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VDOT's Implementation of Corrosion Resistant Reinforcement

FDOT-FHWA Corrosion-Resistant Rebar Seminar
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Introduction

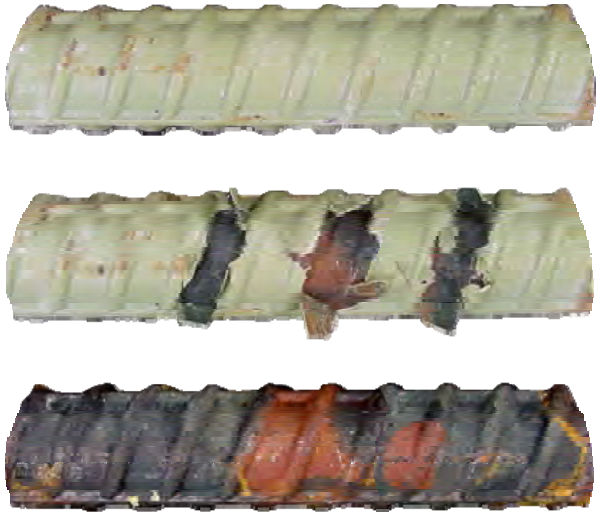
- The number one cause of bridge deterioration is corrosion of the reinforcement.
- In 2004 FHWA reported that a total of $10.5 billion was invested in bridge rehabilitation.

Introduction Continued

- To achieve longer lasting bridges major efforts have been devoted to improving the quality of concrete but little attention has been devoted to using longer lasting reinforcement.
- High performance concrete used today can provide a bridge service life of more than 75 years as currently recommended by FHWA.

Introduction Continued

- Research in Virginia and elsewhere has shown limitations with coated reinforcements (1-3)
- Field Observations
  - Coating failures in less than 20 yr.
  - Rebar section loss up to 100%.



Introduction Continued

- ECR does not perform well in leaking construction joints and cracks that are typically found in high performance concrete decks.
- Research has shown that sealing deck cracks can be expensive (4).

INTRODUCTION Continued

- Although cracks sealing operations are possible, the long term sealing of cracks is not always successful (4).

INTRODUCTION Continued

- Consequently, VDOT has discontinued the use of epoxy coated and galvanized bars and routinely uses corrosion-resistant metallic reinforcing bars (CRR) in bridge decks.
- March 2010 Instructional and Informational Memorandum initially provided bar requirements and method of CRR distribution.
  - All projects advertised after September 1, 2010 shall be with CRR.

Coated → ***Alloyed***

Introduction Continued

- Past 2 years, VDOT has used about 8.8 million lbs of CRR
- 20% of CRR used was stainless steel.

CRR Levels

Effective March 2013 Ad Date

- Class 1: Improved Corrosion Resistance Bars
  - MMFX2, 2101LDX (S32101)
- Class 2: Moderate Corrosion Resistance Bars
  - Stainless Steel Clad, EnduraMet32 (S24100)
- Class 3: High Corrosion Resistance Bars
  - EnduraMet33 (S24000), 2304 (S32304), 304 (S30400), 316L (S31603), 316LN (S31653), 2205 (S31803)

With VDOT approval CRR from a higher class may be substituted.

CRR for Functional Classification

Classification	Class 1	Class 2	Class 3
Freeway			X
Rural Principal Arterial			X
Rural Minor Arterial		X	
Rural Collector Road	X		
Rural Local Road	X		
Urban Principal Arterial			X
Urban Minor Arterial		X	
Urban Collector Street	X		
Urban Local Street	X		

CRR Applications

Use CRR based on functional classification

- New Construction
- Superstructure replacement

Use CRR from Class 1

- Widening
- Repair
- Rehabilitation

Ontario Ministry of Transportation research has shown no adverse affects from lapping CRR with black, epoxy coated or galvanized reinforcement but VDOT is proceeding carefully.

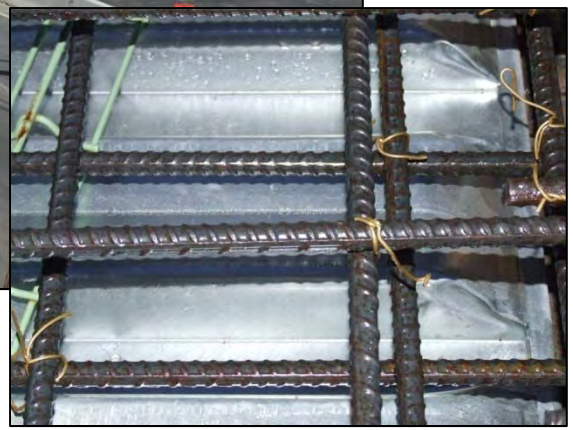
Instructional and Informational Memoranda

