# RIVERFRONT PARK BRIDGES

INSPECTION AND ANALYSIS

## TRIANGLE TRUSS BRIDGE

NOVEMBER 14, 2014 | Final Report

With Revisions – 12/22/2014

kpff Consulting Engineers

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# TRIANGLE TRUSS BRIDGE

## November 14, 2014- With Revisions – 12/22/2014


### Prepared for

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# 1. BRIDGE DESCRIPTION

The Triangle Truss was built for 1974 Expo to carry pedestrians over the north channel of the Spokane River. The deck truss is made of weathering steel with bolted connections. The weathering steel stringers and floorbeams support a timber plank deck. The total span length is 172 feet.


Figure 1: Aerial view of the Triangle Truss Bridge

# 2. DOCUMENT REVIEW

In preparation for this evaluation, Kpff reviewed the following documents related to the Triangle Truss Bridge:

- Structural Drawings G16 – G20
- Previous routine inspection reports

# 3. EVALUATION PROCEDURES

### ROUTINE BRIDGE INSPECTION

A visual inspection of the top of the deck and railings was performed. These components were accessed by foot. A visual inspection of the steel framing system, the steel deck truss, the bearings, and the concrete abutments was also performed. These components were accessed by climbing the lower chord and diagonals of the truss.

### STRUCTURAL ANALYSIS

The timber deck, steel stringers, floorbeams, and truss were load rated using the LRFR method. The analysis was performed using SAP2000. A uniform pedestrian live load of 90 psf and the H10 design vehicle were used in the analysis. The analysis assumed that there was only one vehicle on the bridge at a time and the vehicle load did not act concurrently with the uniform pedestrian live load. Impact was not included in the analysis. A rating factor (RF) greater than or equal to 1.0 means that the bridge can safely carry the loads under investigation.

# 4. EVALUATION FINDINGS

### BRIDGE INSPECTION

The steel components are in good condition with only minor surface rust; there was no measurable surface loss. All of the steel connections are intact. The bearing plates are corroded and have up to 3/4-inch of pack rust. The timber deck has evidence of normal wear and tear, including missing bolts. The north embankment is sloughing and is filling in material around the truss' lower panel point.

The bridge inspection report, bridge component labeling system, and photographs and are included in Appendix A.

### STRUCTURAL ANALYSIS

The load rating analysis is reported as a Rating Factor (RF). The RF is the ratio of available capacity in each primary superstructure component over the specified live load combination under investigation. Based on AASHTO specifications, a RF less than 1.0 is interpreted to mean that one or more of the superstructure components do not meet current minimal capacity code standards and consideration should be given to either strengthening the subject component(s), or posting a sign identifying a maximum allowable load for the structure linked to the actual RF of the structure. Rating factors greater than 1.0 are interpreted to mean that all of the superstructure components have sufficient capacity to safely support the load under investigation, per the AASHTO specifications.

The controlling rating factor is dependent on the timber deck fully bracing the compression (top) flange of the steel stringers. The design drawings show a positive connection between the timber deck, the timber longitudinal nailers, and the steel stringers. This connection could not be inspected, but, assuming it is still intact, the timber deck provides enough rigidity to brace the top flange of the stringers.

For the pedestrian load case, the controlling RF = 1.25. The controlling component is the diagonal truss members. For the vehicle load case, the controlling RF = 0.16 for timber deck members in poor condition. The controlling component is the deck in flexure. The timber deck is not designed to carry vehicle loads, which reflects the low rating factor for the AASHTO H10 design vehicle. The City Parks Department should ensure that the bollards at the abutments remain in place to prevent vehicles from driving across the bridge.

The load rating calculations are included in Appendix C.

# 5. CONCLUSIONS AND RECOMMENDATIONS

If the current condition is maintained, this bridge will serve the community indefinitely.

In general, structural steel components that support bridges are conducive to corrosion from environmental conditions such as water, moisture, salts, air pollution, dirt and plants, bird droppings, and bird nests. The more these items are kept a bay the longer the bridge will last. Maintenance is critical, especially in the form of cleaning and removing debris, bird nests, and droppings from anyplace on the structure they can or do collect. The Triangle Bridge structural components, despite experiencing minor levels of corrosion over the past 30 years, have performed quite well. Currently, there is no reason to suspect that this bridge will not be in service for at least another 50 years and much longer if inspected and maintained on a regular basis.

The steel used for this bridge is weathering steel. Its protective coat is a result of a thin film of rust. It is an excellent system for this environment. However, if this protection system appears to degrade over time, painting the bridge becomes an option which can easily buy another 20 to 30 years of service life.

Maintenance of a few items, discussed below, will also help preserve the bridge and improve safety for the public

## BEARINGS

The bearing plates should be cleaned of all debris and surface rust and should be treated with a protective paint system.

## TIMBER DECK

The twisted and deteriorated boards and missing bolts should be replaced. Alternatively, the City could consider replacing the timber deck with a different material with a longer lifespan. By using a colored concrete mix with a special stamp or form liner, the concrete deck options could resemble a timber plank deck. Appendix B includes typical details and a cost comparison of different deck replacement options. The total estimated cost of the deck replacement, dependant on the material selected, is between $241,000 and $303,000. A timber deck replacement in kind has a lifespan of approximately 10 years. The concrete deck, glulam deck panels, and Ironwood deck have a lifespan of approximately 50 to 75 years.

## STEEL TRUSS

The soil should be removed around panel point “L8” to provide 1 foot of clearance below the truss. This will improve load path clarity and reduce the potential for moisture-driven deterioration of the steel. The debris should be removed from the bottom chord panel points.

## EROSION

The City should consider placing concrete slope protection at the north abutment to prevent further sloughing of the embankment.

### FUTURE INSPECTIONS AND ANALYSIS

A routine walk-through inspection should be performed every two years. KPFF has provided inspection forms, which, if utilized on a continual basis will provide an invaluable record of the bridge condition and areas of continual problems over time, and thereby help inform the best way to care for the bridge over the next 75 years and preserve the City's investment in its infrastructure. The bridge will not need to be re-analyzed unless the bridge will be used in a manner different than considered during the original design, or there is significant deterioration to the primary structural elements.

# 6. PERMITS AND CULTURAL RESOURCE REQUIREMENTS

### PERMITS

An environmental permit matrix was prepared by SWCA Environmental Consultants for the Riverfront Park Bridges. The proposed bridge improvement work may require the following permits or approvals:

- Hydraulic Project Approval permit from the Washington Department of Fish and Wildlife.
- State Environmental Policy Act Threshold Determination from the City of Spokane
- Critical Areas Review from the City of Spokane
- Shoreline Substantial Development Permit from the City of Spokane

More information can be found in SWCA’s report.

# APPENDIX A



## LIST OF PHOTOGRAPHS

# CITY OF SPOKANE

## PEDESTRIAN BRIDGE INSPECTION FORM

| | | | | | |
|---|---|---|---|---|---|
| | | | | **Bridge No.** | 873 |
| **Bridge Name** | Triangle Truss / Lou Barbieri | | **Bridge Location** | SW of Washington St and W North River Dr | |
| **Inspection Date** | 8/13/14 | **Inspector(s)** | M. Frymoyer | **Agency** | KPFF |
| **Access Method** | Harness/Lanyards to tie-off on truss members | | | **Weather** | Sunny/Warm |

| | | | | | |
|---|---|---|---|---|---|
| **Load Rating Date** | Nov. 2014 | | **Live Load** | **Pedestrian**: 90 psf ped | **Vehicle**: H10 |
| **Load Rating Factor(s)** | **Ped.** 1.25 | **Veh.** 0.16 | **Controlling Component** | **Pedestrian**: Stringers | **Vehicle**: Timber Deck |

### Description of Bridge

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### Summary of Condition and Critical Findings

Overall the truss is in good condition. There are a couple of connections that have minor corrosion/flaking. The area of concern is pack rust at bearing plates. The timber deck has evidence of normal wear and tear. Some minor concrete defects were noted.

### Summary of Recommendations

1) Remove debris and surface rust at bearings and paint. 2) Remove soil below panel point "L8" (near north abutment) to provide minimum of 1 ft clearance below truss member. 3) Remove debris at truss panel points. 4) Replace twisted and deteriorating planks and missing bolts in timber deck.

### Summary of Bridge Condition

| | Bridge Component | No. of Compon. | % of ** | Condition Rating* 8 – 7 Good | 6 – 5 Fair | 4 – 3 Poor | Comments |
|---|---|---|---|---|---|---|---|
| 1 | Timber Deck | 1 | area | 70% | 10% | 20% | Twisted, split/cracked planks. Two missing bolts. |
| 2 | Metal Railing | 2 | length | 100% | 0% | 0% | Minor surface rust |
| 3 | Steel Truss | 1 | length | 100% | 0% | 0% | See notes next page. |
| 4 | Steel Floorbeams | 9 | length | 100% | 0% | 0% | Minor corrosion/flaking throughout. |
| 5 | Steel Stringers | 16 | length | 100% | 0% | 0% | Minor corrosion/flaking throughout. |
| 6 | Concrete Abutment | 2 | area | 90% | 10% | 0% | See notes next page. |
| 7 | Bearings | 4 | each | 0% | 100% | 0% | See notes next page. |
| 8 | Expansion Joints | 2 | length | 100% | 0% | 0% | Joints covered with metal plate. |
| 9 | Erosion | 2 | length | 50% | 50% | 0% | North embankment is sloughing. |
| 10 | | | | | | | |
| 11 | | | | | | | |
| 12 | | | | | | | |
| 13 | | | | | | | |

*See Page 2 for detailed descriptions **Condition rating percentages are based on the % of area, length, or each of the bridge components inspected.

### GENERAL NOTES

| DESCRIPTION OF CONDITION OF BRIDGE COMPONENT | | |
|---|---|---|
| **Condition Value** | **Material** | **Description** |
| **8 – 7**<br>Very good → Good<br>2 yr. insp. Cycle<br>No repairs. | Steel | Like new, surface rust, minor pitting, no material loss. Connections are good. No damage. |
| | Concrete | No to minor/ insignificant defects includes: cracks, spalls, chips, consolidation, efflorescence. |
| | Timber | Beams: Minor splits, checks, or defects (one side), no decay or insects – sounds solid.<br>Posts: Splits or cracks less than ⅜" (one side), no decay or insects – sounds solid. |
| | Paint | No defects, no sign of rust including no freckled rust, no peeling, no exposed steel. |
| | Scour / Erosion | None or minor. |
| **6 – 5**<br>Satisfactory → Fair<br>1 – 2 yr insp. cycle<br>Monitor for repairs<br>Paint: Max 10 year life estimate | Steel | Moderate corrosion, pitting, flaking, pack rust. Material loss is evident but barely measurable. Connections have up to moderate corrosion but remain fully functional. No cracks. |
| | Concrete | Some spalling but exposed rebar (if any) is insignificant or exhibits some surface rust; delamination is evident with or without evidence of rebar corrosion. Shear zone cracks are tight, barely measureable, and low density. Flexure zone cracks are measurable but less than .035 inch and low density. Concrete may exhibit: efflorescence (moderate to heavy), surface rust, heavy map cracking, very poor consolidation. Settlement cracks in foundations and wall are stable and less than ¼" wide. |
| | Timber | Beams: Less than ⅜" splits – two sides or greater than ⅜" on one side. Some decay (max 10% by volume), some softness but sounds solid – no insects.<br>Posts: More than ½ "splits – two sides or greater than ¾" on one side. Decay is evident (greater than 20% by volume), timber may have extensive wetness and softness. |
| | Paint | Freckled rust, small areas of exposed steel, some peeling, oxidized. |
| | Scour / Erosion | Evidence of scour, exposed footing, no undermining. Banks are sloughing, protection, if any, needs repair. |
| **4 – 3**<br>Poor → Critical<br>3 mo – 1 yr. insp. cycle (as needed)<br>Repairs needed. (ASAP or one year)<br>Re - paint | Steel | Heavy to severe: corrosion, pitting, pack rust. Measurable material loss. Connections are heavily corroded, missing, and questionable functionality. Fatigue cracks. |
| | Concrete | Large spalls, deep w/ exposed and corroded rebar w/ material loss evident. Cracks are wider, closely spaced, clearly structural in nature both in shear and flexure zone. Concrete quality appears poor w/ heavy scaling, stagilites, efflorescence, map cracking, extensive surface rust and delamination, and very poor consolidation of concrete. Settlement cracks are significant. |
| | Timber | Beams: Greater than ⅜" on two sides. Moderate decay up to 20%, surface softness, do not sound solid – may have insects.<br>Posts: Less than ½ "splits – two sides or greater than ½" on one side. Decay is evident (20%), wetness and soft. |
| | Paint | Extensive freckled rust, larger areas of exposed steel, heavily oxidized, extensive peeling. |
| | Scour / Erosion | Undermining or threatens undermining in a manner that could impact structure stability. Banks are heavily eroded, protection if any is non-functional. |

**Additional Comments by Component Number**

| Bridge Comp. No. | Comments |
|---|---|
| 3 | Minor corrosion/flaking. Member L8-U9 LT has bent lower flange (from construction). |
| 6 | North abutment back wall has exposed rebar and minor cracks. NE wingwall has small delamination. |
| 7 | Bearing plates are corroded, NW/NE bearings have up to 3/4" of pack rust. |
| | |
| | |
| | |
| | |

Photo 1 –Triangle Truss Bridge Deck (Looking South)

Photo 2 – Triangle Truss Bridge Elevation (Looking Southwest)

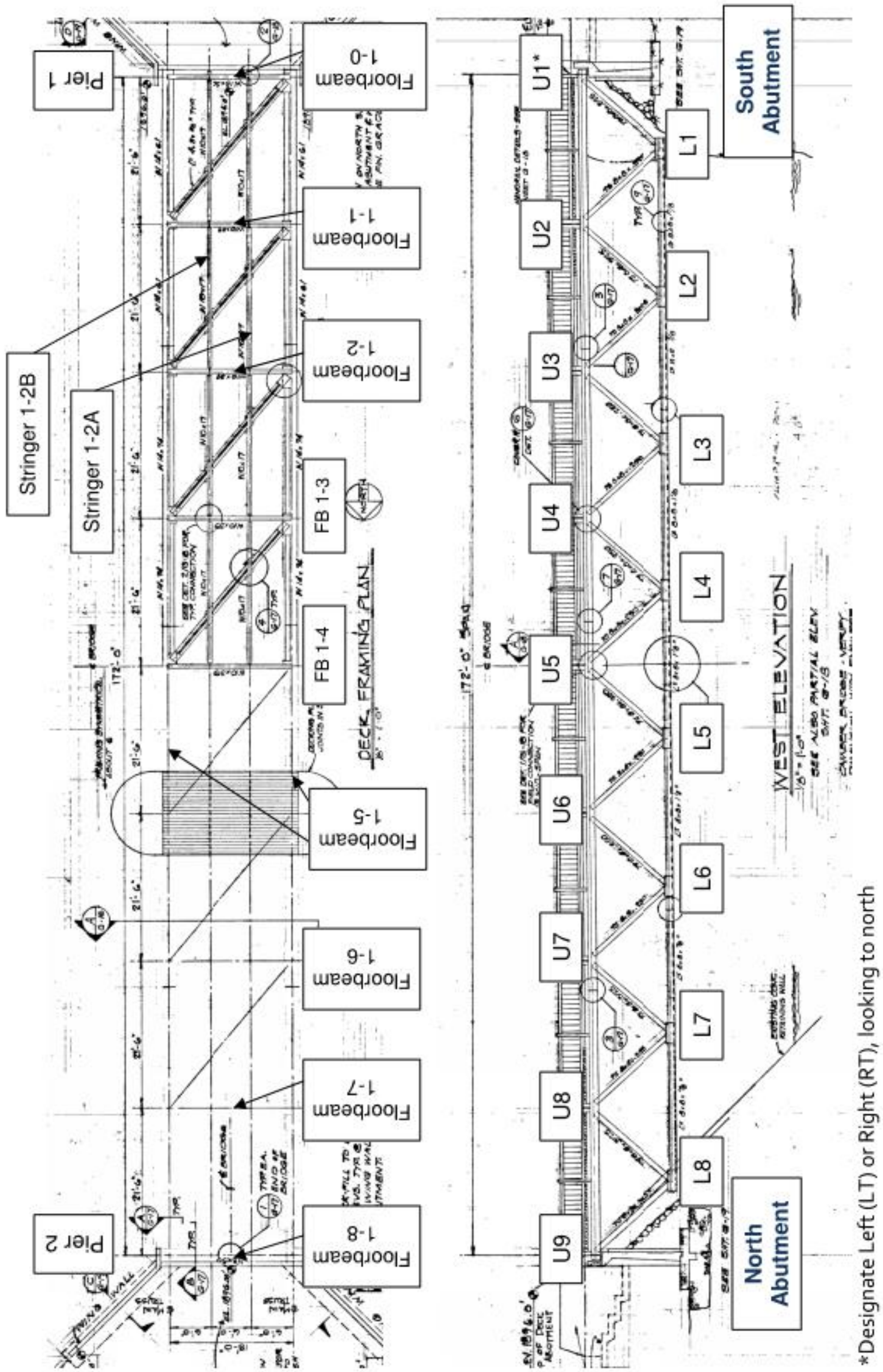
Photo 3 – Cracked and Split Timber Deck Planks

Photo 4 – Missing Bolts in Timber Deck Planks

Photo 5 – Typical Minor Corrosion of Steel Elements


Photo 6 –Northwest Bearings have up to 3/4-inch of Pack Rust

Photo 7 – Soil has Built Up around L8 Panel Point and debris has collected at Lower Truss Panel Points

