Design of Precambered Prestressed Concrete Girders with Moderate to High Levels of Precamber

Amanda Wong, PE
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Tonquin Bridge in Ocean Shores, WA

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Presentation Overview

1. What is a precambered girder?
2. Advantages and Disadvantages of Precambered Girders
3. Precambered girder fabrication
4. Design of Precambered girders
5. Design vs Actual Camber Measurements in Precambered Girders
6. Summary

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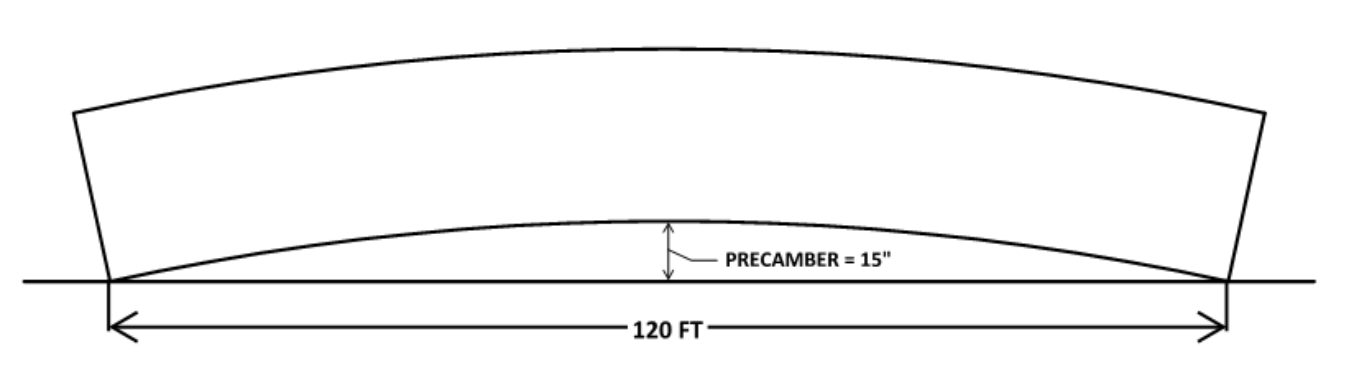
What is a precambered girder?

- Similar to standard non-precambered prestressed concrete girders (standard girders)
- Precamber in girders + Natural camber = total camber
  - Precamber built into girder formwork during girder fabrication



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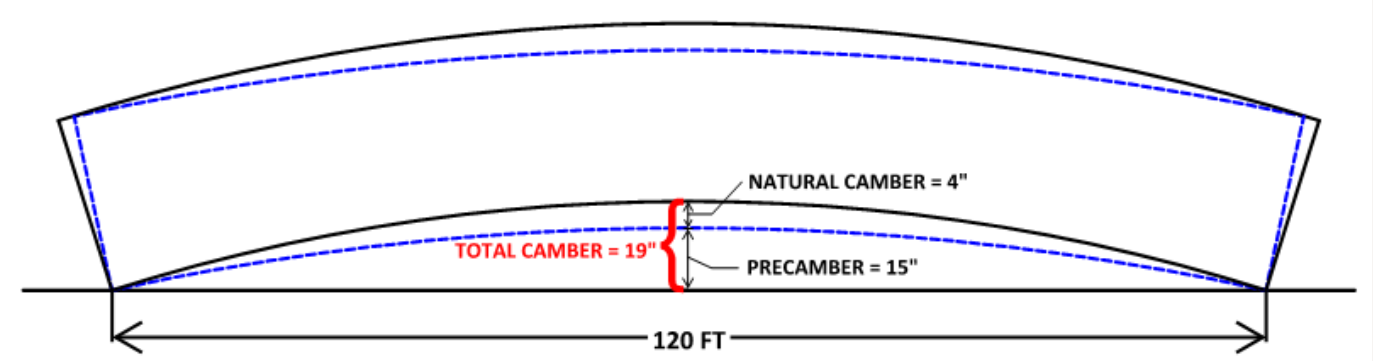

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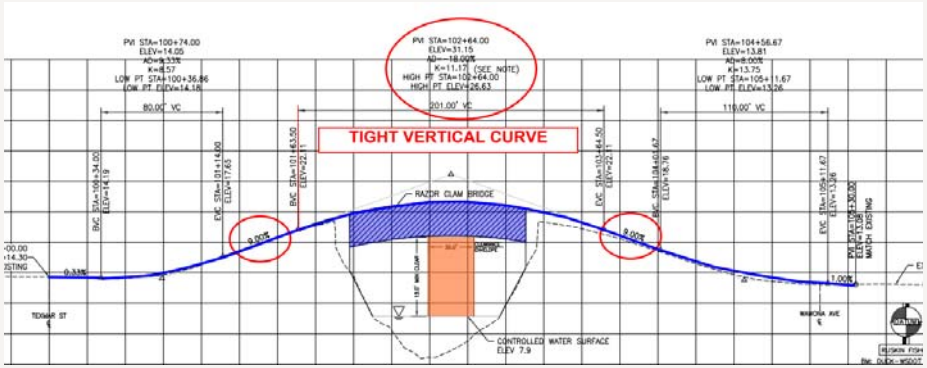
Advantages of Precambered Girders

For roadway profiles with

<u>tight vertical curves</u>

precambered girders can:

- Shorten project limits
- Allow for the use of deeper girder/longer span
- Reduce concrete haunch weight
- Improve aesthetics



Razor Clam Bridge in Ocean Shores, WA

Tonquin Bridge in Ocean Shores, WA

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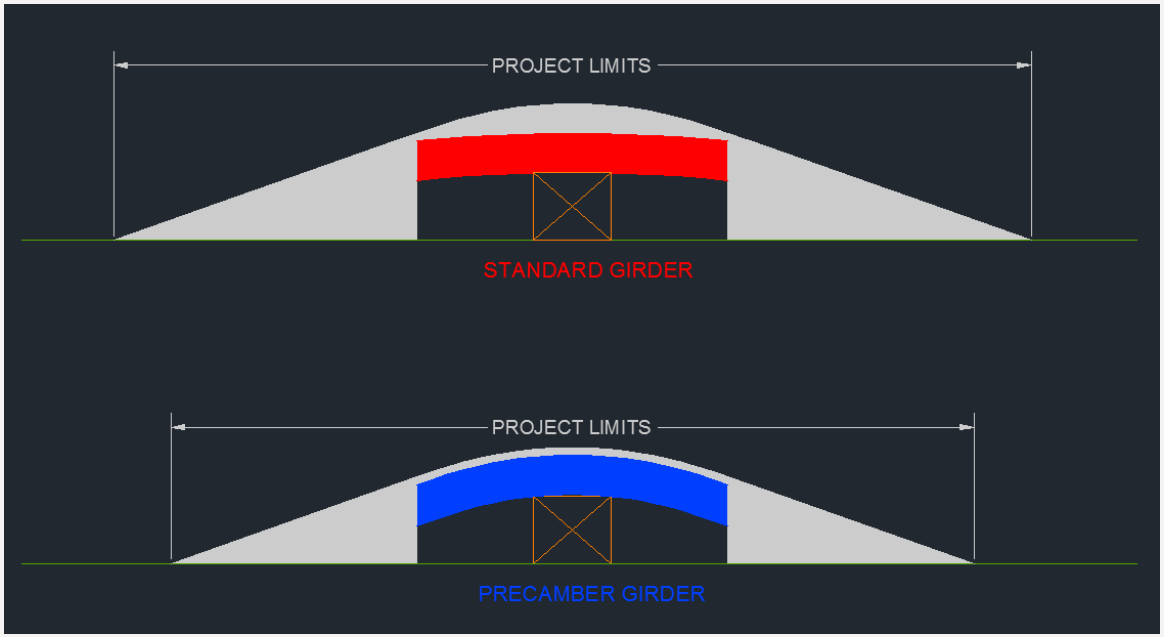
Advantages of Precambered Girders

