Use of Grade 80 Reinforcement in Oregon

Craig Shike, PE

Bridge Operations & Standards Managing Engineer

Oregon Department of Transportation

STATE OF OREGON 1859

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

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

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

AASHTO Standard Specifications for Highway Bridges

Grade 40 bars

1961 – 8th Edition
- Included prestressed concrete section

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 A706 Grade 80 reinforcement is approximately 8-12% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing Grade 80 reinforcement on a regular cycle. Even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

When using A706 Grade 80 reinforcement, the design yield strength is 80 ksi. ASTM A706 reinforcement is weldable. Welding would be needed when A706 Grade 80 reinforcement is used for confinement hoops. The contractor needs to submit a PQR and WPS for approval as is typical for any rebar welding.

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$_2$®), ChroMeX™ 4100, and ChroMeX® 2100. The main difference between the three products is the chromium content; the higher the number, the greater 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 produces ChroMeX® 9100, ChroMeX™ 4100, and ChroMeX® 2100 with a cost premium of approximately 175%, 90%, and 50%, respectively. Cascade Steel carries some inventory in ChroMeX® 9100. For non-stock items, a minimum (combined size and length) of 50 tons is required. However, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

ASTM A615 Grade 100

Grade 100 reinforcement under ASTM A615 will be available soon. Cascade Steel will produce this new ASTM addition, starting in mid-2015. Similar to other high strength reinforcement products, even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

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.

For A1035 Grade 100, the stress-strain property is very different from A706. There is not a well-defined yield plateau. More experimental testing is necessary before its full implementation in members designed to form plastic hinges. The overstrength magnifier as defined for A706 in the Guide Specifications for *LRFD Seismic Bridge Design* may not be appropriate. At this time, an overstrength magnifier of 1.4 is recommended when high strength reinforcement is used in capacity-protected members.

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 bars. Refer to *BDDM Figure 1.9.1C and Figure 1.9.1D* for deck

reinforcement design charts. If different bar sizes are used in transverse and longitudinal directions, the quantity of each bar size needs to meet the minimum order requirement.

- Drilled shafts – Use of high strength reinforcement reduces cost and congestion in drilled shafts thereby making them more constructible. Drilled shafts are designed for elastic seismic performance and so there would typically be no concern with the seismic performance. If there is sufficient quantity to meet the minimum order, high strength reinforcement can also be used for lateral confinement in drilled shafts.

- Crossbeams & End beams – Use of high strength reinforcement can reduce cost and congestion in negative and positive moment areas of crossbeams and end beams. Normally, these members are capacity-protected; therefore they are designed to remain elastic during a seismic event. Even if the same bar size is used for both negative and positive moment areas, the minimum order quantity will normally be met only on a large multi-span bridge. High strength reinforcement can be used for temperature steel and stirrups as well.

Grade 80 bars are anticipated to be a better option for a replacement of Grade 60 bars, due to lower cost premium and shorter development length compared to Grade 100 bars. In addition, Grade 80 has stress-strain behavior similar to Grade 60 with greater yield stress and ultimate strength.

Within the same member, do not mix different rebar grades of the same bar size. This policy is to avoid any confusion that may occur during construction. It is acceptable to specify different rebar grades in the same member, when the different grades of bar are also significantly different in bar size (at least two bar sizes apart). For instance, longitudinal #9 bars in a crossbeam can be Grade 80 bars, whereas #5 stirrups and temperature bars can be Grade 60.

Normally it requires a multi-span structure to have sufficient quantity in selected sizes to meet the minimum order quantity required by the steel mills. Figure 1.5.5.1.17 illustrates rebar quantities in the previously mentioned members that are allowed to be reinforced with high strength reinforcement. Note that the quantities shown in the figure will be different if high strength reinforcement is used. A reduction of 10% - 30% in quantities can be anticipated when Grade 60 rebar is replaced by Grade 80 reinforcement.

All bridges in *Figure 1.5.5.1.17* consist of precast prestressed concrete girders with a CIP deck. Most spans are simple for dead load and made continuous for live load. The bridges include drilled shafts with different lengths depending on the soil condition at the sites. Several bar sizes are grouped together since these bars can be alternately used in the design to reduce a number of different bar sizes. It is good practice to specify only a few bar sizes in each member. Using fewer bar sizes may aid in meeting mill minimums. Common bar sizes (#4, #8, #11) are produced on a regular cycle and may be available from inventory at the local mills.

Bridge No.	Length (ft)	Deck Area (ft^2)	No. Drilled Shaft	Span Description	Deck (tons)		Crossbeams* (tons)		Drilled Shaft (tons)	
					#4 - #6	#7 - #9	#4 - #7	#8 - #11	#5 - #6	#9 - #11
22008	968	44015	8 - 8ft	6 - 150ft + 1 - 50ft deck girder spans	106	45	54	51	43**	218**
21576	249	31665	15 - 6ft	2 - 122ft deck girder spans	87	20	36	55	48	87
21343	524	25152	4 - 8ft	3 - 180ft deck girder spans	75	57	29	18	6	37
22248	84	11344	16 - 3ft	1 - 80 ft deck girder span	33	1	12	8	4	10

*includes intermediate diaphragms, end beams, and cap beams.
**A706 Grade 80 rebar

Figure 1.5.5.1.17

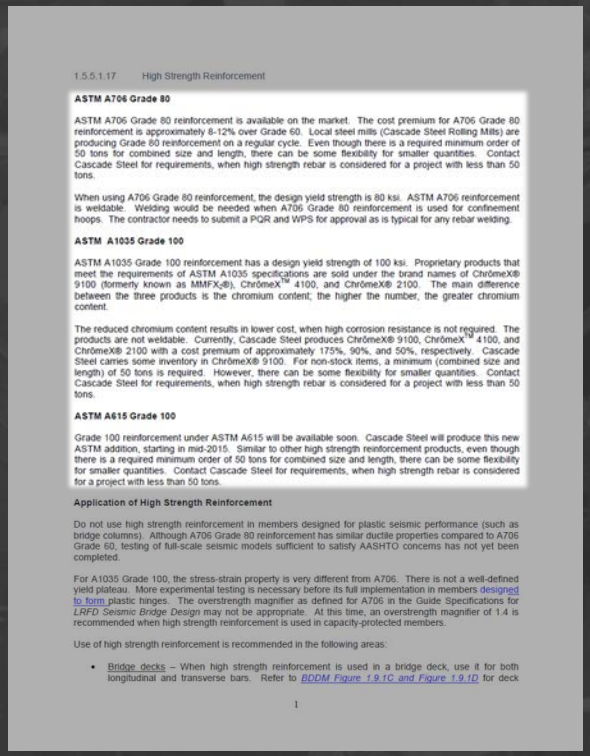
As shown in the Figure, the required minimum quantity can easily be satisfied, especially for deck reinforcement in the first three bridges. The rebar quantities in crossbeams and end beams are not sufficient when a 20% reduction due to the use of high strength rebar is applied. However, if high strength rebar of the same size is also used in other members of the bridges, it is possible that the quantities of each bar size will reach the minimum order requirement.

Showing two options of rebar grades on bridge plans is encouraged to accommodate a Contractor that may not be able to obtain high strength bars during a construction project. When this approach is taken, all dimensions need to be prepared to work with both options, especially details related to splice lengths and development lengths. Splice lengths and development lengths for high strength rebar are longer compared to Grade 60.

Couplers are available on the market for high strength reinforcement. These couplers are capable of meeting 125 percent of yield strength. This is less than required by current specifications (*SP 02510.20*) which require couplers to meet 135 percent of yield strength. However, for the proposed applications above, 125 percent of yield strength provides satisfactory performance. A project specific change to *SP 02510.20* is required when high strength reinforcing bars are used. The ODOT Materials Lab has the capability to test rebar couplers up to #14 bars in Grade 100.

HIGH STRENGTH REINFORCEMENT

BDDM 1.5.5.1.17 – High Strength Reinforcement



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 A706 Grade 80 reinforcement is approximately 8-12% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing Grade 80 reinforcement on a regular cycle. Even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

When using A706 Grade 80 reinforcement, the design yield strength is 80 ksi. ASTM A706 reinforcement is weldable. Welding would be needed when A706 Grade 80 reinforcement is used for confinement hoops. The contractor needs to submit a PQR and WPS for approval as is typical for any rebar welding.