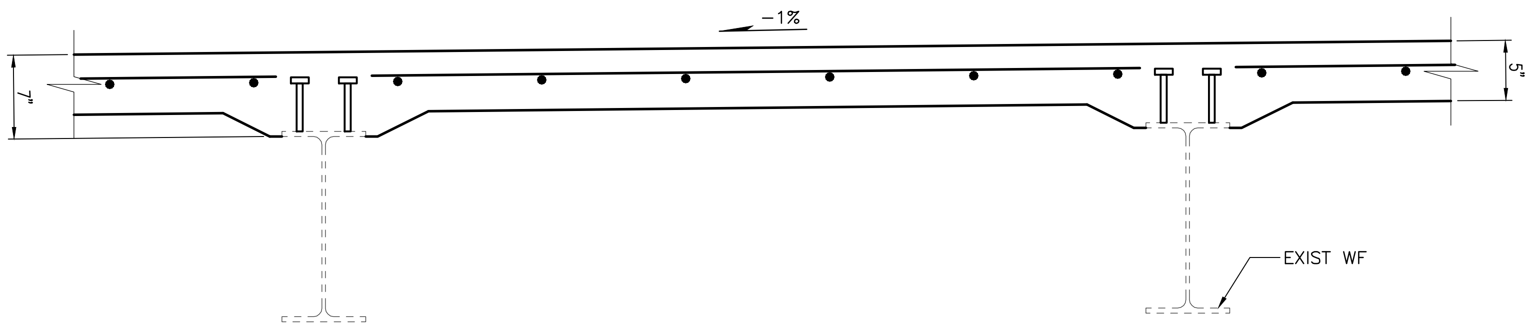



Bridge Component Labeling System

# APPENDIX B

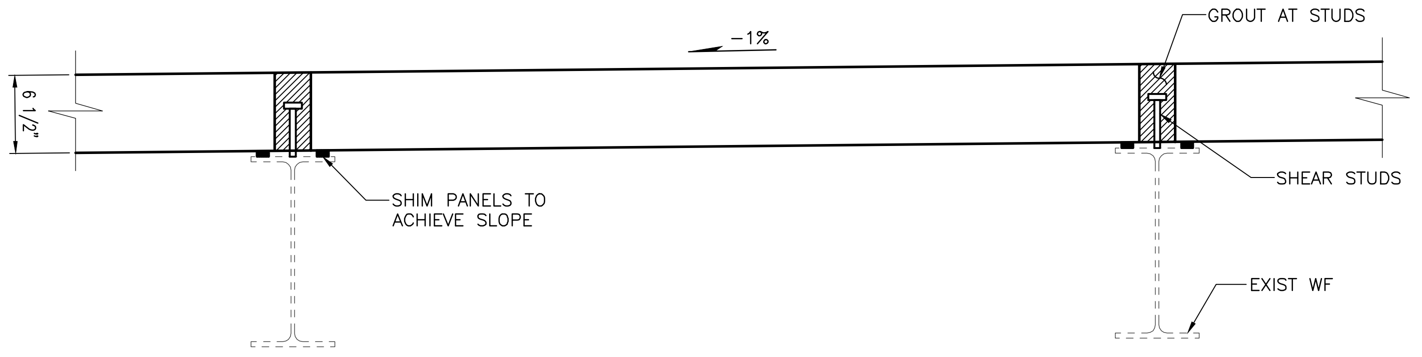
## IMPROVEMENT DETAILS
## COST ESTIMATES

| REGION NO. | STATE | FEDERAL AID PROJECT NO. | SHEET NO. |
|---|---|---|---|
| EASTERN | WASH. | --- | |



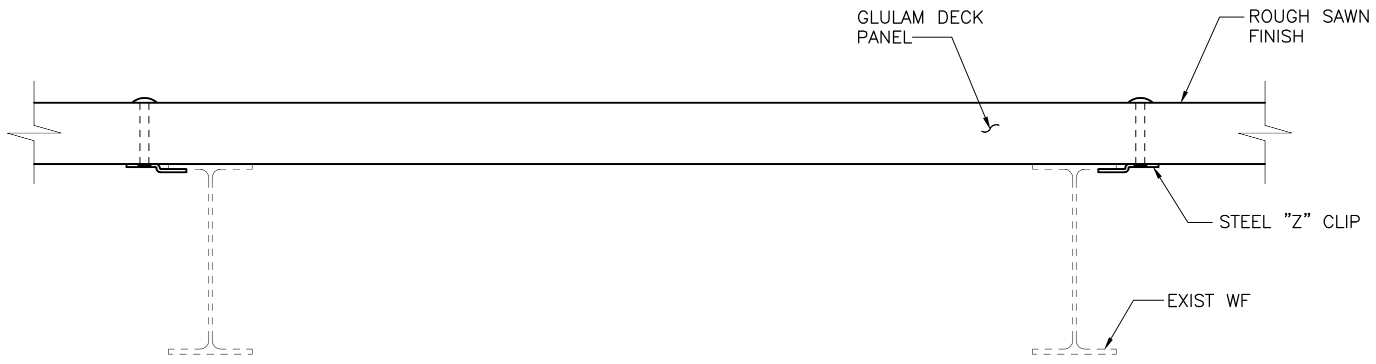

## CAST-IN-PLACE CONCRETE SLAB

SCALE: 1 1/2" = 1'-0"




## PRECAST CONCRETE PANELS

SCALE: 1 1/2" = 1'-0"




## GLULAM DECK PANEL

SCALE: 1 1/2" = 1'-0"

Name: TaunieA Date: Nov 11, 2014-11:45:27am File: V:\114176 (Spokane River Front Bridges)\Deck Replecment\TWB-S01.dwg

| DATE | BY | PROJ. | DESCRIPTION |
|---|---|---|---|
| -/-/- | -- | | --- |

REVISIONS

| DATE | BY | PROJ. | E.P.N. | U.S.N. | FROM | TO | COUNCIL ACCEPT DATE |
|---|---|---|---|---|---|---|---|

AS BUILT

| FROM | TO | ORD. NO. | DATE | FILE NO. |
|---|---|---|---|---|

GRADE ORDINANCE LIST

NAVD88 = (OLD CBM ELEV.) - (13.13)

AS OF JANUARY, 2000 USE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88)

BENCH MARK LOCATION -

NAVD88 ELEV. -

CBM NO. -

NAVD88 DATUM

BAR IS ONE INCH ON ORIGINAL DRAWING.

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

HORIZONTAL PLAN&PROFILE: AS SHOWN

VERTICAL PROFILE ONLY

SCALE

CURRENT C.O.S. DRAFTING STANDARDS ADOPTED FEB,2007

| | BY | DATES |
|---|---|---|
| DRAWN: | HT | 11/14 |
| REVISED: | MLF | 11/14 |
| CHECKED: | TW | 11/14 |
| APPROVED: | MLF | 11/14 |

CITY OF SPOKANE, WASHINGTON

DEPARTMENT OF ENGINEERING SERVICES

808 WEST SPOKANE FALLS BLVD.
SPOKANE, WASHINGTON 99201-3343
(509) 625-6700

PROJECT NAME: RIVERFRONT PARK BRIDGES

BRIDGE NAME: TRIANGLE AND WOODEN BRIDGES

DECK REPLACEMENT

TYPE OF IMPROVEMENT: BRIDGE

CITY PROJECT NUMBER: 2013186

EPN: -

PLAN NUMBER: 1 of 1

CALL BEFORE YOU DIG 1-800-424-5555

WESTERN WOOD
STRUCTURES, INC.

20675 S.W. 105th Ave.
Post Office Box 130
Tualatin, OR 97062-0130

Telephone: (503) 692-6900
Fax: (503) 692-6434

wwsi@westernwoodstructures.com
www.westernwoodstructures.com

# Timber Bridge Maintenance Procedures

Western Wood Structures offers forty years of experience and expertise in the design and fabrication of your modern timber bridge. You can be assured that our state-of-the-art techniques result in a bridge that will deliver an effective service life of 75+ years, with only a few simple maintenance procedures to follow.

A pressure-treated timber bridge typically requires minimal maintenance in order to achieve its projected life expectancy. Our accurate fabrication details allow the bridge members to be fabricated before pressure treatment, thus the initial pressure-treating process provides a comprehensive, protective envelope for the wood.

The following guidelines can be used to further enhance the protections already implemented in a Western Wood Structures timber bridge.

1. A timber bridge is designed to provide air movement around the timber members, which works naturally to reduce moisture. Moisture control is essentially a common sense method of identifying and taking corrective action against sources of moisture, This includes routing the drainage patterns of the approach roadways to channel water away from the bridge. Dirt and debris can trap and retain moisture, and should be removed periodically.

2. All nuts and bolts should be checked and tightened after the first year of service, as necessary. Thereafter, the bridge should be visually inspected on an annual basis.

3. Virtually all bridges designed by Western Wood Structures are pressure-treated, providing a long and useful service life. during the course of several years, as the color of the bridge fades to a driftwood gray, be assured that the effectiveness of the treatment continues.

Following these simple recommendations will provide a long service life for your Western Wood Structures timber bridge. If you need further information, please contact me at (800) 547-5411, or e-mail me at: jagidius@westernwoodstructures.com.


Glulam Deck Rough Sawn Finish (Western Wood Structures, Inc.)


Glulam Deck Rough Sawn Finish Detail (Western Wood Structures, Inc.)

# Bridge Decking and Rail Components

Phone: 414-445-8989
www.ironwoods.com

## Bridge Decking and Rail Components

**Designers, manufacturers and their customers have long recognized the aesthetic, life cycle performance and environmental benefits associated with naturally durable hardwoods like Iron Woods® Ipe in bridge construction.**


*A stream anchor from the Margarita was found with a well-preserved wooden stock. An analysis by Forest Products Laboratories of the U.S. Department of Agriculture showed that it was made of a wood known as ipe or lapacho. On its crown are several well-preserved inscriptions: the date, 1618, and a foundry mark.*

140 years – That's Durability



Phone: 414-445-8989
www.ironwoods.com

# Bridge Decking and Rail Components

Green BY nature™
BUILD WITH CONSCIENCE™

An environmentally  superior alternative to Treated Wood, PVC or Composites… products carrying the 'Green By Nature™ 'Build with Conscience' Certificate of Compliance meet a specific set of Controlled Wood, Chain of Custody, Life Cycle Analysis and Due Diligence criteria that support environmental sustainability initiatives as follows….

All of the material carrying the Green By Nature Certificate of Compliance have been verified as being, legally harvested, transported, exported, imported and documented in compliance with all country of origin, international and domestic laws, rules, regulations and treaties pertaining to the fair and legal trade of forest products including but not limited to the U.S. Department of Agriculture Lacey Act, ITTA (International Tropical Timber Trade Agreement),  CITES (Convention On The International Trade of Endangered Species), and U.S. Buy American Act as per Green By Nature Controlled Wood Chain Of Custody Policies and Procedures.

Additionally, material carrying the Green By Nature Certificate of Compliance, are derived from a naturally occurring, renewable and sustainable resource base and are harvested from forests that have not been converted to plantations or where civil rights are violated. These materials are 100% organic and grown without the use of genetic modification or chemical fertilization and are regenerated naturally or by seeding and replanting. The natural service life of these materials exceeds their natural growth cycle. These materials trap and store carbon and they are able to be reclaimed, reused or recycled. These materials do not require for service any petroleum based or inorganic chemical treatments adhesives or coatings. These materials do not require for service any specialized handling storage or disposal procedures and generate zero post-industrial or post-consumer non-biodegradable waste. These materials are also safe for human and animal contact and meet Low VOC emission standards and meet International Building Code and International Residential Code requirements for naturally durable wood.



Phone: 414-445-8989
www.ironwoods.com

# Bridge Decking and Rail Components

**The following is a summary of technical information designed to assist in the material selection and specification process.**

## Technical Data - Iron Woods® Ipe

| | |
|---|---|
| Features | Iron Woods® Ipe |
| | |
| Composition | Naturally Durable Hardwood Untreated |
| Species | Tabebuia spp. (Lapacho Group) |
| Surface | Dressed / Profiled / Roughsawn |
| Color | Natural |
| Installation | Stainless Steel Fasteners |
| Max overhand beyond joist | 6" |
| Weight per net bf AD 18%+ (avg) | 5.5 - 6 lbs |
| Weight per net bf KD 18% - (avg) | 5 - 5.5 lbs |
| Lengths | To 20' |

| **Property Description** | **ASTM Standard** | **Iron Woods® Ipe** |
|---|---|---|
| Modules of Elasticity | ASTM D-143 | 3145000 psi |
| Bending Strength | ASTM D-143 | 22.475 psi |
| Compression Parallel to Grain | ASTM D-143 | 13,140 psi |
| Compression Perpendicular to Grain | ASTM D-143 | 3,595 psi |
| Shear Parallel to Grain | ASTM D-143 | 2,290 psi |
| | | |
| Screw Pull Out | | Avg. 1102 lbs Max Load |
| | | |
| Coefficient of Friction - Leather | ASTM C1028-89 | Dry - .55 FP / Wet .79 FP (ADA Compliant) |
| Coefficient of Friction - Neolite | ASTM C1028-89 | Dry - .73 FP / Wet .69 FP (ADA Compliant) |
| | | |
| Surface Burning | ASTM E-84 (1989) | NFPA Class A, UBC Class 1 |
| Flame Spread (20 minutes) | ASTM E-84 (1989) | 0 |

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# IRON WOODS

| | | |
|---|---|---|
| Flame Spread (10 minutes) | ASTM E-84 (1989) | 5 |
| Smoke Developed (10 minutes) | ASTM E-84 (1989) | 3 |
| Fuel Contribution (10 minutes) | ASTM E-84 (1989) | 0 |
| Acute Inhalation | NYS Modified Pittsburg Protocol | LC 50 0f 63.60g. |
| Combustion Toxicity Test | NYSUFPBC, Art 15, Part 1120,9 NYCRR 1120 | Pass (19.7g or greater) |
| | | |
| Surface Burning | ASTM E84 (2007) | NFPA Class B |
| Calculated Flame Spread (10 minutes ) | ASTM E84 (2007) | 33.37 |
| Flame Spread Index | ASTM E84 (2007) | 35 |
| Calculated Smoke Developed | ASTM E84 (2007) | 273.3 |
| Smoke Developed Index | ASTM E84 (2007) | 250 |

**Additional Compliance Fire**

| | | |
|---|---|---|
| City Of NY Dept. of Buildings | Fire Retardant Wood Code Sections 27-328 | MEA # 220-01-M (Approved) |
| San Francisco Building Code | Code Section 1511.5 (rooftop decks ) | (Approved) |
| CalFire Wildlife Urban Interface Areas | Code Section Chapter 7A (CSFM 12-7A-4) | (Approved) |
| Materials and Construction Methods | Exterior Wildlife Exposure: Decking | |
| International Building Code | Fire Resistant Wood | (Compliant) |
| International Residential Code | Fire Resistant Wood | (Compliant) |

**Additional Compliance Technical**

| | | |
|---|---|---|
| International Building Code | Naturally Durable Wood | (Class 1 / Compliant) |
| International Residential Code | Naturally Durable Wood | (Class 1 / Compliant) |



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IRON WOODS

TIMBER HOLDINGS USA

# CUMARU

## IRON WOODS® Cumaru

"Iron Woods... Its Only Natural"

Species: Dipteryx Odorta
Common names: Cumaru, Brazilian Teak, Tonka
General Characteristics: Heartwood is reddish-brown to light yellowish-brown. Sapwood is distinct and narrow. It has a low to medium luster with a fine texture and an interlocking grain. Cumaru has a waxy or oily feel; and though it has no distinctive taste, it may have a vanilla-like odor. It is rated as easy to air season with a slight tendency to check and with moderate warping.
Durability: The timbers have a reputation for being very durable.
Working Properties: Slightly abrasive, responds well to planing and other machining operations.
Good nailing, screwing and gluing properties.
Uses: Common applications include heavy construction, decking, dock fenders, flooring, railroad crossties and tool handles.

## Cumaru (Diperyx odorata)

Similar in appearance to Ipe, it can at times be difficult to differentiate to the less trained eye. Cumaru does however have a more coarse and interlocking grain which results in a slightly lower dimensional stability requiring Kiln-drying in dimensions in under 2" nominal in both storage and application. Cumaru is currently being used heavily in the commercial boardwalk industry in 2x4 and 2x6 decking as a lower cost alternative to IPE and where marine borers is not an issue.

## Strength & Durability

Cumaru is a golden to reddish brown species of tropical hardwood with similar technical properties to Ipe with exception of its resistance to marine borers.

How does Iron Woods® Cumaru compare to other lumber and decking products?

| | Cumaru | CCA-Treated Pine | Composite/PVC Decking |
|---|---|---|---|
| Type | Hardwood | Softwood | Plastic Wood |
| Maintenance | Low | High | Low |
| Decay Resistance | High | Varies | Varies |
| Termite Resistance | High | Varies | Varies |
| Strength | High | Medium | Low |
| Movement in Service | Medium-Low | High | High |
| Fire Rating Class | High | Varies | Low |
| Weight per cu. ft. | 67lbs. | 35lbs. | 60 to 64lbs. |
| Bending Strength | 22,400 | 9,900 - 14,500 | 1,423 - 4,500 |
| E-modulus | 3,010,000 | 1,170,000 - 1,510,000 | 175,000 to 480,000 |
| Shear Strength | 2,395 | 1,370 | 561 - 1,010 |
| Hardness | 3,340 | 690 | 940 - 1,390 |

TIMBER HOLDINGS USA IRON WOODS™

# Cumaru

## Availability

Cumaru is sold in two varieties: yellow and red and is typically sold mixed. Cumaru is best used in applications such as commercial decking, boardwalks, bridges, benches and exterior construction.

