Steel Bridge Design and Fabrication

Design and Lifecycle Considerations

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Steel: The Bridge Material of Choice
National Steel Bridge Alliance
A division of the American Institute of Steel Construction
www.steelbridges.org
**Lifecyle and Resiliency**

Perception and Reality

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**A Resilient Solution**

“... the ability to return to the original form, position, etc., after being bent, compressed or stretched.”

* Source: Indiana DOT (I65 bridge over cool creek in Lafayette).

** Source: Valmont Industries (Athabasca River in Alberta, Canada).
A Resilient Solution

Repair, Reuse, Repurpose, Recycle

Resiliency Lifecycle

A Resilient Solution - Repair

A Resilient Solution - Repair?


A Resilient Solution - Reuse

* Image courtesy of Oklahoma DOT of I-40 Crosstown Viaduct - Oklahoma City, OK.
A Resilient Solution - Reuse

* Image courtesy of Oklahoma DOT of I-40 Crosstown Viaduct – Oklahoma City, OK.

2060 Total Steel Beams Suitable for Reuse

350 (50ft) “New” Bridges for Oklahoma Counties

* Image courtesy of Oklahoma DOT of I-40 Crosstown Viaduct - Oklahoma City, OK.
Steel Resiliency – Repurpose

* Source: September 2009 MSC “Just Like New” Article (The Black Bridge - Montana)

A Resilient Solution - Recycle

- Highest recycled content of any material 93%.
- Highest recycling rate of any material 98%.
- Significant potential for material reuse.
- Not down-cycled or just recycled, but up-cycled.

* Source: Three major structural steel shape producers which account for 90% of steel used in United States.
# Material Availability and Guidelines

## Structural Shapes and Plates

<table>
<thead>
<tr>
<th>M 270 grade</th>
<th>ASTM specification</th>
<th>Product Categories</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>HPS 100W</td>
<td>A709</td>
<td>✔</td>
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Material Availability

Material Availability and Guidelines
Structural Shapes
Structural Shape Availability

- Generally more economical.
- Availability dependent on rolling schedules.
- Allow plate girder alternate (show on bid documents).
### Structural Shape Availability

#### Maximums

<table>
<thead>
<tr>
<th>Producer**</th>
<th>Maximum Depth (in)</th>
<th>Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucor-Yamato Steel</td>
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<td>120*</td>
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<td>Gerdau Ameristeel</td>
<td>36</td>
<td></td>
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<tr>
<td>Steel Dynamics</td>
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</tbody>
</table>

* Maximum length for some beam sizes may be shorter.

** These mills account for over 90% of all wide flange shapes produced in the United States.

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### Nucor-Yamato Announces New Quenching and Self-Tempering (QST) Process

- High Strength A913 Grade 65
- High Strength A913 Grade 70

- Provides excellent weldability while achieving good toughness at low temperatures.

- Common applications include gravity columns for use in high-rise buildings and long-span trusses.
Material Availability and Guidelines
Grade 50 Plate

Mill Plate Availability

[Map showing steel plate availability with locations for ArcelorMittal Burns Harbor, ArcelorMittal Coatesville & Coatskillhocken, SSAB Montpelier, Nucor Tuscaloosa, SSAB Mobile, and Nucor Hertford]
### Plate Availability Maximums

<table>
<thead>
<tr>
<th>Producer</th>
<th>Maximum Thickness (in)</th>
<th>Maximum Width (in)</th>
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</thead>
<tbody>
<tr>
<td>Arcelor-Mittal</td>
<td>4</td>
<td>195</td>
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<tr>
<td>Nucor Steel</td>
<td>3</td>
<td>123</td>
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<tr>
<td>SSAB</td>
<td>3</td>
<td>120</td>
</tr>
</tbody>
</table>

*Approximately 700,000 tons of plate used annually for construction projects in the United States.*

### Mill Plate Availability – Grade 50

- **Thickness Increments**
  - 1/8” for plate up to 2½” thick.
  - 1/4” for plate over 2½” thick.