- Shortening of project limits



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Advantages of Precambered Girders

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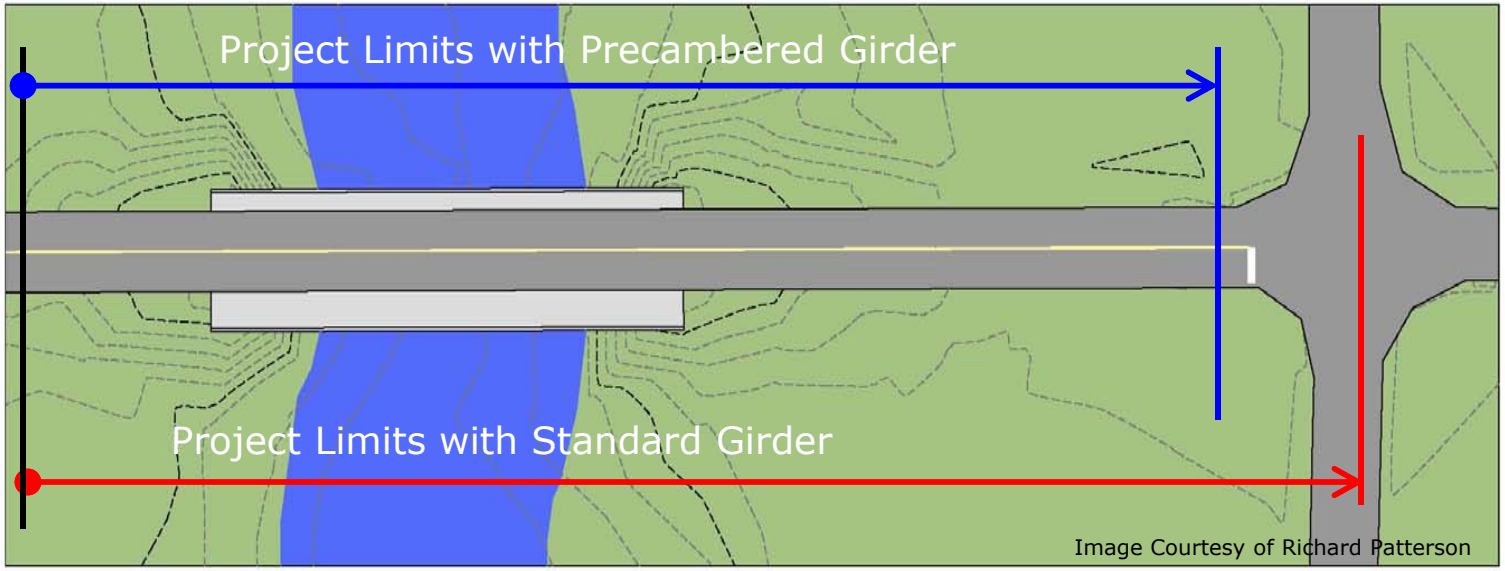

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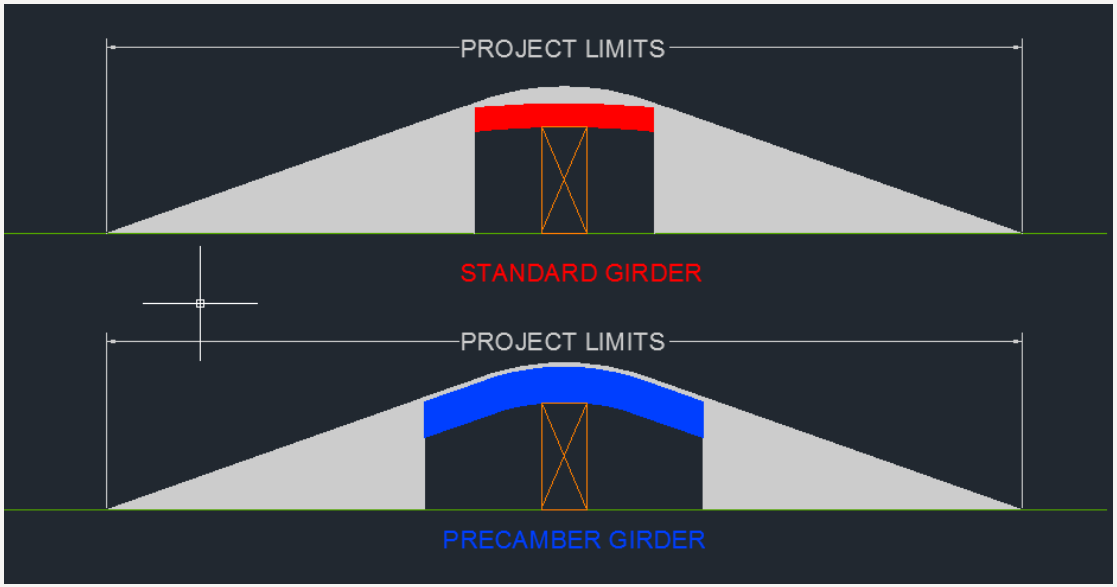
Advantages of Precambered Girders