Decking – 1x4, 1x6, 5/4x6, 2x4, 2x6

Timbers – up to 12x12 by special order only.

All other dimensions up to 12x12 clear of heart center are special order only.

## Finishing

We recommend coating Cumaru to assist the acclimation process and reduce checking. For best performance, coat all four sides and the ends of each board before installation. Use high-quality penetrating oil or water-based exterior sealers that contain mildewcides, fungicides, and UV inhibitors. Ask your local dealer about factory finishing.

**"See Installation Guide for Pre Installation Handling and Storage Requirements"**

## Green by Nature

Green by Nature products meet a specific set of Life Cycle environmental criteria defined as:

* Product derived froma naturally occuring, renewable and sustainable resources.
* Not endangered or at risk as per CITES (Convention On the International Trade of Endangered Species)
* Not harvested from forest areas where traditional or civil rights are violated, converted for plantations or non-forest use.
* Harvested legally and sourced in compliance with all international laws and regulations pertaining to the trade of plant products and more specifically in U.S. Department of Agriculture "Lacey Act Compliant".
* 100% organic, grown without the use of genetic modification or chemical fertilization.
* Service life exceeds natural growth cycle, sequesters and stores carbon throughout its life cycle.
* Generates zero post industrial and post consumer non-biodegradable waste.
* Does not require for service, any specialized handling, storage or disposal procedures. Generates zero post industrial and post consumer non-biodegradable waste.
* Does not require petroleum based or inorganic chemicals treatments, safe for human and animal contact and meets low VOC emmission standards.

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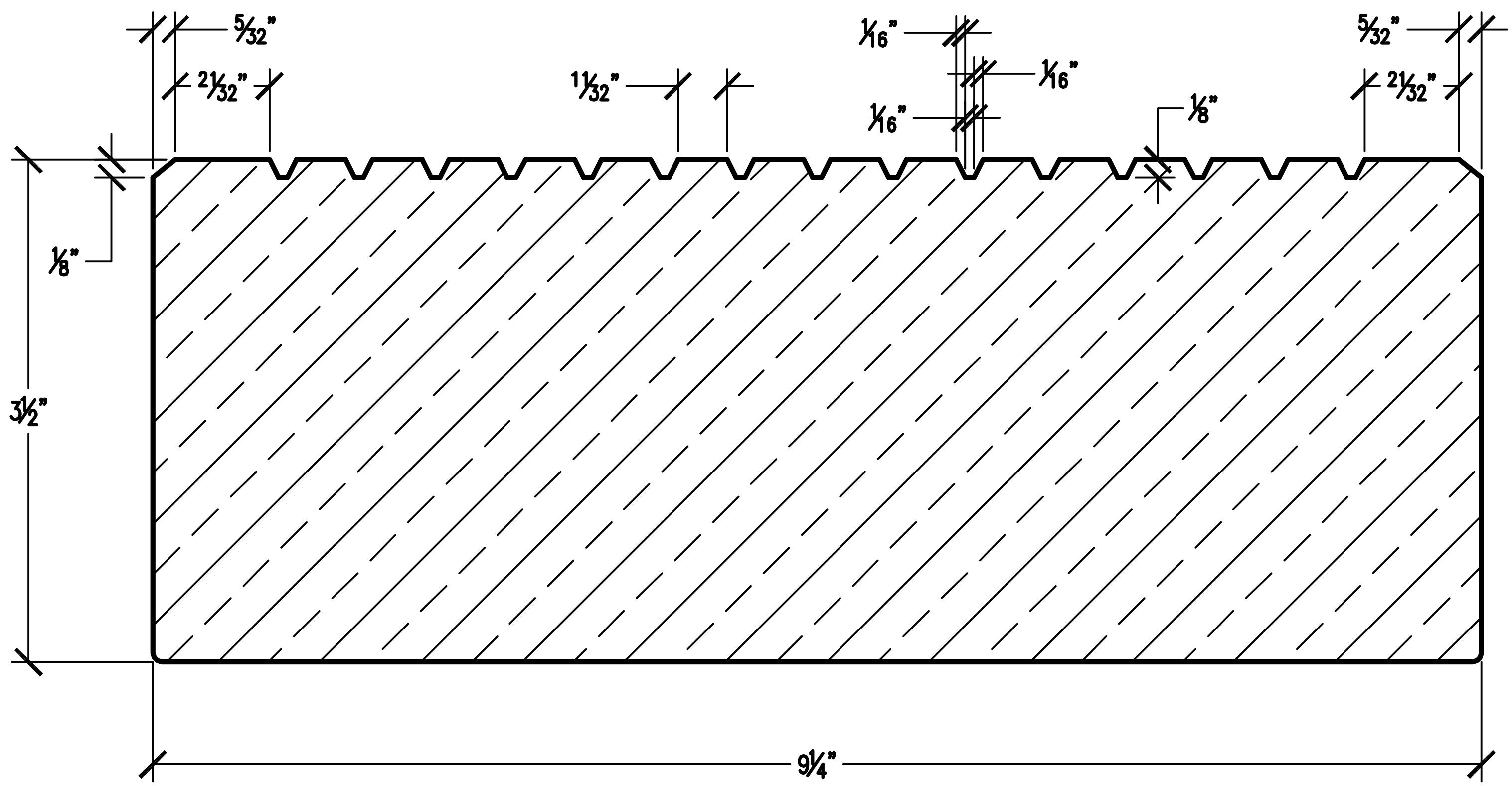


## GROOVE DETAIL

SCALE: 3/4"=1"

| Rev. # | Appr. By | Date | Description | Rev. By |
|---|---|---|---|---|

DATE: 01/08/13
SCALE: AS SHOWN
DRAWN BY: EGH
CHECKED BY: GN
APPROVED: JD
JOB No.
ACCT. No.


CEC GENERAL CONTRACTOR, INC.
P.O. Box 22621 Lake Buena Vista, FL 32830
Phone 407 938-0177 FAX 407 938-0195

Structural Engineer of Record
Janine Pardee 407-595-3617
2513 Catalina Dr, Orlando, FL 32805
Professional Engineer PE 29522


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GROOVED 4x10 IPE DECK BOARD

GROOVE DETAIL

SHEET 1 OF 1

**City of Spokane Pedestrian Bridges** Nov-14

**Cost Estimates for Bridge Improvements Based on the 2014 KPFF Inspection and Analysis Recommendations**

**Bridge Name:** Triangle Truss Bridge

**Bridge Length and Width (feet)** 172 20

**Recommendations for Improvements - Include:** Deck Replacement

**Option 1 - Cast in Place Concrete Deck**

| Item no | Item Description | Cost Unit | Quantity | Unit Cost | Item Cost |
|---|---|---|---|---|---|
| 1 | Existing Rail Remove and Re-install | LF | 344 | 35 | $ 12,040 |
| 2 | Remove Existing Deck | SF | 3440 | 4 | $ 13,760 |
| 3 | New Deck | SF | 3440 | 25 | $ 86,000 |
| 4 | Misc | LS | 1 | 25000 | $ 25,000 |
| | Total | | | | $ 136,800 |

**Option 2 - Precast Concrete Panels**

| Item no | Item Description | Cost Unit | Quantity | Unit Cost | Item Cost |
|---|---|---|---|---|---|
| 1 | Existing Rail Remove and Re-install | LF | 344 | 35 | $ 12,040 |
| 2 | Remove Existing Deck | SF | 3440 | 4 | $ 13,760 |
| 3 | New Deck | SF | 3440 | 30 | $ 103,200 |
| 4 | Misc | LS | 1 | 25000 | $ 25,000 |
| | Total | | | | $ 154,000 |

**Option 3 - Glulam Deck Panels/Ironwood Deck**

| Item no | Item Description | Cost Unit | Quantity | Unit Cost | Item Cost |
|---|---|---|---|---|---|
| 1 | Existing Rail Remove and Re-install | LF | 344 | 35 | $ 12,040 |
| 2 | Remove Existing Deck | SF | 3440 | 4 | $ 13,760 |
| 3 | New Deck | SF | 3440 | 35 | $ 120,400 |
| 4 | Misc | LS | 1 | 25000 | $ 25,000 |
| | Total | | | | $ 171,200 |

**Option 4 - Timber Deck Planks**

| Item no | Item Description | Cost Unit | Quantity | Unit Cost | Item Cost |
|---|---|---|---|---|---|
| 1 | Existing Rail Remove and Re-install | LF | 344 | 35 | $ 12,040 |
| 2 | Remove Existing Deck | SF | 3440 | 4 | $ 13,760 |
| 3 | New Deck | SF | 3440 | 17 | $ 58,480 |
| 4 | Misc | LS | 1 | 25000 | $ 25,000 |
| | Total | | | | $ 109,280 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | Mobilization | 10% | (of option 2) | | $ 15,400 |
| 6 | Design, Permits, Survey | 20% | (of option 2) | | $ 30,800 |
| 7 | Construction Management | 13% | (of option 2) | | $ 19,250 |
| 8 | Taxes | 8% | (of option 2) | | $ 12,320 |
| 9 | Contingency | 30% | (of option 2) | | $ 46,200 |
| 10 | Excalation (1 year) | 3% | (of option 2) | | $ 4,620 |
| 11 | Agency Project Development & Mngmt. | 5% | (of option 2) | | $ 7,700 |
| | Total | | | | $ 136,290 |

| | |
|---|---|
| **Option 1 Total Project Cost (2015)** | **$ 273,090** |
| Option 1 Square Foot Cost - ($/SF) | $ 79 |
| **Option 2 Total Project Cost (2015)** | **$ 290,290** |
| Option 2 Square Foot Cost - ($/SF) | $ 84 |
| **Option 3 Total Project Cost (2015)** | **$ 307,490** |
| Option 3 Square Foot Cost - ($/SF) | $ 89 |
| **Option 4 Total Project Cost (2015)** | **$ 245,570** |
| Option 4 Square Foot Cost - ($/SF) | $ 71 |

*Ironwood Deck cost is comparable to glulam deck panels

# APPENDIX C

## LOAD RATING RESULTS AND CALCULATIONS

# Structural Analysis – Load Rating Summary

## LRFR Bridge Rating Summary

### Strength I – Rating Factors (RF):

| | Pedestrian | | Vehicle | |
|---|---|---|---|---|
| | **Inventory** | **Operating** | **Inventory** | **Operating** |
| Deck (Moment) RF | 5.18 | 6.72 | **0.16** | **0.21** |
| Controlling Point | Deck, Between Stringers | | Deck, Between Stringers | |
| Steel (Axial) RF | **1.25** | **1.62** | 1.08 | 1.40 |
| Controlling Point | Diagonals | | Stringers | |

Maximum Wheel Live Load:

Inventory = 0.16*8,000 lb = 1268 lb
Operating = 0.21*8,000 lb = 1643 lb

Pedestrian = 90 psf uniform distributed load

Vehicle = H-10 Truck
(16,000 lb. front axle, 4,000 lb. rear axle, 14' axle spacing)

Figures C3.1-1 and C3.1-2 from the *LRFD Guide Specifications for the Design of Pedestrain Bridges* (December 2009) give a visual representation of the uniform pedestrian live load.

Figure C3.1-1—Live Load of 50 psf

Figure C3.1-2—Live Load of 100 psf

# Structural Analysis - Load Rating

Design Parameters:

*Steel*

Yield Stress, fy = 50 ksi
Modulus of Elasticity, E = 29,000 ksi

*Timber Deck*

Pine
G = 0.5
σ = 8.8 psf

*Dead Loads*

Superstructure self weight
Railing
(SAP2000 Load Combination – Dead Envelope)

*Live Loads*

Pedestrian Uniform Load = 90 psf
(SAP2000 Load Combination – Pedestrian Envelope)
Vehicle Load = 20,000 lb H-10 Truck
(SAP2000 Load Combination – Moving Vehicle Envelope)
Impact is not included
Pedestrian and Vehicle Loads do not act concurrently

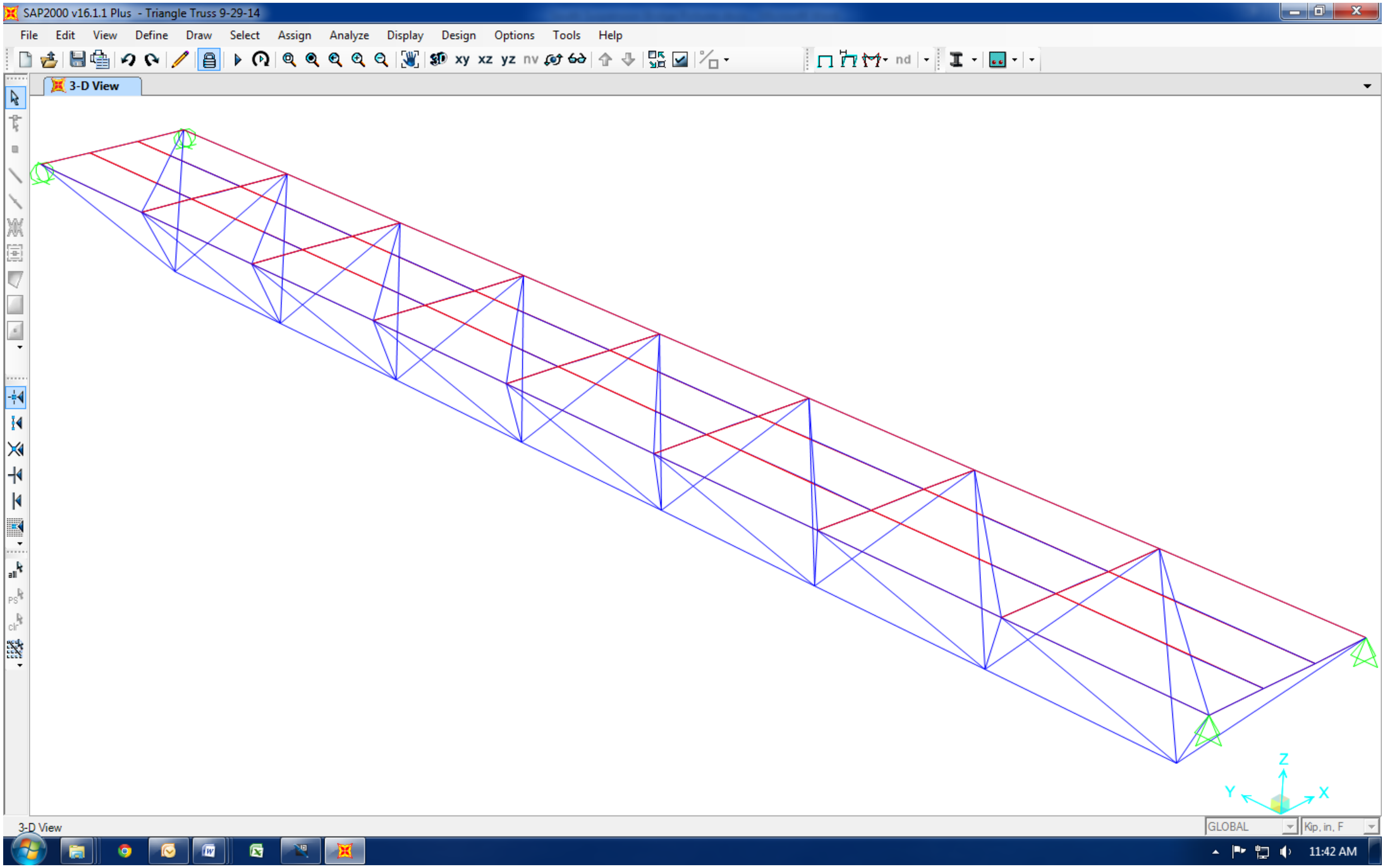
Analysis Methods:

The bridge geometry and section properties were modeled in SAP2000 based on the "As Built" drawings. These drawings showed that tube members were used for the diagonals, however during the inspection these members were found to be wide flange beams. Measurements were taken in the field to determine the sizing of the diagonals. The moment, shear, and axial demands due to dead loads and live loads were exported from SAP2000 to Excel. The moment, shear, and axial capacities were calculated in Excel. The Strength I rating factors were calculated in Excel using the peak demands in each element type.