- **Width Preferences**
  - Fabricators prefer 72” and 96” widths.
  - Increases generally in 6” increments.
Usable Mill Plate Area

- **Web Plate**
  - **Width**: 1” – 4”
  - **Length**: 1” – 6”
  - Material loss will increase if web is haunched or cambered.

- **Flange Plate**
  - **Width**: 1” – 4” total plus an additional 1/4” per burn.
  - **Length**: 1” – 6”
  - A fabricator may choose to increase flange widths specified by the Engineer from 1/4" - 3/8".

- **Can vary between fabricators.**
Mill Plate Availability – Grade 50

• Composite Mill Plate Tables

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>72&quot;</th>
<th>78&quot;</th>
<th>84&quot;</th>
<th>90&quot;</th>
<th>96&quot;</th>
<th>102&quot;</th>
<th>108&quot;</th>
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</tr>
</tbody>
</table>

* A709-50 and A709-50W (Non-FC) Availability only.
** Refer to September 2011 issue of Modern Steel Construction Magazine.

More Information

• Plate Availability for Highway Bridges
  • September 2011 Modern Steel Construction Magazine.

• Modern Steel Construction Magazine
  • www.modernsteel.com
More Information

Material Availability and Guidelines

High Performance Steel (HPS)
High Performance Steels

• Before Development of HPS
  - Steels with yield strength greater than 50 ksi were very sensitive to welding conditions.
  - Fabricators often encountered welding problems.

• After Development of HPS
  - Base metal weldability concerns essentially eliminated.
  - Enhanced fracture toughness compared to non-HPS grades.

Mill Plate Availability – HPS70W

• Plate Availability Maximums

<table>
<thead>
<tr>
<th>Producer</th>
<th>Maximum Thickness (in)</th>
<th>Maximum Width (in)</th>
<th>Maximum Length (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcelor-Mittal (Q&amp;T)</td>
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<td>195</td>
<td>600</td>
</tr>
<tr>
<td>Arcelor-Mittal (TMCP)</td>
<td>1 3/8</td>
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<td>1500</td>
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<tr>
<td>Nucor Steel (TMCP)</td>
<td>2</td>
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<td>580</td>
</tr>
<tr>
<td>SSAB (TMCP)</td>
<td>2</td>
<td>103</td>
<td>1140</td>
</tr>
</tbody>
</table>

* Q&T: Quench and Tempered.
** TMCP: Thermomechanical Controlled Process.
Hybrid and Mixed Design

• Mixed Design: Homogeneous material grades within each field piece, but may vary the material strength between field pieces.

• Hybrid Designs: Mix steel grades within design sections.

Hybrid and Mixed Design

• Research has shown that hybrid girder designs allowed economical incorporation of HPS 70W.
  - Optimum used HPS 70W material in all bottom flanges and top flanges of negative moment regions.
  - All girder webs and positive moment region top flange plates used Grade 50 steel.

• Generally, hybrid design can be optimized at a shallower depth than can Grade 50 girders.

* Source: Steel Bridge Design Handbook – "Bridges: Making the Right Choices".
Shipping and Handling
Field Section Properties

Field-Section Lengths

- Field sections - Girder sections fabricated and shipped to the bridge site.

- Shipping and handling concerns are important.
  - Affect field section lengths selected in design.
  - Curved members can require additional field splices to reduce size of shipping piece.
Field-Section Lengths

- Shipment by truck is the most common means
  - Weight: 100 Tons Maximum, 40 Tons No Permit.
  - Height: 10 ft.