- Allows for the use of deeper girder/longer spans



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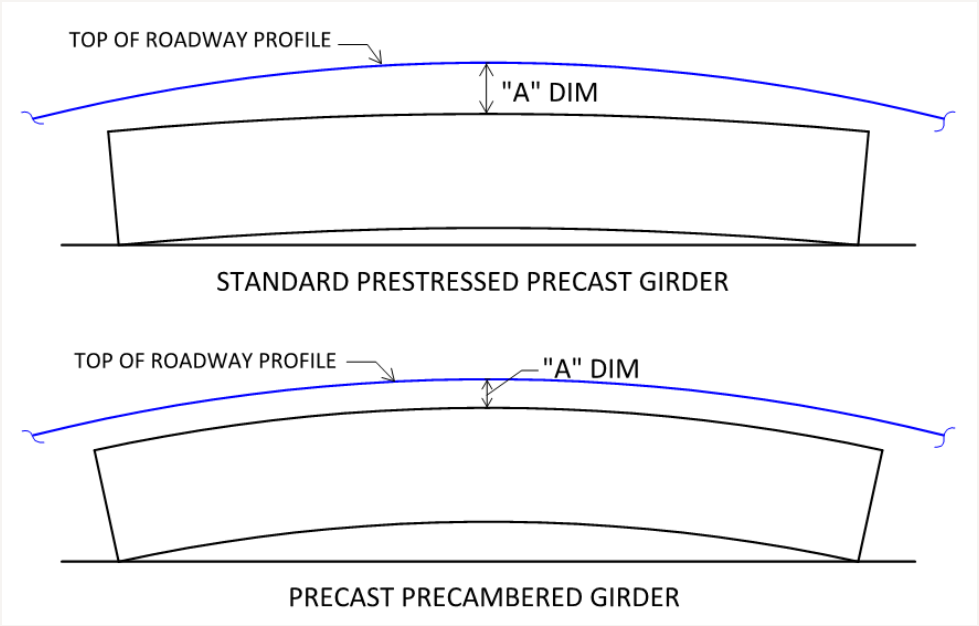
Advantages of Precambered Girders

- Reduces concrete haunch weight



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Advantages of Precambered Girders

- Improved Aesthetics
  - Subtle arched profile.

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Disadvantages of Precambered Girders

- Requires additional analysis and design effort
- Less stable during transportation

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Disadvantages of Precambered Girders

- May require special detailing at bearings to accommodate increased slope at girder ends

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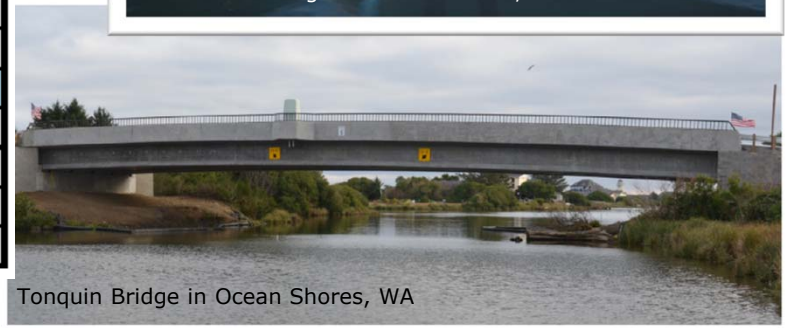
Example Projects

Bridge Name	Girder Type	Girder Length L_{girder} [ft]	Precamber $\Delta_{precamber}$ [in]	$\Delta_{precamber}/L_{girder}$
Tonquin Avenue Bridge*	WF58G	146.0	21.5	1/81
Razor Clam Bridge	WF50G	118.8	17.3	1/83
Interurban Trail*	W64DBT	167.5	22.3	1/90
SR19 Royal Brougham*	WF58G	123.5	13.4	1/111
South Lander Bridge	WF50G	114.0	10.3	1/134
Marshall Avenue*	W65DBT	137.5	10.5	1/157
Burlington Northern*	WF83G	186.8	13.0	1/172
NW Dogwood Street Bridge*	W35DBT	93.1	5.6	1/199
SR167 8th Street*	WF74G	180.7	3.0	1/723

*Data Courtesy of Concrete Technology Corporation


Razor Clam Bridge in Ocean Shores, WA


Tonquin Bridge in Ocean Shores, WA


South Lander Bridge in Seattle, WA

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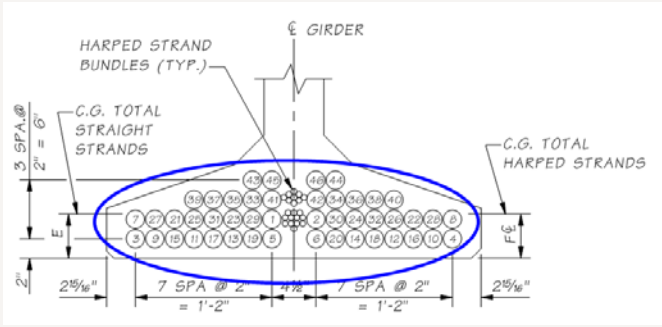
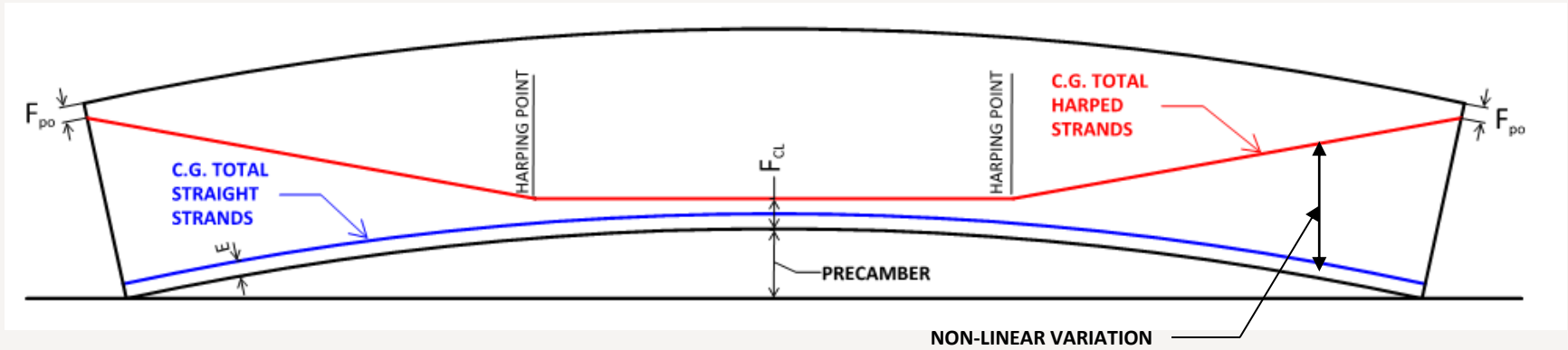
Precambered Girder Fabrication

- Straight strands are installed parallel to the parabolic girder profile
- Harped strand profile is established similarly to standard prestressed girders





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Precambered Girder Fabrication

- Precambered girders fabricated using a series of straight formwork segments arranged to create a chorded girder profile, approximately following intended the parabolic profile

Contributors: Concrete Technology Corporation

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Precambered Girder Fabrication