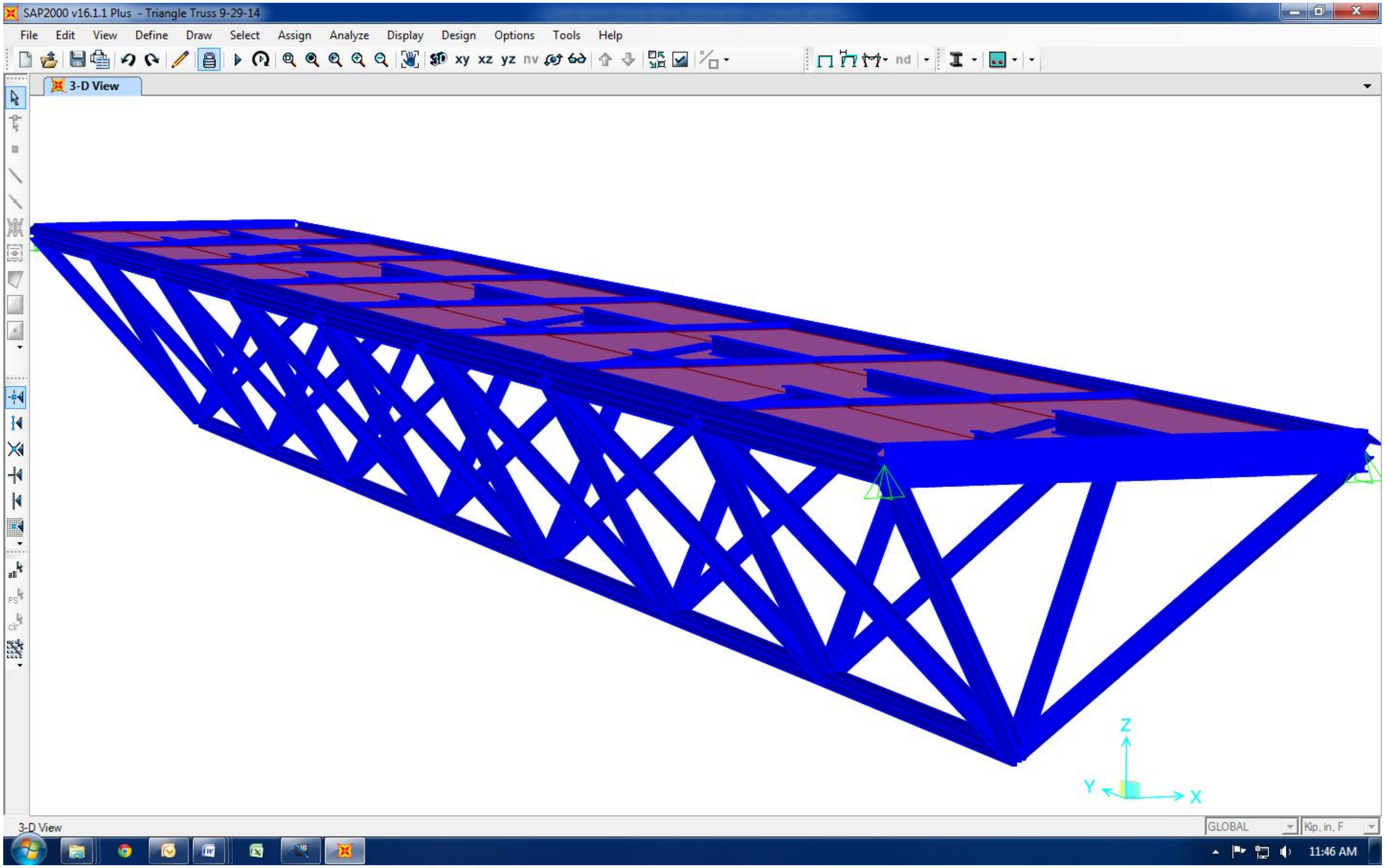
The visual bridge inspection completed on August 14, 2014 found the deck to be in poor condition. All other superstructure components were shown to be in good condition. The condition rating factor, $\varphi_c$, is equal to 1.0 for good members and 0.85 for the poor deck. The system rating factor, $\varphi_s$ is equal to 1.0 for the deck due to its redundant nature, but 0.85 for all other members.

The Strength I Load Rating checks flexure, shear, and axial capacities, as well as combined concurrent moment and axial capacity. Each member except the deck was checked individually and compared to the demands given in the SAP2000 model. The deck demands from the SAP2000 model were not used as these demands were instead calculated in Excel.

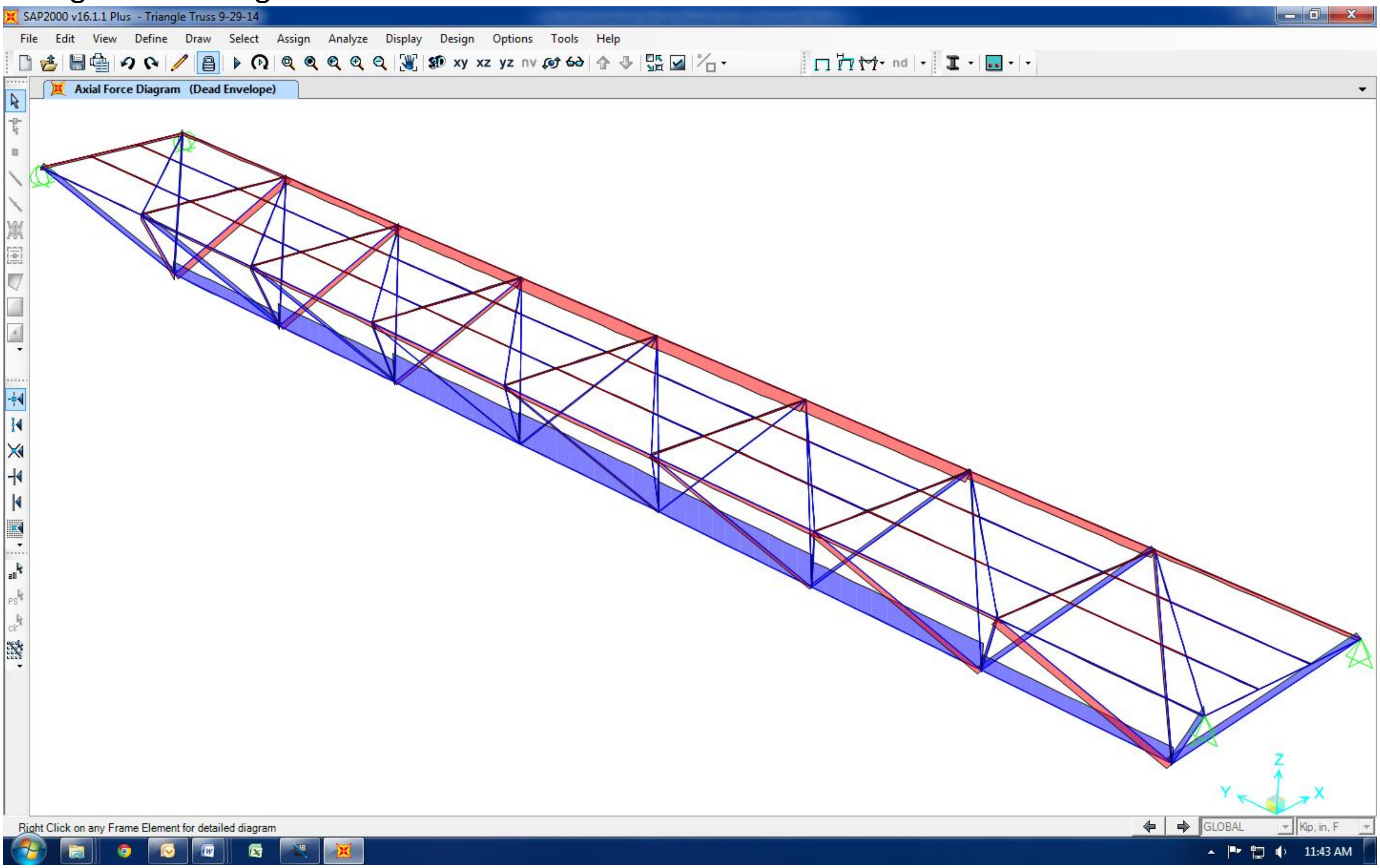
# Triangle Truss Bridge Undeformed



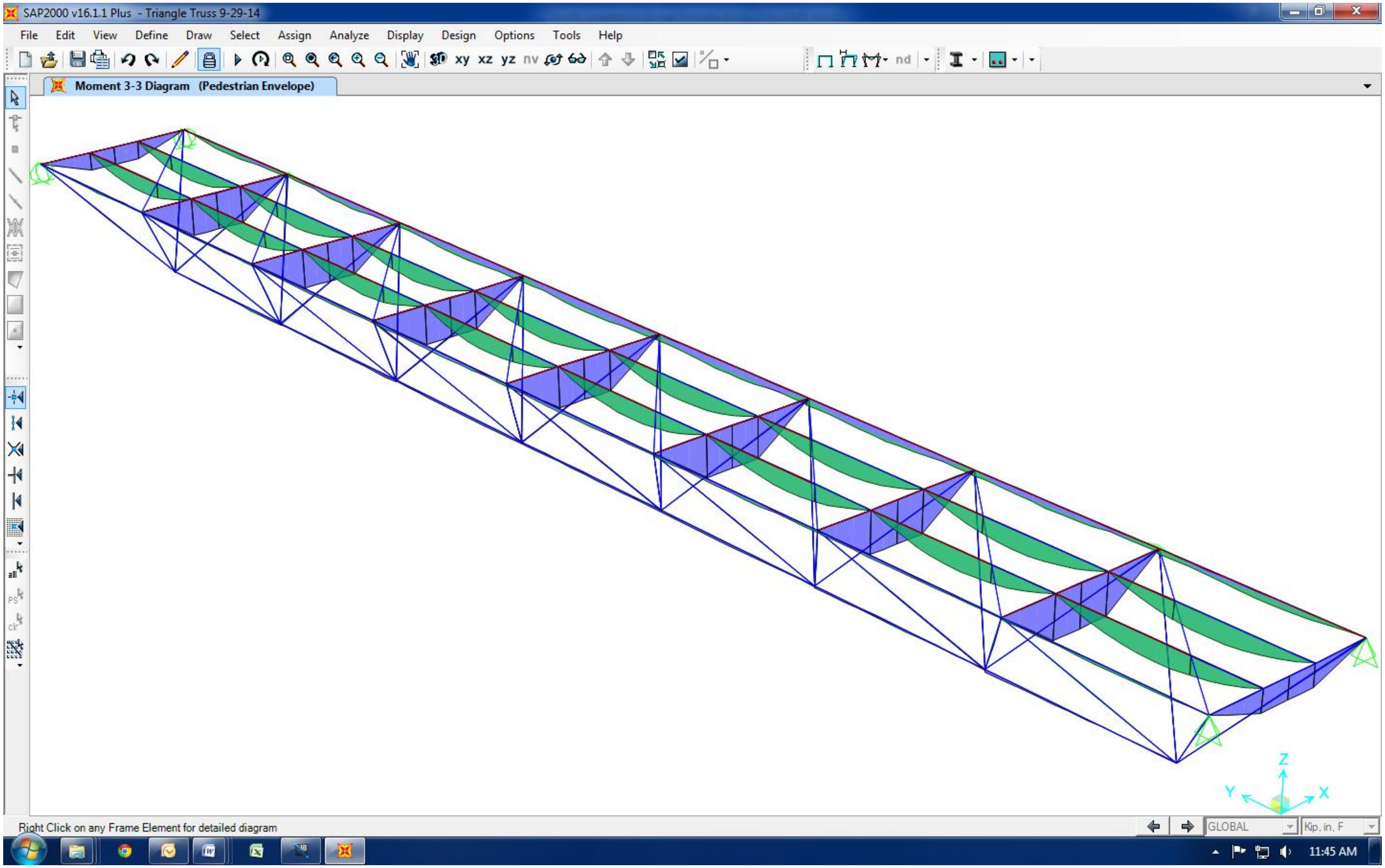
# Triangle Truss Bridge Extruded View



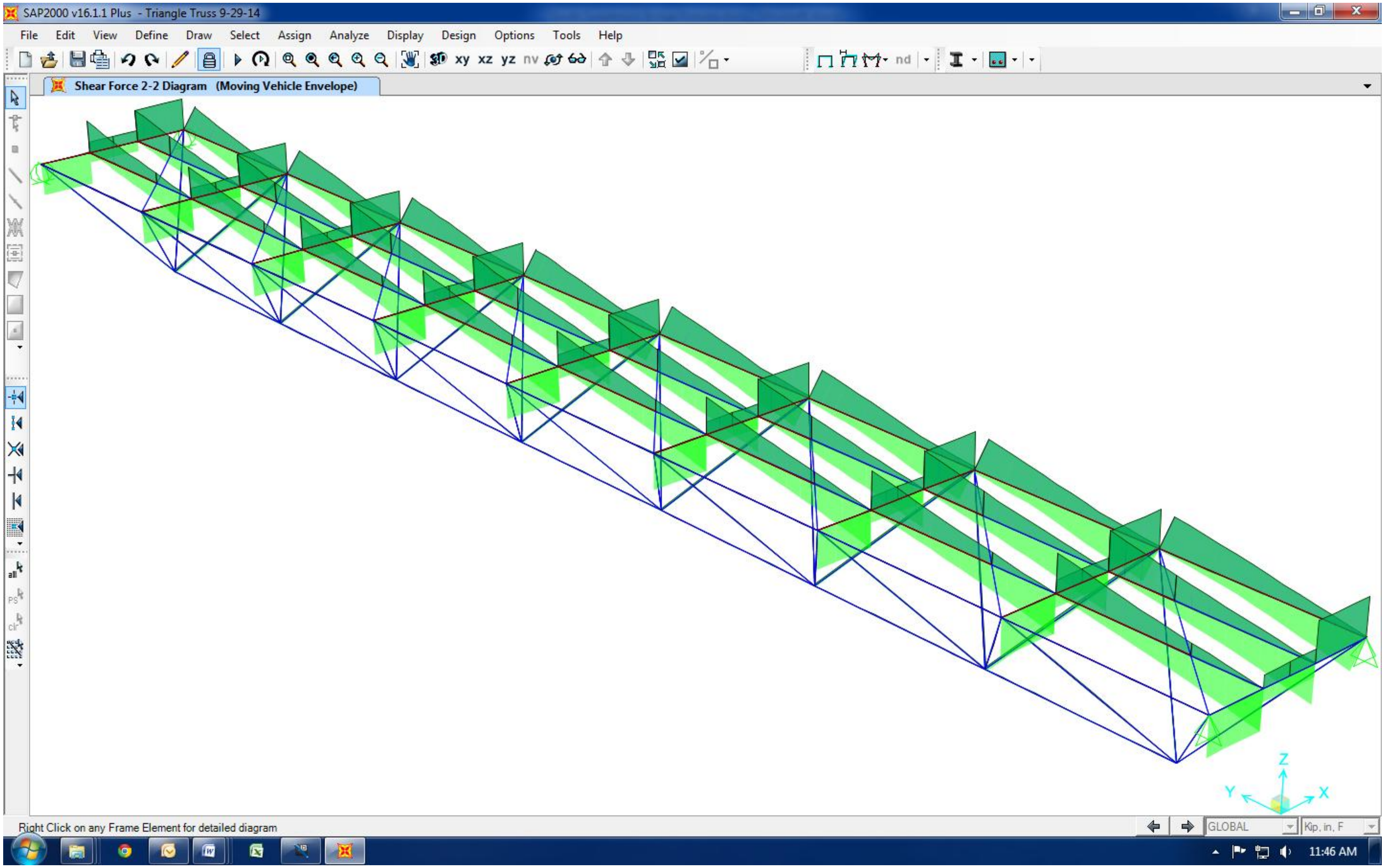
# Triangle Truss Bridge Dead Load Axial Force



# Triangle Truss Bridge Pedestrian Moment



# Triangle Truss Bridge Vehicular Shear



# Triangle Truss Load Rating (LRFR Method)

## Timber Plank Decking

| | | | | | |
|---|---|---|---|---|---|
| Pine | | G | 0.55 | | NDS Table 11.3.2A |
| | | $\gamma_{water}$ | 62.4 | *pcf* | |
| $w_{plank}$ | 7.375 *in* | $\gamma_{timber}$ | 34.3 | *pcf* | |
| $d_{plank}$ | 3.375 *in* | $\sigma_{timber}$ | 9.65 | *psf* | |

Check timber planks as simple spans between steel stringers

| | | | |
|---|---|---|---|
| Stringer Spacing | $L_{c\text{-}c}$ | 6 | *ft* |
| Nailer Beam | $b_{beam}$ | 5.5 | *in* |
| Clear Spacing | $L_{clear}$ | 5.54 | *ft* |

**Dead Loads** Self Weight of deck is only dead load

| | | | | |
|---|---|---|---|---|
| *Weight* | $W_{deck}$ = | $w_{plank}*\sigma_{timber}$ = | 5.93 | *plf* |
| *Moment* | $M_{deck}$ = | $W*L^2/8$ = | 22.8 | *lb-ft* |
| *Shear* | $V_{deck}$ = | $W*L/2$ = | 16.4 | *lb* |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* AASHTO LRFD Ped Bridge 3.1

| | | | | |
|---|---|---|---|---|
| *Weight* | $W_{PL}$ = | $PL*w_{plank}$ = | 55.3 | *plf* |
| *Moment* | $M_{PL}$ = | $W*L^2/8$ = | 212 | *lb-ft* |
| *Shear* | $V_{PL}$ = | $W*L/2$ = | 153 | *lb* |

*Vehicular:* LL H10 Truck AASHTO LRFD Ped Bridge 3.2

wheel 1 8 *k*
wheel 2 2 *k*
(Use maximum wheel load)

for planks under 10" wide, reduce wheel load by $w_{plank}$/10" AASHTO 4.6.2.1.3

$W_{wheel}$ 5900 *lb*

*Weight* distribute wheel load over 20" tire width AASHTO 3.6.1.2.5

$W_{LL}$ = $W_{wheel}$ / 20" = 3540 *plf*

*Moment* place wheel load at midspan of plank

$R = W_{wheel}/2$ = 2950 *lb* reaction at stringer

a = (L-20")/2 = 1.94 *ft*

$M_{LL}$ = $R*(a+R/2W_{LL})$ = 6945 *lb-ft*

*Shear* place wheel load at distance from support = min(3d, 1/4L) AASHTO 4.6.2.2.2

3d 0.844 *ft*

1/4L 1.385 *ft*

b = L - min(3d, 1/4L) = 4.70 *ft*

$V_{LL}$ = $W_{wheel}*b/L$ = 5002 *lb*

**Capacity**

*Moment*

$\Phi M_n = \Phi F_b * S * C_L$ — AASHTO 8.6.2-1

| | | |
|---|---|---|
| $\Phi_{flexure}$ | 0.85 | AASHTO 8.5.2.2 |
| $C_L$ | 1 | AASHTO 8.6.2 |
| $S = b_{plank} * d_{plank}^2/6 =$ | 14.0 *in³* | |