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 ChrōmeX® 9100 (formerly known as MMFX$_2$®), ChrōmeX™ 4100, and ChrōmeX® 2100. The main difference between the three products is the chromium content; the higher the number, the greater 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 produces ChrōmeX® 9100, ChrōmeX™ 4100, and ChrōmeX® 2100 with a cost premium of approximately 175%, 90%, and 50%, respectively. Cascade Steel carries some inventory in ChrōmeX® 9100. For non-stock items, a minimum (combined size and length) of 50 tons is required. However, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

ASTM A615 Grade 100

Grade 100 reinforcement under ASTM A615 will be available soon. Cascade Steel will produce this new ASTM addition, starting in mid-2015. Similar to other high strength reinforcement products, even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

Application of High Strength Reinforcement

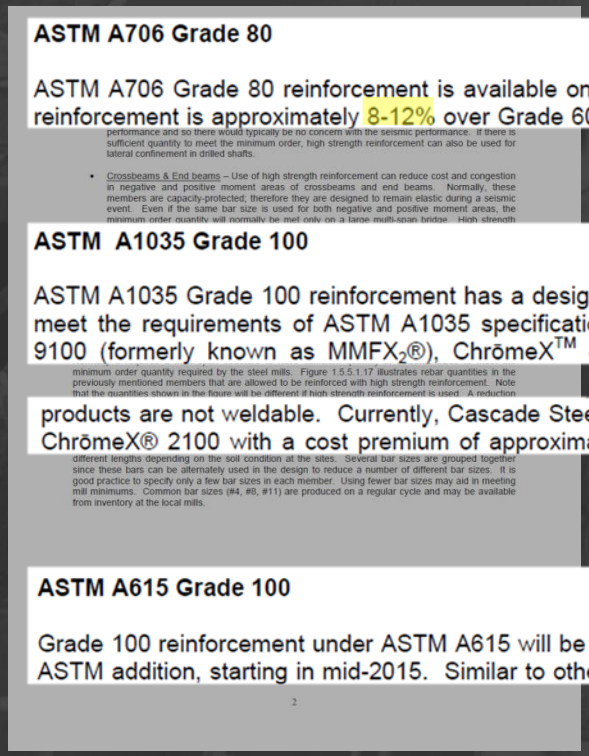
Do not use high strength reinforcement in members designed for plastic seismic performance (such as bridge columns). Although A706 Grade 80 reinforcement has similar ductile properties compared to A706 Grade 60, testing of full-scale seismic models sufficient to satisfy AASHTO concerns has not yet been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

For A1035 Grade 100, the stress-strain property is very different from A706. There is not a well-defined yield plateau. More experimental testing is necessary before its full implementation in members designed to form plastic hinges. The overstrength magnifier as defined for A706 in the Guide Specifications for *LRFD Seismic Bridge Design* may not be appropriate. At this time, an overstrength magnifier of 1.4 is recommended when high strength reinforcement is used in capacity-protected members.

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 bars. Refer to *BDDM Figure 1.9.1C and Figure 1.9.1D* for deck

1



ASTM A706 Grade 80

ASTM A706 Grade 80 reinforcement is available on the market. The cost premium for A706 Grade 80 reinforcement is approximately 8-12% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are

performance and so there would typically be no concern with the seismic performance. If there is sufficient quantity to meet the minimum order, high strength reinforcement can also be used for lateral confinement in drilled shafts.

- Crossbeams & End beams – Use of high strength reinforcement can reduce cost and congestion in negative and positive moment areas of crossbeams and end beams. Normally, these members are capacity-protected; therefore they are designed to remain elastic during a seismic event. Even if the same bar size is used for both negative and positive moment areas, the minimum order quantity will normally be met only on a large multi-span bridge. High strength

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 ChrōmeX® 9100 (formerly known as MMFX$_2$®), ChrōmeX™ 4100, and ChrōmeX® 2100. The main difference

minimum order quantity required by the steel mills. Figure 1.5.5.1.17 illustrates rebar quantities in the previously mentioned members that are allowed to be reinforced with high strength reinforcement. Note that the quantities shown in the figure will be different if high strength reinforcement is used. A reduction

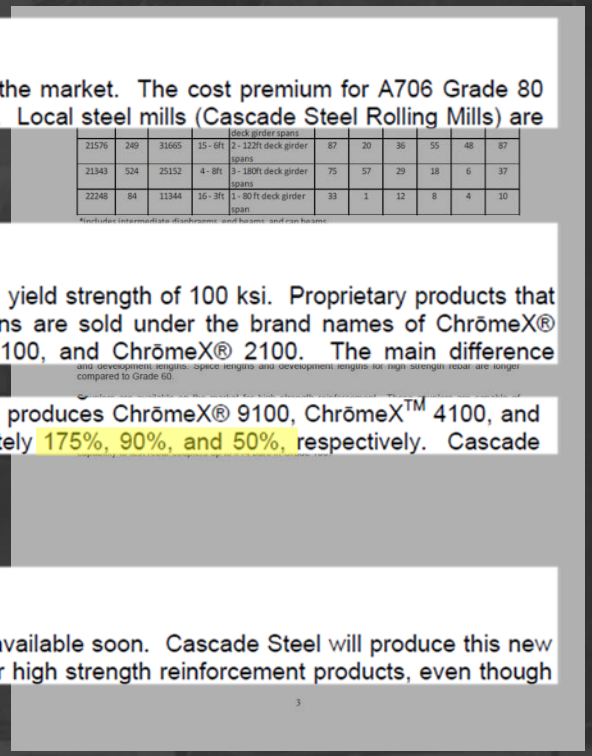
products are not weldable. Currently, Cascade Steel produces ChrōmeX® 9100, ChrōmeX™ 4100, and ChrōmeX® 2100 with a cost premium of approximately 175%, 90%, and 50%, respectively. Cascade

different lengths depending on the soil condition at the sites. Several bar sizes are grouped together since these bars can be alternately used in the design to reduce a number of different bar sizes. It is good practice to specify only a few bar sizes in each member. Using fewer bar sizes may aid in meeting mill minimums. Common bar sizes (#4, #6, #11) are produced on a regular cycle and may be available from inventory at the local mills.

ASTM A615 Grade 100

Grade 100 reinforcement under ASTM A615 will be available soon. Cascade Steel will produce this new ASTM addition, starting in mid-2015. Similar to other high strength reinforcement products, even though

2



deck girder spans

21576	249	31665	15 - 6ft	2 - 122ft deck girder spans	87	20	36	55	48	87
21343	524	25152	4 - 8ft	3 - 180ft deck girder spans	75	57	29	18	6	37
22248	84	11344	16 - 3ft	1 - 80 ft deck girder span	33	1	12	8	4	10

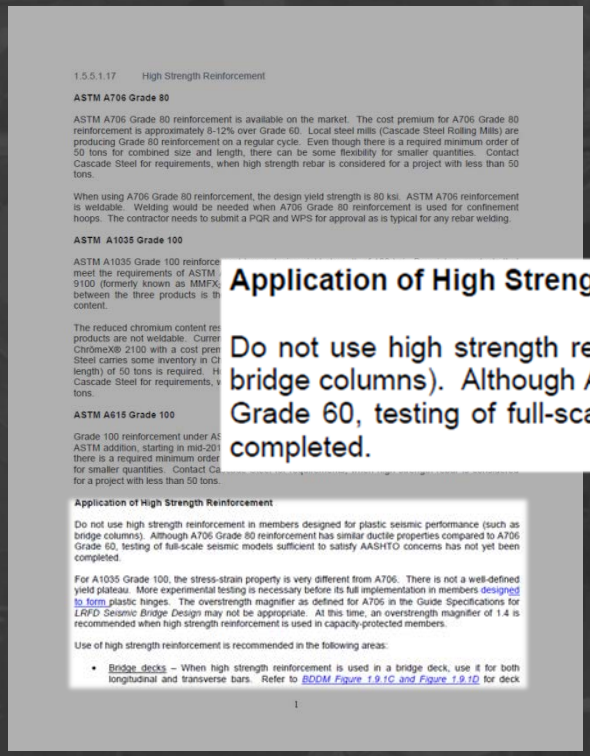
*Includes intermediate diaphragms, end beams, and cap beams

compared to Grade 60.

3

HIGH STRENGTH REINFORCEMENT

BDDM 1.5.5.1.17 – High Strength Reinforcement



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 A706 Grade 80 reinforcement is approximately 8-12% over Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing Grade 80 reinforcement on a regular cycle. Even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements, when high strength rebar is considered for a project with less than 50 tons.

When using A706 Grade 80 reinforcement, the design yield strength is 80 ksi. ASTM A706 reinforcement is weldable. Welding would be needed when A706 Grade 80 reinforcement is used for confinement hoops. The contractor needs to submit a PQR and WPS for approval as is typical for any rebar welding.

ASTM A1035 Grade 100

ASTM A1035 Grade 100 reinforce
meet the requirements of ASTM
9100 (formerly known as MMFX
between the three products is th
content.

The reduced chromium content re
products are not weldable. Curren
Chrōmex® 2100 with a cost pren
Steel carries some inventory in Ch
length) of 50 tons is required. H
Cascade Steel for requirements, v
tons.

ASTM A615 Grade 100

Grade 100 reinforcement under AS
ASTM addition, starting in mid-201
there is a required minimum order
for smaller quantities. Contact Ca
for a project with less than 50 tons.

