MnDOT’s Fiber Reinforced Concrete Roundabout and Joint Activation of 5” FRC Whitetopping

NCC Meeting – Denver, CO
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April 2, 2019
Locations of Fiber Reinforced Concrete Pavements

5” Whitetoppings

Roundabout
Fiber Reinforced Concrete Roundabout
Snapshot from https://youtu.be/GmrP8G46_v4
Courtesy Greg Bauer, CPAM
Why build a jointless roundabout?

• District 7 Mankato Materials Engineer contacted the Concrete Office to discuss the idea of constructing a Continuously Reinforced Concrete (CRC) Roundabout
  • Goal was to not worry about jointing pattern
  • Concern about cost and constructability
  • Presentation at a NCC meeting discussing FRC roundabouts prompted the idea to build FRC roundabout without joints

• Lots and lots of discussion...
Fiber Requirements

Provide Type III structural synthetic fibers meeting the requirements of ASTM C 1116 and the following:

a. **Minimum mean residual strength of 175 psi (F175),** when tested in accordance with ASTM C1609

b. A monofilament or bundled monofilament with a minimum length of 1.5 in and a maximum length of 2.25 in., and

c. A maximum aspect ratio (length divided by the equivalent diameter of the fiber) of 150, and with a target aspect ratio between 50 and 100.
TH 4 Roundabout with fibers

- Cemstone/Hoffmann
  - Required Test Data and Test Pour
  - Mean residual strength of 175 psi (equivalent strength ratio)
- BASF Macro 360FF
  - Dosage Rate 6 lb/cy
  - Used for temperature and drying shrinkage control
  - a synthetic micro- and macrofibers, is manufactured from a proprietary blend of polypropylene resins
Quality Control Plan

• Identify dedicated personnel involved in introduction of synthetic fibers to mix

• Proposed method for adding the synthetic fibers into the mixer to ensure uniform distribution and random orientation of the fibers throughout the concrete mixture

• Mitigation strategies needed if unmixed fiber balls are identified after concrete mixing or during concrete placement.
• Minimum 5 cubic yard trial placement with the contractor-designed mix to demonstrate slump, air loss, and workability with the Contractor’s mix design.

• Any trial batching of the FRC mix designs are at the Contractor’s discretion with no additional cost to the Agency.

• Ensure the manufacturer’s technical representative is available by phone or in person to troubleshoot fiber inclusion into the mix during the trial batching.
• Plan to place the FRC inside the isolated circle of the roundabout in one continuous placement.

• Provide active crack control (notch) on the outside edge of the roundabout:
  • 15 inch long saw cut,
  • At a depth of 1.5 inch, and
  • Every 4 feet on the outside edge of the roundabout.

• Seal the active crack control (notch) saw cuts using hot pour
Fiber Reaction to Vibration
Aerial View of Roundabout
Fiber Reinforced Concrete Roundabout

9/10/18 - Legs Poured
9/13/18 - Roundabout Poured

Cracking Locations
9/16/18 - R5, R7**
9/17/18 - R1**, R2, R3**, R8
9/18/18 - R4, R6**
3/28/19 – R9, R10, R11
** Cracked off Sawed Notch

Cracks as of 3/28/19
Fiber Reinforced Concrete Roundabout
Fiber Reinforced Concrete Roundabout
TH 63 5” Whitetopping with fibers
TH 63 5” Whitetopping with fibers

• Croell, Inc. – Iowa Contractor
  • 12.379 Miles
  • Engineer’s Estimate $6.1 Million
  • Low Bidder $6.9 Million
  • Placement (177, 319 SY) – EE $5.87, Croell $4.30
  • Structural Conc (24,900 CY) – EE $59.89, Croell $92.50
  • SP 12.5 WE (2,B) (20,863 Tons) – EE $44.22, Croell $51.50
TH 63 5” Whitetopping with fibers

- Typical 6’ x 6’ panels
- ½ mile test section - 12’ long x 6’ wide panels
- 3D Profile Milling of Asphalt
- Stringless Paving
TH 63 5” Whitetopping with fibers

• Croell tried 3 different fibers
  • Forta Concrete Fiber - Forta Ferro One Macro
    • Virgin Copolymer/Polypropylene
    • Monofilament/Fibrillated Fiber System
  • Grace Construction Products - Strux 90/40 Synthetic Macrofiber
  • Mapei/GRT Advantage Macrosynthetic Fiber
    • Embossed tape fiber comprised of a blend of polypropylene and polyethylene resins
Delivery of Fibers

• High production paving using Fibers was major concern
• Mixing Time may need to be increased
  • Croell has batched at increased batching times (15-30 sec) – once dialed in back to about 50 – 60 secs
  • Similar experience found in trial placement in Iowa in 2017
Automated Fiber Dispensing/Conveying

