35W Replacement Bridge
and Sustainability

October 28, 2009
Superstructure construction
Temporary scaffolding and forms will be built to provide a mold for the parts of the bridge over land. Each side of the river will have this superstructure cast on-site. Once this is completed, the center span can be put in place.

Foundation
The foundation consists of drilled shafts, four for each of the eight central span piers. Each has a steel casing over concrete.

Pier construction
Each pier for the main span will be cast on-site atop the footings on each bank.

Completion of the central span
The final segment
After all the segments are in place, the final gap between the assembled sides is cast in concrete, completing the central span.

Assembly
Segments are linked together by steel cables threaded through them, with each segment linked to the adjacent ones and full-length cables linking the entire array.

Segment placement
The center span’s box-girder segments are precast and will be fitted by lowering them from a crane positioned on the bridge deck.

Finishing work
The deck, railings, paint, lighting, monitoring systems and sculptural elements are added in the final phase.

NOTE: All drawings are schematic. Sources: Minnesota Department of Transportation, Figg Bridge Engineers Inc., Flatiron Constructors Inc. Graphic by MARK BOSWELL © 2007 Star Tribune Modified by Figg December 2007
35 MPa SCC w 40 percent OPC

45 MPa concrete
70 percent OPC

27.5 MPa concrete
18 percent OPC

35 MPa SCC w 40 percent OPC

35 MPa SCC w 40 percent OPC
Concrete Performance Requirements

- Many requirements – some conflict
- Caisson concrete to super structure concrete
- Most are mass concrete
- Early strength a priority
Concrete Performance Requirements

- Low permeability and low shrinkage
- Congested sections, blind areas
- Small environmental footprint
- Wide range of weather
X-RAY VAULT

Demonstration of a Low CO₂ Footprint Concrete
VAULT DESIGN

27 M x 18 M x 11 M high
1 M thick walls
Reinforce concrete
f'c = 27.5 MPa at 56 days
Air Content  6 ± 1.5%
Concrete Mix

Virgin Material
- 48.6 kg Portland Cement
- 19 oz. HRWRA
- 2 oz. AEA

Recovered By Products
- 2101 kg Slag
- 2101 kg Fly Ash
- 2101 kg Coarse Aggregate
- 2101 kg Sand

- 145 kg Water

W/Cm 0.45
Recycled Content 98%

Proprietary mix of Cemstone Products Company
# Test Data

## Compressive Strength, MPa

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>3.4</td>
</tr>
<tr>
<td>4 days</td>
<td>13.8</td>
</tr>
<tr>
<td>7 days</td>
<td>20.7</td>
</tr>
<tr>
<td>28 days</td>
<td>29.6</td>
</tr>
<tr>
<td>56 days</td>
<td>31.7</td>
</tr>
<tr>
<td>1 year</td>
<td>32.3</td>
</tr>
<tr>
<td>2 years</td>
<td>32.9</td>
</tr>
</tbody>
</table>

## Air Void Parameters

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Content, %</td>
<td>5.5</td>
</tr>
<tr>
<td>Entrained, %</td>
<td>4.7</td>
</tr>
<tr>
<td>Entrapped, %</td>
<td>0.8</td>
</tr>
<tr>
<td>Spacing Factor, in.</td>
<td>0.2 mm</td>
</tr>
</tbody>
</table>

## Set Time

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>4 hr 33 min</td>
</tr>
<tr>
<td>Final</td>
<td>8 hr 20 min</td>
</tr>
</tbody>
</table>
Concrete Temperature Monitoring

Temperature (°F)

Time Elapsed (Hr)

Series 4
<table>
<thead>
<tr>
<th>Environmental Footprint</th>
<th>344 Kg/m³ Portland Cement Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Reduction</td>
<td>80%</td>
</tr>
<tr>
<td>Embodied Energy Reduction</td>
<td>75%</td>
</tr>
</tbody>
</table>
**Description of Structure**

- **Clear Cover** = 125 mm
- **Volumetric** $\rho$ = 1.2%
- **Design Life** = 100 years
- **Discount Rate** = 3.0

**Properties of Scenarios**

**Base Case**
- Mix Design: w/cm = 0.42, Cost 100 $/m^3
- $D_{28} = 8.87 \times 10^{-12}$ m$^2$/s, $m = 0.20$, $C_t = 0.05$ %wt conc
- Epoxy Coated Steel (1.33 $/kg$), Propagate = 20 years

**HPC**
- Mix Design: w/cm = 0.42, Cost 100 $/m^3$
- Silica fume = 5%, Fly ash = 20%
- $D_{28} = 3.90 \times 10^{-12}$ m$^2$/s, $m = 0.36$, $C_t = 0.05$ %wt conc
- Epoxy Coated Steel (1.33 $/kg$), Propagate = 20 years

**HPC 2**
- Mix Design: w/cm = 0.35, Cost 100 $/m^3$
- Silica fume = 5%, Fly ash = 20%
- $D_{28} = 2.65 \times 10^{-12}$ m$^2$/s, $m = 0.36$, $C_t = 0.05$ %wt conc
- Epoxy Coated Steel (1.33 $/kg$), Propagate = 20 years

**HPC 3**
- Mix Design: w/cm = 0.42, Cost 100 $/m^3$
- Fly ash = 20%
- $D_{28} = 8.87 \times 10^{-12}$ m$^2$/s, $m = 0.36$, $C_t = 0.05$ %wt conc
- Epoxy Coated Steel (1.33 $/kg$), Propagate = 20 years
Shaft Concrete

- 60 Percent Pozzolan Replacement
- 24 inch spread
- Air entrained
- RCP
- Shrinkage
- Strength at 28 days (lab cure) 37.9 MPa
- Cores from 21 day old Shaft  70.7 MPa
Temperature Rise and Maximum Temperature Gradient
8 foot Diameter Shaft in Bedrock Shaft Mixture

Lumped Capacity Finite Difference Model

Heat of Hydration

0-25 hrs
25-100
>100

225 W/m³
75
20

Maximum Temperature
I-35W St. Anthony Falls Bridge
Remote Thermocouple Monitoring Data

Note: Graph is updated every hour.