Application of High Strength Reinforcement

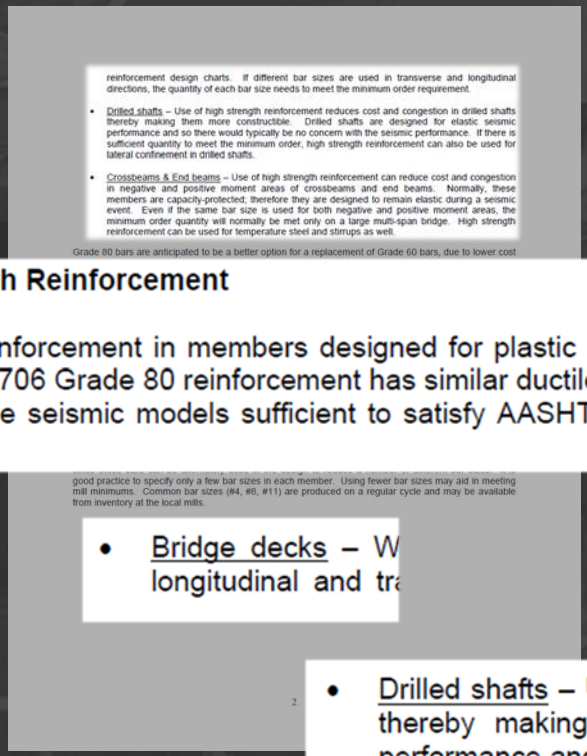
Do not use high strength reinforcement in members designed for plastic seismic performance (such as bridge columns). Although A706 Grade 80 reinforcement has similar ductile properties compared to A706 Grade 60, testing of full-scale seismic models sufficient to satisfy AASHTO concerns has not yet been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

For A1035 Grade 100, the stress-strain property is very different from A706. There is not a well-defined yield plateau. More experimental testing is necessary before its full implementation in members designed to form plastic hinges. The overstrength magnifier as defined for A706 in the Guide Specifications for *LRFD Seismic Bridge Design* may not be appropriate. At this time, an overstrength magnifier of 1.4 is recommended when high strength reinforcement is used in capacity-protected members.

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 bars. Refer to *BDDM Figure 1.9.1C and Figure 1.9.1D* for deck

1



reinforcement design charts. If different bar sizes are used in transverse and longitudinal directions, the quantity of each bar size needs to meet the minimum order requirement.

- Drilled shafts – Use of high strength reinforcement reduces cost and congestion in drilled shafts thereby making them more constructible. Drilled shafts are designed for elastic seismic performance and so there would typically be no concern with the seismic performance. If there is sufficient quantity to meet the minimum order, high strength reinforcement can also be used for lateral confinement in drilled shafts.
- Crossbeams & End beams – Use of high strength reinforcement can reduce cost and congestion in negative and positive moment areas of crossbeams and end beams. Normally, these members are capacity-protected, therefore they are designed to remain elastic during a seismic event. Even if the same bar size is used for both negative and positive moment areas, the minimum order quantity will normally be met only on a large multi-span bridge. High strength reinforcement can be used for temperature steel and stirrups as well.

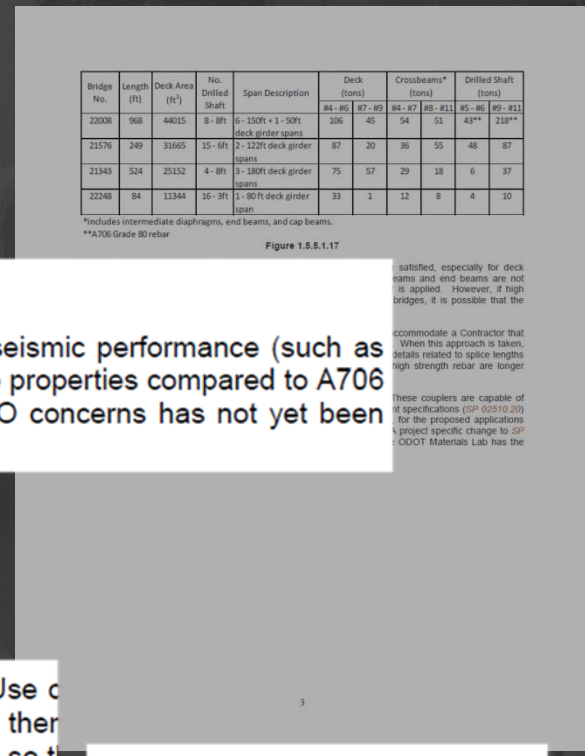
Grade 80 bars are anticipated to be a better option for a replacement of Grade 60 bars, due to lower cost

good practice to specify only a few bar sizes in each member. Using fewer bar sizes may aid in meeting mill minimums. Common bar sizes (#4, #8, #11) are produced on a regular cycle and may be available from inventory at the local mills.

- Bridge decks – W
  longitudinal and tr

- Drilled shafts – Use c
  thereby making ther
  performance and so t

2



Bridge No.	Length (ft)	Deck Area (ft^2)	No. Drilled Shaft	Span Description	Deck (tons)		Crossbeams* (tons)		Drilled Shaft (tons)	
					#4 - #6	#7 - #9	#4 - #7	#8 - #11	#5 - #6	#9 - #11
22008	968	44015	8 - 8ft	6 - 150ft + 1 - 50ft deck girder spans	106	45	54	51	43**	218**
21576	249	31665	15 - 6ft	2 - 122ft deck girder spans	87	20	36	55	48	87
21343	524	25152	4 - 8ft	3 - 180ft deck girder spans	75	57	29	18	6	37
22248	84	11344	16 - 3ft	1 - 80 ft deck girder span	33	1	12	8	4	10

*includes intermediate diaphragms, end beams, and cap beams.
**A706 Grade 80 rebar

Figure 1.5.5.1.17

satisfied, especially for deck
eams and end beams are not
is applied. However, if high
bridges, it is possible that the

ccommodate a Contractor that
When this approach is taken,
details related to splice lengths
igh strength rebar are longer

These couplers are capable of
nt specifications (*SP 023.10.20*)
for the proposed applications
A project specific change to *SP*
ODOT Materials Lab has the

3

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.