Corrosion Protection

Uncoated Weathering Steel (UWS)
UWS - Availability

- Available in ASTM A709 Grades
  - 50W
  - HPS 50W
  - HPS 70W
  - HPS 100W

UWS - How it Works

- Steel rusts in the presence of air and water resulting in iron oxide.
- Control rate oxygen can react with the surface.
- Non-Weathering Steel
  - Relatively porous oxide layer, which can hold moisture and promote further corrosion.
  - Rust layer delaminates and exposes the surface causing more damage.
- Weathering Steel
  - Not as porous because it adheres more firmly to the base metal.
  - Rate of corrosion initially same as ordinary steel, but levels out.
UWS - Appropriate Use

- Protective oxide layer develops from wet/dry cycles.
- Eliminate details that trap moisture for long periods of time.
- FHWA Technical Advisory 5140.22
  - Not appropriate in foggy, coastal regions
  - Not for use in tunnel-like conditions where deicing salts are used
  - Evaluation needed in heavy industrial areas (corrosive chemicals).

UWS - Research

- Ongoing research at University of Delaware.
- In use for nearly 50 years in United States.
- Design and maintenance practices may be more influential to UWS performance than climate.
- UWS bridges generally perform well in relation to non-UWS bridges.

UWS - Benefits

- During Fabrication
  - No additional 3rd party handling and transportation expenses are incurred.
  - Surface preparation nothing more aggressive than simple shot blasting.
  - Once surface preparation is completed no additional rework required.
  - Lower fabrication costs and shorter fabrication time.

- During Use
  - No Field Painting
  - Natural Appearance
  - Minimal Maintenance
  - Lower Life Cycle Cost

UWS - The Elephant in the Room

“I suppose I’ll be the one to mention the elephant in the room.”
Uncoated Weathering Steel
Design and Construction Strategies

UWS - Preventing Staining

- Construction Time Strategy - Pier Wrapping
UWS - Preventing Staining

- Design Strategy - Jointless Bridge

UWS - Preventing Staining

- Design Strategy - Drip Pans
UWS - Preventing Staining

- Design Strategy – Drip Bars

UWS - Preventing Staining

- Design Strategy – Wide Overhangs
UWS - Preventing Staining

- Design Strategy - “Architectural Relief”

UWS - Preventing Staining

- Design Strategy - Substructure Coatings
UWS - Preventing Staining

• Design Strategy - Weathering Steel Substructure

UWS - Preventing Staining

• Design Strategy - Partial Paint (Not Recommended)
  - Increased lifecycle costs associated with maintaining paint.
  - Paint failure will result in staining anyway if not addressed quickly.
  - Periodic surface blasting of staining is a better option.
UWS - Preventing Staining

- County Road A-34 over I-35, Iowa.

UWS - Preventing Staining

UWS - Preventing Staining

- Caldwell Ln over Suncoast Parkway, Florida

Uncoated Weathering Steel
Cost Considerations
UWS – First Time Costs

- Material premium of 3 - 4 cents/pound.
- 10% - 20% lower first time cost versus painting.
- Net costs favors Weathering Steel.
- Additional savings over the life of the bridge.

UWS – Case Study

- Lewisburg, PA
UWS – Case Study

- 1223’ bridge length (886 tons total)
- Material extra (@ $.03): $ 53,160
- Painting cost avoided (3 coats): $ 270,674
- Net 1st Cost Savings: $ 217,514
- Life Cycle Cost Savings (est.): $ 1.5 M

UWS - Recommendations

- Always consider making weathering steel the first option.
- Incorporate strategies for controlling water and moisture.
- Blast fascia only for aesthetic patina.
- Paint fascia only if aesthetic are important.
More Information

Online Access

- National Steel Bridge Alliance
  - [www.steelbridges.org](http://www.steelbridges.org)

- Steel Bridge Suite
  - [www.steelbridges.org/SoftwareRegistration](http://www.steelbridges.org/SoftwareRegistration)

- Continuous Steel Bridge Standards
  - [www.steelbridges.org/SpanSolutions](http://www.steelbridges.org/SpanSolutions)

- Modern Steel Construction Magazine
  - [www.modernsteel.com](http://www.modernsteel.com)
THANK YOU...

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