$F_b = F_{bo} * C_{KF} * C_M * C_F * C_{fu} * C_i * C_d * C_\lambda$ — AASHTO 8.4.4.1

| | | |
|---|---|---|
| $F_{bo}$ | 1.2 *ksi* | AASHTO Table 8.4.1.1.4-1 - No. 1 |
| $C_{KF}$ | 2.94 | AASHTO 8.4.4.2 - format conversion factor |
| $C_M$ | 0.85 | AASHTO 8.4.4.3 - wet service factor |
| $C_F$ | 1 | AASHTO 8.4.4.4 - size factor |
| $C_{fu}$ | 1.05 | AASHTO 8.4.4.6 - flat use factor |
| $C_i$ | 0.8 | AASHTO 8.4.4.7 - incising factor |
| $C_d$ | 1.15 | AASHTO 8.4.4.8 - deck factor |
| $C_{\lambda\ (Str-I)}$ | 0.8 | AASHTO 8.4.4.9 - time effect factor |

$F_b =$ 2.32 *ksi*

$\Phi M_n =$ 2299 *lb-ft*

*Shear*

$\Phi V_n = \Phi F_v * b * d/1.5$ — AASHTO 8.7-2

| | | |
|---|---|---|
| $\Phi_{shear}$ | 0.75 | AASHTO 8.5.2.2 |

$F_v = F_{vo} * C_{KF} * C_M * C_i * C_\lambda$ — AASHTO 8.4.4.1

| | | |
|---|---|---|
| $F_{vo}$ | 0.175 *ksi* | AASHTO Table 8.4.1.1.4-1 - No. 1 & Btr |
| $C_{KF}$ | 3.33 | AASHTO 8.4.4.2 - format conversion factor |
| $C_M$ | 0.97 | AASHTO 8.4.4.3 - wet service factor |
| $C_i$ | 0.8 | AASHTO 8.4.4.7 - incising factor |
| $C_{\lambda\ (Str-I)}$ | 0.8 | AASHTO 8.4.4.9 - time effect factor |

$F_v =$ 0.36 *ksi*

$\Phi V_n =$ 4507 *lb*

**Rating Factors**

$$RF = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$$

AASHTO MBE 6A.4.2.1-1

$C_{Str\text{-}I} = \Phi_c \Phi_s \Phi_n R_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c \Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 1 AASHTO MBE 6A.4.2.4

| | |
|---|---|
| $\gamma_{DC}$ | 1.25 |
| $\gamma_{LL\ inv.}$ | 1.75 |
| $\gamma_{LL\ op.}$ | 1.35 |
| IM | 0 |

AASHTO LRFD Ped. Bridge Manual 3.2

Max wheel load = $P_{wheel}$*$RF_{vehcile}$

**Flexure**

| Condition | Good | Fair | Poor |
|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 |
| C [lb-ft] | 2299 | 2184 | 1954 |
| **$RF_{pedestrian\ inventory}$** | **6.11** | **5.80** | **5.18** |
| **$RF_{pedestrian\ operating}$** | **7.92** | **7.52** | **6.72** |
| **$RF_{vehicle\ inventory}$** | **0.19** | **0.18** | **0.16** |
| **$RF_{vehicle\ operating}$** | **0.24** | **0.23** | **0.21** |
| | | | |
| **Max wheel load $_{(inv.)}$ [lb]** | **1495** | **1419** | **1268** |
| **Max wheel load $_{(op.)}$ [lb]** | **1938** | **1840** | **1643** |

**Shear**

| Condition | Good | Fair | Poor |
|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 |
| C [lb] | 4507 | 4282 | 3831 |
| **$RF_{pedestrian\ inventory}$** | **16.7** | **15.9** | **14.2** |
| **$RF_{pedestrian\ operating}$** | **21.7** | **20.6** | **18.4** |
| **$RF_{vehicle\ inventory}$** | **0.51** | **0.49** | **0.44** |
| **$RF_{vehicle\ operating}$** | **0.66** | **0.63** | **0.56** |
| | | | |
| **Max wheel load $_{(inv.)}$ [lb]** | **4100** | **3894** | **3483** |
| **Max wheel load $_{(op.)}$ [lb]** | **5315** | **5048** | **4514** |

# Triangle Truss Load Rating (LRFR Method)

## Girders/Top Chords

| | | |
|---|---|---|
| L | 172 | *ft* |
| Spacing | 18 | *ft* |
| $w_{trib.}$ | 9.83 | *ft* |
| Floorbeam Spacing | 21.5 | *ft* |

Size

| 0'<L<43' : W14x61 | | | 43'<L<midspan' : W14x74 | | |
|---|---|---|---|---|---|
| $A_g$ | 17.9 | $in^2$ | $A_g$ | 21.8 | $in^2$ |
| $b_f$ | 10 | *in* | $b_f$ | 10.1 | *in* |
| $t_f$ | 0.645 | *in* | $t_f$ | 0.785 | *in* |
| $r_{t\ AISC}$ | 2.78 | *in* | $r_{t\ AISC}$ | 2.82 | *in* |
| $r_{t\ AASHTO}$ | 2.77 | *in* | $r_{t\ AASHTO}$ | 2.80 | *in* |
| d | 13.9 | *in* | d | 14.2 | *in* |
| D | 12.6 | *in* | D | 12.6 | *in* |
| $D_c$ | 4.41 | *in* | $D_c$ | 4.42 | *in* |
| $t_w$ | 0.375 | *in* | $t_w$ | 0.45 | *in* |
| $S_x$ | 92.1 | $in^3$ | $S_x$ | 112 | $in^3$ |
| $S_y$ | 21.5 | $in^3$ | $S_y$ | 26.6 | $in^3$ |
| $Z_x$ | 102 | $in^3$ | $Z_x$ | 126 | $in^3$ |
| $Z_y$ | 32.8 | $in^3$ | $Z_y$ | 40.5 | $in^3$ |
| $I_x$ | 640 | $in^4$ | $I_x$ | 795 | $in^4$ |
| $I_y$ | 107 | $in^4$ | $I_y$ | 134 | $in^4$ |

| | | | |
|---|---|---|---|
| $F_{yc}$ | 50 | *ksi* | |
| $F_{yt}$ | 50 | *ksi* | |
| $F_{yf}$ | 50 | *ksi* | |
| $F_{yw}$ | 50 | *ksi* | |
| $F_{yr}$ | 35 | *ksi* | |
| E | 29000 | *ksi* | |
| Rotation | 36.87 | ° | (measured from vertical, about the longitudinal axis) |

**Dead Loads** (from SAP2000 Model)

| | | W14x61 | W14x74 | | |
|---|---|---|---|---|---|
| *Moment* | $M_{33\ max}$ | 49.2 | 72.6 | *k-in* | |
| | $M_{22\ max}$ | 41.4 | 32.8 | *k-in* | |
| *Shear* | $V_{max}$ | 1.16 | 1.21 | *k* | |
| *Axial* | $P_{max}$ | 40.0 | 69.6 | *k* | (compression) |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* AASHTO LRFD Ped Bridge 3.1

*Weight* $W_{PL} = PL*w_{trib.} =$ 885 *plf*

| | | W14x61 | W14x74 | | (from SAP2000 Model) |
|---|---|---|---|---|---|
| *Moment* | $M_{33\ max}$ | 119.1 | 167.0 | *k-in* | |
| | $M_{22\ max}$ | 93.0 | 63.7 | *k-in* | |
| *Shear* | $V_{max}$ | 2.61 | 2.48 | *k* | |
| *Axial* | $P_{max}$ | 97.3 | 168.5 | *k* | (compression) |

*Vehicular:*

| | | | |
|---|---|---|---|
| LL | H10 Truck | | AASHTO LRFD Ped Bridge 3.2 |
| wheel 1 | 8 | *k* | |
| wheel 2 | 2 | *k* | |
| wheel spacing | 6 | *ft* | |
| axle spacing | 14 | *ft* | |

| | | W14x61 | W14x74 | | (from SAP2000 Model) |
|---|---|---|---|---|---|
| *Moment* | $M_{33\ max}$ | 297.4 | 253.6 | *k-in* | |
| | $M_{22\ max}$ | 232.7 | 174.2 | *k-in* | |
| *Shear* | $V_{max}$ | 7.01 | 6.92 | *k* | |
| *Axial* | $P_{max}$ | 15.9 | 23.5 | *k* | (compression) |

**Capacity**

| *Local Buckling Resistance* | W14x61 | W14x74 | |
|---|---|---|---|
| $\lambda_f = b_{fc}/2t_{fc}$ = | 7.75 | 6.43 | AASHTO 6.10.8.2.2-3 |
| $\lambda_{pf} = 0.38*\sqrt{(E/F_{yc})}$ = | 9.15 | 9.15 | AASHTO 6.10.8.2.2-4 |
| $\lambda_{rf} = 0.56*\sqrt{(E/F_{yr})}$ = | 13.49 | 13.49 | AASHTO 6.10.8.2.2-5 |

| | | | |
|---|---|---|---|
| $\lambda_f < \lambda_{pf}$ → | $F_{nc} = R_b*R_h*F_{yc}$ | | AASHTO 6.10.8.2.2-1 |
| → | $M_{nc} = R_{pc}*M_{yc}$ | | AASHTO A6.3.2-1 |
| | $M_{yc} = F_{yc}*S_x$ | | AASHTO D6.2 |
| | $R_b$ | 1 | AASHTO 6.10.1.10.2 |
| | $R_h$ | 1 | AASHTO 6.10.1.10.1 (constructability is not checked) |

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $M_{yc}$ | 4605 | 5600 | *k-in* | |
| $D_{cp}$ | 6.305 | 6.315 | *in* | AASHTO D6.3.2 |
| $\lambda_{rw}$ | 137.3 | | | AASHTO A6.2.1-3 |
| $\lambda_{pw(Dcp)}$ | 93.31 | 89.93 | | AASHTO A6.2.1-2 |
| $2D_{cp}/t_w$ | 33.63 | 28.07 | | |
| $2D_{cp}/t_w < \lambda_{pw(Dcp)}$ → | | Compact | | |
| $R_{pc} = M_p/M_{yc} = Z_x/S_x$ = | 1.11 | 1.13 | | AASHTO A6.2.1-4 & A6.2.2-4 |

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $F_{nc}$ = | 50 | 50 | *ksi* | |
| $M_{nc}$ = | 5100 | 6300 | *k-in* | AASHTO D6.2 |

| *Lateral Torsional Buckling* | W14x61 | W14x74 | | AASHTO 6.10.8.2.3 |
|---|---|---|---|---|
| $L_b$ | 21.5 | 21.5 | *ft* | |
| $L_p = r_t*\sqrt{(E/F_{yc})}$ = | 5.58 | 5.66 | *ft* | AASHTO 6.10.8.2.3-4 |
| $L_r = \pi*r_t*\sqrt{(E/F_{yr})}$ = | 20.95 | 21.25 | *ft* | AASHTO 6.10.8.2.3-5 |

$L_b > L_r \rightarrow$ $F_{nc} = F_{cr} \leq R_b*R_h*F_{yc}$ AASHTO 6.10.8.2.3-3

$\rightarrow$ $M_{nc} = F_{cr}*S_{xc} \leq R_{pc}*M_{yc}$ AASHTO A6.3.3-3

$$F_{cr} = \frac{C_b*R_b*\pi^2*E}{(L_b/r_t)^2}$$ AASHTO 6.10.8.2.3-8

$C_b = 1.75 - 1.05(M_1/M_2) + 0.3(M_1/M_2)^2 \leq 2.3$ AASHTO A6.3.3-7

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $M_{2\ (veh.)}$ = | -40.9 | -165.5 | *k-in* | largest moment at end of braced length |
| $M_{mid\ (veh.)}$= | 297.4 | 253.6 | *k-in* | moment at middle of braced length |
| $M_{0\ (veh.)}$ = | -204.6 | -165.5 | *k-in* | smallest moment at end of braced length |
| $M_{1\ (veh.)} = M_{0\ (veh.)}$ = | | | | AASTHO A6.3.3-12 |
| | -204.6 | -165.5 | *k-in* | |
| $C_{b\ (vehicle)}$ = | 2.30 | 1.00 | | |

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $M_{2\ (ped.)}$ = | 97.8 | 127.1 | *k-in* | largest moment at end of braced length |
| $M_{mid\ (ped.)}$= | 119.1 | 167.0 | *k-in* | moment at middle of braced length |
| $M_{0\ (ped.)}$ = | -68.4 | 112.4 | *k-in* | smallest moment at end of braced length |
| $M_{1\ (ped.)} = M_{0\ (ped.)}$ = | | | | AASTHO A6.3.3-12 |
| | -68.4 | 112.4 | *k-in* | |
| $C_{b\ (ped.)}$ = | 2.30 | 1.06 | | |

| | W14x61 | W14x74 | |
|---|---|---|---|
| $F_{cr\ (vehicle)}$ = | 76.4 | 34.2 | *ksi* |
| $F_{cr\ (ped.)}$ = | 76.4 | 36.1 | *ksi* |

$2D_{cp}/t_w < \lambda_{pw(Dcp)} \rightarrow$ Compact

$R_{pc} = M_p/M_{yc} = Z_x/S_x$ = AASHTO A6.2.1-4

| | W14x61 | W14x74 |
|---|---|---|
| $R_{pc}$ | 1.11 | 1.13 |

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $F_{nc}$ = | 50.0 | 34.2 | *ksi* | |
| $M_{nc}$ = | 5100 | 3830 | *k-in* | AASHTO D6.2 |

*Tension Flange Flexural Resistance*

$F_{nt} = R_h*F_{yt}$ — AASHTO 6.10.8.3-1

$M_{nt} = R_{pt}*M_{yt}$ — AASHTO A6.4-1

$M_{yt} = F_{yt}*S_x$ — AASHTO D6.2

| | W14x61 | W14x74 | |
|---|---|---|---|
| $M_{yt}$ | 4605 | 5600 | *k-in* |

$2D_{cp}/t_w < \lambda_{pw(Dcp)}$ → Compact

$R_{pt} = M_p/M_{yt} = Z_x/S_x =$ — AASHTO A6.2.1-5

| W14x61 | W14x74 |
|---|---|
| 1.11 | 1.13 |

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $F_{nt}$ = | 50 | 50 | *ksi* | |
| $M_{nt}$ = | 5100 | 6300 | *k-in* | AASHTO D6.2 |

*Minimum Flexural Resistance*

$\Phi M_{n\ 33} = \Phi_f*\min(M_{nc},M_{nt})$

$\Phi_f$ 1 — AASHTO 6.5.4.2

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi M_{n\ 33}$ = | 5100 | 3830 | *k-in* |

*Weak Axis Flexure* — AASHTO 6.12.2.2.1

$\lambda_{pf} = 0.038*\sqrt{(E/F_{yf})}$ = 0.915 *in* — AASHTO 6.10.8.2.2-4

$\lambda_{rf} = 0.83*\sqrt{(E/F_{yf})}$ = 20.0 *in* — AASHTO 6.10.8.2.2-5

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $\lambda_f = b_f/(2t_f)$ = | 7.75 | 6.43 | *in* | AASTHO 6.12.2.2.1-3 |

$\lambda_{pf} < \lambda_f < \lambda_{rf}$ →

$M_n = [1 - (1 - S_y/Z_y)((\lambda_f - \lambda_{pf})/(0.45*sqrt(E/F_{yf})))]F_{fy}Z_y$ — AASHTO 6.12.2.2.1-2

$\Phi_f$ 1 — AASHTO 6.5.4.2

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi M_{n\ 22}$ = | 1284 | 1671 | *k-in* |

*Unstiffened Web Shear Resistance* — AASHTO 6.10.9.2

$\Phi V_n = \Phi_v V_{cr} = \Phi_v C V_p$

$\Phi_v$ 1 — AASHTO 6.5.4.2

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| $V_p = 0.58*F_{yw}*D*t_w$ = | 137.1 | 164.8 | *k* | AASHTO 6.10.9.2-2 |
| $D/t_w$ | 33.6 | 28.1 | | |
| k | 5 | 5 | | |
| $1.12*\sqrt{(E*k/F_{yw})}$ = | 60.3 | 60.3 | | |

if $D/t_w < 1.12*\sqrt{(E*k/F_{yw})}$ → C=1

| | W14x61 | W14x74 |
|---|---|---|
| C | 1 | 1 |

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi V_n$ = | 137.1 | 164.8 | *k* |

*Tensile Reistance* AASHTO 6.8.2.1

$\Phi P_n = \Phi_y * F_y * A_g$

$\Phi_y$ 0.95 AASHTO 6.5.4.2

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi P_n$ = | 850 | 1036 | *k* |

*Compression Resistance* AASHTO 6.9.4.1.1

| | | | | |
|---|---|---|---|---|
| K | 0.75 | | | AASHTO 4.6.2.5 |
| $\Phi_c$ | 0.9 | | | AASHTO 6.5.4.2 |

$$P_e = \frac{\pi^2 E * A_g}{(K*l/r_s)^2}$$ AASHTO 6.9.4.1.2-1

$P_o = QF_yA_g$ AASHTO 6.9.4.1.1

| | W14x61 | W14x74 | | |
|---|---|---|---|---|
| k | 0.56 | | | AASHTO Table 6.9.4.2.1-1 |
| b | 5 | 5.05 | *in* | |
| t | 0.645 | 0.785 | *in* | |
| b/t | 7.75 | 6.43 | → Nonslender | |
| $k*\sqrt{(E/F_y)}$ | 13.5 | | | |
| Q | 1.0 | 1.0 | | AASHTO 6.9.4.2 |

| | W14x61 | W14x74 | |
|---|---|---|---|
| $P_e$ | 1057 | 1325 | *k* |
| $P_o$ | 895 | 1090 | *k* |
| $P_e/P_o$ = | 1.18 | 1.22 | |

