Standard Girder Sections

First standard girder sections developed in 1950s
- AASHTO/PCI standard shapes developed to give national standard
- Standard shapes needed for efficiency in design and fabrication

Later, the PCI bulb-tee girders were standardized
States also developed their own shapes
In 1990s, some new shapes were developed
- Larger bottom flanges to allow more strands
- Wider top flanges to improve stability
- PCI Northeast developed a regional standard Mid-Atlantic states took that shape and modified it removing curves

Standard Girder Sections

*PCI Journal article in Nov-Dec 1997 issue*

Design, Fabrication and Construction of the New England Bulb-Tee Girder

- Developed in metric units
- Curves instead of fillets
Standard Girder Sections

Mid-Atlantic PCEF shapes developed in 1999
- Developed in English units
- No curves were used to simplify diaphragm construction
- Intended to be equivalent to NEBT with nearly equal section properties

<table>
<thead>
<tr>
<th></th>
<th>Xb 00-67</th>
<th>Xb 100</th>
<th>Xb 200</th>
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<td>in.</td>
<td>in.</td>
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<tr>
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<td>in.²</td>
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<tr>
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<td>lb. 180</td>
<td>lb. 180</td>
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<tr>
<td>Moment</td>
<td>lb. 180 in.</td>
<td>lb. 180 in.</td>
<td>lb. 180 in.</td>
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<tr>
<td></td>
<td>@ 150 lb/ft³</td>
<td>@ 150 lb/ft³</td>
<td>@ 150 lb/ft³</td>
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<td>NEBT</td>
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<td>796.5</td>
<td>166.6</td>
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<td>PCEF</td>
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<td>+0.6%</td>
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<tr>
<td>NEBT</td>
<td>95.0</td>
<td>866.7</td>
<td>26.0</td>
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<tr>
<td>PCEF</td>
<td>95.1</td>
<td>857.2</td>
<td>26.2</td>
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<th>Xb 360</th>
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<td>in.</td>
<td>in.</td>
</tr>
<tr>
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</tr>
<tr>
<td>NEBT</td>
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<td>% Diff.</td>
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<td>+0.2%</td>
<td>+0.2%</td>
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</table>

Note: % Diff. is computed as (NEBT - PCEF) / NEBT x 100%

Standard Girder Sections

Compare NEBT and PCEF section properties - from 1999 PCEF document

- Metric unit conversion affects the comparison
- Section property differences are small: +1.0% to -2.0%
- Section properties vary slightly from NEBT values given in NYSDOT standard drawing BD-PC1SE

Proposed Mid-Atlantic PCEF shapes included variable dimensions
- 9 girder depths
- 3 web widths: 6, 7, and 8 in.
- 3 top flange widths: 48, 60, and 72 in.
- 2 bottom flange depths: 7 and 9 in.
- Resulted in a family of 162 shapes
  • A bit over-ambitious
  • DOTs in region adopted limited combinations of dimensions
Standard Girder Sections

Examples of PCEF sections adopted by DOTs
- 7 in. web
- 3'-11" top flange
- 2'-8" bottom flange
- Bottom flange thickness varies, which affects depth
  - NYSDOT: 9" flange with 55" depth
  - VDOT: 7" flange with 53" depth
  - NEBT has 9" flange

<table>
<thead>
<tr>
<th>NYSDOT</th>
<th>VDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCEF-55</td>
<td>PCBT-55S</td>
</tr>
</tbody>
</table>

Other Standard Bridge Sections

All of these are very good for ABC projects because the deck is precast in the plant

NEXT beams – 3 types
NE decked bulb tee
Full-depth precast deck

Standard details and more info on PCINE website: [www.pcine.org](http://www.pcine.org)
Design 2 – Girder Sections & Camber

Camber

For prestressed concrete girders, cambers are estimated

Camber estimating methods
- Multiplier Methods
- Improved Multiplier Methods – Factors in estimates of prestress loss
- Detailed Analytical Methods – Numerical, time-step evaluation

Many factors affect the actual camber – see hidden slides

Factors Affecting Camber

Prestress
- Total no. of strands = Force (P)
- Strand pattern (e)
- Method for stress control (draped or straight with debonding)

Geometry
- Beam length
- Support locations
- Girder type → section properties
- Girder spacing and deck dimensions

These factors are well known and can be controlled
Factors Affecting Camber

Materials properties – Specified and actual
- $f'_{cc}$ and $f'_{cm}$
- $E_o$ and $E_i$
- $w_o$ of girder
- Prestress losses

Fabrication & construction timing
- Age at transfer of prestress
- Age at erection

Environmental conditions

These factors are based on estimates and some cannot be controlled

Multiplier Method

Most popular method in current practice
Developed by Martin (PCI Journal article in 1977)

Straightforward calculations
Apply multipliers to each component of elastic deflection to predict long-term behavior
- Prestress uplift
- Self-weight deflections

Assumptions for Elastic Deflections

Use appropriate concrete properties, effective prestress for stage being considered
- Use $E_o$ and $f_p$ for initial camber
- Use $E_o$ at ages > 28 days (final after losses)

Girder remains uncracked at all load stages
- Gross (uncracked) section properties
- Transformed deck
- Transformed prestressing strand may be included
Initial Camber of Bare Beam

