2017 Minnesota Concrete Council

# MnDOT's Experience With High Performance Concrete Bridge Decks & Reinforcement

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MINNESOTA BRIDGES AND STRUCTURES

## Overview

I. Historical Perspective
*"Where We've Been – How We Got Here"*

II. Current Policies
*"Where We Are"*

III. Research/Future Outlook
*" Where We're Going"*

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## 1960's Design

6.5" – 7.5" deck thickness
1.5" cover black bars
ASTM 615 grade 40/60

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## Bridge Deck Deterioration

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## MnDOT Research

Initiated in 1972 - 12 Systems Studied:

- Modified Asphalt
- Waterproof Membrane & Bituminous Overlay
- Linseed Oil
- Cathodic Protection
- Epoxy and Sand
- Epoxy Overlays
- Conventional Conc Overlays
- Low Slump Overlays
- Latex Conc Overlays
- Latex Mortar
- Epoxy Coated Rebars
- Galvanized Rebars

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## Low Slump Concrete Overlay Development

- 1st Constructed in 1974
- 32+ Million Square on Bridges
- 72% of State Owned Bridges w/ a Deck
- 2025 Bridges with Overlay
- 56% After Initial Construction (1141 Brs)
- 44% As Part of Initial Construction (844 Brs)
- 66% Are Older than 20 years
- Cost $6-$9 Per SF (4-6% of Total Br Cost)
- Tremendously Successful

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## Low Slump Concrete Overlays

- 835 lbs of Cement, w/c = 0.33, 5600 psi
- 3/8" Granite, Trap Rock
- Maximum Allowable Water Reducer
- 6.5% Air Content

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## Low Slump Concrete Overlay

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## Low Slump Concrete Overlay

### Advantages

- 2nd Chance For Good "Profile"
- Assurance of 3" Cover
- 35+ Years of Proven Performance
- Competent Contractors & Equipment

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## Low Slump Concrete Overlay

### Disadvantages

- Add'l Construction Sequence & Curing Time
- Specialized Equipment
- Single Pass Width Limit of 24 Feet
- 72 Hour Delay for Next Pass
- Cutoff Dates/Temp Restrictions
- 5-10% Higher Cost
- Recent Map Cracking Issues

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## High Performance Mix Design Evolution

- Silica Fume
  - 1997 Bridge 27072 on TH 55
- High Fly Ash
  - 2004 Bridge 9443-9146 on I-94
- Low Cement Content
  - 2007 Bridge 27V84 on Diamond Lake over I-35W
- Contractor Mix Design
  - 2008 Bridge 27409, 27410 on I-35W over Miss River
- Internal Curing
  - 2016 Bridge 62892 – Ped bridge over I-94

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## Silica Fume Mix Design

- Same as NYDOT
- 75% Portland cement, 20% Fly ash, and 5% Silica Fume
- Well Graded Aggregates Should Lower Water Demand and Permeability
- Air Content 6.5%
- W/C = 0.40

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## Silica Fume Requirements

Fogging and 7 Day Wet Cure

Surface Smoothness Requirements

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## Silica Fume Early Issues

Shrinkage Cracking

Silica Fume "Balling"

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## Silica Fume Concrete

**Advantages**

- Reduced Construction Time (no overlay)
- Reduced Permeability (70% reduction)
- Longer Construction Season
- Longer Service Life

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## Silica Fume Concrete Disadvantages

- Requires Well Run Automated Production Plant
- Additional Admixtures
- Susceptible to Drying Shrinkage Cracking
- Weather Restrictions at Time of Placement
- Monolithic Pour May Require Surface Planing To Achieve Good "Ride"
- Higher "Risk" Placement
- Scaling

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## High Fly Ash Mix Design

- Minimum Cementitious Content of 611 Pounds per CY (70% cement, 30% F Fly Ash)
- Well Graded Aggregate Specification
- Air content 6.5%
- W/C < 0.40
- Incorporated in Most Mixes since 1980 (15%)
- Can Delay Strength Gain
- Improves Workability and Pumpability
- Reduces Permeability

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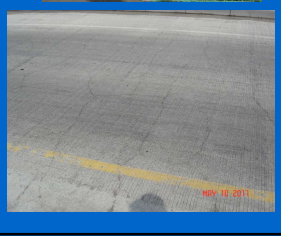
## High Fly Ash Concrete



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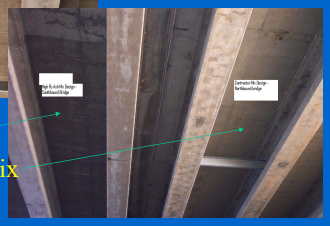
## High Fly Ash Concrete

62092 TH 61 over Gem Lake



Left Fly Ash
Right Contractor Mix

## Low Cracking Mix (KU)

- 500-535 lb/yd$^3$ Cement
- Pozzolans Not Needed. Easier for Out of Metro Plants to Produce
- Aggregate Gradation Key for Pumping
- 1.5”-3” Slump
- 14 Day Wet Cure
- w/c ratio 0.42-0.45
- Qualification Slab
- 3YLCHPC-(M) or (S)

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## Low Cracking Mix

Bridge 9725 TH 47

8 cracks in low cracking KU mix

50 cracks in twin with conventional (3Y36)

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## Low Cracking Concrete

Bridge 82806 TH 694

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## Low Cracking Mix Design Innovations

