surface & subsurface defects.
- **Dye Penetrant Test** – Method involves applying an oil based liquid penetrant & a developer around a suspected crack. Surface must be very clean. Effective in finding cracks open to the surface

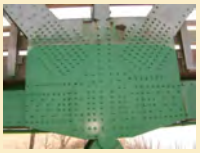
Fatigue, Fracture & Gusset Plates

GUSSET PLATE INSPECTION:

- **Background**
- **Inspection Procedures**
- **General Findings**








Fatigue, Fracture & Gusset Plates

BACKGROUND: I-35W over Mississippi R. Collapse

- August 1, 2007 failure of 14 span deck truss
- Loss of 13 motorists lives
- February 2009, FHWA Pub. No. FHWA-IF-09-014: Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges
- January 29, 2010, FHWA Tech Advisory 5140.31: Inspection of Gusset Plates using Non-Destructive Evaluation
- May 11, 2010, IDOT ABD Memo 10.2: Load Rating Guidance for Bolted and Riveted Gusset Plate in Steel Truss Bridges
- 2010 – IDOT Local Roads CL 2010-09 recommends Gusset Plate inspections & ratings for all qualifying bridges
- October 2015, IDOT ABD Memo 15.5: Revised Load Rating Guidance for Gusset Plates

Fatigue, Fracture & Gusset Plates

BACKGROUND: GP Locations & Numbers

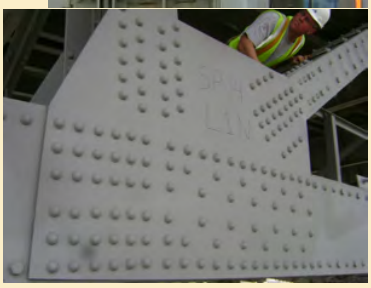
840 Gusset Plates

596 Gusset Plates

Fatigue, Fracture & Gusset Plates

GP INSPECTION PROCEDURES

- Arms length access to FC-GP
- Equipment needs:
  - Appropriate access equipment
  - Measurement tools
- Key Indicators:
  - Section Loss
  - Cracks
  - Plate Distortions
  - Damaged Fasteners



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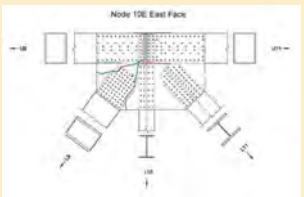
Fatigue, Fracture & Gusset Plates

GENERAL FINDINGS: Gusset Plate Condition

- **Condition varies depending on location**
- **Age & maintenance history important factors**
- **Locations above “splash line” generally good**
- **Locations below the splash line more susceptible**
- **Areas at PL or member connections more susceptible**



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Fatigue, Fracture & Gusset Plates

Field Photos: GP in good condition




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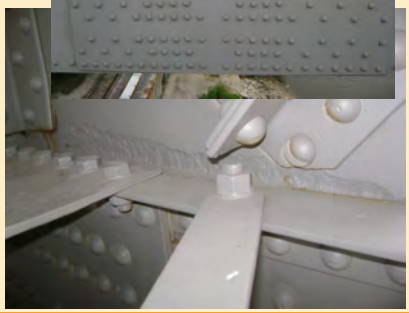
Fatigue, Fracture & Gusset Plates

Field Photos:

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Fatigue, Fracture & Gusset Plates

Field Photos:

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Fatigue, Fracture & Gusset Plates

Field Photos:

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Fatigue, Fracture & Gusset Plates

Field Photos: Poor repairs