CALCULATING SECTION LOSS IN STEEL MEMBERS

Illinois Department of Transportation

Bureau of Bridges & Structures

Introduction

2

○ **Class Instructor: Mike Cima, PE, SE**

○ **Background:**

  ○ Over 22 years of bridge structure experience

  ○ 17+ with IDOT BB&S, 4+ with Hampton Lenzini & Renwick Engineering (Elgin/Springfield/Romeoville)

  ○ Past experience includes bridge inspection, design and policy development

  ○ Inspection experience includes most types of structures

  ○ Licensed PE and SE in Illinois

Introduction

3

- **If you have Questions or Comments during the course of the webinar do the following:**

  - Look on your computer screen for a "red box with an arrow in it", click on this to open the Question Function.

  - Type in and enter your questions to send to us.

  - We fill pause periodically during the webinar to answer questions verbally.

Webinar Agenda

4

- Purpose
- Background
- Common Steel Members
- Critical Areas
- Measuring Equipment
- Taking Measurements
- Documentation
- Calculating Section Loss
- Examples

Purpose of Course

5

The purpose of this webinar is to refresh the skills of personnel conducting bridge field inspections in the process of documentation and calculation of section loss in steel structural members.

The resultant section loss information, used in conjunction with IDOT's Structure Information and Procedure (SIP) Manual criteria for Items # 59 & 60, Steel Superstructure or Substructure, will allow the inspector to determine the correct element condition rating.

Background

6

o **Why is Section Loss measurement important?**

o When a structural member loses area from its design section the engineering properties of the member are changed.

o This can have a negative effect on the following structural capacities of the member:
  o Flexure (moment of inertia & section modulus)
  o Shear (cross sectional area)
  o Tension & Compression (cross sectional area)
  o Bearing (cross sectional area)

Background

Why is Section Loss measurement important?

o If the degree of section loss becomes too great the member affected could become structurally unstable.

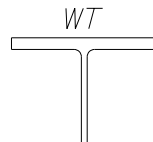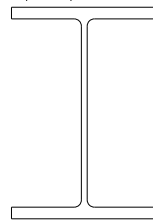o This could result in the partial or complete failure of the structure.
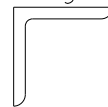

Common Steel Members

o Many types of steel members are used in bridge structures.

o A few of the most commonly used shapes are shown on the following slides.

W, WF, B, CB, I, S, HP...

Angle

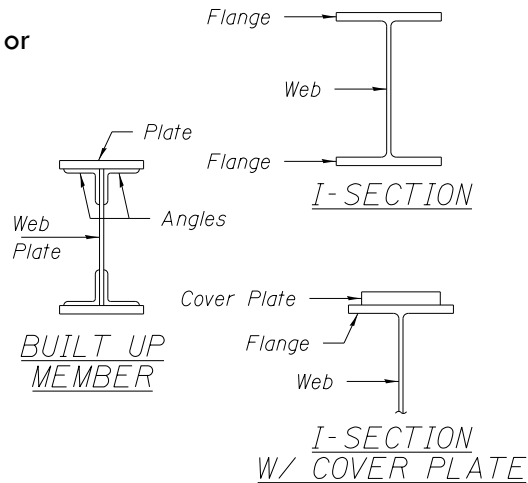C or CB

WT

Common Steel Members

- o **Common Sections:**
  - o Plate Girder (welded or built up member)
  - o Wide Flange
  - o Other "I" Sections

- o Member may also include flange cover plates.

- o Typically used as longitudinal girders in bridges and in truss floor systems.

Flange

Web

Flange

I-SECTION

Plate

Web
Plate

Angles

BUILT UP MEMBER

Cover Plate

Flange

Web

I-SECTION W/ COVER PLATE

Common Steel Members

- o **Channels:** (often used singularly or in pairs).

- o **Angles:** (often used singly or in groups of two or four).

- o These members are common in truss bridges and bracing systems.

