Serviceability-based Design for Vertical Beam End Reinforcement

Rodney T. Davis, PhD, PE
Eric D. Crispino, MAJ US Army
C. Dale Buckner, PhD, PE
Celik Ozyildirim, PhD, PE

Virginia Transportation Research Council

Beam End Design Objectives

• Produce and put into service new Bulb-T beams with highest possible condition rating
• Allow customization of design for various environmental and material considerations

Beam End Region

Web Panel
General Zone
Developing a Design Method

- Use models and calculations similar to those already used in practice
- Calibrate the model based on analytical study and field performance
- Provide parametric study for quick check
  - By the designer
  - By the precaster and owner

Current Serviceability Problems

- Cracks extending beyond beam end reinforcement
- Cracks too wide
- Too many cracks (of smaller width)
- Cracks extending into regions of high structural importance
  - Splice girder segments
  - Embedded simple span ends
Current Serviceability Problems

0.025" to 0.035"

Current Serviceability Problems

Designs for Short Sections

Type II AASHTO
Minimal Cracking
Major Assumptions (Calibrations)

- Transformed sectional analysis at a section distance $h$ from beam end
- Uniform stress in the smeared ties
- Ignore increased bar density near beam end when designing for upper crack

Major Assumptions (Calibrations)

- Lower and end cracks controlled within $h/3$ or $h/4$
- Upper diagonal cracks controlled within $3h/4$
- Ignore dead load
Working Stress for Reinforcement

- 18ksi for normal weight concrete in non-aggressive environments
- 12ksi for lightweight concrete (or reduced tensile strength, lower modulus)
- 12ksi for normal weight concrete in aggressive environments
- 8ksi for extreme cases, splice girders

Results Parametric Study

Force in Vertical Beam End Reinforcement
All Bars Operating at the Design Stress Level

- Percentage of Pjacks from All Strands
- Depth of Virginia Bulb-T (Inches)
Results Parametric Study

Force in Vertical Beam End Reinforcement
All Bars Operating at the Design Stress Level

Percentage of P_{jack} from All Strands

Depth of Virginia Bulb-T (Inches)

Case Studies
Results Parametric Study

Force in Vertical Beam End Reinforcement
All Bars Operating at the Design Stress Level

Case Studies

Total 7.7%
63° Bulb-T
P_{max} = 1239 k
Span = 104'
End 4.5%

95.5° PCBT Drop-in Segment (Typ crack pattern)

As Built:
End – h/4: 3.4%
End – 3h/4: 7.9%

Recommended:
End – h/4: 7.71%
End – 3h/4: 15.4%
LW SCC Test Beam
PCBT53, 32- ½"dia. 270ksi strands

18ksi Design Stress

12ksi Design Stress
Future Beam End Performance

- For correct designs and sufficiently mature concrete at the beam end:
  - Lower cracks less than \( \frac{h}{4} \) in length
  - Diagonal cracks terminate within \( \frac{h}{2} \)
  - Crack widths 0.008" or less
  - Problems evident if crack widths > 0.012"

- Design Tables
  - Guide for designers and fabricators
  - Not applicable for custom beams or segments

Thank You