- TH 63 Spec requires automated fiber dispensing or conveying system – Contractor fabricated their own
- Batched 10 cy loads – Used 8 – 5 # bags per load

Used a screw to keep bags separated – so laser eye could keep count of when to shut off belt for each load
Placing the fiber reinforced concrete
Placing the fiber reinforced concrete
Comparison of Performances of Structural Fibers and Development of a Specification for Using Them in Thin Concrete Overlays

Manik Barman, Principal Investigator
University of Minnesota Duluth
Department of Civil Engineering

August 2018

Joint Activation of Fiber Reinforced Concrete

Photo courtesy of Dr. Manik Barnam, UMD
A 20 mils crack width has a Loaded Side Peak Displacement of 11.25 mils and at 70 mils cracked width has a Loaded Side Peak Displacement of 14 mils. A 20% difference in Loaded Side Peak Displacement just by reducing the crack width. Also, using 0.25% Vf would be cheaper that using 0.5% Vf for the same Loaded Side Peak Displacement results.
Report Conclusion

• Fibers help keep cracks and joints tight and improve load transfer across cracks and joints in thin concrete overlays.

• Synthetic fibers provide equal or better performance than steel fibers, which are expensive, heavy and difficult to mix.

• Dosages less than 0.25 percent fiber volume fraction of concrete mixture did not improve post-crack flexural or load transfer efficiency across the joint.

• Dosage levels and crack width strongly affected joint performance. Overall, it was found that fibers can increase the load transfer by 30 percent and can reduce the slab displacement by 50 percent.
• GOAL: Influence the number of working joints! Narrow joint widths – fibers more beneficial

• HOW: Drive on pavement to activate joints
Concrete Maturity

Curve Coefficients:

- $S_u = 1108.79$
- $t = 965.85$
- $a = 0.7210586$

Comments:

- Required Strength for Opening: 500 psi
- Required TTF for Opening: 1320 C-hours

Put traffic on pavement

Phase 1

Phase 2

Maturity Curve
• No loading 1 day – every 24 joints
• Phase 1 (24 hours old) – 350 psi flexural (maturity)
  • Didn’t see much change
  • Felt concrete too strong
  • Did see increased activation when heavier construction traffic started driving on concrete
• Phase 2 (14 hours old) – 150 psi flexural (maturity)
  • 3800 ft section
  • First 1000 ft – 17 joints working
  • Next 2800 ft – 5 joints working
  • Per District – Cracking every 4 to 6 joints more quickly
Sawing Through Transverse Joints Fully

• Important to Note:
  • MN specs require sawing all the way through edge
  • IA specs do not
  • I requested Croell saw all the way through edge for TH 63 project
  • Not sure if it made a difference but I don’t think it hurt
An 800-foot stretch of Highway 63 north of Rochester is ruined after a 95-year-old man drove through wet concrete.

Repair estimates top $100,000.
CSAH 25 5” Whitetopping with fibers

- Croell, Inc. – Iowa Contractor
  - 7.0 Miles
  - Engineer’s Estimate $3.8 Million
  - Low Bidder $3.26 Million
  - Placement (94,677 SY) – EE $6.11, Croell $4.54
  - Structural Conc (15,188 CY) – EE $92.25, Croell $92.00

- Supplemental Agreement to add fibers
  - Dosage rate of 4 lbs/cy at $21.00/cy
  - Total Additional Cost = $329,910.00
Panel size 6’W x 7’L
1) Select a 500-foot section for each day of paving or per mile of pavement, whichever is greater.
   • Perform daily inspection of any new cracks that have developed.
   • Mark/spray paint the new cracks on the side of the pavement.

2) Note the relative spacing and location of new cracks.

3) Document the timing of the water truck loading relative to the paving date and time.
   • Fully loaded water truck on the pavement
   • 12 hours and then 24 hours after placement
Early Transverse Joint Deployment

Observation (pavement edge) age range: 1 to 5 days

5" FRC Pavement Placed 8/2/2018

Ave. 1 Day Spacing ~ 55 ft

5" FRC Pavement Placed 8/6/2018

Ave. 1 Day Spacing ~ 52 ft

5" Pavement Placed 8/3/2018

Ave. 3 Day Spacing ~ 77 ft

5" Pavement Placed on 8/8/2018

Ave. 1 Day Spacing ~ 70 ft
The Contractor may at their own risk allow passenger vehicles (total gross vehicle weight not to exceed 10,000 lbs) to drive on the concrete pavement no earlier than 12 hours after pavement placement and after satisfactory completion of all initial joint establishment in accordance with 2301.3.N.2, “Joint Establishment.”

Prior to placement of any concrete pavement, provide a Quality Control Plan to the Engineer for acceptance which provides the Contractor’s plan for management of local traffic during concrete pavement placement.
Thank you!

Any Questions?