Use of Grade 80 Reinforcement in Oregon

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Bridge Operations & Standards Managing Engineer
PRESENTATION OUTLINE

Material Properties of High Strength Reinforcement

Recent Grade 80 Research

Potential Cost Savings

Recommendations for Implementation
HIGH STRENGTH REINFORCEMENT

Changes in AASHTO Bridge Design Specifications

2013 – 6th Edition with interim revisions
- Allowed high strength bars up to 100 ksi

1973 – 11th Edition
- Added load factors
- Allowed Grade 60 bars

1961 – 8th Edition
- Included prestressed concrete section

Not yet for design
- Shear combined with torsion
- Horizontal shear
- etc.

AASHTO Standard Specifications for Highway Bridges

Grade 40 bars
HIGH STRENGTH REINFORCEMENT

BDDM 1.5.5.1.17 – High Strength Reinforcement

ASTM A416 Grade 46

Grade 46 reinforcement is produced on a metal slabs. The yield strength of ASTM A416 Grade 46 reinforcement is 50,800 psi. The ultimate strength of ASTM A416 Grade 46 reinforcement is 66,000 psi. The elongation of ASTM A416 Grade 46 reinforcement is 10%. The modulus of elasticity of ASTM A416 Grade 46 reinforcement is 29.5 x 10^6 psi.

ASTM A416 Grade 60

Grade 60 reinforcement is produced on a metal slabs. The yield strength of ASTM A416 Grade 60 reinforcement is 60,000 psi. The ultimate strength of ASTM A416 Grade 60 reinforcement is 75,000 psi. The elongation of ASTM A416 Grade 60 reinforcement is 10%. The modulus of elasticity of ASTM A416 Grade 60 reinforcement is 29.5 x 10^6 psi.

ASTM A416 Grade 80

Grade 80 reinforcement is produced on a metal slabs. The yield strength of ASTM A416 Grade 80 reinforcement is 80,000 psi. The ultimate strength of ASTM A416 Grade 80 reinforcement is 95,000 psi. The elongation of ASTM A416 Grade 80 reinforcement is 10%. The modulus of elasticity of ASTM A416 Grade 80 reinforcement is 29.5 x 10^6 psi.

ASTM A416 Grade 100

Grade 100 reinforcement is produced on a metal slabs. The yield strength of ASTM A416 Grade 100 reinforcement is 100,000 psi. The ultimate strength of ASTM A416 Grade 100 reinforcement is 123,000 psi. The elongation of ASTM A416 Grade 100 reinforcement is 10%. The modulus of elasticity of ASTM A416 Grade 100 reinforcement is 29.5 x 10^6 psi.
HIGH STRENGTH REINFORCEMENT

BDDM 1.5.5.1.17 – High Strength Reinforcement

ASTM A706 Grade 80

ASTM A706 Grade 80 reinforcement is available on the market. The cost premium for ASTM Grade 60 reinforcement is approximately 10-20% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing ASTM Grade 80 reinforcement and are available in a variety of shapes and sizes, including bars, shapes, and tubes. When using ASTM Grade 60 reinforcement, the design yield strength is 46 ksi. ASTM A706 reinforcement is available at a cost premium of approximately 8-12% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing this grade and are available in a variety of shapes and sizes. The cost premium for ASTM Grade 80 reinforcement is approximately 10-20% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing ASTM Grade 80 reinforcement and are available in a variety of shapes and sizes, including bars, shapes, and tubes.

ASTM A1035 Grade 100

ASTM A1035 Grade 100 reinforcement has a design yield strength of 100 ksi. Proprietary products that meet the requirements of ASTM A1035 specifications are sold under the brand names of Chromex® 9100 (formerly known as MMFX®, ChromexTM 4100, and Chromex® 2100. The main difference in these products is the chromium content. The higher the number, the greater the chromium content. The reduced chromium content results in lower cost, when high corrosion resistance is not required. The products are not weldable. Currently, Cascade Steel will produce this new A1035 addition starting mid-2015. Designing with high strength reinforcement products, such as High Strength Reinforcement, has some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength reinforcement is considered for a project with less than 10 tons.