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

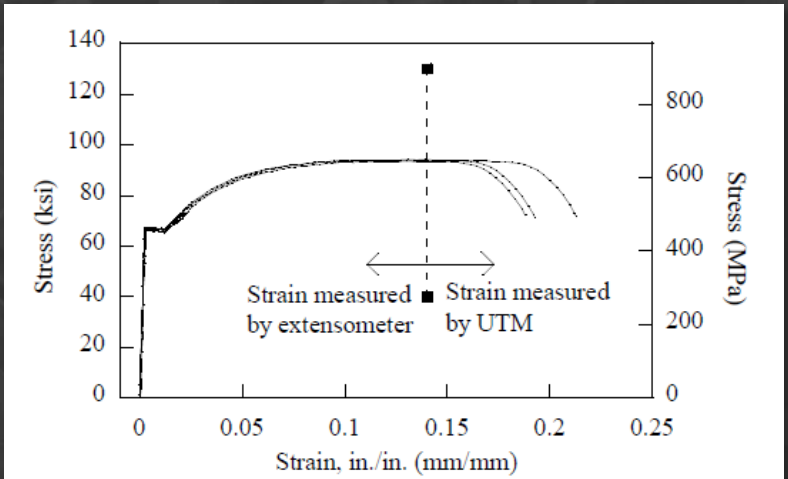


Figure 4.3: Stress-strain plot of Grade 60 #5 (#16M) reinforcing bars

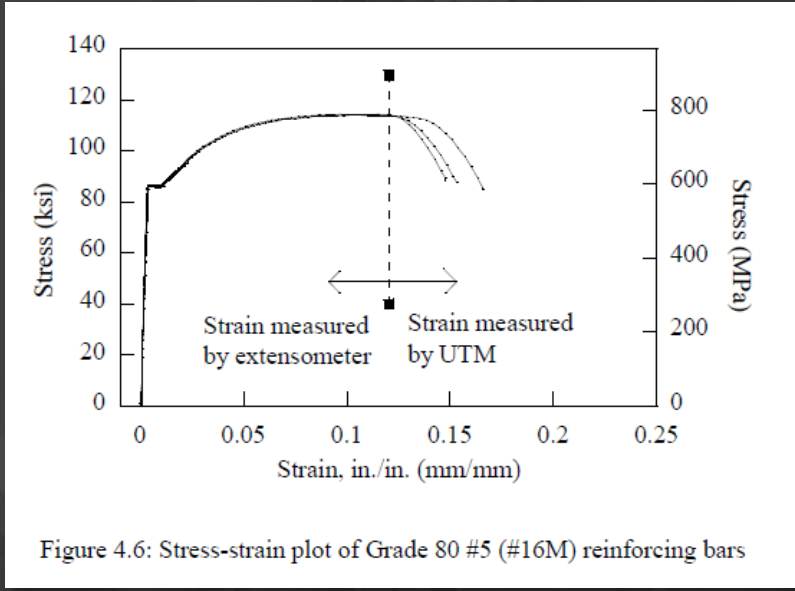
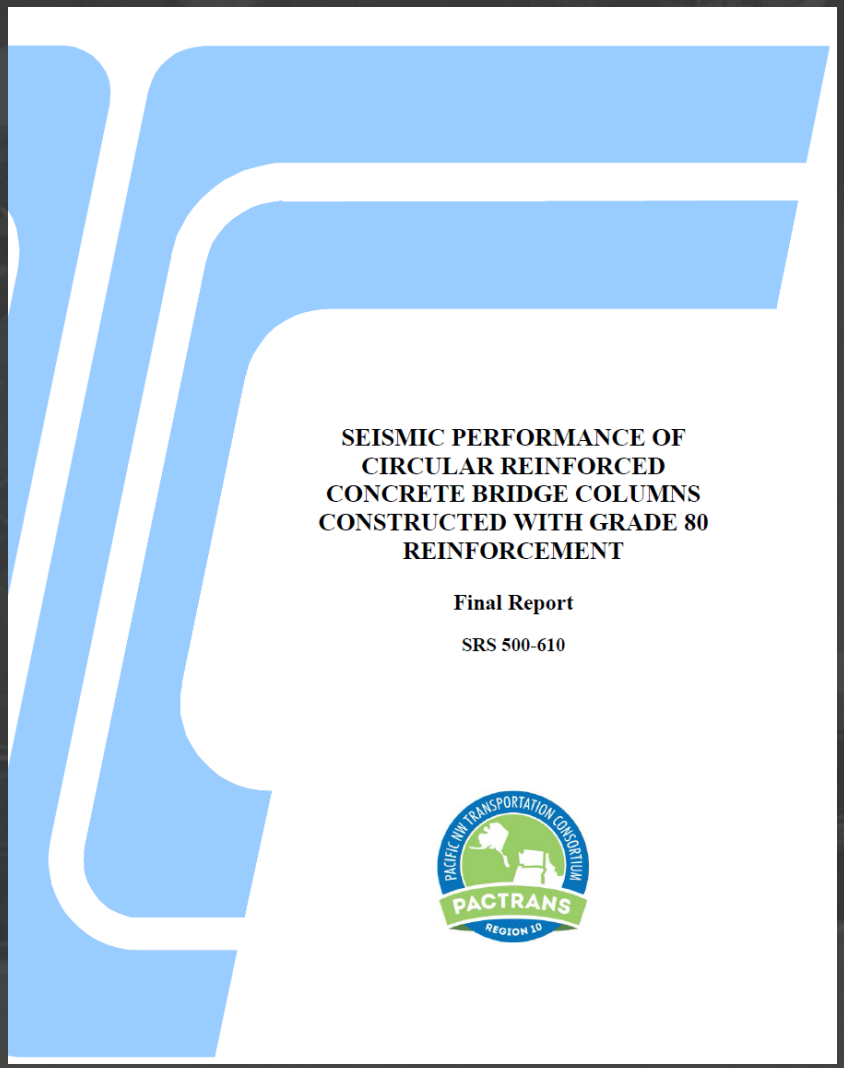


Figure 4.6: Stress-strain plot of Grade 80 #5 (#16M) reinforcing bars

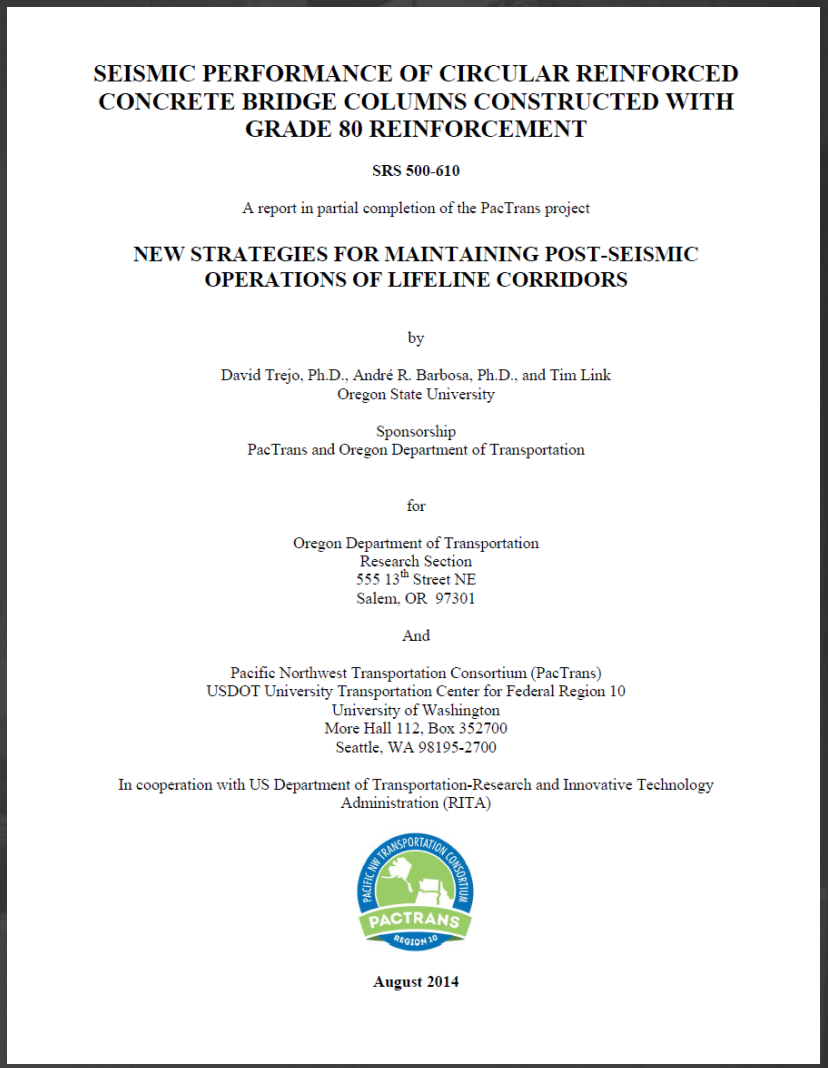
HIGH STRENGTH REINFORCEMENT



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

SRS 500-610

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
PacTrans and Oregon Department of Transportation

for

Oregon Department of Transportation
Research Section
555 13th Street NE
Salem, OR 97301

And

Pacific Northwest Transportation Consortium (PacTrans)
USDOT University Transportation Center for Federal Region 10
University of Washington
More Hall 112, Box 352700
Seattle, WA 98195-2700

In cooperation with US Department of Transportation-Research and Innovative Technology Administration (RITA)

August 2014

HIGH STRENGTH REINFORCEMENT

DESIGN GUIDELINES FOR CONCRETE BEAMS REINFORCED WITH MMFX MICROCOMPOSITE REINFORCING BARS

M. Dawood , H Seliem, Dr. T. Hassan, Dr. S. Rizkalla
Department of Civil, Construction and Environmental Engineering, NCSU
2414 Campus Shore Dr., Raleigh, NC, 27695-7533, USA, Sami_Rizkalla@ncsu.edu