Channel

Double Angle
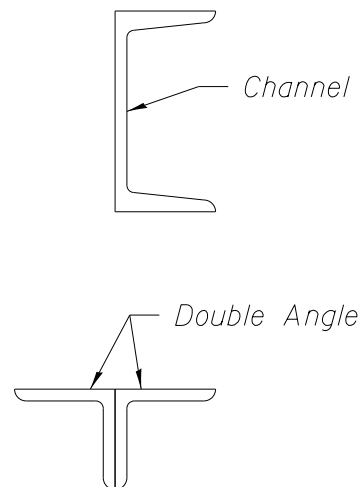
Critical Areas - Defined

11

- o **Critical Areas,** as defined in determining condition ratings using the IDOT SIP Manual, apply to areas on structural members where if damage occurred, it could significantly affect the capacity of the member.

- o These areas can vary with the type of member, where the member is used and the location of the damage on the member within the structural system.

- o Critical areas on some of the most common steel member types are covered in the following slides.
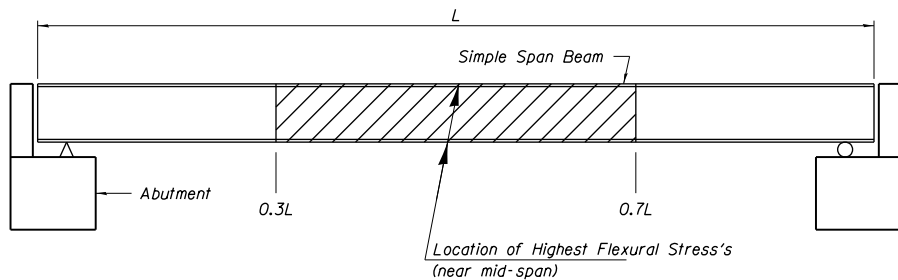
Critical Areas – Flexural Members

12

- o Members in flexure typically develop the highest bending stress at the flanges, making this a critical area.

- o Section Loss in the flange reduces the members flexural capacity.
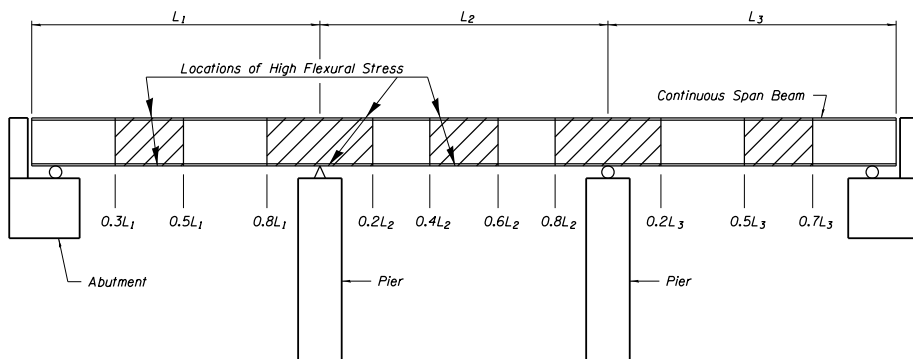
Critical Area
Flexure

Flange

Web

Flange
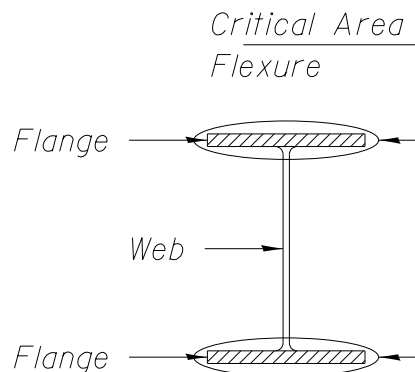
Critical Areas – Flexural Members

High flexural stress in **<u>simple span</u>** structural members is typically found in the location shown below.

L

Simple Span Beam

Abutment

0.3L

0.7L

Location of Highest Flexural Stress's
(near mid-span)

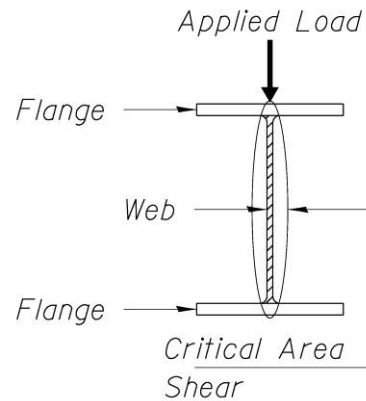# Critical Areas – Flexural Members

High flexural stress's in **<u>continuous span</u>** structural members are typically found in the locations shown below. (Note: These locations vary depending on the span ratios.)

