Precast Prestressed Concrete Beams and Girders
For Virginia Highway Bridges
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Economical Bridge Designs Using Normal Weight Concrete
Virginia PCBT's set as simple spans, CIP deck

- Span to beam depth h ratio of 18 to 21, with 20 being about optimal
- Beam spacing up to about 10 feet
- Beam Concrete 8000psi
- Beam web width 7 inches
- Equivalent of 0.8 ½” dia. strands per inch of beam depth h
- Deck concrete 4000psi
- Continuity diaphragms and integral backwalls

Economical Bridge Designs
Virginia PCBT's set as simple spans, CIP deck

- Span to beam depth h ratio greater than 20
- Beam spacing of about 10 feet maintained with span to depth ratios up to 24 requires LW deck
- Beam Concrete 8000psi (normal weight unless reduced superstructure weight is needed, reduced modulus and reduced self-weight offset in pretensioned beams)
- Lightweight deck concrete up to 5000psi and down to 110pcf
- Add beam lines only if necessary

Spliced Girder Superstructures

- Use typical spliced girder construction for spans from 170 feet to 380 feet
- Try span to girder depth h ratios of 21 at the pier and 29 near midspan
- Girder concrete strength 8000psi
- Use individual splices with moment capacity as reinforced concrete section
- Use conventional 4000psi CIP deck
- Use 4 or more tendons, spread them out in web
- Need P/T duct specification similar to Florida DOT, but we don't need nor want the plastic duct

Spliced Girder Superstructures

- Girder weight has important influence as span length increases
- Modify section
- Reduce beam and deck densities
- Add girder lines
- Increase girder strength last option
- Pier segments use custom form
- No massive elements in girders
**Properties for Design**

**Tensile Strength**
- Lightweight concretes are exhibiting about 7/8th of the tensile strength of the equivalent normal weight concrete.
- Slower cure results in higher tensile strength relative to the compressive strength.

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splitting Tensile</td>
<td>0.090 $f_{ct}$</td>
<td>0.080 $f_{ct}$</td>
</tr>
<tr>
<td>Beam Rupture</td>
<td>0.085 $f_{ct}$</td>
<td>0.075 $f_{ct}$</td>
</tr>
<tr>
<td>Tension Field</td>
<td>0.069 $f_{ct}$</td>
<td>0.055 $f_{ct}$</td>
</tr>
</tbody>
</table>

**Modulus of Elasticity**
- Modulus of elasticity of lightweight concrete is dependent on the volume of lightweight aggregate, and the paste density.
- Modulus of elasticity of normal weight concrete is dependent on the type of aggregate, and the paste density.

<table>
<thead>
<tr>
<th>Interval</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Transfer</td>
<td>4200-5600 ksi</td>
<td>3100-3300 ksi</td>
</tr>
<tr>
<td>In Service (VA)</td>
<td>5000-6500 ksi</td>
<td>3300-3500 ksi</td>
</tr>
<tr>
<td>Dried at 50% RH</td>
<td></td>
<td>3100 ksi</td>
</tr>
</tbody>
</table>

**Creep Coefficient for P/S plus Self-weight**
- Beam concretes using slag (and presumably fly ash) show a marked increase in early age creep as well as strength when cured at lower temperatures (less than 135 degF).
- Range of values in the table are for peak concrete temperatures during curing from 130 to 165 degF.
- Creep from prestress transfer and self-weight is complete in 7 to 60 days depending on curing regimen.

<table>
<thead>
<tr>
<th>Interval</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer to day 7 - 60</td>
<td>0.25 - 1.2</td>
<td>0.25 - 1.2</td>
</tr>
</tbody>
</table>

**Autogenous Shrinkage of Beam Concrete**
- Use of lightweight aggregates is known to reduce autogenous shrinkage and its associated stresses.
- This is a difficult strain to measure as it is occurring during the accelerated curing of the beams.
- Vertical cracking of beams during cooling and before prestress transfer indicates that the beam has shortened during the curing process.
- Reduces camber at transfer.

<table>
<thead>
<tr>
<th>Intervals</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microstrain</td>
<td>about 250</td>
<td>lower</td>
</tr>
</tbody>
</table>

**Mix Design**

**Beam Concretes**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement</td>
<td>450 pcy</td>
<td>480 pcy</td>
</tr>
<tr>
<td>Slag</td>
<td>300 pcy</td>
<td>320 pcy</td>
</tr>
<tr>
<td>Water</td>
<td>232 pcy</td>
<td>248 pcy</td>
</tr>
<tr>
<td>w/c ratio</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>1050 pcy</td>
<td>1150 pcy</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>2100 pcy</td>
<td>1050 pcy</td>
</tr>
</tbody>
</table>

**Total Shrinkage of Beam Concrete**
- Lightweight concrete exhibited more shrinkage than the normal weight concrete after leaving the form.
- Beams cured at lower temperature showed more shrinkage after leaving the form than beams cured above 150 degF.

<table>
<thead>
<tr>
<th>Total Shrinkage Strain</th>
<th>NWC</th>
<th>LWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microstrain</td>
<td>about 350</td>
<td>about 350-450</td>
</tr>
</tbody>
</table>
Problem Areas - Precast Prestressed Beams and Girders

- Beam end cracking at transfer of prestress
- Thermal stress induced web cracking and cold joints
- Creep and shrinkage, camber growth

Upper and Lower Strut-and-Tie Models for Beam End Design

Sectional Analysis at h

Working Stress for Vertical Beam End Reinforcement

- 22ksi for normal weight concrete in non-aggressive environments
- 19ksi for lightweight concrete
- 16ksi for aggressive environments, spliced girder segment ends

Design Forces for Beam End Reinforcement

Using 0.5" dia. 270ksi Strand

Using 0.6" dia. 270ksi Strand
Curing Method of Precast Prestressed Beams

- Higher temperature, shorter duration
  - Lower final tensile and compressive strength
  - Little creep and less shrinkage after prestress transfer
  - Improved production
- Lower temperature, longer duration
  - Higher final tensile and compressive strength
  - More creep and shrinkage after prestress transfer
  - Camber growth may be unacceptable for LW beams, and will not meet 50% camber growth spec

Fabrication of Beams

- Casting should proceed quickly and continuously
- Upon initial set enclosure temperature should be ramped at a rate such that the form temperature does not exceed the concrete temperature by more than a few degrees
- Beam temperature should be kept constant until transfer strength has been achieved
- Strands should be cut as quickly as possible after steam has been stopped
- Best results have been achieved when ramp rate is slower, and transfer strengths are above 6400psi

Rte. 33 over the Mattaponi River at West Point, Virginia