Grade 100 reinforcement under ASTM A415 will be available soon. Cascade Steel will produce this new ASTM addition starting mid-2015. Designing with high strength reinforcement products, such as High Strength Reinforcement, has some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength reinforcement is considered for a project with less than 10 tons.

ASTM A615 Grade 100

Grade 100 reinforcement under ASTM A415 will be available soon. Cascade Steel will produce this new ASTM addition starting mid-2015. Designing with high strength reinforcement products, such as High Strength Reinforcement, has some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength reinforcement is considered for a project with less than 10 tons.

Different sections are presented in this document to simplify the design process. Steel bars are presented together with their corresponding bar size. These sections are designed to provide a quick reference for selecting the appropriate bar size for a given application. The sections are organized to provide a comprehensive overview of the various types of high strength reinforcement products available, along with their corresponding specifications and performance characteristics. Additionally, the sections include detailed information on the installation and application of these products, including guidelines for proper handling and storage, as well as information on the advantages and disadvantages of each type of product. The sections are designed to be easy to navigate and provide a clear and concise overview of the various options available for high strength reinforcement products.
HIGH STRENGTH REINFORCEMENT

BDDM 1.5.5.1.17 – High Strength Reinforcement

Application of High Strength Reinforcement

Do not use high strength reinforcement in members designed for plastic seismic performance (such as bridge columns). Although A706 Grade 80 reinforcement has similar ductile properties compared to A706 Grade 60, testing of full-scale seismic models sufficient to satisfy AASHTO concerns has not yet been completed.

Use of high strength reinforcement is recommended in the following areas:

- Bridge decks – When high strength reinforcement is used in a bridge deck, use it for both longitudinal and transverse loads. Refer to Bridge Figure 11.3-11 and Bridge Figure 11.3-10 for deck design.
- Drilled shafts – Use of high strength reinforcement makes them more ductile, thereby making their low-cycle fatigue performance and so their ductility better in negative and positive moments. Crossbeams & End beams – Use of high strength reinforcement makes them more ductile, thereby making their low-cycle fatigue performance and so their ductility better in negative and positive moments. Crossbeams & End beams – Use of high strength reinforcement makes them more ductile, thereby making their low-cycle fatigue performance and so their ductility better in negative and positive moments.

<table>
<thead>
<tr>
<th>Bridge No.</th>
<th>Length (ft)</th>
<th>Deck Area (in.)</th>
<th>No. Drilled Shaft</th>
<th>Spec. Description</th>
<th>Deck Effort</th>
<th>Crossbeam Effort</th>
<th>Drilled Nxt Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>12006</td>
<td>1000</td>
<td>48x400</td>
<td>0-85</td>
<td>45 x 100 ft deck</td>
<td>85</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>11175</td>
<td>1000</td>
<td>36x300</td>
<td>0-85</td>
<td>45 x 100 ft deck</td>
<td>85</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>25400</td>
<td>1000</td>
<td>36x300</td>
<td>0-85</td>
<td>45 x 100 ft deck</td>
<td>85</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>22200</td>
<td>1000</td>
<td>36x300</td>
<td>0-85</td>
<td>45 x 100 ft deck</td>
<td>85</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

*Includes intermediate crossbeams, end beams, and cap beams.
HIGH STRENGTH REINFORCEMENT

ASTM A706 Grade 80

- Cost 10% premium
- Stress – strain behavior
- Ductility
- Weldability

Minimum order of 50 Tons for each size and cut length! (Verify with local mill)
HIGH STRENGTH REINFORCEMENT