L_1

L_2

L_3

Locations of High Flexural Stress

Continuous Span Beam

$0.3L_1$ $0.5L_1$ $0.8L_1$ $0.2L_2$ $0.4L_2$ $0.6L_2$ $0.8L_2$ $0.2L_3$ $0.5L_3$ $0.7L_3$

Abutment

Pier

Pier

Critical Areas – Shear

15

o Members in shear carry stress primarily parallel to the axis of the applied load.

o In I-shaped flexural members the bulk of the shear stress is typically carried by the web making this a critical area.

o Section loss in this area decreases the members shear capacity.

Applied Load

Flange

Web

Flange

Critical Area
Shear

Critical Areas – Shear

16

High shear stress in structural members is typically found in the locations shown below near the bearing points. (Note: These locations vary depending on the span ratios.)

L_1

L_2

Locations of High Shear Stress
(near supports)

$0.2L_1$ $0.8L_1$ $0.2L_2$ Beam $0.8L_2$

Abutment   Pier
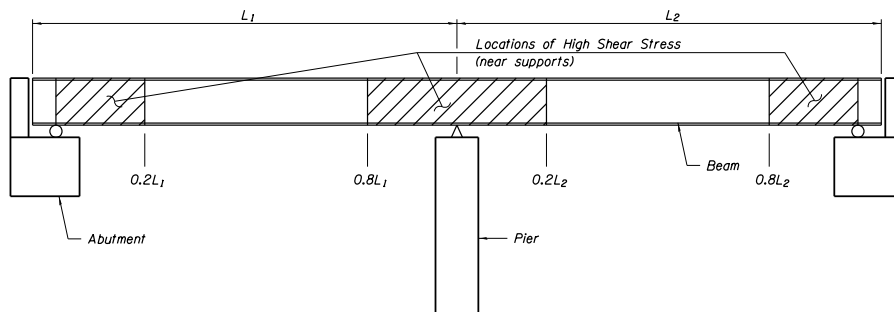
Critical Areas – Tension & Compression

17

o Tension & Compression members come in many types: W, angle, channel, pipes, rods, bars, etc.

o The tens./comp. stress is often roughly evenly distributed in the member through most of its length.

o The critical area on these members is generally any point on the member.

Critical Area
Tension or
Compression
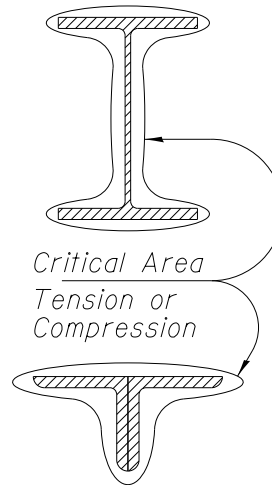
Critical Areas – Tension & Compression

18

High tension or compressive stresses in structural members are typically found in the locations shown below.

High Compressive Stress
(upper cord)

Truss Bridge

Abutment

High Tensile Stress
(lower cord)
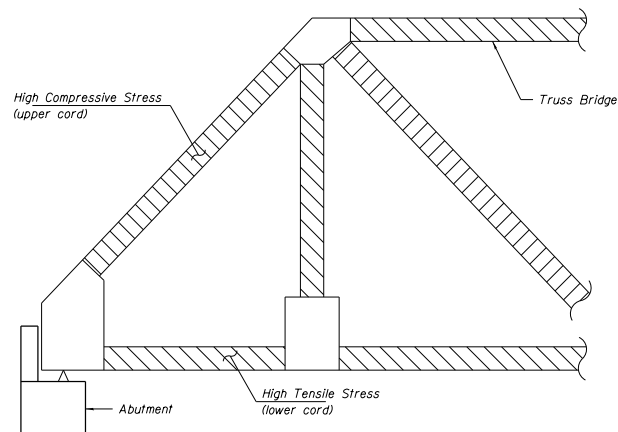
Critical Areas – Bearing

19

o Bearing occurs where one structure member rests on and transfers load to another through contact, such as a superstructure girder resting on a substructure cap.

o Bearing stress is highest in the steel girder immediately above and adjacent to the bearing location.

o The critical area in this case is the beam web.