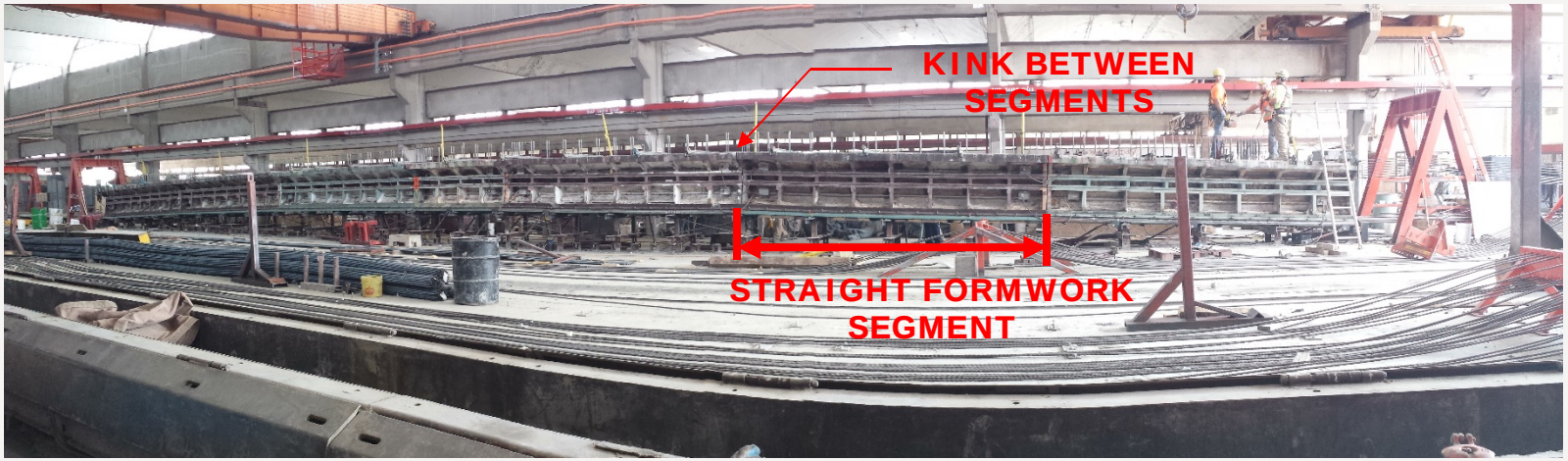

Photo Courtesy of Concrete Technology Corporation

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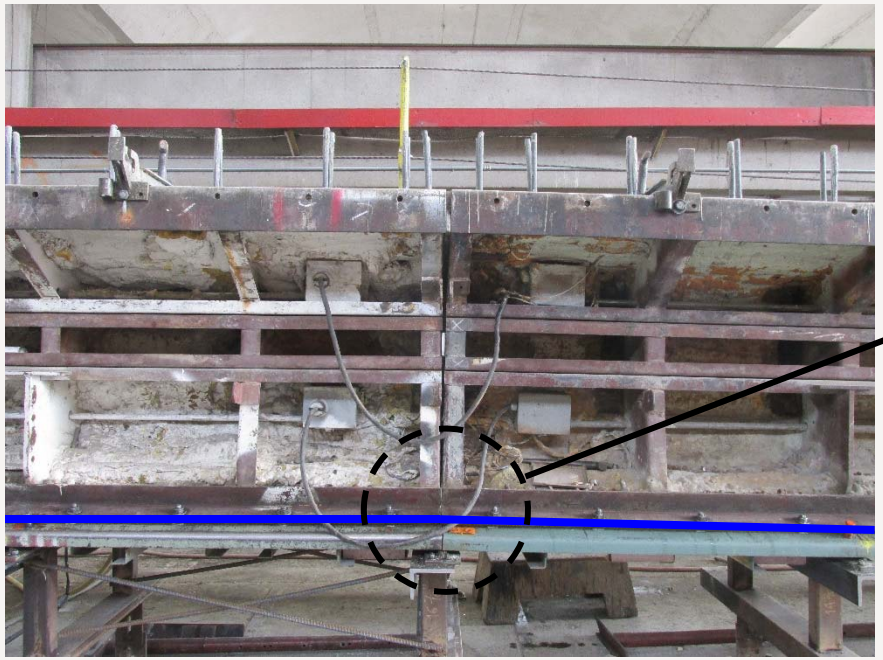
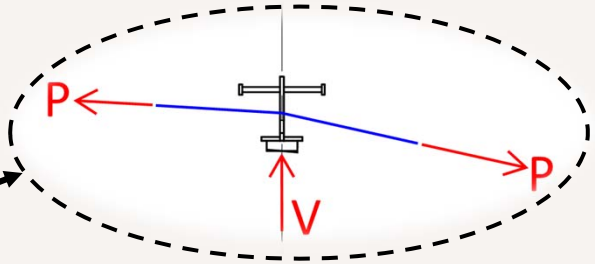
Precambered Girder Fabrication





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Precambered Girder Fabrication

STRAIGHT STRAND DEVIATOR

EMBEDDED GIRDER PLATE

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Slide 18

AW5 Straight strands are installed parallel to the chorded profile created with the use of a straight strand deviator placed at a maximum 20' increments along the length of the girder
Localized downward forces at each of these locations
Amanda Wong, 8/15/2017

Precambered Girder Fabrication

Photo Courtesy of Concrete Technology Corporation

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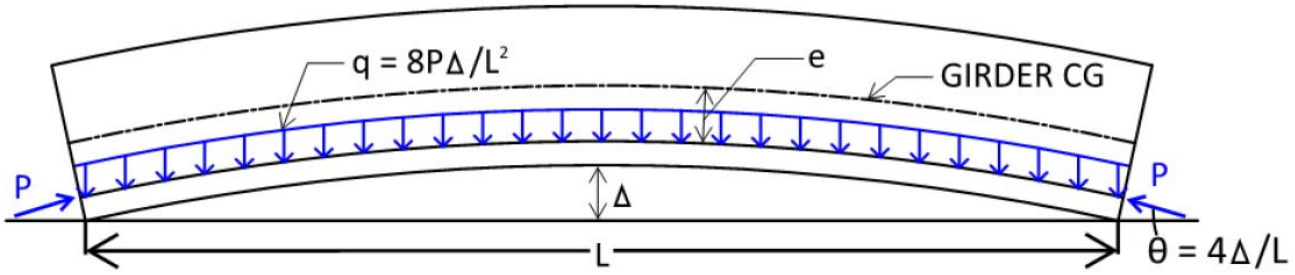
Design of Precambered Girders

Design is similar to that of standard girders, but with the following additional considerations/checks:

1. Straight Strand Analysis
2. Non-linear variation of harped strand configuration
3. Reduced deck haunch thickness
4. Transportation stability
5. Downward reaction at straight strand deviator locations
6. Levelling detail at bearing locations