Sum of upward effect of PS and downward effect of girder deadload

\[
(\Delta_{\text{rel}})_{\text{rel}} = (\Delta_{\text{ps}})_{\text{rel}} \uparrow + (\Delta_{\text{gdl}})_{\text{rel}} \downarrow
\]

Factors affecting estimated initial camber
- Age at release (usually about 18 hours)
- Concrete properties
- Curing conditions, concrete temperature, and ambient conditions
- Prestress losses
- Storage and support conditions

Equations available (hidden slides) for computing camber due to PS

Elastic Deflections at Midspan

See PCI BDM and PCI Handbook
- Dead load – use standard equation
- Two-point draped strands

\[
\Delta_{\text{max}} = \frac{P l^4}{48EI} \left[ 3\beta_c - (3\beta_p - \beta_{\text{rel}}) \right] b^3
\]

- There is also an equation for single point drape

BDM Table 8.7-1 Camber & Rotations

Use superposition to combine different patterns
Deflections at Other Locations

General equations
Moment-Area Method
Conjugate Beam Method
- Load beam with M/EI diagram
- Moments in conjugate beam correspond to deflections
- Use when debonding present
- Method can be used for any moment diagram resulting from prestress or loads

Final Deflection of Structure

Sum of all effects, with only PS acting upward

\[
\frac{\Delta_{\text{max}}}{L_0} = \frac{\Delta_{\text{ps}}}{L_0} \uparrow + \frac{\Delta_{\text{psf}}}{L_0} \downarrow + \frac{\Delta_{\text{psfi}}}{L_0} \downarrow + \frac{\Delta_{\text{psfi2}}}{L_0} \downarrow
\]

Additional factors affecting final camber
- Age of girder when deck placed
- Creep
- Differential shrinkage
- Environmental conditions
- Temperature
- Structural system

Multiplier Method for Estimating Camber

<table>
<thead>
<tr>
<th>PS Element with Composite Deck (PCI Handbook 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Erection</td>
</tr>
<tr>
<td>Definition (downward) component - apply to the elastic deflection due to the member weight at release of prestress</td>
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</tbody>
</table>
Multipler Method for Estimating Camber

<table>
<thead>
<tr>
<th>PS Element - no Composite Deck (PCI Handbook 1994)</th>
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<tr>
<td>At Erection</td>
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<td>Deflection (downward) component - apply to the elastic deflection due to the member weight at release of prestress</td>
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</tr>
<tr>
<td>Multipliers for “Final” conditions are generally not used for composite girders.</td>
</tr>
</tbody>
</table>

Computing Camber & Deflection

At Release
\[ \Delta_{\text{def}} = \Delta_{\text{up}} + \Delta_{\text{down}} \]

At Erection
\[ \Delta_{\text{def}} = 1.85 \Delta_{\text{up}} + 1.85 \Delta_{\text{down}} \]

Added Dead Loads
\[ \Delta_{\text{def}} = \Delta_{\text{up}} + \Delta_{\text{down}} + \Delta_{\text{dead load}} \]

Final
\[ \Delta_{\text{final}} = \Delta_{\text{up}} + \Delta_{\text{down}} \]

Determining Specified Build-Up at CL Bearings

Specifying correct build-up at CL of bearings is important to provide minimum build-up at critical location at midspan
- Add minimum build-up requirement at midspan to estimated camber to define build-up at CL bearings
- Consider effect of cross-slope and camber (next slide)

Contractor should determine top flange elevations of erected girders before setting screed elevations for deck
- Bearing seat elevations can be adjusted to accommodate significant differences in camber between predictions and actual
Horizontal Curve Effect on Required Build-up

Build-up varies across top flange due to roadway cross-slope or super-elevation.

- With cross-slope, critical point for minimum build-up moves from CL of girder to edge of girder flange.
- With curvature, critical point for minimum build-up is shifted again because grade line is offset from CL of girder, further reducing the build-up.

Defining required build-up at CL bearings that is used to set bearing seat elevations must account for all of these effects.

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Other Camber Issues

- **Thermal camber**
  - Sun exposure increases camber.
  - Measure camber early in day.

- **Bearing location during storage**
  - Moving support locations in from end reduces span and increases camber.
  - Moving supports in also improves stability.

- **Differential camber between girders**
  - Complicates fit up for adjacent members.
  - Minimize effect with pre-assembly in plant for adjacent members.

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Camber - Summary

Camber predictions are estimates. Even so-called “more exact methods” are only as accurate as the accuracy of data and assumptions.

Girder fabricators often have a good understanding of their materials and processes so may have a better estimate of expected cambers.

Consider the impact of camber variation:
- Extra deck concrete, especially for wide-top girders.
- Encroachment of girder into deck.
Camber - Summary

Detail structure to accommodate variation in camber
- Build-up is intended to provide some tolerance for variation in camber
- Provide minimum build-up in design to avoid top of girder moving into deck during construction

Methods to address cambers that differ from expected values in design
- Modify beam seats or bearing plates
- Revise roadway profile

The plant generally can do little to control or modify cambers
Some variation in camber between girders of the same design is normal

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Prestressed Concrete Bridge Design Seminar
Session 2 – April 20, 2021

Design 2 – Girder Sections & Camber

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