Critical Area Bearing

Steel Girder

Bearing

Substructure
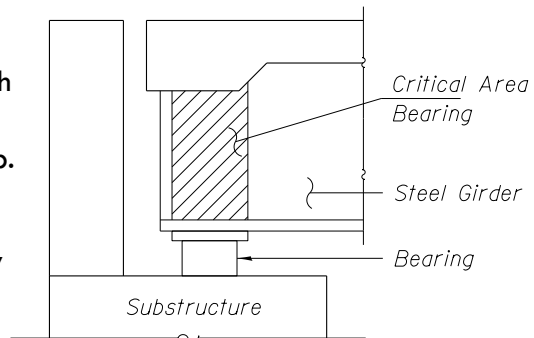
Measuring Equipment

20

Ultrasound Thickness (UT) Gauge:

o Used to measure homogenous metal thickness remaining.

o <u>Often best choice</u> for determining steel thickness remaining.

o Need a relatively clean and smooth surface to measure from.

Taking Measurements

21

What do you need to consider when taking Section Loss measurements?

o Where is the critical location.

o What line to measure along.

o How many measurements to take.

Taking Measurements
Determine Critical Location

22

o Review the damaged sections of the steel member being inspected.

o Determine the location(s) with the greatest section loss.

o If you are unsure where the critical location is, take measurements at multiple damage points with heavy section loss.

o A hole in a member does not mean the member has 100% section loss.

Taking Measurements
Determine Line of Measurement

23

o The line of measurement to determine the max section loss is often at right angles to the longitudinal axis of the member.

o The line passes through the location of greatest overall section loss in that area as shown.

o In some cases however; the line of maximum section loss may occur at an angle other than right angles to the member.

W-Beam Flange

90° *90°*

Heaviest Section Loss

Line of Measurement

90°

60°

PLAN VIEW
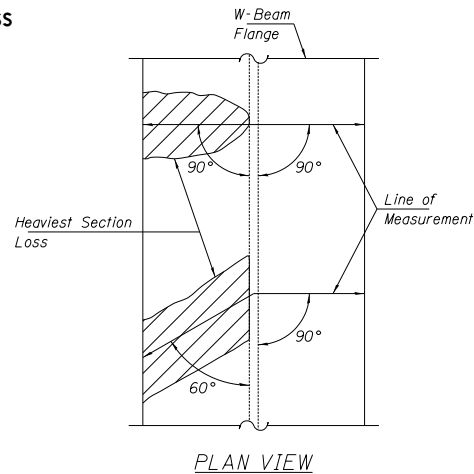
Taking Measurements
Determine How Many Measurements

24

o The number of measurements required depends on the length of the "line of measurement" on the damaged member.

o A minimum of three (3) measurements is generally desirable or one measurement every 2-3 inches.

o Take the measurements at equal spacing along the line of measurement.

o The inspector must use good judgment in determining the number of measurements to take.

Documentation

25

What Information is needed to Document the Section Loss?

o Sketch of member with measurement readings.

o Documenting the sketch and inspection findings.

o Photo(s) of damage.

08.18.2011

Documentation
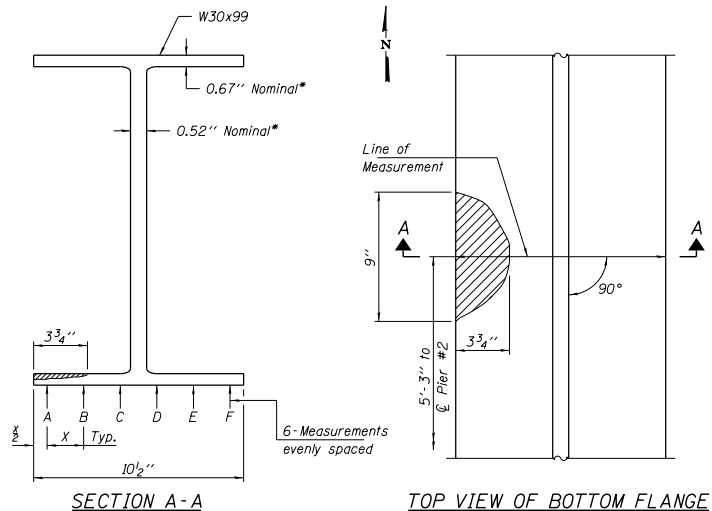## Damage Sketch - Example

26

DAMAGE SKETCH
Inspected by M.D.C.
Date: 08/08/2011
S.N. 001-0001
IL-1000 over Crooked Cr.
West Fascia Beam
Span-3