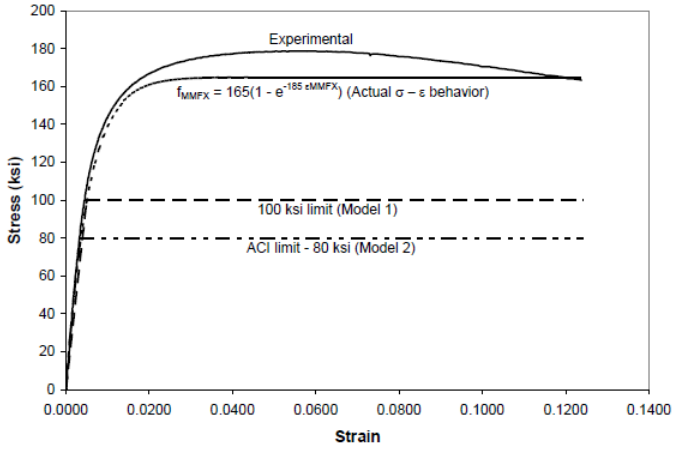
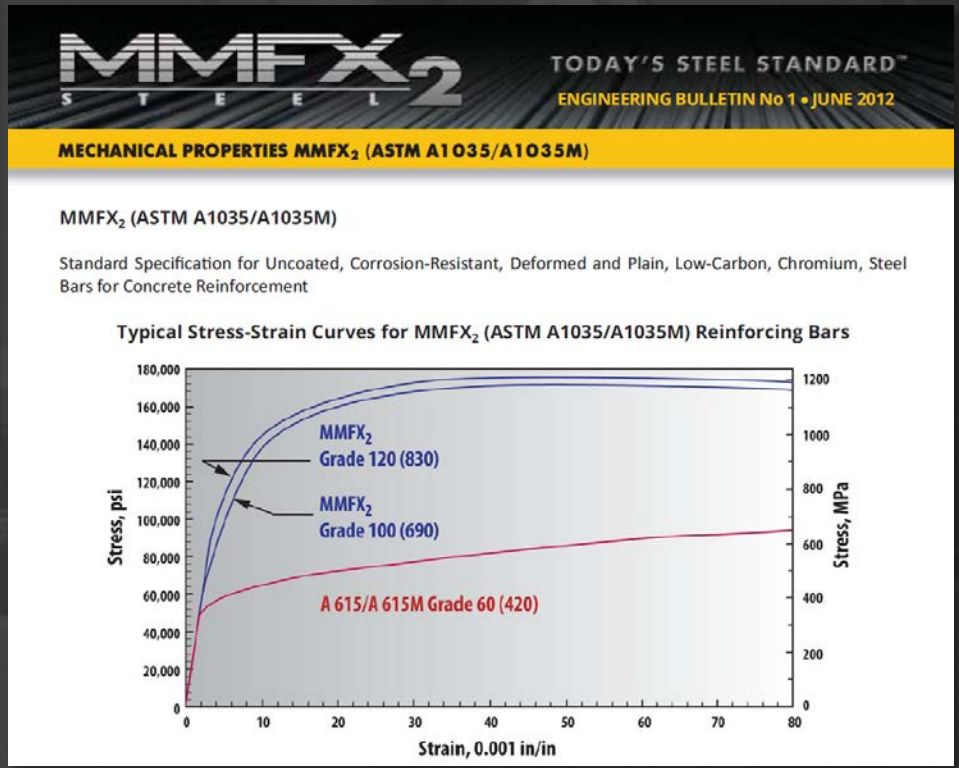
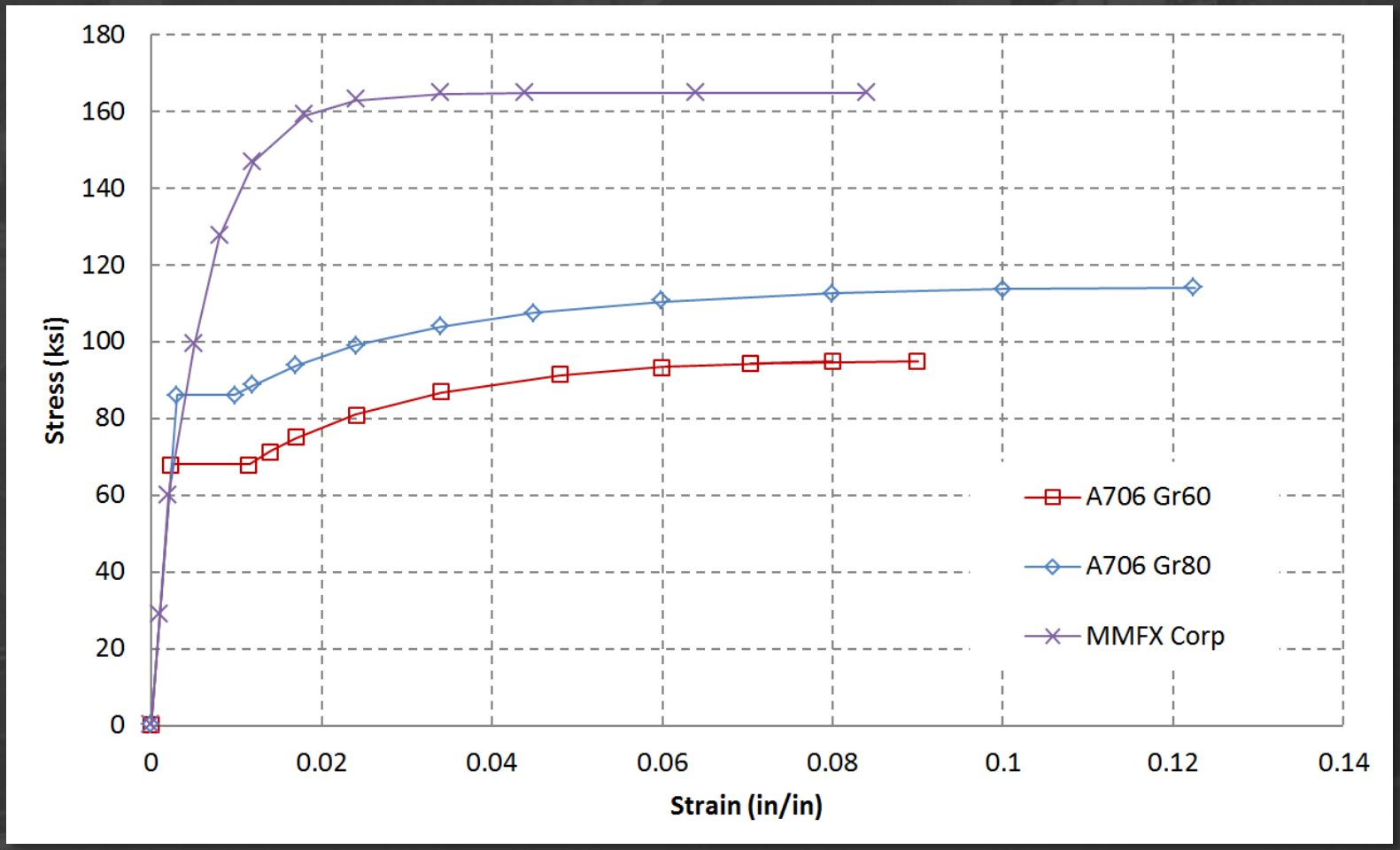


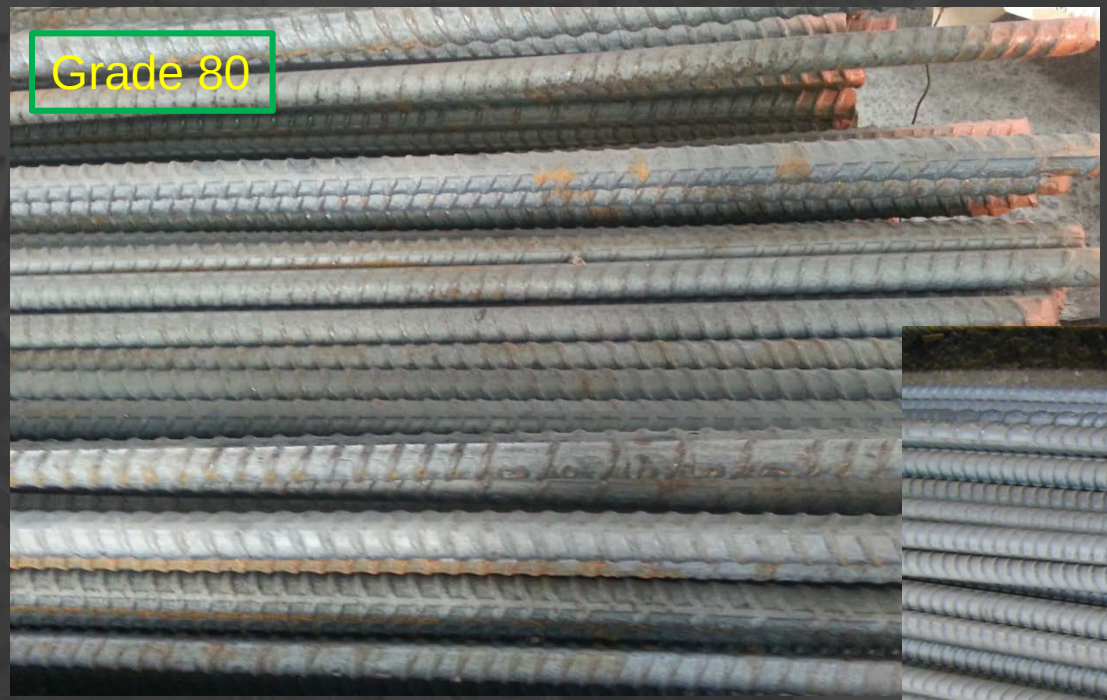
Figure 2: Comparison of Proposed MMFX Material Models



HIGH STRENGTH REINFORCEMENT



HIGH STRENGTH REINFORCEMENT



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**

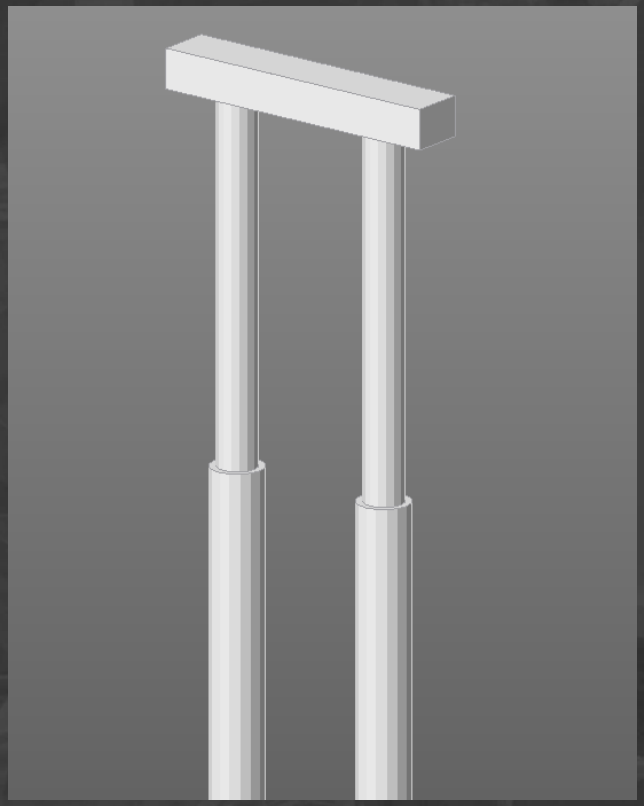
  Tilikum Crossing, Bridge of the People