ASTM A706 Grade 80

Figure 4.3: Stress-strain plot of Grade 60 #5 (#16M) reinforcing bars

Figure 4.6: Stress-strain plot of Grade 80 #5 (#16M) reinforcing bars
SEISMIC PERFORMANCE OF CIRCULAR REINFORCED CONCRETE BRIDGE COLUMNS CONSTRUCTED WITH GRADE 80 REINFORCEMENT

Final Report
SRS 500-610

SEISMIC PERFORMANCE OF CIRCULAR REINFORCED CONCRETE BRIDGE COLUMNS CONSTRUCTED WITH GRADE 80 REINFORCEMENT

A report in partial completion of the PacTrans project

NEW STRATEGIES FOR MAINTAINING POST-SEISMIC OPERATIONS OF LIFELINE CORRIDORS

by
David Trejo, Ph.D., André R. Barbosa, Ph.D., and Tim Link
Oregon State University

Sponsorship
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HIGH STRENGTH REINFORCEMENT

DESIGN GUIDELINES FOR CONCRETE BEAMS REINFORCED WITH MMFX MICROCOMPOSITE REINFORCING BARS

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Figure 2: Comparison of Proposed MMFX Material Models

MECHANICAL PROPERTIES MMFX₂ (ASTM A1035/A1035M)

MMFX₂ (ASTM A1035/A1035M)
Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement

Typical Stress-Strain Curves for MMFX₂ (ASTM A1035/A1035M) Reinforcing Bars
HIGH STRENGTH REINFORCEMENT
HIGH STRENGTH REINFORCEMENT

Grade 80

Grade 60
HIGH STRENGTH REINFORCEMENT

8 foot diameter shaft
HIGH STRENGTH REINFORCEMENT

Bridge Projects in Oregon

- Newberg – Dundee Bypass Project
  Chehalem Creek Bridge (22008)

- Sellwood Bridge Project – Multnomah County
  Sellwood Bridge (21493)

- Portland – Milwaukie Light Rail Transit Project
  Tilikum Crossing, Bridge of the People
HIGH STRENGTH REINFORCEMENT

Br. 22002 - Hess Creek
HIGH STRENGTH REINFORCEMENT

Bents 3 – 6
6 ft column (50 – 60 ft long)
38 - #11 (1.5% reinforcement ratio)

8 ft drilled shaft (~100 ft long)
Bending moment = 30,000 kips-ft
Shear = 1,300 kips
#11 vertical bars
#6 stirrup
HIGH STRENGTH REINFORCEMENT

30 ft long section

Grade 60
21,150 Lbs

Grade 80
16,350 Lbs
-23%

Bid unit price
$0.77/Lb

Bid unit price for Grade 60
$0.80/Lb
HIGH STRENGTH
REINFORCEMENT

Bridge Projects in Oregon

• Newberg – Dundee Bypass Project
  Chehalem Creek Bridge (22008)

• Sellwood Bridge Project – Multnomah County
  Sellwood Bridge (21493)

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  Tilikum Crossing, Bridge of the People
HIGH STRENGTH REINFORCEMENT