Design of Precambered Girders

1. Straight Strand Analysis
   - No additional moment due to pre-camber



At Midspan

Downward uniform force "q" causes → Positive Moment

P-Δ effect from force "P" due to precamber causes → Negative moment

CANCEL EACH OTHER

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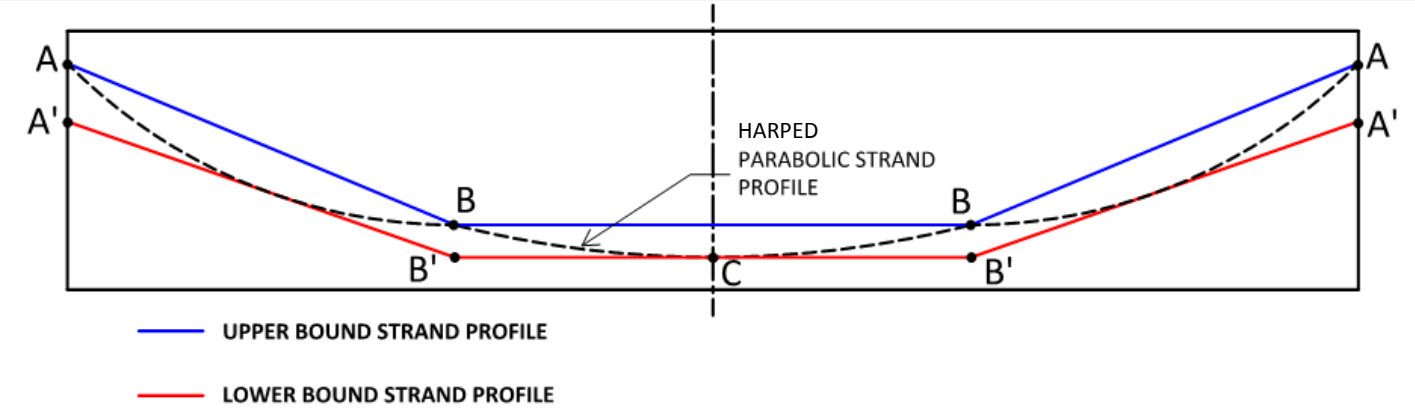
Design of Precambered Girders

2. Non-linear variation of harped strand configuration
   - PGSuper designed for straight prestressed precast girders
   - Effective Upper and Lower Bound Analysis used to envelope non-linear harped strand configuration within precambered girders.



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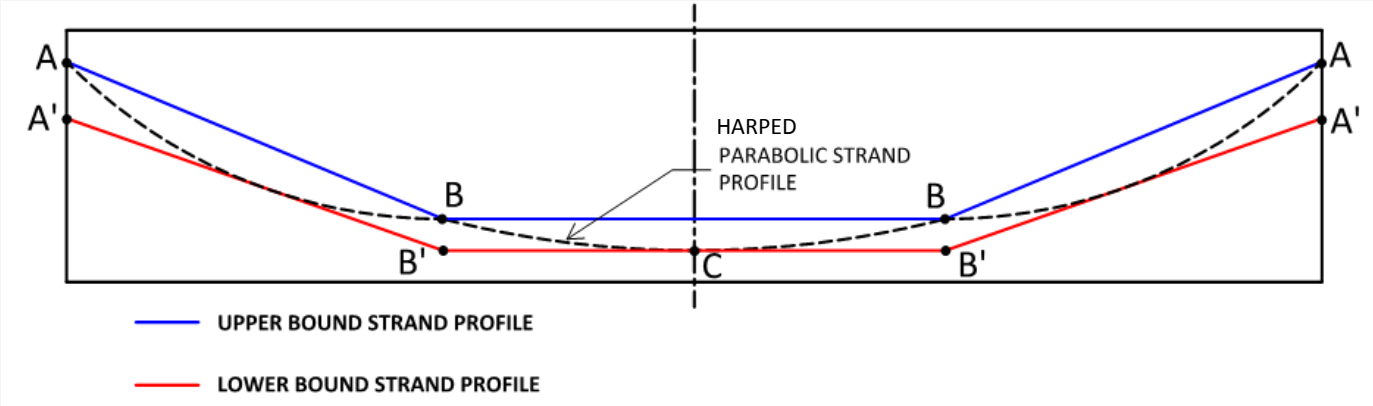
Design of Precambered Girders

2. Non-linear variation of harped strand configuration

- Girder design is done similarly to standard prestressed concrete girders once effective harped strand girder profiles are determined.
- Iterative process to balance service and strength design checks, and deflection of girders
  - Δ_{excess} = precamber + (D-C)



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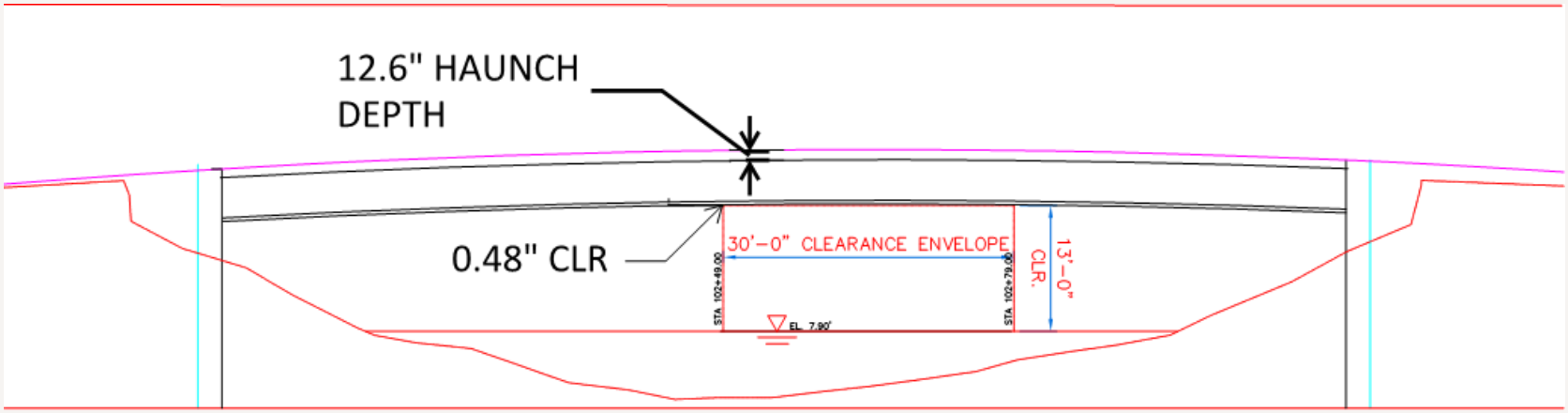
Design of Precambered Girders

2. Non-linear variation of harped strand configuration
   - Upper Bound Analysis: governs vertical clearance
     - Camber at time of deck casting, D, is based on 50% D40
     - Haunch depth is based on 50% D40