Oregon Department of Transportation

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

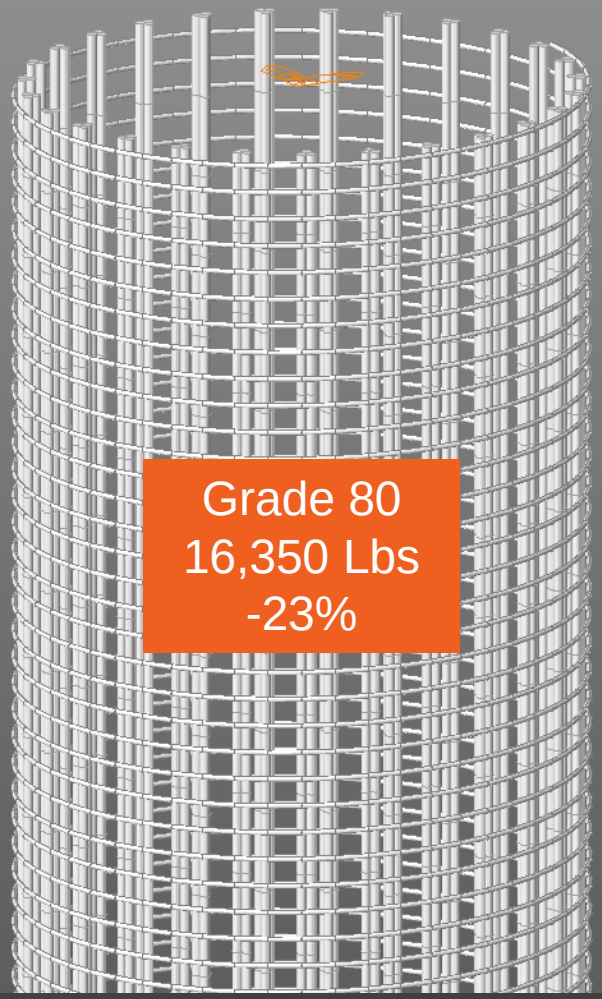
#6 stirrup

HIGH STRENGTH REINFORCEMENT

Bid unit price
$0.77/Lb

Bid unit price for Grade 60
$0.80/Lb

30 ft long section



HIGH STRENGTH REINFORCEMENT

Bridge Projects in Oregon

- **Newberg – Dundee Bypass Project**

  Chehalem Creek Bridge (22008)

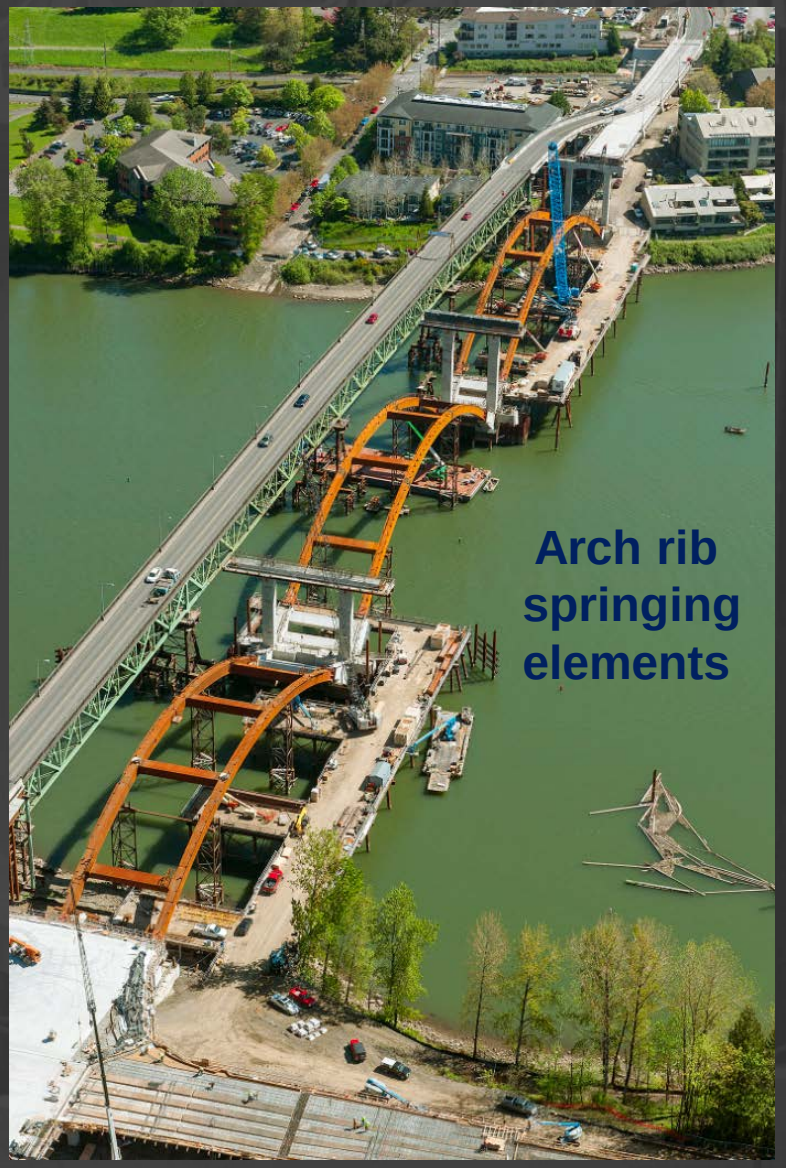
- **Sellwood Bridge Project – Multnomah County**

  Sellwood Bridge (21493)