W30x99

0.67'' Nominal*

0.52'' Nominal*

DAMAGE KEY

Hole

Section Loss

Full Section

Location	Measurement
A	0.24"
B	0.58"
C	0.66"
D	0.67"
E	0.67"
F	0.66"

*Do not use readings > nominal.

3¾''

A B C D E F

x/2

x Typ.

10½''

SECTION A-A

6-Measurements evenly spaced

Line of Measurement

9''

A

A

90°

3¾''

5'-3'' to ℄ Pier #2

N

TOP VIEW OF BOTTOM FLANGE

Documentation
Damage Sketch - Documentation

27

- o Place identification data on the sketch:
  - o Name of inspector
  - o Date of inspection
  - o Structure Number and bridge location
  - o Damage location information
- o Provide a sketch of the damaged member with details:
  - o Sketch out an adequate portion of the damaged member to clearly communicate where the damage is located.
  - o Detail each type of distress in a distinctive maner and provide a key to distinguish the types if necessary.
  - o Place linear and area dimensions on the distress as appropriate.

Documentation
Damage Sketch - Documentation

28

- o Place a dimension to the damaged location from an easily recognized known point of reference on the structure.

- o Provide a cross section sketch(s) through the most heavily damaged locations.

- o Show the "Line of Measurement", angle of measurement, measurement point locations and measurement reading at each measurement point.

Documentation
Damage Photo(s)

29

o Take clear photos of the damaged area.

o Use an object for scale reference if necessary.

o Keep a log to identify the location and direction each picture was taken from.

o Use adequate distance from location to allow for overall perspective.

Calculating Section Loss

30

o For I-shaped flexural members, these areas include:
  o Flexure locations – the individual flanges
  o Shear locations – the web
  o Bearing locations – the web above the bearing

o Tension & Compression Members – full member area

Calculating Section Loss

31

o To calculate the percent Section Loss (SL) for a critical area do the following:

- o Calculate the original cross sectional area of the element according to its "as built dimensions" on the design plans or from measurements taken at an equivalent undamaged location.
- o Calculate the current area of the element according to its "current dimensions" taking into consideration the SL that has occurred.
- o Then complete the following calculation:

%SL = [(original area – current area) / original area] x 100

o The above formula provides the % SL for that element.

Examples

32

Four section loss measurement examples are included in the following slides. They cover:

o Example 1: Flange Section Loss on Beam

o Example 2: Web Section Loss on Beam

o Example 3: Bearing Section Loss on Beam

o Example 4: Tension Member Section Loss
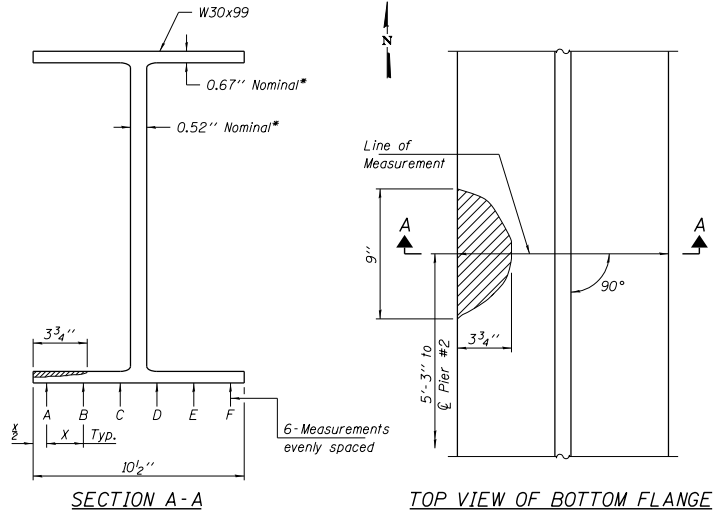
Example 1: Flange Section Loss on Beam