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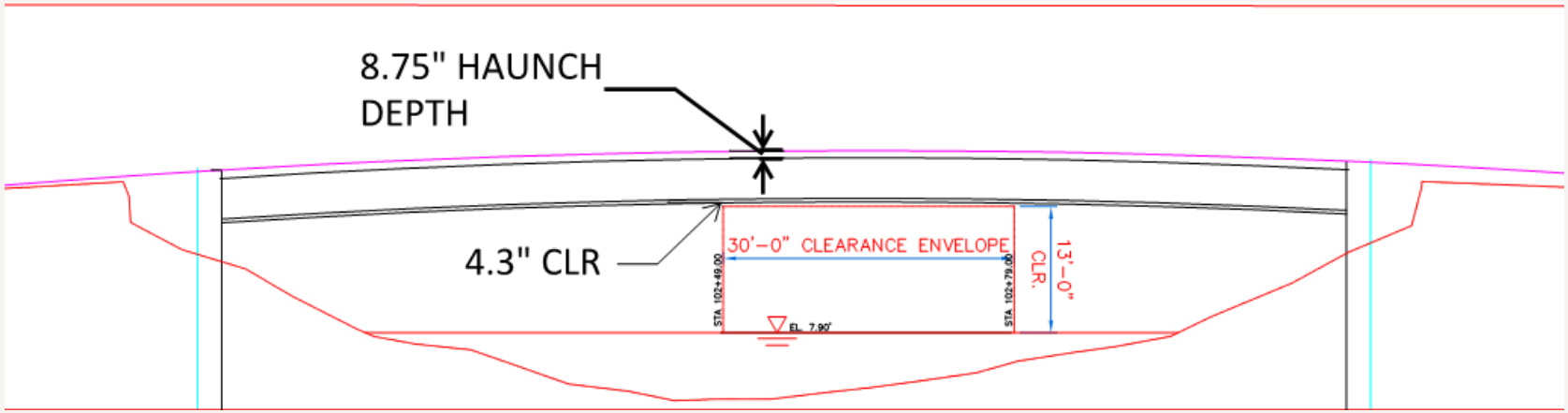
Design of Precambered Girders

2. Non-linear variation of harped strand configuration
   - Lower Bound Analysis: governs minimum haunch at midspan
     - Camber at time of deck casting, D, is based on D120
     - Haunch depth is based on D120



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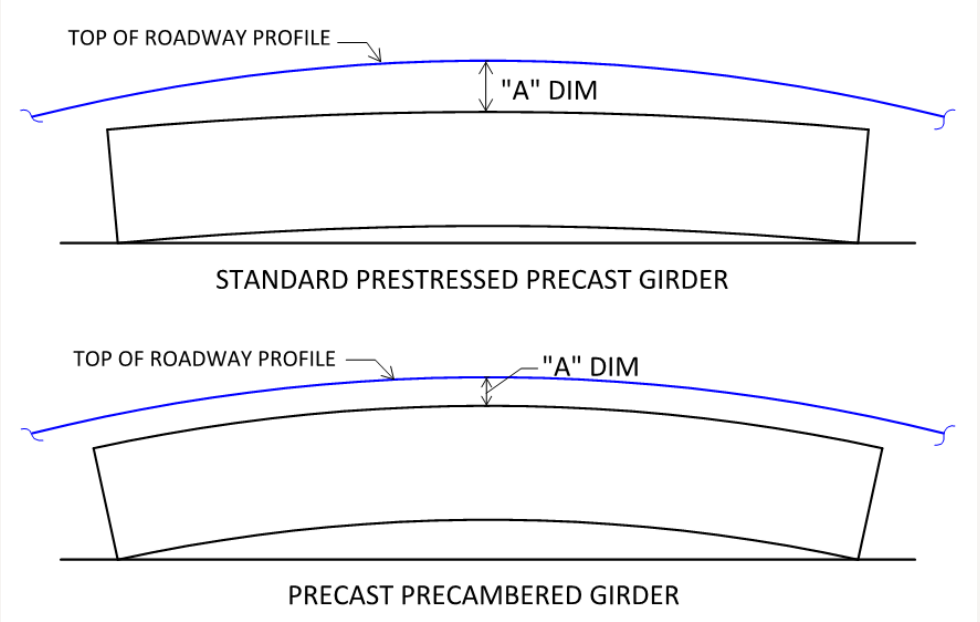
Design of Precambered Girders

3. Reduced deck haunch thickness
   - Where a tighter vertical curve is required for the roadway profile, precambered girders are better able to match the roadway profile than standard prestressed precast girders resulting in a reduced deck haunch thickness
   - Reduction in weight results in reduced project costs



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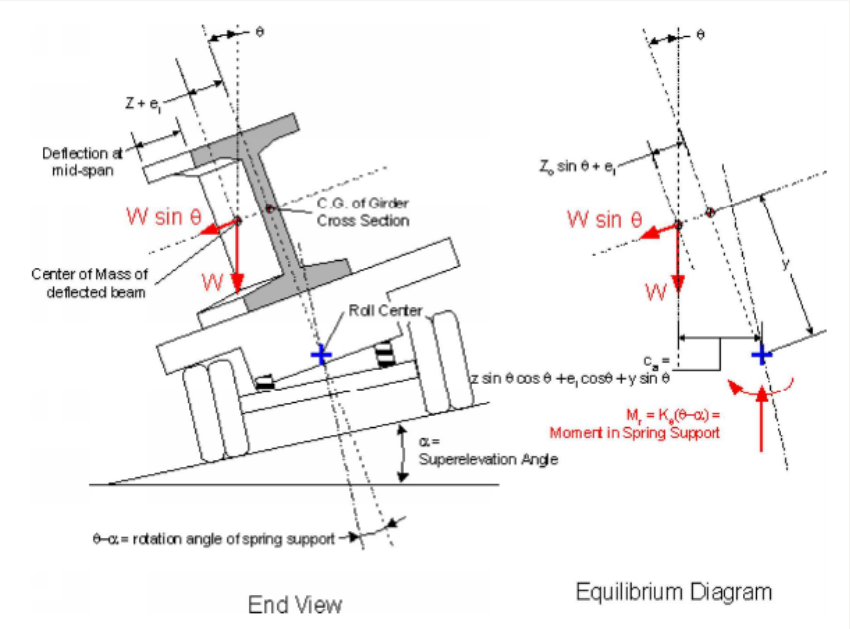
Design of Precambered Girders

4. Transportation stability
   - Higher center of gravity resulting in less stable transportation of the girder
   - PGSuper analysis equations modified to reflect higher center of gravity



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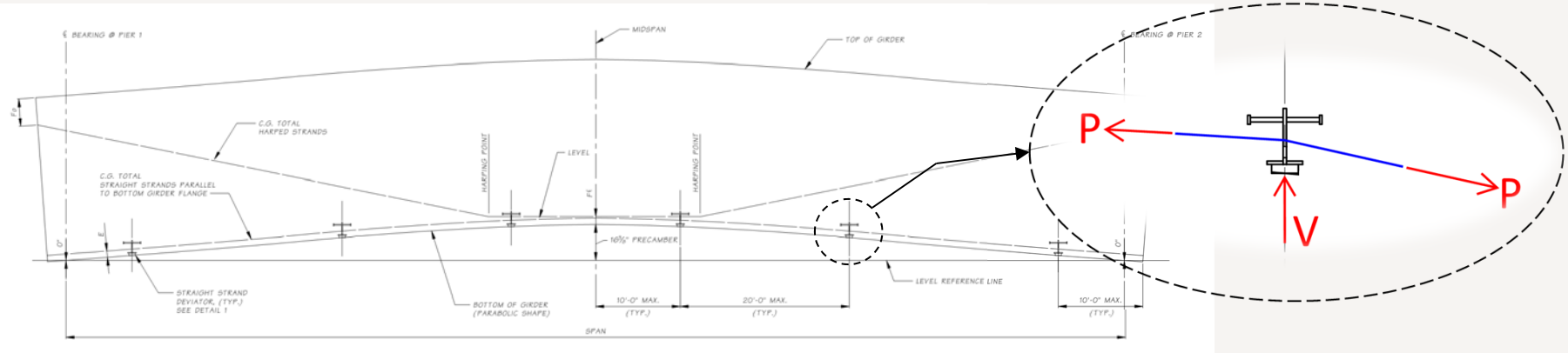
Design of Precambered Girders