- **Portland – Milwaukie Light Rail Transit Project**

  Tilikum Crossing, Bridge of the People

HIGH STRENGTH REINFORCEMENT



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

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

HIGH STRENGTH REINFORCEMENT

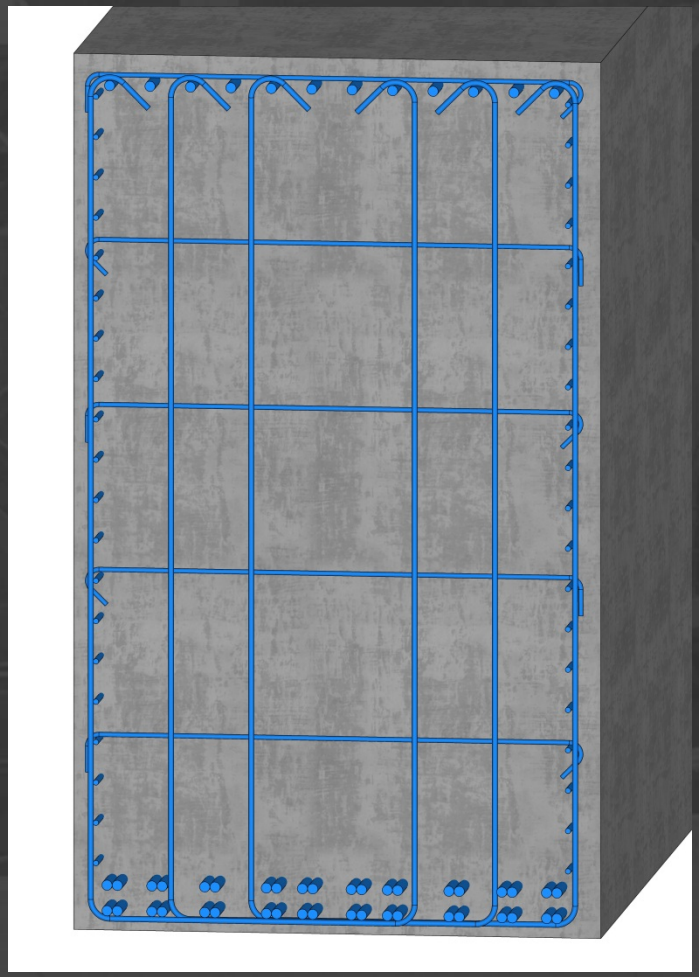
Grade 80 in a Typical Deck

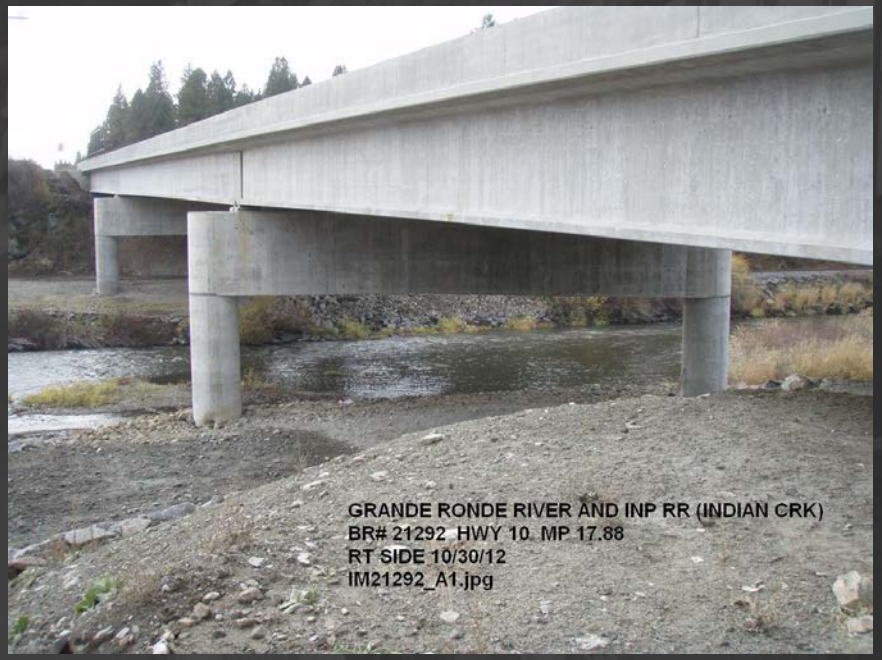
Grade 60		**Grade 80**
#5 @ 7.5”	Transverse bars	#4 @ 6.5” in P/S girder segments #4 @ 6” in CIP box girder segments
131,300 Lbs (66 tons)	Total weight	110,800 Lbs (16% reduction) (55 Tons)
$ 118,200 ($0.90 / Lb)	Cost	$ 105,300 ($ 12,900 reduction = 11%) (0.95 / Lb)

Price where Grade 80 is the same cost as Grade 60 = **$1.07 / Lb** (+ 17¢)