$P_e/P_o > 0.44$ → AASHTO 6.9.4.1.1-1

$P_n = (0.658\text{^}(P_o/P_e))P_o$

| | W14x61 | W14x74 | |
|---|---|---|---|
| $P_n$ = | 628 | 773 | *k* |

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi P_n$ = | 565 | 695 | *k* |

**Rating Factors**

$$RF_{general} = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$$

AASHTO MBE 6A.4.2.1-1
(Impact for vehicles only)

$C_{Str-I} = \Phi_c\Phi_s\Phi_n R_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c\Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 0.85 AASHTO MBE 6A.4.2.4

if $P_u/P_r > 0.2$ :

$$RF_{M+A} = \frac{1 - \gamma_{DC}[P_{DC}/F_r + (8/9)*\delta_b*(M_{DC}/M_r)]}{\gamma_{LL}[P_{LL+IM}/P_r + (8/9)*\delta_b*(M_{LL+IM}/M_r)]}$$

AASHTO MBE Appendix H6A pg. 6-73

$$\delta_b = \frac{C_m}{1-P_u/\Phi P_e} = \frac{C_m}{1-(\gamma_{DC}P_{DC} + RF*\gamma_{LL}P_{LL})/\Phi P_e} > 1.0$$

| | | |
|---|---|---|
| $C_m$ | 1 | AASHTO 4.5.3.2.2b, conservative |

$$P_e = \frac{\pi^2 EI}{(K*l_u)^2}$$ AASHTO 4.5.3.2.2b-5

| | | | |
|---|---|---|---|
| K | 0.75 | | AASHTO 4.6.2.5 |
| $l_u$ | 21.5 *ft* | | |
| $\Phi_{comp}$ | 0.9 | | AASHTO 6.5.4.2 |

| | W14x61 | W14x74 | |
|---|---|---|---|
| $\Phi P_{e\ strong\ axis}$ | 4403 | 5469 | *k* |
| $\Phi P_{e\ weak\ axis}$ | 736 | 922 | *k* |

| | | |
|---|---|---|
| $\gamma_{DC}$ | 1.25 | |
| $\gamma_{LL\ inv.}$ | 1.75 | |
| $\gamma_{LL\ op.}$ | 1.35 | |
| IM | 0 | AASHTO LRFD Ped. Bridge Manual 3.2 |

| | W14x61 | | W14x74 | |
|---|---|---|---|---|
| | Strong | Weak | Strong | Weak |
| $\delta_{b\ ped.\ inv.}$ | 1.1 | 1.43 | 1.1 | 2.08 |
| $\delta_{b\ ped.\ op.}$ | 1.0 | 1.33 | 1.1 | 1.75 |
| $\delta_{b\ vehicle\ inv.}$ | 1.0 | 1.12 | 1.0 | 1.21 |
| $\delta_{b\ vehicle\ op.}$ | 1.0 | 1.11 | 1.0 | 1.19 |

**Biaxial Flexure + Axial**

| | W14x61 | | | W14x74 | | |
|---|---|---|---|---|---|---|
| Condition | Good | Fair | Poor | Good | Fair | Poor |
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| $C_{axial}$ [k] | 480 | 480 | 480 | 591 | 591 | 591 |
| $C_{M33}$ [k-in] | 4335 | 4335 | 4335 | 3255 | 3255 | 3255 |
| $C_{M22}$ [k-in] | 1091 | 1091 | 1091 | 1420 | 1420 | 1420 |
| **$RF_{pedestrian\ inventory}$** | **1.39** | **1.39** | **1.39** | **1.05** | **1.05** | **1.05** |
| **$RF_{pedestrian\ operating}$** | **1.85** | **1.85** | **1.85** | **1.42** | **1.42** | **1.42** |
| **$RF_{vehicle\ inventory}$** | **1.56** | **1.56** | **1.56** | **1.87** | **1.87** | **1.87** |
| **$RF_{vehicle\ operating}$** | **2.03** | **2.03** | **2.03** | **2.45** | **2.45** | **2.45** |

**Shear**

| | W14x61 | | | W14x74 | | |
|---|---|---|---|---|---|---|
| Condition | Good | Fair | Poor | Good | Fair | Poor |
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| C [k] | 117 | 117 | 117 | 140 | 140 | 140 |
| **$RF_{pedestrian\ inventory}$** | **25.2** | **25.2** | **25.2** | **31.9** | **31.9** | **31.9** |
| **$RF_{pedestrian\ operating}$** | **32.7** | **32.7** | **32.7** | **41.3** | **41.3** | **41.3** |
| **$RF_{vehicle\ inventory}$** | **9.39** | **9.39** | **9.39** | **11.4** | **11.4** | **11.4** |
| **$RF_{vehicle\ operating}$** | **12.2** | **12.2** | **12.2** | **14.8** | **14.8** | **14.8** |

# Triangle Truss Load Rating (LRFR Method)

## Stringers

| | | | |
|---|---|---|---|
| L | 21.5 *ft* | | Braces frame in at 1/3 or 2/3 length |
| Spacing | 6 *ft* | | |
| $w_{trib.}$ | 6 *ft* | | |

| | | | | |
|---|---|---|---|---|
| Size | W10x17 | | $F_{yc}$ | 50 *ksi* |
| | $b_f$ | 4.01 *in* | $F_{yt}$ | 50 *ksi* |
| | $t_f$ | 0.33 *in* | $F_{yw}$ | 50 *ksi* |
| | $r_{t\ AISC}$ | 1.04 *in* | $F_{yr}$ | 35 *ksi* |
| | $r_{t\ AASHTO}$ | 1.06 *in* | E | 29000 *ksi* |
| | d | 10.1 *in* | | |
| | D | 9.44 *in* | | |
| | $D_c$ | 3.30 *in* | (Assuming 35% of web is in compression) | |
| | $t_w$ | 0.24 *in* | | |
| | $S_x$ | 16.2 $in^3$ | | |
| | $Z_x$ | 18.7 $in^3$ | | |

**Dead Loads**

| | | | |
|---|---|---|---|
| *Moment* | $M_{max}$ | 51.0 *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 0.79 *k* | |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* — AASHTO LRFD Ped Bridge 3.1

*Weight* $W_{PL} = PL*w_{trib.} =$ 540 *plf*

| | | | |
|---|---|---|---|
| *Moment* | $M_{max}$ | 374.4 *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 5.81 *k* | |

*Vehicular:* LL H10 Truck — AASHTO LRFD Ped Bridge 3.2

| | |
|---|---|
| wheel 1 | 8 *k* |
| wheel 2 | 2 *k* |
| wheel spacing | 6 *ft* |
| axle spacing | 14 *ft* |

| | | | |
|---|---|---|---|
| *Moment* | $M_{max}$ | 461.5 *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 8.69 *k* | |

**Capacity**

| *Local Buckling Resistance* | | AASHTO 6.10.8.2.2 |
|---|---|---|
| $\lambda_f = b_{fc}/2t_{fc} =$ | 6.08 | AASHTO 6.10.8.2.2-3 |
| $\lambda_{pf} = 0.38*\sqrt{(E/F_{yc})} =$ | 9.15 | AASHTO 6.10.8.2.2-4 |
| $\lambda_{rf} = 0.56*\sqrt{(E/F_{yr})} =$ | 13.49 | AASHTO 6.10.8.2.2-5 |

| | | | | |
|---|---|---|---|---|
| $\lambda_f < \lambda_{pf} \rightarrow$ | $F_{nc} = R_b*R_h*F_{yc}$ | | | AASHTO 6.10.8.2.2-1 |
| | $\rightarrow M_{nc} = R_{pc}*M_{yc}$ | | | AASHTO A6.3.2-1 |
| | $M_{yc} = F_{yc}*S_x$ | | | AASHTO D6.2 |
| | $R_b$ | 1 | | AASHTO 6.10.1.10.2 |
| | $R_h$ | 1 | | AASHTO 6.10.1.10.1 (constructability is not checked) |
| | $M_{yc}$ | 810 | *k-in* | |
| | $D_{cp}$ | 4.72 | *in* | AASHTO D6.3.2 |
| | $\lambda_{rw}$ | 137.3 | | AASHTO A6.2.1-3 |
| | $\lambda_{pw(Dcp)}$ | 84.67 | | AASHTO A6.2.1-2 |
| | $2D_{cp}/t_w$ | 39.33 | | |
| | $2D_{cp}/t_w < \lambda_{pw(Dcp)} \rightarrow$ | Compact | | |
| | $R_{pc} = M_p/M_{yc} = Z_x/S_x =$ | 1.15 | | AASHTO A6.2.1-4 & A6.2.2-4 |
| | $F_{nc} =$ | 50 | *ksi* | |
| | $M_{nc} =$ | 935 | *k-in* | AASHTO D6.2 |

*<u>Bracing</u>* — Check bracing strength of timber deck planks — AISC 6.3.1a

$P_{br} = 0.008*M_r*C_d/h_o$ (Required brace strength) — AISC A-6-5

| | | | |
|---|---|---|---|
| $h_o$ | 9.77 | *in* | (Distance between flange centroids) |
| $C_d$ | 1 | | (For bending single curvature) |
| $M_r$ | 871 | *k-in* | (Factored moment with LRFD factors) |

$P_{br} =$ 0.714 *k*

$\Phi P_n = \Phi*F_c*A_g*C_p$ — AASHTO 8.8.2-1

| | | | |
|---|---|---|---|
| $\Phi_{comp.}$ | 0.9 | | AASHTO 8.5.2 |
| $A_{g\ actual}$ | 24.89 | $in^2$ | |
| Deck condition factor | 0.5 | | (to reduce strength) |
| $A_{g\ reduced}$ | 12.45 | $in^2$ | |

$F_c = F_{co}*C_{KF}*C_M*C_F*C_i*C_\lambda$ — AASHTO 8.4.4

| | | | |
|---|---|---|---|
| $F_{co}$ | 1.45 | *ksi* | AASHTO Table 8.4.1.1.4-1 - No. 1 |
| $C_{KF}$ | 2.78 | | AASHTO 8.4.4.2 - format conversion factor = 2.5/Φ |
| $C_M$ | 0.8 | | AASHTO 8.4.4.3 - wet service factor, ≤ 4" thick |
| $C_F$ | 1.05 | | AASHTO 8.4.4.4-1, Size Effect Factor, 8" width & $F_{co}$ |
| $C_i$ | 0.8 | | AASHTO 8.4.4.7 - incising factor |
| $C_{\lambda\ (Str-I)}$ | 0.8 | | AASHTO 8.4.4.9 - time effect factor |
| $F_c$ | 2.17 | *ksi* | |

$C_p = (1+B)/2c - \sqrt{((1+B)/2c)^2 - B/c} \le 1$ AASHTO 8.8.2-2

| | | |
|---|---|---|
| $K_{cE}$ | 0.52 | AASHTO 8.8.2 |
| K | 1 | AASHTO 4.6.2.5 (assume pinned-pinned) |
| L | 72 *in* | (Stringer spacing) |
| $L_e = KL =$ | 72 *in* | AASHTO 8.8.2 |
| $E_o$ | 1500 *ksi* | AASHTO Table 8.4.1.1.4-1 - No. 1 |
| $E = E_o{*}C_M{*}C_i$ | | AASHTO 8.4.4.1-6 |
| = | 960 *ksi* | |
| $F_{cE} = K_{cE}{*}E{*}d^2/L_e^2$ | | AASHTO 8.8.2-4 |
| = | 1.10 *ksi* | |
| $B = F_{cE}/F_c \le 1$ | | AASHTO 8.8.2-3 |
| = | 0.51 | |
| c | 0.8 | AASHTO 8.8.2, for sawn lumber |
| $C_p$ | 0.44 | |

$\Phi P_n$ 10.6 *k*

$\beta_{br} = 1/\Phi{*}(4{*}M_r{*}C_d)/(L_b{*}h_o)$ (Required brace stiffness) AISC A-6-6

| | | |
|---|---|---|
| $\Phi$ | 0.75 | |
| $L_b$ | 172 *in* | (length between steel braces) |

$\beta_{br}$ 2.77 *k/in*

$k_{timber\ planks} = A_{red.}{*}E/L$ (timber stiffness)

= 165.9 *k/in*

$\Phi P_n \ge P_{br}$ & $k_{planks} \ge \beta_{br}$ → Deck/nailer effectively braces stringers, LTB not considered

*Tension Flange Flexural Resistance*

$F_{nt} = R_h{*}F_{yt}$ AASHTO 6.10.8.3-1

$M_{nt} = R_{pt}{*}M_{yt}$ AASHTO A6.4-1

| | | |
|---|---|---|
| $M_{yt} = F_{yt}{*}S_x =$ | 810 *k-in* | AASHTO D6.2 |
| $2D_{cp}/t_w < \lambda_{pw(Dcp)}$ → | Compact | |
| $R_{pt} = M_p/M_{yt} = Z_x/S_x =$ | 1.15 | AASHTO A6.2.1-5 |
| $F_{nt} =$ | 50 *ksi* | |
| $M_{nt} =$ | 935 *k-in* | AASHTO D6.2 |

*Minimum Flexural Resistance*

$\Phi M_n = \Phi_f{*}\min(M_{nc},M_{nt})$

| | | |
|---|---|---|
| $\Phi_f$ | 1 | AASHTO 6.5.4.2 |
| $\Phi M_n =$ | 935 *k-in* | |

*Unstiffened Web Shear Resistance* AASHTO 6.10.9.2

$\Phi V_n = \Phi_v V_{cr} = \Phi_v C V_p$

| | | |
|---|---|---|
| $\Phi_v$ | 1 | AASHTO 6.5.4.2 |
| $V_p = 0.58 * F_{yw} * D * t_w =$ | 65.7 *k* | AASHTO 6.10.9.2-2 |
| $D/t_w$ | 39.3 | |
| k | 5 | |
| $1.12*\sqrt{(E*k/F_{yw})} =$ | 60.3 | |
| if $D/t_w < 1.12*\sqrt{(E*k/F_{yw})} \rightarrow C=1$ | | |
| C | 1 | |

$\Phi V_n =$ 65.7 *k*

**Rating Factors**

$$RF = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$$ AASHTO MBE 6A.4.2.1-1

$C_{Str-I} = \Phi_c \Phi_s \Phi_n R_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c \Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 1 AASHTO MBE 6A.4.2.4

| | | |
|---|---|---|
| $\gamma_{DC}$ | 1.25 | |
| $\gamma_{LL\ inv.}$ | 1.75 | |
| $\gamma_{LL\ op.}$ | 1.35 | |
| IM | 0 | AASHTO LRFD Ped. Bridge Manual 3.2 |

Max wheel load = $P_{wheel} * RF_{vehcile}$

**Flexure**

| Condition | Good | Fair | Poor |
|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 |
| C [k-in] | 935 | 888 | 795 |
| **$RF_{pedestrian\ inventory}$** | **1.33** | **1.26** | **1.12** |
| **$RF_{pedestrian\ operating}$** | **1.72** | **1.63** | **1.45** |
| **$RF_{vehicle\ inventory}$** | **1.08** | **1.02** | **0.91** |
| **$RF_{vehicle\ operating}$** | **1.40** | **1.32** | **1.17** |

**Shear**

| Condition | Good | Fair | Poor |
|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 |
| C [k-in] | 65.7 | 62.4 | 55.8 |
| **$RF_{pedestrian\ inventory}$** | **6.37** | **6.05** | **5.40** |
| **$RF_{pedestrian\ operating}$** | **8.26** | **7.84** | **7.00** |
| **$RF_{vehicle\ inventory}$** | **4.25** | **4.04** | **3.61** |
| **$RF_{vehicle\ operating}$** | **5.51** | **5.23** | **4.67** |

# Triangle Truss Load Rating (LRFR Method)

## Floorbeams

| | | |
|---|---|---|
| L | 18 | *ft* |
| Spacing | 21.5 | *ft* |
| Stringer Spacing | 6 | *ft* |

Size

| Interior: | W10x39 | | Ends: | W18x50 | |
|---|---|---|---|---|---|
| $A_g$ | 11.5 | $in^2$ | $A_g$ | 14.7 | $in^2$ |
| $b_f$ | 7.99 | *in* | $b_f$ | 7.50 | *in* |
| $t_f$ | 0.53 | *in* | $t_f$ | 0.57 | *in* |
| $r_t$ | 2.24 | *in* | $r_t$ | 1.98 | *in* |
| d | 9.92 | *in* | d | 18 | *in* |
| D | 8.86 | *in* | D | 16.9 | *in* |
| $D_c$ | 3.10 | *in* | $D_c$ | 5.90 | *in* |
| $t_w$ | 0.315 | *in* | $t_w$ | 0.355 | *in* |
| $S_x$ | 42.1 | $in^3$ | $S_x$ | 88.9 | $in^3$ |
| $I_x$ | 209 | $in^4$ | $I_x$ | 800 | $in^4$ |
| $Z_x$ | 46.8 | $in^3$ | $Z_x$ | 101 | $in^3$ |

| | | |
|---|---|---|
| $F_{yc}$ | 50 | *ksi* |
| $F_{yt}$ | 50 | *ksi* |
| $F_{yw}$ | 50 | *ksi* |
| $F_{yr}$ | 35 | *ksi* |
| E | 29000 | *ksi* |