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## Low Cracking Mix Design

**Advantages**

- No Pozzolans
- No Complicated Mix Designs
- Reduced Cracking

**Disadvantages**

- Pumpability Concerns
- Longer Wet Cure

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## Contractor Mix Design

- Strength 4 ksi
- w/c ratio 0.35-0.45
- Air Content 6.5%
- Maximum Ternary Blends 40%
  - Fly Ash 30% Slag 35% Silica Fume 5%
- Slump 1-4”
- Maximum Permeability
  - < 2500 coulombs at 28 Days < 1500 coulombs at 56 Days
- Freeze Thaw >90% at 300 cycles
- Shrinkage < 0.040 at 28 Days
- Scaling Visual Rating < 1 at 50 cycles

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## Contractor Mix Design

- Bridge 27409, 27410 - 35W over Mississippi
- Strength 6.5 ksi min (8 ksi actual)
- Cementitious Material 700 lb/ft$^3$
- w/c ratio 0.35
- Cement 71%
- Fly Ash 25%
- Slag 0%
- Silica Fume 4%
- Permeability <250 coulomb at 28 and 90 days
- Shrinkage 0.04% at 56 days ASTMC157
- Diffusion coefficient 4x10-8 ft$^2$/h

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## Contractor Mix Design

### Advantages

- Contractor and Supplier Preference
- Reduced Cracking
- Used for Majority of Projects

### Disadvantages

- Complicated Mix Designs
- No Control for Type of Design

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## Internal Cure Mix Design

**Br 62892**

- **w/c =0.45**
- **8% Air**
- **No Fly Ash but up to 35% Slag**
- **150 lb Lightweight Sand**
- **< 10% of Aggregate is Lightweight**

## Internally Cured Concrete Decks

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## MnDOT Use of HPC Decks

- Minimize cracking issues in concrete decks
  - Chloride content 20x at bar level at cracks
- Decreased permeability
- Extends construction season (decks placed until Oct 15, overlay cutoff)
- Have found costs of 9" HPC decks slightly less than 7" deck plus 2" OL
- Wet cure very important

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## High Performance Decks Mixes

| Type of HPC | Years of Placement | Number of Decks | Results |
|---|---|---|---|
| Silica Fume | 1997-2004 | 23 | Fair to good.<br>Pop outs, need good wet cure,<br>More difficult to work with. |
| High Fly Ash | 2004-2009 | 35 | Fair to very good.<br>Contractors prefer this mix |
| Low Cracking (KU) 3YLCHPC | 2007-Present | 30+ | Fair to good. Need to keep w/c near 0.44. Pumpability issues. Use for remote areas. |
| Contractor Mix 3YHPC | 2008-Present | 80+ | Generally good. Lowering of cracking density |
| Lightweight Deck | 2015-? | 2 | Trial placements |
| Internal Curing | 2016-? | 2 | Need more data. |

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## Deck Placement Research

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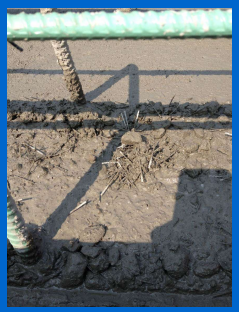
## Concrete Fibers



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## Concrete Fibers

Add'l 1" slump to 5"

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## Concrete Fibers

- Lessons learned on fiber introduction
- No issues with carpet drag, tining needs a drag technique, always can be diamond ground
- Clumps removed
- Polypropylene perform best

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## Steel Rebar Development

- ASTM A775 – Epoxy
- 1977 Top Mat Only
- 1987 All Bars Except footing

- Rebar grade
- 1964 – ASTM 615 grade 40
- 1972 - ASTM 615 grade 60
- 1988 - ASTM 706 grade 60

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## Stainless Steel Reinforcing

- 1st Use - 2009
- Both mats in bridge deck, and in barriers
- Solid bars

- In 2011 MnDOT Issued Policy
- > $25 million
- Box Girders

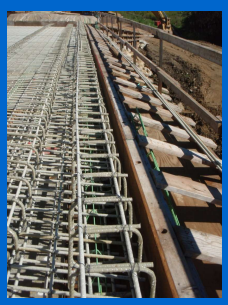
## Glass Fiber Reinforced Polymer (GFRP) Rebars

1st Use - 2016

Both mats in bridge deck, and in barriers

Solid bars

## GFRP Rebars



## Future

- Optimum Mix Design
- Epoxy Bars/Stainless/GFRP/??
- HPC in Lieu of Low Slump Overlays? Policy?
- Fibers and Long Term Performance
- Cure and Placement Requirements
  - Gang Vibrators
  - Night placements
  - 15 Minute Wet Cure
  - Minimum 14 Day Wet Cure
  - Shrinkage Reducing Admixtures
  - Shrinkage Compensating Admixtures

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## MnDOT's Experience With High Performance Concrete Bridge Decks & Reinforcement

# *Questions?*

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## Current Deck Protection Policy

- All Bars Epoxy Coated (Footings)
- Top Bar Cover of 3"
- Low Slump Overlays:
  - **ALL BRIDGES CARRYING INTERSTATE TRAFFIC**
  - **ALL BRIDGES AT INTERCHANGE W/ THE INTERSTATE**
  - **MUNICIPALITIES W/ POPULATION > 5,000**
  - **BRIDGES W/ 20 YR PROJECTED ADT > 2,000**


- Cutoff Dates (Sept 15, Oct 1st)
- Night Placement Req'd if Temp > 80 degrees

## 1995/2006 Field Examination

- 4 Bridges – 3 w/ black bar bottom mat
  28-33 yrs Old, 2 w/ Overlay, 2 w/o Overlay
- After 30 years of service, the overall condition of epoxy-coated bars in these decks is good to very good, with or modest levels of corrosion. Corrosion on Br 19015, but had thin coating (25% thin).
- Based on observed performance…cover of 3.5 inches, should exhibit no corrosion for another 20 to 25 years.
- Delaminated and spalled areas less than 1.1%
- Improvements in coating technology, application, and thickness requirements.

## Concrete Cover