5. Downward reaction at straight strand deviator locations

- Concentrated downward reaction is the resultant of a kink in the straight strands at deviator locations; typically spaced at a maximum 20' spacing along length of girder



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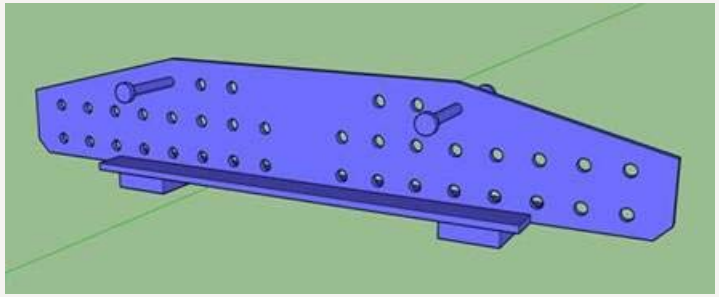
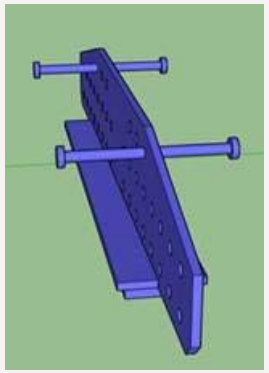
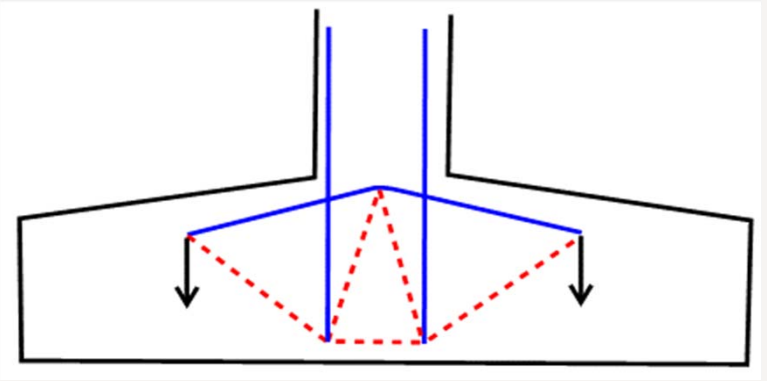
Design of Precambered Girders

5. Downward reaction at straight strand deviator locations
   - Strands inflict downward reaction on straight strand deviator → shear studs engage concrete in bottom flange of girder → additional reinforcement placed on each side of straight strand deviator is engaged transferring load into girder webs







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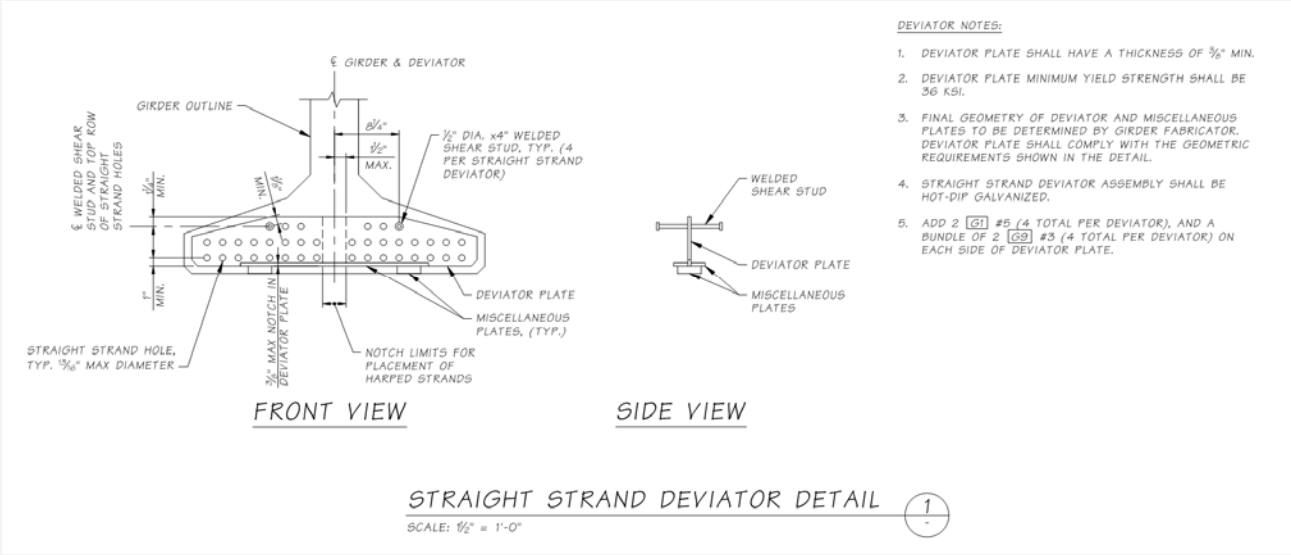
Design of Precambered Girders

5. Downward reaction at straight strand deviator locations



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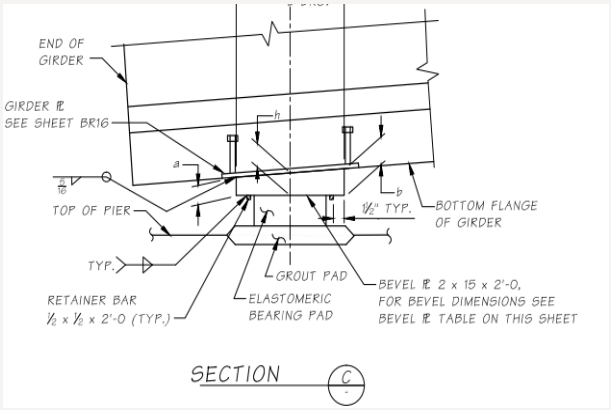
Design of Precambered Girders

6. Levelling detail at bearing locations

- Precamber in the girders results in a steeper angle at bearing locations. Therefore, a typical recess in the bottom of the girder is not sufficient to provide a level bearing interface between the girder and bearing.