10-ft drilled shaft
#18 vertical bars
#8 welded hoops

Arch rib springing elements
HIGH STRENGTH REINFORCEMENT

Bridge Projects in Oregon

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HIGH STRENGTH REINFORCEMENT

Lower portion of pylons and cross frame

Edge girders for bridge deck

Foundation
HIGH STRENGTH REINFORCEMENT

Grade 80 in a Typical Deck - Jackson School Road Over Hwy 47

82.2 ft width x 277.2 ft length = 22,800 ft²
## HIGH STRENGTH REINFORCEMENT

Grade 80 in a Typical Deck

<table>
<thead>
<tr>
<th>Grade 60</th>
<th>Grade 80</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5 @ 7.5” Transverse bars</td>
<td>#4 @ 6.5” in P/S girder segments</td>
</tr>
<tr>
<td>131,300 Lbs (66 tons)</td>
<td>#4 @ 6” in CIP box girder segments</td>
</tr>
<tr>
<td>$ 118,200 ($0.90 / Lb)</td>
<td>110,800 Lbs (55 Tons) (16% reduction)</td>
</tr>
<tr>
<td>$ 118,200 (0.90 / Lb)</td>
<td>$ 105,300 ($ 12,900 reduction = 11%)</td>
</tr>
<tr>
<td>Price where Grade 80 is the same cost as Grade 60 = $1.07 / Lb (+ 17¢)</td>
<td>Price where Grade 80 is the same cost as Grade 60 = $1.07 / Lb (+ 17¢)</td>
</tr>
</tbody>
</table>
HIGH STRENGTH REINFORCEMENT

Crossbeam – Grade 60

Top: 12 - #11 bars

Bottom, Row 2 – 20 - #11 bars

Bottom, Row 1 – 20 - #11 bars

#6 stirrups @ 6” ctrs
HIGH STRENGTH REINFORCEMENT

Crossbeam - Grade 80

Top: 9 - #11 bars

Bottom, Row 2: 12 - #11 bars

Bottom, Row 1: 18 - #11 bars

Stirrups #6 @ 8” ctrs
HIGH STRENGTH REINFORCEMENT

Crossbeam - Grade 100

Top: 8 - #11 bars

Bottom, Row 2: 8 - #11 bars

Bottom, Row 1: 16 - #11 bars

Stirrups #6 @ 10” ctrs
## HIGH STRENGTH REINFORCEMENT

Cost Comparison – (based on two crossbeams)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Weight</th>
<th>Cost</th>
<th>Savings</th>
<th>Cost per Lb</th>
<th>Tons of #11 Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grade 60</strong></td>
<td>61,250 Lbs</td>
<td>$55,100 (@0.90/Lb)</td>
<td>$6,500 savings</td>
<td>$1.08 per Lb (+18¢)</td>
<td>16 Tons of #11 bar</td>
</tr>
<tr>
<td><strong>Grade 80</strong></td>
<td>51,150 Lbs (-16%)</td>
<td>$45,600 (@0.95/Lb)</td>
<td></td>
<td>$1.22 per Lb (+32¢)</td>
<td>13 Tons of #11 bar</td>
</tr>
<tr>
<td><strong>Grade 100</strong></td>
<td>45,200 Lbs (-18%)</td>
<td>$47,500 (@1.05/Lb)</td>
<td>$7,600 savings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Equivalent Grade 60 cost:
- $6,500 savings
- 12% cost reduction

Grade 80:
- $7,600 savings
- 14% cost reduction
HIGH STRENGTH REINFORCEMENT

Grade 40 – 60 – 80 – 100
(Positive moment only)

Grade 40
108 - #11 bars

Grade 60
70 - #11 bars
35% < Gr 40
Top row of bundled bars eliminated
HIGH STRENGTH REINFORCEMENT

Grade 40 – 60 – 80 – 100
(Positive moment only)

Grade 80
54 - #11 bars
23% < Gr 60
Some 3-bar bundles reduced to 2-bar bundles

Grade 100
44 - #11 bars
37% < Gr 60
No 3-bar bundles
HIGH STRENGTH REINFORCEMENT

Concerns & Issues

• Seismic performance not established
  • Research ongoing for Grade 80

• Availability & cost needs to be verified
  • Cost likely to increase as high-strength becomes more available

• Splice lengths, hook lengths, development lengths are longer

• Minimum steel, crack control, temperature steel requirements
HIGH STRENGTH REINFORCEMENT

Recommendations

- Decks, Crossbeams, Drilled Shafts
  - Reduced congestion and lower cost
  - ~ 21,000 ft² of deck area req’d for 50 ton minimum order

- Verify availability and cost with local rebar suppliers
  - The market is likely to change significant in the next few years
  - Current cost savings with Grade 80 approx. 10-12% for OR projects

- If < 50 tons, consider detailing both Grade 60 and HS

- Combining Grades okay if at least two bar size difference