HIGH STRENGTH REINFORCEMENT

Crossbeam – Grade 60





Top: 12 - #11 bars

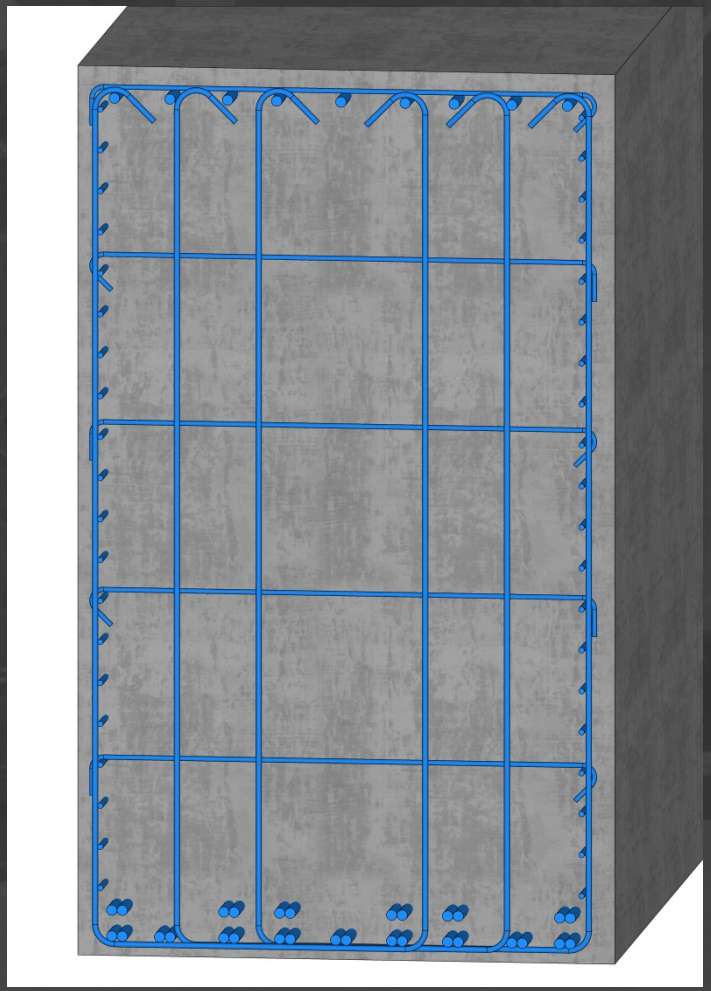
Bottom, Row 2 – 20 - #11 bars

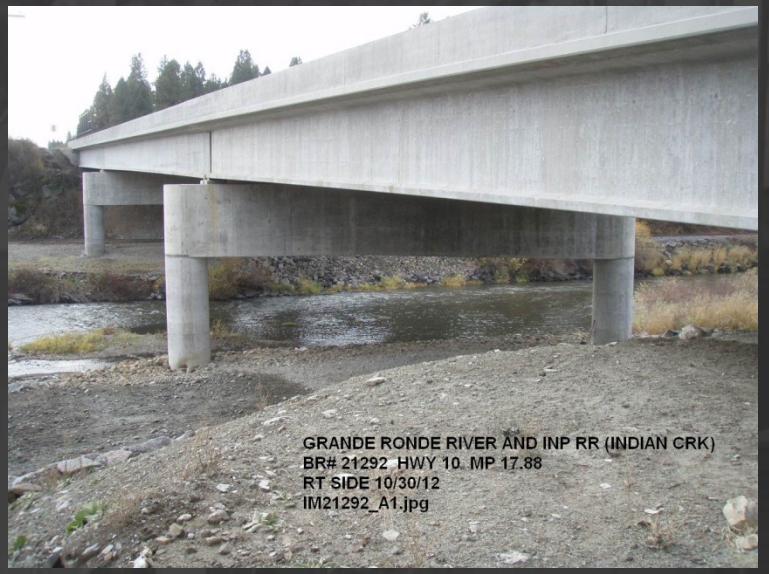
Bottom, Row 1 – 20 - #11 bars

#6 stirrups @ 6” ctrs

HIGH STRENGTH REINFORCEMENT

Crossbeam - Grade 80





Top: 9 - #11 bars

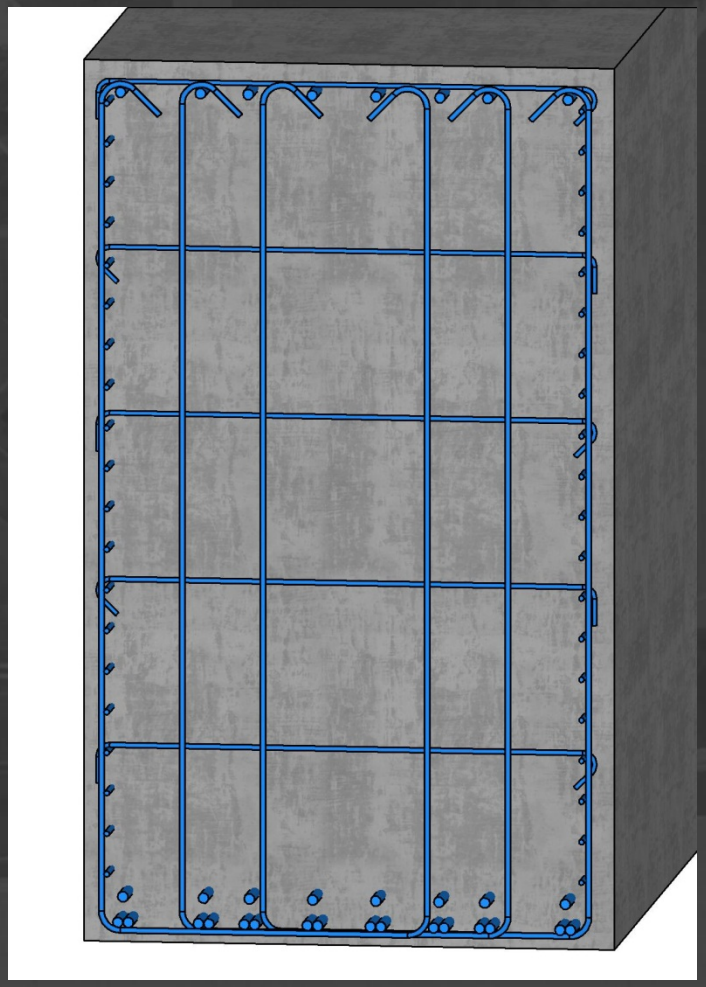
Bottom, Row 2: 12 - #11 bars

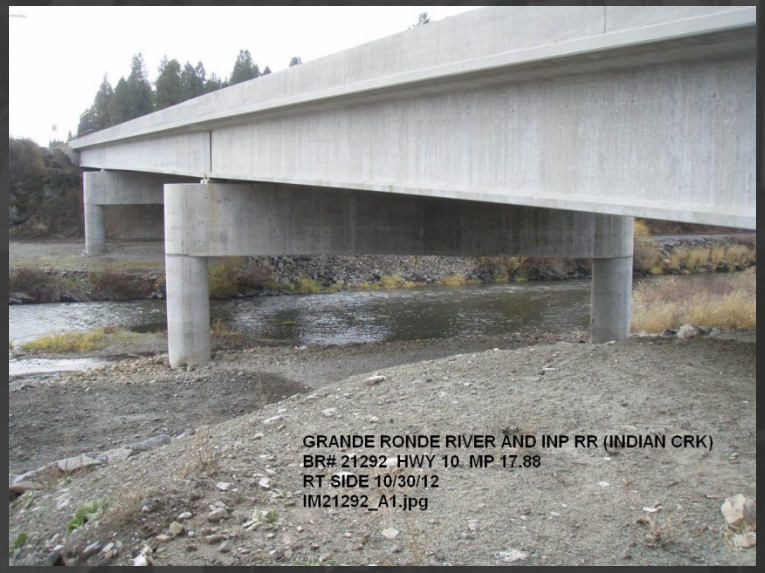
Bottom, Row 1: 18 - #11 bars

Stirrups #6 @ 8” ctrs

HIGH STRENGTH REINFORCEMENT

Crossbeam - Grade 100





Top: 8 - #11 bars

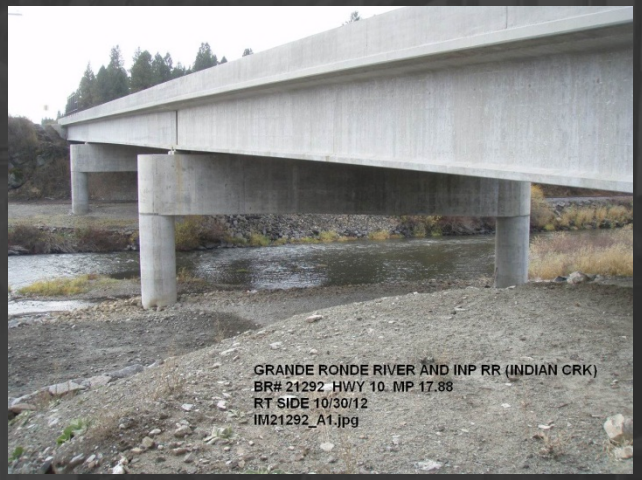
Bottom, Row 2: 8 - #11 bars

Bottom, Row 1: 16 - #11 bars

Stirrups #6 @ 10” ctrs

HIGH STRENGTH REINFORCEMENT

Cost Comparison – (based on two crossbeams)

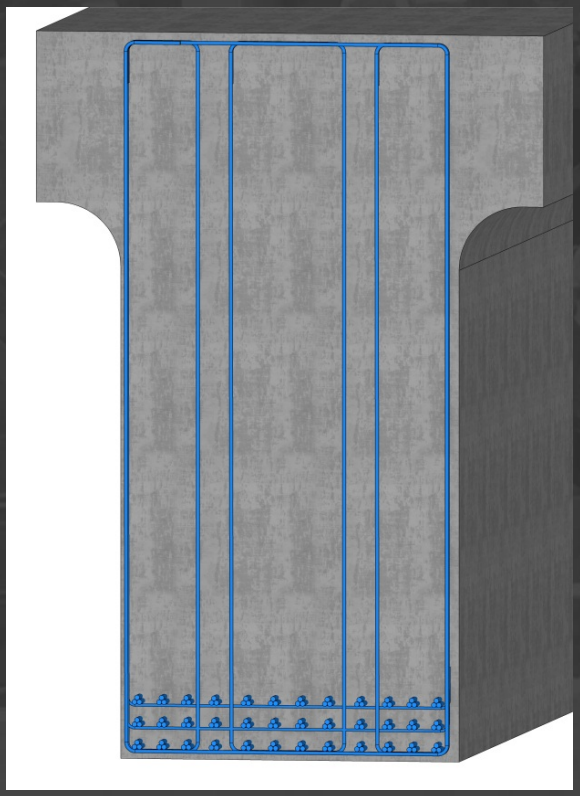


	Grade 60	Grade 80	Grade 100
	61,250 Lbs	51,150 Lbs (-16%)	45,200 Lbs (-18%)
	$55,100 (@ 0.90/Lb)	**$45,600** (@0.95/Lb)	**$47,500** (@1.05/Lb)
		$ 6,500 savings	$ 7,600 savings
		12% cost reduction	14% cost reduction
Equivalent Grade 60 cost		$ 1.08 per Lb (+18¢)	$ 1.22 per Lb (+32¢)
		16 Tons of #11 bar	13 Tons of #11 bar

HIGH STRENGTH REINFORCEMENT

Grade 40 – 60 – 80 – 100

(Positive moment only)



Grade 40

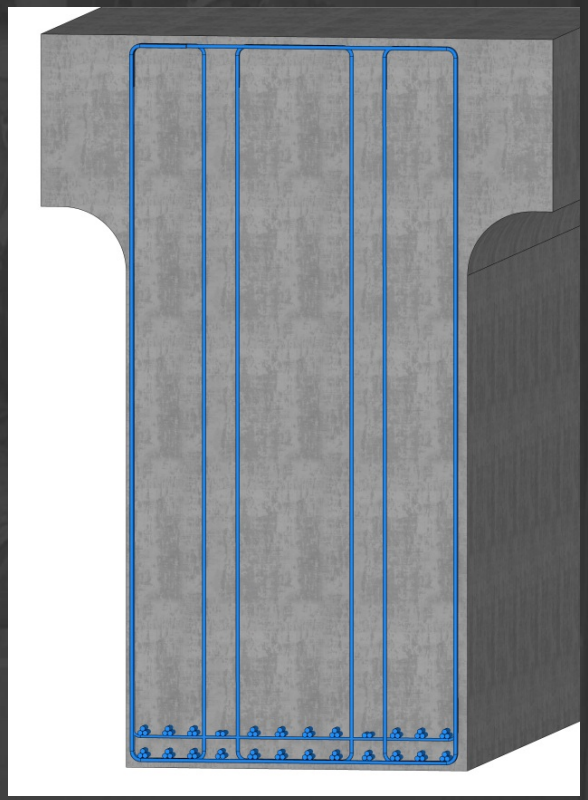
108 - #11 bars

Grade 60

70 - #11 bars

35% < Gr 40

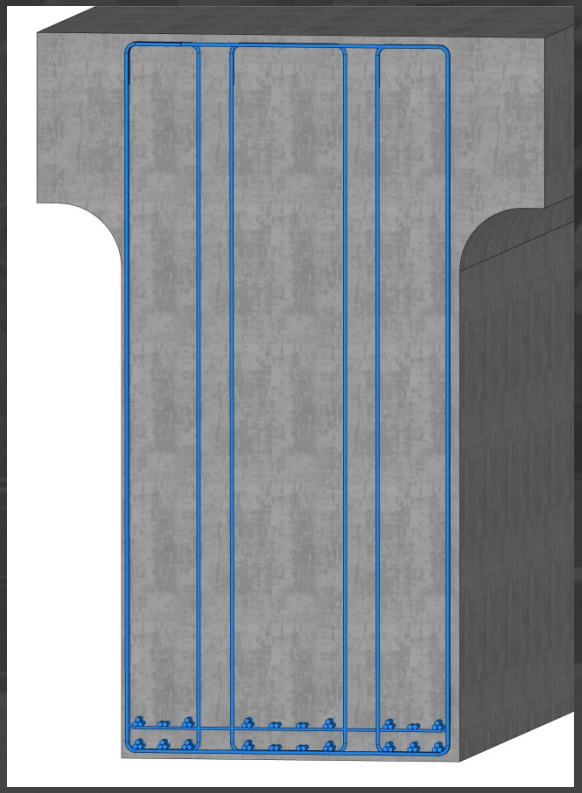
Top row of bundled bars eliminated



HIGH STRENGTH REINFORCEMENT

Grade 40 – 60 – 80 – 100

(Positive moment only)



Grade 80

54 - #11 bars

23% < Gr 60

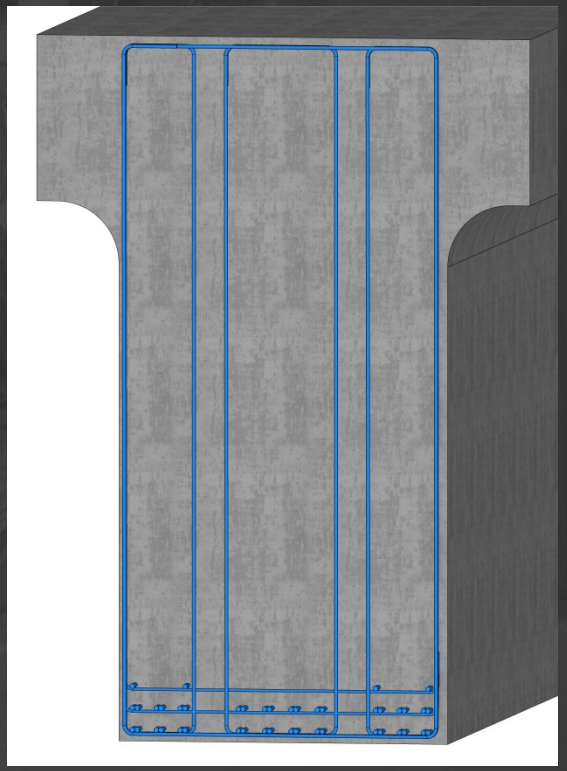
Some 3-bar bundles reduced to 2-bar bundles

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 ft^2 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**


?
or
Comments