DAMAGE SKETCH
Inspected by M.D.C.
Date: 08/08/2011
S.N. 001-0001
IL-1000 over Crooked Cr.
West Fascia Beam
Span-3

DAMAGE KEY

Hole

Section Loss

Full Section

Location	Measurement
A	0.24"
B	0.58"
C	0.66"
D	0.67"
E	0.67"
F	0.66"

*Do not use readings > nominal.

W30x99

0.67'' Nominal*

0.52'' Nominal*

3 3/4''

A B C D E F

x/2   X   Typ.

10 1/2''

SECTION A-A

6-Measurements evenly spaced

N

Line of Measurement

9''

A   A

90°

5'-3'' to ℄ Pier #2

3 3/4''

TOP VIEW OF BOTTOM FLANGE

Example 1: Flange Section Loss on Beam

- ○ Calculate the % SL from the readings taken in the field at the "line of measurement" in the Example 1 Damage Sketch.

- ○ The beam in this example is one of the primary longitudinal girders of the bridge and the damage is in a **critical area for flexure.**

- ○ First **calculate the original area** of the cross section at the "critical area" being analyzed. In this case, the critical section is the bottom flange of the beam:

  Original Area = flange width x flange thickness

  Original Area = 10.5 in. x 0.67 in. = 7.03 in²

Example 1: Flange Section Loss on Beam

35

○ Next **calculate the current area** of the element using the measurements shown in the table at the lower left side of the sketch:

Calculate the average current flange thickness

Avg. = (sum of the individual readings)/(number of readings)

Avg. = (0.24+0.58+0.66+0.67+0.67+0.66)/6 = 0.58 in.

Calculate the current area of the flange

Current Area = flange width x Avg. current flange thickness

Current Area = 10.5" x 0.58" = $\underline{6.09\ in^2}$

Example 1: Flange Section Loss on Beam

36

○ Now **calculate the % SL** at the element:

%SL = [(original area – current area) / original area] x 100

%SL = [(7.03 – 6.09) / 7.03] x 100 = $\underline{13.4\ \%}$

○ Using the **IDOT SIP Manual, Item Number 59 "Steel Superstructure",** we find that a critical area with 13.4% SL falls under **Condition Rating 4, POOR,** which allows section loss from: $10\% < SL \leq 30\%$.
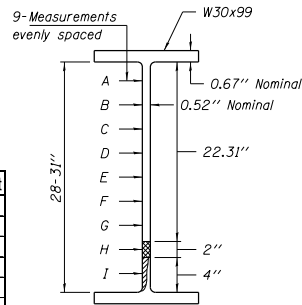
Example 2: Web Section Loss on Beam

37

DAMAGE SKETCH
Inspected by M.D.C.
Date: 08/10/2011
S.N. 001-0001
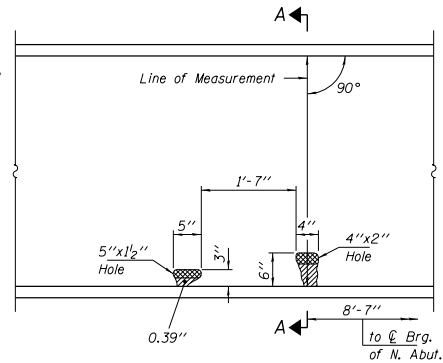IL-1000 over Crooked Cr.
East Fascia Beam
Span-1

DAMAGE KEY

▓ Hole
▨ Section Loss
☐ Full Section

Location	Measurement
A	0.52"
B	0.52"
C	0.51"
D	0.52"
E	0.52"
F	0.52"
G	0.51"
H	0.0"
I	0.31"

9-Measurements evenly spaced

W30x99

A → 0.67'' Nominal
B → 0.52'' Nominal
C
D → 22.31''
E
F
G
H → 2''
I → 4''

28-31''

SECTION A-A

A ◀

Line of Measurement — 90°

1'-7''

5''
5''x1½'' Hole
3''
6''
4''
4''x2'' Hole

0.39''

8'-7''
to ℄ Brg. of N. Abut.