- VDOT Structure and Bridge Division oversees Instructional and Informational Memoranda (IIM)
- Corrosion Resistant Reinforcing Steels are covered by IIM-S&B-81
- IIM-S&B-81.4 current version
- IIM-S&B-81.5 effective for March 2013 ad date

Link to S&B IIM website:

http://www.virginiadot.org/business/bridge-ii-memoranda-index.asp

VDOT Deck with ASTM A1035 Reinforcement



VDOT Deck with ASTM A955 Reinforcement

Costs

- The initial cost of solid stainless CRR is a function of the reinforcement specified and has ranged from about 2 to 3 times the cost of ECR.
- The additional initial cost of solid stainless CRR is typically less than 5 percent of the total project cost.
- The cost of one deck overlay far exceeds the extra cost of CRR.

Implementation Lessons Learned: Design to Construction

- Education
  - designers, inspectors, suppliers and contractors
- Accessories
  - chairs, ties, etc.
- Isolation of stainless bars from contact
  - A36, prestress steel, etc.

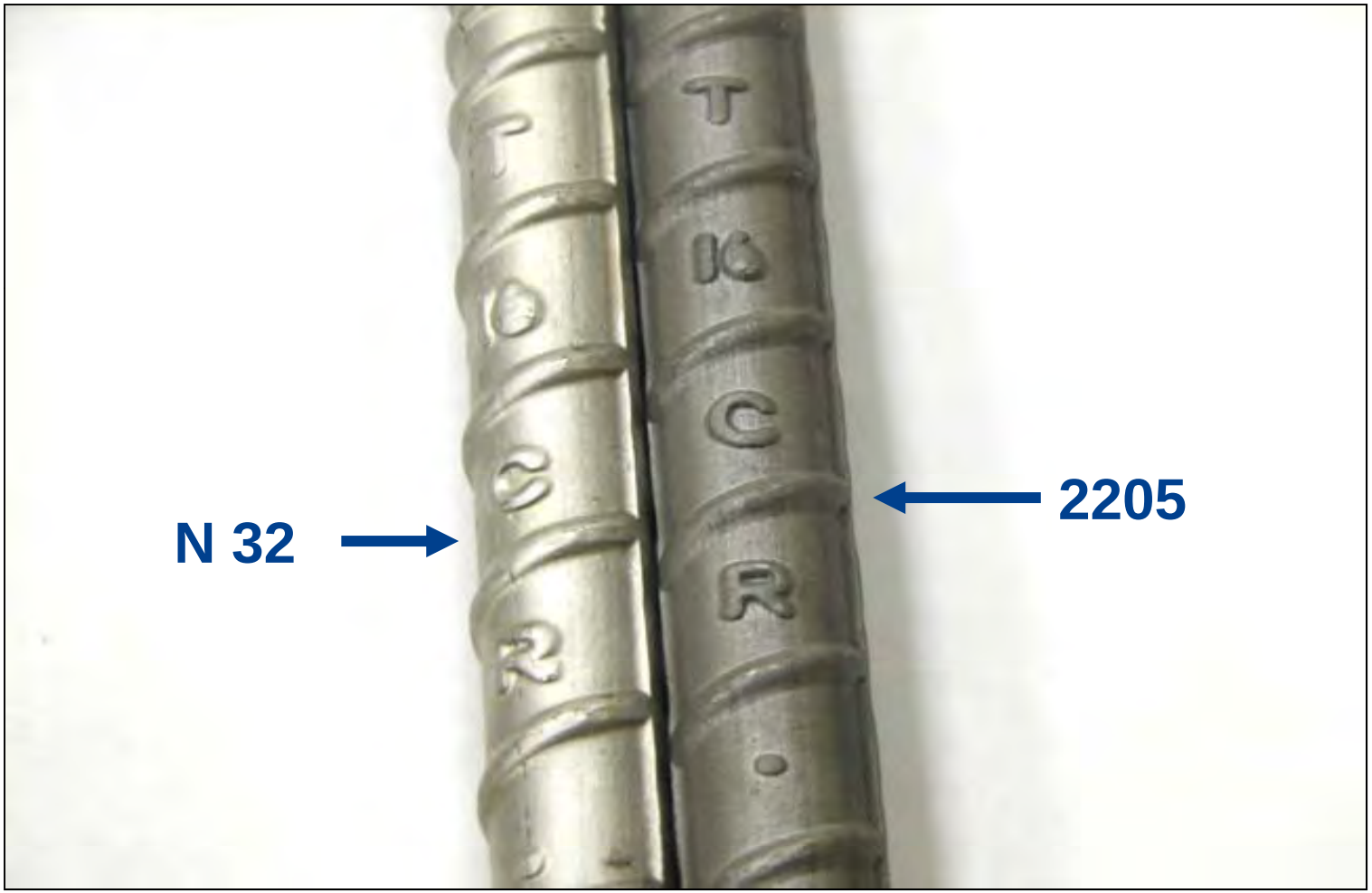
Implementation Lessons Learned: Multiple Alloy Grades