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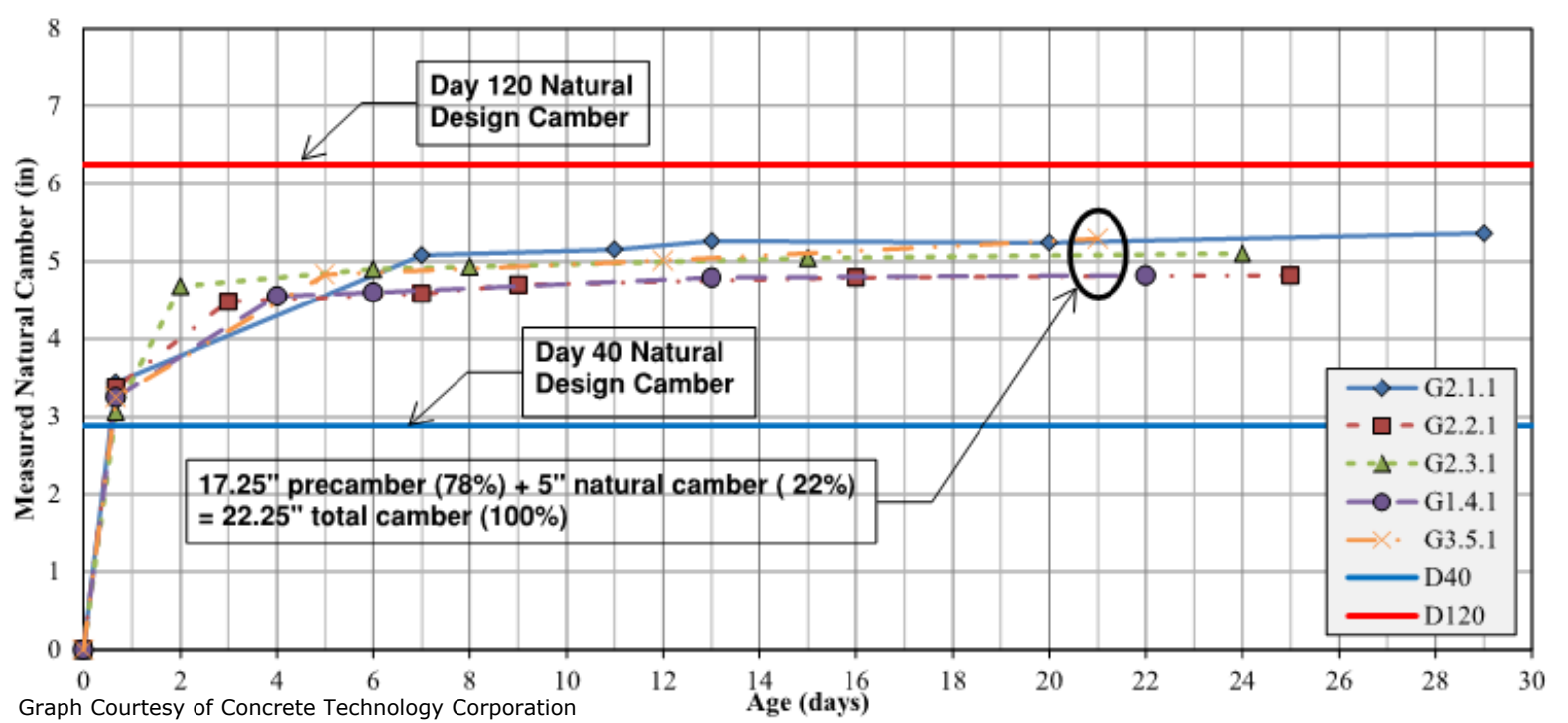
Design vs Actual Camber in Precambered girders



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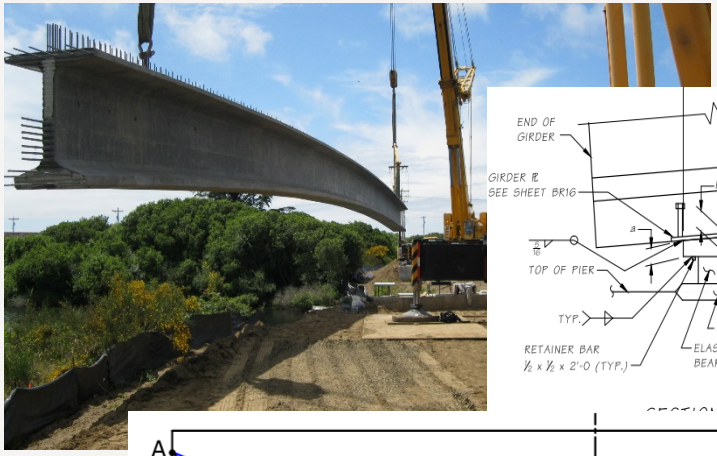
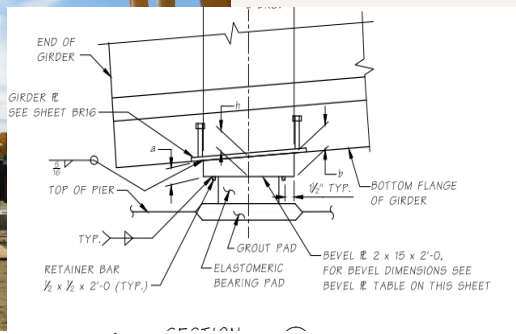
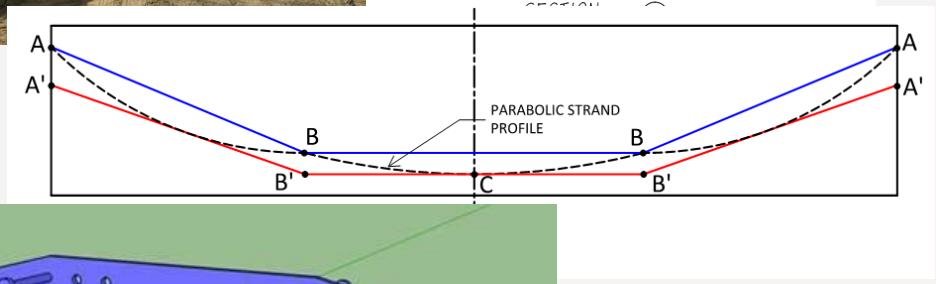
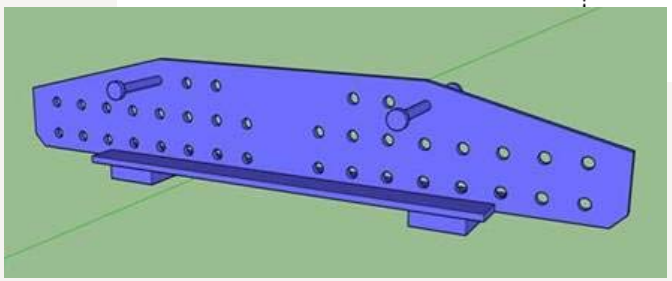
Summary

- Despite proven benefits, precambered girders are still underutilized as a result of lack of familiarity with their benefits, fabrication and design
- Attempt to further the understanding of precambered girders with the presented design approach methodology









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