**Dead Loads**

| | | W10x39 | W18x50 | | |
|---|---|---|---|---|---|
| *Moment* | $M_{max}$ | 129.8 | 80.06 | *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 1.89 | 1.23 | *k* | |
| *Axial* | $P_{max}$ | 6.4 | 17.9 | *k* | (compression) |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* AASHTO LRFD Ped Bridge 3.1

*Weight* $P_{PL} = PL*A_{trib.} =$ 11.61 *k* (two point loads of this mag.)

| | | W10x39 | W18x50 | | |
|---|---|---|---|---|---|
| *Moment* | $M_{max}$ | 841.0 | 421.6 | *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 11.68 | 5.86 | *k* | |
| *Axial* | $P_{max}$ | 18.6 | 43.3 | *k* | (compression) |

*Vehicular:* LL H10 Truck AASHTO LRFD Ped Bridge 3.2

| | | |
|---|---|---|
| wheel 1 | 8 | *k* |
| wheel 2 | 2 | *k* |
| wheel spacing | 6 | *ft* |
| axle spacing | 14 | *ft* |

| | | W10x39 | W18x50 | | |
|---|---|---|---|---|---|
| *Moment* | $M_{max}$ | 617.4 | 626.2 | *k-in* | (from SAP2000 Model) |
| *Shear* | $V_{max}$ | 8.58 | 8.70 | *k* | |
| *Axial* | $P_{max}$ | 6.9 | 6.2 | *k* | (compression) |

**Capacity**

| *Local Buckling Resistance* | W10x39 | W18x50 | AASHTO 6.10.8.2.2 |
|---|---|---|---|
| $\lambda_f = b_{fc}/2t_{fc}$ = | 7.54 | 6.58 | AASHTO 6.10.8.2.2-3 |
| $\lambda_{pf} = 0.38*\sqrt{(E/F_{yc})}$ = | 9.15 | 9.15 | AASHTO 6.10.8.2.2-4 |
| $\lambda_{rf} = 0.56*\sqrt{(E/F_{yr})}$ = | 13.49 | 13.49 | AASHTO 6.10.8.2.2-5 |

$\lambda_f < \lambda_{pf} \rightarrow$ $F_{nc} = R_b*R_h*F_{yc}$ AASHTO 6.10.8.2.2-1

$\rightarrow M_{nc} = R_{pc}*M_{yc}$ AASHTO A6.3.2-1

$M_{yc} = F_{yc}*S_x$ AASHTO D6.2

$R_b$ 1 AASHTO 6.10.1.10.2

$R_h$ 1 AASHTO 6.10.1.10.1 (constructability is not checked)

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $M_{yc}$ | 2105 | 4445 | *k-in* | |
| $D_{cp}$ | 4.43 | 8.43 | *in* | AASHTO D6.3.2 |
| $\lambda_{rw}$ | 137.3 | | | AASHTO A6.2.1-3 |
| $\lambda_{pw(Dcp)}$ | 92.49 | 87.88 | | AASHTO A6.2.1-2 |
| $2D_{cp}/t_w$ | 28.13 | 47.49 | | |
| $2D_{cp}/t_w < \lambda_{pw(Dcp)} \rightarrow$ | Compact | | | |
| $R_{pc} = M_p/M_{yc} = Z_x/S_x$ = | 1.11 | 1.14 | | AASHTO A6.2.1-4 & A6.2.2-4 |

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $F_{nc}$ = | 50 | 50 | *ksi* | |
| $M_{nc}$ = | 2340 | 5050 | *k-in* | AASHTO D6.2 |

| *Lateral Torsional Buckling* | W10x39 | W18x50 | | AASHTO 6.10.8.2.3 |
|---|---|---|---|---|
| $L_b$ | 6 | 6 | *ft* | |
| $L_p = r_t*\sqrt{(E/F_{yc})}$ = | 4.50 | 3.97 | *ft* | AASHTO 6.10.8.2.3-4 |
| $L_r = \pi*r_t*\sqrt{(E/F_{yr})}$ = | 16.88 | 14.9 | *ft* | AASHTO 6.10.8.2.3-5 |

$L_p < L_b < L_r \rightarrow$

$F_{nc} = C_b[1-(1-F_{yr}/(R_hF_{yc}))((L_b-L_p)/(L_r-L_p))]R_bR_hF_{yc} < R_bR_hF_{yc}$ AASHTO 6.10.8.2.3-2

$M_{nc} = C_b[1-(1-(F_{yr}*S_{xc})/(R_{pc}M_{yc}))((L_b-L_p)/(L_r-L_p))]R_{pc}M_{yc} < R_{pc}M_{yc}$ AASHTO A6.3.3-2

$C_b = 1.75 - 1.05(M_1/M_2) + 0.3(M_1/M_2)^2 \leq 2.3$ AASHTO 6.10.8.2.3-7

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $M_{2\ (veh.)}$ = | 617.4 | 626.2 | *k-in* | largest moment at end of braced length |
| $M_{mid\ (veh.)}$= | 308.7 | 313.1 | *k-in* | moment at middle of braced length |
| $M_{0\ (veh.)}$ = | 0.0 | 0.0 | *k-in* | smallest moment at end of braced length |
| $M_{1\ (veh.)} = M_{0\ (veh.)}$ = | | | | AASTHO A6.3.3-12 |
| | 0.0 | 0.0 | *k-in* | |
| $C_{b\ (vehicle)}$ = | 1.75 | 1.75 | | |

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $M_{2\ (ped.)}$ = | 841.0 | 421.6 | *k-in* | largest moment at end of braced length |
| $M_{mid\ (ped.)}$= | 420.5 | 210.8 | *k-in* | moment at middle of braced length |
| $M_{0\ (ped.)}$ = | 0.0 | 0.0 | *k-in* | smallest moment at end of braced length |
| $M_{1\ (ped.)} = M_{0\ (ped.)}$ = | | | | AASTHO A6.3.3-12 |
| | 0.0 | 0.0 | *k-in* | |
| $C_{b\ (ped.)}$ = | 1.75 | 1.75 | | |

$2D_{cp}/t_w < \lambda_{pw(Dcp)} \rightarrow$ Compact

$R_{pc} = M_p/M_{yc} = Z_x/S_x$ = AASHTO A6.2.1-4

| | W10x39 | W18x50 |
|---|---|---|
| | 1.11 | 1.14 |

| | W10x39 | W18x50 | |
|---|---|---|---|
| $F_{nc}$ = | 50 | 50 | *ksi* |
| $M_{nc}$ = | 2340 | 5050 | *k-in* |

*<u>Tension Flange Flexural Resistance</u>*

$F_{nt} = R_h*F_{yt}$ AASHTO 6.10.8.3-1

$M_{nt} = R_{pt}*M_{yt}$ AASHTO A6.4-1

$M_{yt} = F_{yt}*S_x$ AASHTO D6.2

| | W10x39 | W18x50 | |
|---|---|---|---|
| $M_{yt}$ | 2105 | 4445 | *k-in* |

$2D_{cp}/t_w < \lambda_{pw(Dcp)} \rightarrow$ Compact

$R_{pt} = M_p/M_{yt} = Z_x/S_x$ = AASHTO A6.2.1-5

| | W10x39 | W18x50 |
|---|---|---|
| | 1.11 | 1.14 |

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $F_{nt}$ = | 50 | 50 | *ksi* | |
| $M_{nt}$ = | 2340 | 5050 | *k-in* | AASHTO D6.2 |

*<u>Minimum Flexural Resistance</u>*

$\Phi M_n = \Phi_f*\min(M_{nc},M_{nt})$

$\Phi_f$ 1 AASHTO 6.5.4.2

| | W10x39 | W18x50 | |
|---|---|---|---|
| $\Phi M_n$ = | 2340 | 5050 | *k-in* |

*Unstiffened Web Shear Resistance* AASHTO 6.10.9.2

$\Phi V_n = \Phi_v V_{cr} = \Phi_v C V_p$

$\Phi_v$ 1 AASHTO 6.5.4.2

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| $V_p = 0.58 * F_{yw} * D * t_w =$ | 80.9 | 173.6 | *k* | AASHTO 6.10.9.2-2 |
| | | | | |
| $D/t_w$ | 28.1 | 47.5 | | |
| k | 5 | 5 | | |
| $1.12 * \sqrt{(E*k/F_{yw})} =$ | 60.3 | 60.3 | | |

if $D/t_w < 1.12 * \sqrt{(E*k/F_{yw})} \rightarrow C=1$

| | W10x39 | W18x50 | |
|---|---|---|---|
| C | 1 | 1 | |
| $\Phi V_n =$ | 80.9 | 173.6 | *k* |

*Tensile Reistance* AASHTO 6.8.2.1

$\Phi P_n = \Phi_y * F_y * A_g$

$\Phi_y$ 0.95 AASHTO 6.5.4.2

| | W10x39 | W18x50 | |
|---|---|---|---|
| $\Phi P_n =$ | 546 | 698 | *k* |

*Compression Resistance* AASHTO 6.9.4.1.1

K 0.75 AASHTO 4.6.2.5

$\Phi_c$ 0.9 AASHTO 6.5.4.2

$$P_e = \frac{\pi^2 E * A_g}{(K*l/r_s)^2}$$ AASHTO 6.9.4.1.2-1

$P_o = QF_yA_g$ AASHTO 6.9.4.1.1

| | W10x39 | W18x50 | | |
|---|---|---|---|---|
| k | 0.56 | | | AASHTO Table 6.9.4.2.1-1 |
| b | 3.995 | 3.75 | *in* | |
| t | 0.530 | 0.570 | *in* | |
| b/t | 7.54 | 6.58 | → Nonslender | |
| $k * \sqrt{(E/F_y)}$ | 13.5 | | | |
| Q | 1.0 | 1.0 | | AASHTO 6.9.4.2 |

| | W10x39 | W18x50 | |
|---|---|---|---|
| $P_e$ | 629 | 629 | *k* |
| $P_o$ | 575 | 735 | *k* |
| $P_e/P_o =$ | 1.09 | 0.86 | |

$P_e/P_o > 0.44 \rightarrow$ AASHTO 6.9.4.1.1-1

$P_n = (0.658^{(P_o/P_e)}) P_o$

| | W10x39 | W18x50 | |
|---|---|---|---|
| $P_n =$ | 392 | 451 | *k* |

| | W10x39 | W18x50 | |
|---|---|---|---|
| $\Phi P_n$ = | 353 | 405 | *k* |

**Rating Factors**

$$RF = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_{P}P)}{\gamma_{LL}LL(1+IM)}$$ AASHTO MBE 6A.4.2.1-1

$C_{Str-I} = \Phi_c\Phi_s\Phi_nR_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c\Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 1 AASHTO MBE 6A.4.2.4

$$RF_{M+A} = \frac{1 - \gamma_{DC}[P_{DC}/F_r + (8/9)*\delta_b*(M_{DC}/M_r)]}{\gamma_{LL}[P_{LL+IM}/P_r + (8/9)*\delta_b*(M_{LL+IM}/M_r)]}$$ AASHTO MBE Appendix H6A

$$\delta_b = \frac{C_m}{1-P_u/\Phi P_e} = \frac{C_m}{1-(\gamma_{DC}P_{DC} + RF*\gamma_{LL}P_{LL})/\Phi P_e} > 1.0$$

$C_m$ 1 AASHTO 4.5.3.2.2b, conservative

$$P_e = \frac{\pi^2 EI}{(K*l_u)^2}$$ AASHTO 4.5.3.2.2b-5

K 0.75 AASHTO 4.6.2.5

$l_u$ 6 *ft*

$\Phi_{comp}$ 0.9 AASHTO 6.5.4.2

| | W10x39 | W18x50 | |
|---|---|---|---|
| $\Phi P_e$ | 18463 | 70671 | *k* |

| | | |
|---|---|---|
| $\gamma_{DC}$ | 1.25 | |
| $\gamma_{LL\ inv.}$ | 1.75 | |
| $\gamma_{LL\ op.}$ | 1.35 | |
| IM | 0 | AASHTO LRFD Ped. Bridge Manual 3.2 |

| | W10x39 | W18x50 |
|---|---|---|
| $\delta_{b\ ped.\ inv.}$ | 1.0 | 1.0 |
| $\delta_{b\ ped.\ op.}$ | 1.0 | 1.0 |
| $\delta_{b\ vehicle\ inv.}$ | 1.0 | 1.0 |
| $\delta_{b\ vehicle\ op.}$ | 1.0 | 1.0 |

**Flexure**

| Condition | W10x39 Good | W10x39 Fair | W10x39 Poor | W18x50 Good | W18x50 Fair | W18x50 Poor |
|---|---|---|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| C [k-in] | 2340 | 2223 | 1989 | 5050 | 4798 | 4293 |
| $RF_{pedestrian\ inventory}$ | **1.48** | **1.40** | **1.24** | **6.71** | **6.37** | **5.68** |
| $RF_{pedestrian\ operating}$ | **1.92** | **1.82** | **1.61** | **8.70** | **8.25** | **7.37** |
| $RF_{vehicle\ inventory}$ | **2.02** | **1.91** | **1.69** | **4.52** | **4.29** | **3.83** |
| $RF_{vehicle\ operating}$ | **2.61** | **2.47** | **2.19** | **5.86** | **5.56** | **4.96** |

**Flexure + Axial**

| Condition | W10x39 Good | W10x39 Fair | W10x39 Poor | W18x50 Good | W18x50 Fair | W18x50 Poor |
|---|---|---|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| $C_{axial}$ [k] | 353 | 335 | 300 | 405 | 385 | 345 |
| $C_{flex.}$ [k-in] | 2340 | 2223 | 1989 | 5050 | 4798 | 4293 |
| $RF_{pedestrian\ inventory}$ | **1.40** | **1.33** | **1.17** | **2.92** | **2.77** | **2.45** |
| $RF_{pedestrian\ operating}$ | **1.82** | **1.72** | **1.52** | **3.79** | **3.59** | **3.18** |
| $RF_{vehicle\ inventory}$ | **2.06** | **1.94** | **1.72** | **4.21** | **3.98** | **3.53** |
| $RF_{vehicle\ operating}$ | **2.67** | **2.52** | **2.23** | **5.46** | **5.16** | **4.58** |

**Shear**

| Condition | W10x39 Good | W10x39 Fair | W10x39 Poor | W18x50 Good | W18x50 Fair | W18x50 Poor |
|---|---|---|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| C [k] | 80.9 | 76.9 | 68.8 | 174 | 165 | 148 |
| $RF_{pedestrian\ inventory}$ | **3.84** | **3.65** | **3.25** | **16.8** | **15.9** | **14.2** |
| $RF_{pedestrian\ operating}$ | **4.98** | **4.73** | **4.21** | **21.8** | **20.7** | **18.5** |
| $RF_{vehicle\ inventory}$ | **5.24** | **4.97** | **4.43** | **11.3** | **10.7** | **9.59** |
| $RF_{vehicle\ operating}$ | **6.79** | **6.44** | **5.74** | **14.7** | **13.9** | **12.4** |

# Triangle Truss Load Rating (LRFR Method)

## Bottom Chord

| | | | | | | |
|---|---|---|---|---|---|---|
| L | 150.5 *ft* | | | | | |
| Joint Spacing | 21.5 *ft* | | | | | |
| Size | 1st 2 bays: 2L8x8x$^7/_8$ | | | Middle 3 bays: 2L8x8x1$^1/_8$ | | |
| | $A_g$ | 26.6 $in^2$ | | | $A_g$ | 33.6 $in^2$ |
| | seperation | 0.5 *in* | | | seperation | 0.5 *in* |
| | $r_t$ | 3.54 *in* | | | $r_t$ | 3.59 *in* |
| | | | | | $x_p$ | 0.311 *in* |
| $F_y$ | 50 *ksi* | | | | $L_{bolted\ con.}$ | 50.75 *in* |
| $F_u$ | 65 *ksi* | | | | $d_{bolts}$ | 1.25 *in* |
| E | 29000 *ksi* | | | | | |

**Dead Loads**

| | | 2L8x8x$^7/_8$ | 2L8x8x1$^1/_8$ | (from SAP2000 Model) |
|---|---|---|---|---|
| *Axial* | $P_{max}$ | 152.4 | 203.8 *k* | (tension) |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* AASHTO LRFD Ped Bridge 3.1

| | | 2L8x8x$^7/_8$ | 2L8x8x1$^1/_8$ | (from SAP2000 Model) |
|---|---|---|---|---|
| *Axial* | $P_{max}$ | 374.7 | 499.1 *k* | (tension) |

*Vehicular:* LL H10 Truck AASHTO LRFD Ped Bridge 3.2

| | |
|---|---|
| wheel 1 | 8 *k* |
| wheel 2 | 2 *k* |
| wheel spacing | 6 *ft* |
| axle spacing | 14 *ft* |

| | | 2L8x8x$^7/_8$ | 2L8x8x1$^1/_8$ | (from SAP2000 Model) |
|---|---|---|---|---|
| *Axial* | $P_{max}$ | 52.3 | 69.0 *k* | (tension) |

**Capacity**

*Tensile Reistance* AASHTO 6.8.2.1

$\Phi P_n = \min(\Phi_y * F_y * A_g, \Phi_u * F_u * A_n * R_p * U)$

| | | |
|---|---|---|
| $\Phi_y$ | 0.95 | AASHTO 6.5.4.2 |
| $\Phi_u$ | 0.8 | AASHTO 6.5.4.2 |

| | 2L8x8x$^7/_8$ | 2L8x8x1$^1/_8$ |
|---|---|---|
| $A_n$ | | 30.98 $in^2$ |
| $R_p$ | | 1.00 |
| U | | 0.99 |
| $\Phi P_n$ = | 1264 | 1596 *k* |