- Performance testing of alloy grades
- Cost differences of alloy grades
- Specifying cost effective alloy grades
- Acceptance testing of alloy grades
- Different alloy grades can look similar

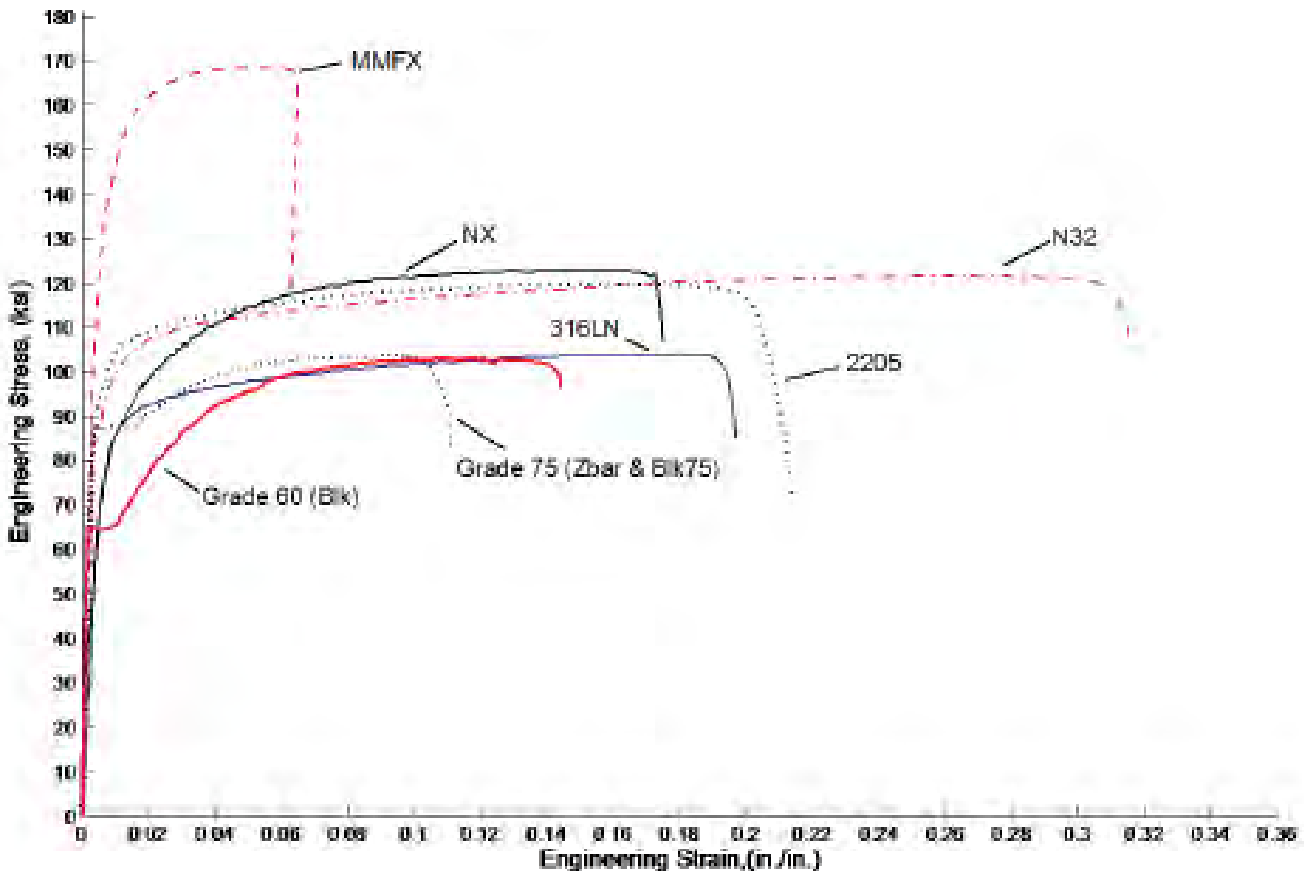
Implementation Lessons Learned: Visual Assessment

- Care must be taken when accepting bars at the jobsite based on visual assessment and markings.
  - A magnet can be used as a rough sorting method to differentiate between magnetic and non-magnetic alloys.
  - Handheld XRF devices can be useful in determining alloy composition.
- ASTM needs to revise the standards that govern the bar markings and include a requirement that markings indicating type of steel be added.