A ◀

BEAM ELEVATION - LOOKING WEST

Example 2: Web Section Loss on Beam

38

○ Calculate the % SL from the readings taken in the field at the "line of measurement" in the Example 2 Damage Sketch.

○ The beam in this example is one of the primary longitudinal girders of the bridge and the damage is in a **critical area for shear.**

○ First **calculate the original area** of the cross section at the "critical area" being analyzed. In this case, the critical section is the web of the beam:

Original Area = web depth x web thickness

Original Area = 28.31 in. x 0.52 in. = <u>14.72 in²</u>

Example 2: Web Section Loss on Beam

39

o Next **calculate the current area** of the element using the measurements shown in the table at the lower left side of the sketch:

Calculate the average current web thickness

Avg. = (sum of the individual readings)/(number of readings)
Avg. = (0.52+0.52+0.51+0.52+0.52+0.52+0.51+0.0+0.31)/9
Avg. = 0.44 in.

Calculate the current area of the web
Current Area = web depth x Avg. current web thickness
Current Area = 28.31" x 0.44" = 12.46 in^2

Example 2: Web Section Loss on Beam

40

o An alternate method to calc. the remaining web area when small sections of SL are present is as follows:

Calculate the current area of the web (Alternate Method)

Current Area = original area – deteriorated area
Current Area = 14.72 in^2 – (2"x0.52") – [4"x(0.52"-0.31")]
= 12.84 in^2 (Note: this method is more accurate)

Example 2: Web Section Loss on Beam

o Now **calculate the % SL** at the element:

%SL = [(original area – current area) / original area] x 100

%SL = [(14.72 – 12.46) / 14.72] x 100 = 15.4 %

o Using the **IDOT SIP Manual, Item Number 59 "Steel Superstructure",** we find that a critical area with 15.4% SL falls under **Condition Rating 4, POOR,** which allows section loss from: $10\% < SL \leq 30\%$.
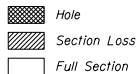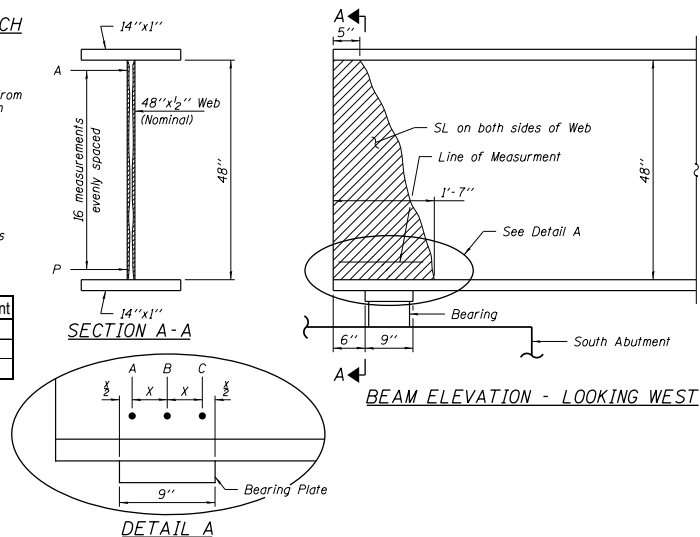
Example 3: Bearing Section Loss on Beam

Example 3: Bearing Section Loss on Beam

43

- o Calculate the % SL from the readings taken in the field at the "line of measurement" in the Example 3 Damage Sketch.

- o The beam in this example is one of the primary longitudinal girders of the bridge and the damage is in a **critical area for bearing.**

- o First **calculate the original area** of the cross section at the "critical area" being analyzed. In this case, the critical section is the web of the beam:

  Original Area = web length over bearing x web thickness
  Original Area = 9.0 in. x 0.5 in. = <u>4.5 in^2</u>

Example 3: Bearing Section Loss on Beam

44

- o Next **calculate the current area** of the element using the measurements shown in the table at the lower left side of the sketch:

  Calculate the average current web thickness
  Avg. = (sum of the individual readings)/(number of readings)
  Avg. = (0.29+0.32+0.35)/3 = 0.32 in.