No splice in 2L8x8x$^7/_8$ so only need to calculate fracture on net

**Rating Factors**

$$RF = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$$ AASHTO MBE 6A.4.2.1-1

$C_{Str-I} = \Phi_c\Phi_s\Phi_n R_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c\Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 0.85 AASHTO MBE 6A.4.2.4

| | |
|---|---|
| $\gamma_{DC}$ | 1.25 |
| $\gamma_{LL\ inv.}$ | 1.75 |
| $\gamma_{LL\ op.}$ | 1.35 |
| IM | 0 |

IM: AASHTO LRFD Ped. Bridge Manual 3.2

**Axial**

| | 2L8x8x7/8 | | | 2L8x8x11/8 | | |
|---|---|---|---|---|---|---|
| Condition | Good | Fair | Poor | Good | Fair | Poor |
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| C [k] | 1074 | 1074 | 1074 | 1357 | 1357 | 1357 |
| **$RF_{pedestrian\ inventory}$** | **1.35** | **1.35** | **1.35** | **1.26** | **1.26** | **1.26** |
| **$RF_{pedestrian\ operating}$** | **1.75** | **1.75** | **1.75** | **1.64** | **1.64** | **1.64** |
| **$RF_{vehicle\ inventory}$** | **9.65** | **9.65** | **9.65** | **9.13** | **9.13** | **9.13** |
| **$RF_{vehicle\ operating}$** | **12.5** | **12.5** | **12.5** | **11.8** | **11.8** | **11.8** |

# Triangle Truss Load Rating (LRFR Method)

## Diagonals

L 18.45 *ft*

Size

| | End 8: W8x35 | | | Middle 16: W8x31 | | |
|---|---|---|---|---|---|---|
| $A_g$ | 10.3 | $in^2$ | | $A_g$ | 9.12 | $in^2$ |
| $b_f$ | 8.02 | *in* | | $b_f$ | 8 | *in* |
| $t_f$ | 0.495 | *in* | | $t_f$ | 0.435 | *in* |
| $r_s$ | 2.28 | *in* | | $r_s$ | 2.26 | *in* |

$F_y$ 50 *ksi*
E 29000 *ksi*

**Dead Loads** (from SAP2000 Model)

| | | W8x35 | W8x31 | |
|---|---|---|---|---|
| *Axial* | $P_{max\ tension}$ | 41.7 | 20.5 | *k* |
| | $P_{max\ comp.}$ | 39.6 | 17.8 | *k* |

**Live Loads** Pedestrian and Vehicular loads act seperately

*Pedestrian:* PL 90 *psf* AASHTO LRFD Ped Bridge 3.1

(from SAP2000 Model)

| | | W8x35 | W8x31 | |
|---|---|---|---|---|
| *Axial* | $P_{max\ tension}$ | 99.8 | 45.6 | *k* |
| | $P_{max\ comp.}$ | 99.5 | 45.6 | *k* |

*Vehicular:* LL H10 Truck AASHTO LRFD Ped Bridge 3.2

| | | |
|---|---|---|
| wheel 1 | 8 | *k* |
| wheel 2 | 2 | *k* |
| wheel spacing | 6 | *ft* |
| axle spacing | 14 | *ft* |

(from SAP2000 Model)

| | | W8x35 | W8x31 | |
|---|---|---|---|---|
| *Axial* | $P_{max\ tension}$ | 22.2 | 16.2 | *k* |
| | $P_{max\ comp.}$ | 22.2 | 16.3 | *k* |

**Capacity**

*Tensile Reistance* AASHTO 6.8.2.1

$\Phi P_n = \Phi_y * F_y * A_g$

$\Phi_y$ 0.95 AASHTO 6.5.4.2

| | W8x35 | W8x31 | |
|---|---|---|---|
| $\Phi P_n =$ | 489 | 433 | *k* |

*Compression Resistance* AASHTO 6.9.4.1.1

K 0.75 AASHTO 4.6.2.5

$\Phi_c$ 0.9 AASHTO 6.5.4.2

$P_e = \dfrac{\pi^2 E * A_g}{(K*l/r_s)^2}$ AASHTO 6.9.4.1.2-1

$P_o = QF_yA_g$ AASHTO 6.9.4.1.1

| | W8x35 | W8x31 | | |
|---|---|---|---|---|
| k | 0.56 | | | AASHTO Table 6.9.4.2.1-1 |
| b | 4.01 | 4 | *in* | |
| t | 0.495 | 0.435 | *in* | |
| b/t | 8.10 | 9.20 | → Nonslender | |
| $k*\sqrt{(E/F_y)}$ | 13.5 | | | |
| Q | 1.0 | 1.0 | | AASHTO 6.9.4.2 |

| | W8x35 | W8x31 | |
|---|---|---|---|
| $P_e$ | 556 | 483 | *k* |
| $P_o$ | 515 | 456 | *k* |
| $P_e/P_o$ = | 1.08 | 1.06 | |

$P_e/P_o > 0.44$ →

$P_n = (0.658^{\wedge}(P_o/P_e))P_o$ AASHTO 6.9.4.1.1-1

| | W8x35 | W8x31 | |
|---|---|---|---|
| $P_n$ = | 349 | 307 | *k* |

| | W8x35 | W8x31 | | |
|---|---|---|---|---|
| $\Phi P_n$ = | 314 | 277 | *k* | → Compression Controls |

**Rating Factors**

$RF = \dfrac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$ AASHTO MBE 6A.4.2.1-1

$C_{Str\text{-}I} = \Phi_c\Phi_s\Phi_n R_n$ AASHTO MBE 6A.4.2.1-2

$\Phi_c\Phi_s \geq 0.85$ AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 0.85 AASHTO MBE 6A.4.2.4

| | | |
|---|---|---|
| $\gamma_{DC}$ | 1.25 | |
| $\gamma_{LL\ inv.}$ | 1.75 | |
| $\gamma_{LL\ op.}$ | 1.35 | |
| IM | 0 | AASHTO LRFD Ped. Bridge Manual 3.2 |

<u>**Axial**</u>

| | W8x35 | | | W8x31 | | |
|---|---|---|---|---|---|---|
| Condition | Good | Fair | Poor | Good | Fair | Poor |
| $\Phi_c$ | 1 | 0.95 | 0.85 | 1 | 0.95 | 0.85 |
| C [k] | 267 | 267 | 267 | 267 | 267 | 267 |
| **$RF_{pedestrian\ inventory}$** | **1.25** | **1.25** | **1.25** | **3.07** | **3.07** | **3.07** |
| **$RF_{pedestrian\ operating}$** | **1.62** | **1.62** | **1.62** | **3.98** | **3.98** | **3.98** |
| **$RF_{vehicle\ inventory}$** | **5.59** | **5.59** | **5.59** | **8.59** | **8.59** | **8.59** |
| **$RF_{vehicle\ operating}$** | **7.25** | **7.25** | **7.25** | **11.1** | **11.1** | **11.1** |

kpff Consulting Engineers

# Triangle Truss Load Rating (LRFR Method)

## Crossbracing

| | | | |
|---|---|---|---|
| L | | 9.35 | *ft* |
| Size | 2L4x3x$^3/_8$ SLBB | | |
| | $A_g$ | 4.98 | *in* $^2$ |
| | b | 4 | *in* |
| | $t_f$ | 0.375 | *in* |
| | $r_s$ | 1.79 | *in* |
| $F_y$ | | 50 | *ksi* |
| E | | 29000 | *ksi* |

**Dead Loads**

| | | | | |
|---|---|---|---|---|
| *Axial* | $P_{max\ tension}$ | 3.58 | *k* | (from SAP2000 Model) |
| | $P_{max\ comp.}$ | 3.74 | *k* | |

**Live Loads** Pedestrian and Vehicular loads act seperately

| | | | | |
|---|---|---|---|---|
| *Pedestrian:* | PL | 90 | *psf* | AASHTO LRFD Ped Bridge 3.1 |
| *Axial* | $P_{max\ tension}$ | 8.32 | *k* | (from SAP2000 Model) |
| | $P_{max\ comp.}$ | 8.73 | *k* | |
| *Vehicular:* | LL | H10 Truck | | AASHTO LRFD Ped Bridge 3.2 |
| | wheel 1 | 8 | *k* | |
| | wheel 2 | 2 | *k* | |
| | wheel spacing | 6 | *ft* | |
| | axle spacing | 14 | *ft* | |
| *Axial* | $P_{max\ tension}$ | 13.0 | *k* | (from SAP2000 Model) |
| | $P_{max\ comp.}$ | 13.9 | *k* | |

**Capacity**

*Tensile Reistance* — AASHTO 6.8.2.1

$\Phi P_n = \Phi_y * F_y * A_g$

$\Phi_y$ 0.95 — AASHTO 6.5.4.2

$\Phi P_n =$ 237 *k*

*Compression Resistance* — AASHTO 6.9.4.1.1

| | | | |
|---|---|---|---|
| K | 0.75 | | AASHTO 4.6.2.5 |
| $\Phi_c$ | 0.9 | | AASHTO 6.5.4.2 |
| $P_e = \frac{\pi^2 E * A_g}{(K*l/r_s)^2}$ | | | AASHTO 6.9.4.1.2-1 |
| $P_o = QF_yA_g$ | | | AASHTO 6.9.4.1.1 |
| k | 0.56 | | AASHTO Table 6.9.4.2.1-1 |
| b | 2 | *in* | |
| t | 0.375 | *in* | |
| b/t | 5.33 | | → Nonslender |
| $k*\sqrt{(E/F_y)}$ | 13.5 | | |
| Q | 1.0 | | AASHTO 6.9.4.2 |

| | | |
|---|---|---|
| $P_e$ | 645 | *k* |
| $P_o$ | 249 | *k* |
| $P_e/P_o$ = | 2.59 | |

$P_e/P_o > 0.44$ → — AASHTO 6.9.4.1.1-1

$P_n = (0.658^{(P_o/P_e)})P_o$

$P_n$ = 212 *k*

$\Phi P_n$ = 191 *k* → Compression Controls

**Rating Factors**

$$RF = \frac{(C - \gamma_{DC}DC - \gamma_{DW}DW +/- \gamma_P P)}{\gamma_{LL}LL(1+IM)}$$ AASHTO MBE 6A.4.2.1-1

$C_{Str-I} = \Phi_c\Phi_s\Phi_n R_n$ — AASHTO MBE 6A.4.2.1-2

$\Phi_c\Phi_s \geq 0.85$ — AASHTO MBE 6A.4.2.1-3

$\Phi_s$ 0.85 — AASHTO MBE 6A.4.2.4

| | | |
|---|---|---|
| $\gamma_{DC}$ | 1.25 | |
| $\gamma_{LL\ inv.}$ | 1.75 | |
| $\gamma_{LL\ op.}$ | 1.35 | |
| IM | 0 | AASHTO LRFD Ped. Bridge Manual 3.2 |

**Axial** — **W8x35**

| Condition | Good | Fair | Poor |
|---|---|---|---|
| $\Phi_c$ | 1 | 0.95 | 0.85 |
| C [k] | 162 | 162 | 162 |
| **$RF_{pedestrian\ inventory}$** | **10.3** | **10.3** | **10.3** |
| **$RF_{pedestrian\ operating}$** | **13.4** | **13.4** | **13.4** |
| **$RF_{vehicle\ inventory}$** | **6.48** | **6.48** | **6.48** |
| **$RF_{vehicle\ operating}$** | **8.39** | **8.39** | **8.39** |

# Triangle Truss Load Rating (LRFR Method)

## Summary

*Timber decking is in poor condition → $\Phi_c$ = 0.85

*All other members are in good condition → $\Phi_c$ = 1

*M+A = Combined axial and bending

| Controlling Rating Factor & Failure Force | Pedestrian | | | Vehicle | | |
|---|---|---|---|---|---|---|
| | Force | Inventory | Operating | Force | Inventory | Operating |
| **Timber Deck** | Moment | 5.18 | 6.72 | **Moment** | **0.16** | **0.21** |
| **Girders/Top Chords** | M+A | 1.39 | 1.85 | M+A | 1.56 | 2.03 |
| **Stringers** | Moment | 1.33 | 1.72 | Moment | 1.08 | 1.40 |
| **Floorbeams** | M+A | 1.40 | 1.82 | Moment | 2.02 | 2.61 |
| **Bottom Chord** | Axial | 1.26 | 1.64 | Axial | 9.13 | 11.8 |
| **Diagonals** | **Axial** | **1.25** | **1.62** | Axial | 5.59 | 7.25 |
| **Crossbracing** | Axial | 10.3 | 13.4 | Axial | 6.48 | 8.39 |

**Maximum Wheel Load (Inventory):** **1268** ***lb***
**Maximum Wheel Load (Operating):** **1643** ***lb***
(timber decking governs)

# APPENDIX D

## PHOTOGRAPH LOG
## PHOTOGRAPH CONTACT SHEET

kpff Consulting Engineers
1601 Fifth Avenue, Suite 1600 Seattle, WA 98101
(206) 622-5822 fax (206) 622-8130

| | | | | |
|---|---|---|---|---|
| Project | Riverfront Park Bridges Inspection | By | MLF | Sheet No. |
| Location | Spokane | Date | 8/14/2014 | 1 OF 1 |
| Client | City of Spokane | | | Job No. |
| Inspection Photo Log | | | | 114176.12 |

Bridge Name: Triangle Truss (Lou Barbieri)

Date of Inspection: 8/13/2014

| Photo No. | Location | Notes | By |
|---|---|---|---|
| | | | |
| 1962 | Pier 2, West Bearing | Pack rust and debris | MF |
| 1963 | L8 | Debris in and below panel point L8 | MF |
| 1964 | L8 | Debris in and below panel point L8 | MF |
| 1965 | Pier 2, West Bearing | Pack rust and debris | MF |
| 1966 | Pier 2, Backwall | Exposed rebar in backwall | MF |
| 1967 | Pier 2, Backwall | Cracks/spalls in backwall | MF |
| 1968 | Pier 2, Backwall | Crack in backwall | MF |
| 1969 | Pier 2, East Bearing | Pack rust | MF |
| 1970 | Pier 2, Backwall | Exposed rebar | MF |
| 1971 | Pier 2, East Wingwall | Delamination | MF |
| 1972<br>1973<br>1974 | General | Flaking, corrosion of floorbeam, stringer, top chord of truss | MF |
| 1975 | Deck | Twisted planks | MF |
| 1976 | Deck | Missing bolts | MF |
| 1977 | Pier 1, West Bearing | Up to 1/4" pack rust | MF |
| 1978 | Pier 2, East Bearing | 1/4" pack rust | MF |
| 1979 | Pier 1 | Corrosion in top chord | MF |
| 1980 | General | Bottom chord | MF |
| 1982 | Deck | Deck, Looking south | MF |
| 1983 | Elevation | Elevation, Looking east | MF |
| | | | MF |
| 2015 | General | Truss | MF |
| 2016 | General | Truss | MF |
| 2017 | General | Truss | MF |
| 2018 | General | Truss | MF |
| | | | |
| | | | |
| 2022 | U4, RT | Top chord has moderate corrosion | JPG |
| 2024 | General | Truss panel points collecting debris | JPG |
| 2025 | U3, RT | Top chord has moderate corrosion | JPG |
| | | | |
| 2030 | General | Truss, bottom chord | JPG |
| 2031 | Floorbeam 1-0 | Corrosion on top flange | JPG |
| 2032 | General | Truss | JPG |
| 2033 | General | Truss, splice | JPG |
| 2034 | Deck | Splits in longitudinal deck member | MF |
| 2035 | Deck | Splits in longitudinal deck member | MF |
| | | | |
| 2037 | Deck | Splits in longitudinal deck member | MF |
| 2038 | L8-L9 | Bent flange (from construction?) | MF |
| 2039 | Deck | Split members | MF |
| 2040 | Deck | Split members | MF |
| | | | |
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| | | | |

# Triangle Truss Bridge Photographs


IMG_2040.JPG


IMG_1962.JPG


IMG_1963.JPG


IMG_1964.JPG


IMG_1965.JPG


IMG_1966.JPG


IMG_1967.JPG


IMG_1968.JPG


IMG_1969.JPG


IMG_1970.JPG

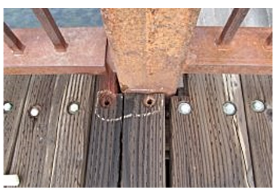

IMG_1971.JPG


IMG_1972.JPG


IMG_1973.JPG


IMG_1974.JPG


IMG_1975.JPG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IMG_1977.JPG


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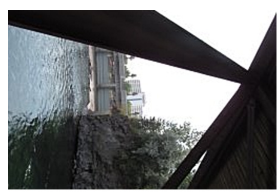
IMG_1979.JPG


IMG_1980.JPG


IMG_1982.JPG


IMG_1983.JPG


IMG_2015.JPG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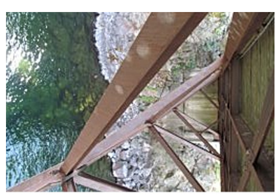
IMG_2017.JPG


IMG_2018.JPG


IMG_2022.JPG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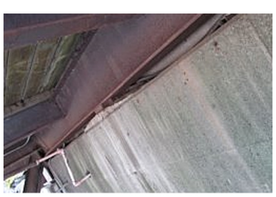
IMG_2025.JPG


IMG_2030.JPG


IMG_2031.JPG


IMG_2032.JPG


IMG_2033.JPG


IMG_2034.JPG


IMG_2035.JPG

# Triangle Truss Bridge Photographs


IMG_2037.JPG


IMG_2038.JPG


IMG_2039.JPG