Implementation Lessons Learned: Example of Alloy Markings



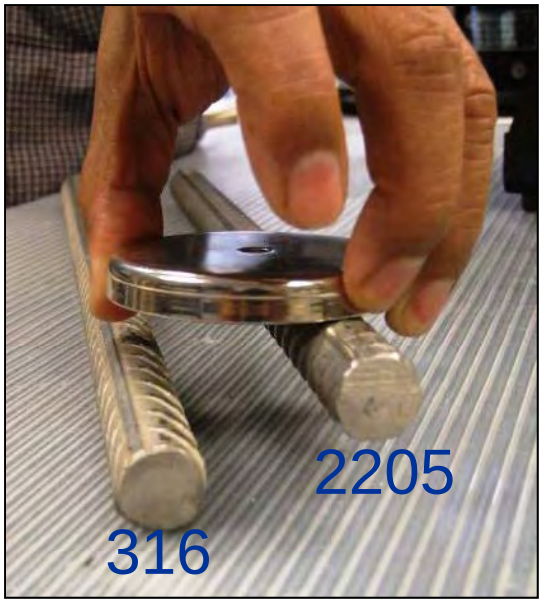
Implementation Lessons Learned: Example of Uniaxial Test Results



Implementation Lessons Learned: Magnetic Response

Bar	Black	2101	2304	2205	End32	304	316
Steel	**Fer./ Pear.**	**Dup.**	**Dup.**	**Dup.**	**Aus.**	**Aus.**	**Aus.**
Res†	**0.85**	**0.91**	**1.3**	**2.7**	**>25**	**>25**	**>25**

†Response measured using coating thickness gage



Implementation Lessons Learned: Example of Percent Reduction in Cross-Section

Bar	Black Steel	SS Clad	N32	MMFX 2	316 LN	Dura Corr
Red.(%)	7.5	21.5	35.8	38.5	48.5	52.6

Implementation Lessons Learned: Example of Elongation

Bar	MMFX 2	Dura Corr	Black Steel	SS Clad	2304	2205	N32
Elong (%)	8	10	12	19	20	28	39

Implementation Lessons Learned: Understanding CRR

- Knowledge of the material properties and how each bar performs in concrete is important.
  - Alloying affects corrosion resistance and mechanical properties.
  - Bars with different alloys from different companies can be expected to perform differently when subjected to a corrosive environment and loaded to failure.
  - Differences in relative rib area affects mechanical performance.

Summary

- VDOT has discontinued the use of epoxy coated and galvanized bars and to use corrosion-resistant metallic reinforcing bars (CRR) to achieve a 75+ year bridge service life.
- CRR has been placed in one of three classes based on corrosion performance data. The CRR class specified is based on the functional classification of the bridge.
- Care must be taken when accepting bars at the jobsite based on visual assessment and markings.

Summary Continued

- Mechanical properties are not being used to specify the size and spacing of CRR but can be used to refine deck designs and reduce cost.
- Corrosion and mechanical testing of CRR is necessary to identify the most cost effective bars.
- CRR is more cost effective than ECR and greater savings are anticipated as new lower cost bars become available and deck designs are refined.

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Thank You.

References

1. Michael C. Brown, Ph.D., P.E., Richard E. Weyers, Ph. D.,P.E., and Megan C. Wheeler, 2003, VTRC Report 04-CR7, *Corrosion Protection Service Life of Epoxy-Coated Reinforcing Steel in Virginia Bridge Decks.*
2. R. E. Weyers, M. M. Sprinkel, and M. C. Brown, 2006, VTRC Report 06-R29, *Summary Report on the Performance of Epoxy-Coated Reinforcing Steel in Virginia*.
3. Kessler, R.J., and Powers, R.G. 1988. *Corrosion of Epoxy-Coated Rebar, Keys Segmental Bridges,* Florida Department of Transportation, Materials Office, Corrosion Research Laboratory, Gainesville.
4. Stephen R. Sharp and Audrey K. Moruza, VTRC Report 09-R9, *Field Comparison of the Installation and Cost of Placement of Epoxy-Coated and MMFX 2 Steel Deck Reinforcement: Establishing a Baseline for Future Deck Monitoring*