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 110 pcf
- 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

Tensile Strength of Typical 8000psi Beam Concretes		
Failure mode	NWC	LWC
Splitting Tensile	0.090 f_c'	0.080f_c'
Beam Rupture	0.085 f_c'	0.075 f_c'
Tension Field	0.060 f_c'	0.055 f_c'

Properties for Design
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

Modulus of Elasticity of Typical 8000psi Beam Concretes		
	NWC	LWC
At Transfer	4200-5600 ksi	3100-3300 ksi
In Service (VA)	5000-6500 ksi	3300-3500 ksi
Dried at 50% RH		3100 ksi

Properties for Design
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 prestess transfer and self-weight is complete in 7 to 60 days depending on curing regiment

Creep Coefficient for Typical 8000psi Beam Concretes		
Interval	NWC	LWC
Transfer to day 7 - 60	0.25 -1.2	0.25 - 1.2

Properties for Design
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

Autogenous Shrinkage Strain for Typical 8000psi Beam During Accelerated Cure		
	NWC	LWC
Microstrain	about 250	lower

Properties for Design
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

Total Shrinkage Strain for Typical 8000psi Beams		
	NWC	LWC
Microstrain	about 350	about 350-450

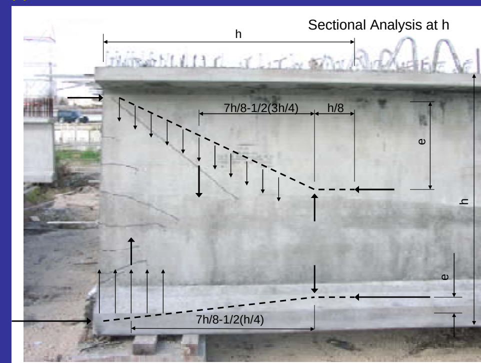
Mix Design
Beam Concretes

Typical 8000psi Beam Concrete Constituents		
	NWC	120 PCF LWC
Portland Cement	450 pcy	480 pcy
Slag	300 pcy	320 pcy
Water	232 pcy	248 pcy
w/cm ratio	0.31	0.31
Fine Aggregate	1050 pcy	1150 pcy
Coarse Aggregate	2100 pcy	1050 pcy

Problem Areas - Precast Prestressed Beams and Girders

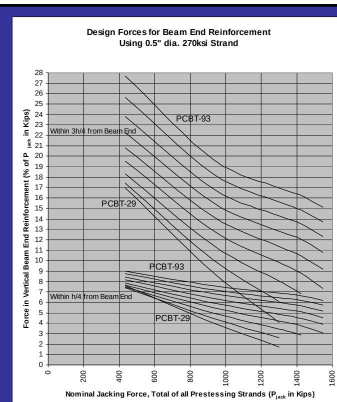
- Beam end cracking at transfer of prestress
- Thermal stress induced web cracking and cold joints
- Creep and shrinkage, camber growth

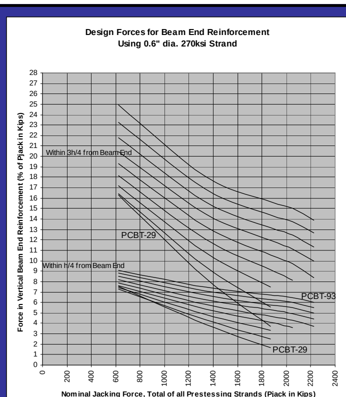
Upper and Lower Strut-and-Tie Models for Beam End Design



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





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 that 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