  Calculate the current area of the web over the bearing
  Current Area = web length x Avg. current web thickness
  Current Area = 9.0" x 0.32" = <u>2.88 in^2</u>

Example 3: Bearing Section Loss on Beam

o Now **calculate the % SL** at the element:

%SL = [(original area – current area) / original area] x 100
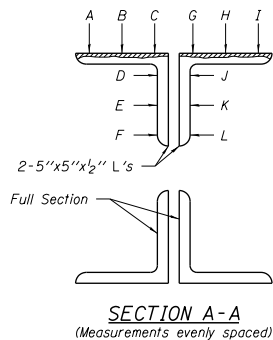
%SL = [(4.5 – 2.88) / 4.5] x 100 = <u>36.0 %</u>

o Using the **IDOT SIP Manual, Item Number 59 "Steel Superstructure",** we find that a critical area with 36.0 % SL falls under **Condition Rating 3, SERIOUS,** which allows section loss from: 30% < SL ≤ 50%.
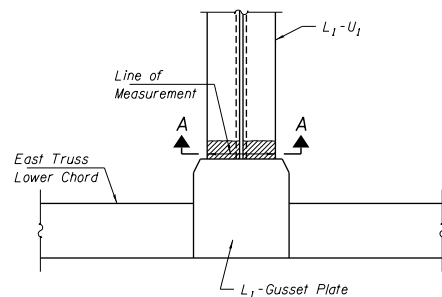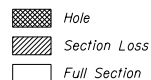
Example 4: Tension Member Section Loss

DAMAGE SKETCH
Inspected by M.D.C.
Date: 08/10/2011
S.N. 001-0002
IL-1000 over IL-999
Span-2
East Truss
Vertical Member $L_1 - U_1$

2-5''x5''x$\frac{1}{2}$'' L's

Full Section

SECTION A-A
(Measurements evenly spaced)

$L_1 - U_1$

Line of
Measurement

A   A

East Truss
Lower Chord

L_1-Gusset Plate

TRUSS ELEVATION - LOOKING WEST

Location	Measurement
A	0.31"
B	0.36"
C	0.39"
D	0.49"
E	0.50"
F	0.48"
G	0.40"
H	0.40"
I	0.34"
J	0.50"
K	0.50"
L	0.48"

DAMAGE KEY

Hole

Section Loss

Full Section

Example 4: Tension Member Section Loss

47

○ Calculate the % SL from the readings taken in the field at the "line of measurement" in the Example 4 Damage Sketch.

○ The member in this example is one of the primary vertical supports of the bridge and the damage is in a **critical area for tension.**

○ First **calculate the original area** of the cross section at the "critical area" being analyzed. In this case, the critical section is the full area of the double angles:

Original Area = angle area x 4

Original Area = 4.75 in^2 x 4 = <u>19.0 in^2</u>

Example 4: Tension Member Section Loss

48

○ Next **calculate the current area** of the element using the measurements shown in the table at the lower left side of the sketch:

Calculate the average current damaged angle leg thickness

Avg. = (sum of the individual readings)/(number of readings)

Avg. = (0.31+0.36+0.39+0.40+0.40+0.34)/6 = 0.37 in.

Calculate the current area of the double angles

Current Area = original area – loss area

Current Area = 19.0 in^2 – [(0.5"-0.37")x10.0"] = <u>17.7 in^2</u>

Example 4: Tension Member Section Loss

49

○ Now **calculate the % SL** at the element:

%SL = [(original area – current area) / original area] x 100
%SL = [(19.0 – 17.7) / 19.0] x 100 = 6.8 %

○ Using the **IDOT SIP Manual, Item Number 59 "Steel Superstructure",** we find that a critical area with 6.8 % SL falls under **Condition Rating 5, FAIR,** which allows section loss up to 10%.

PDH Certificate

50

○ A PDH certificate is available to those who participated in the live version of this webinar.

○ To receive a PDH certificate send an email to the following address: mjmuir@hlreng.com.

○ Title the email "PDH Certificate for IDOT BI Section Loss Class"

○ Include the full name of the individual to receive the certificate as well as a mailing address in the email.