Fabrication and design of precambered precast, prestressed concrete bridge girders

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- Precast, prestressed concrete bridge girders can be fabricated with a precamber to follow the roadway vertical profile, reducing buildup haunch depths and dead load on the girders.
- Several bridge projects with precambered girders have been successfully constructed in Washington State.
- This paper discusses fabrication, girder design, and shipping and handling considerations for precambered bridge girders.

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Building an intentional vertical curve into a precast concrete girder formwork system and the prestressing strand layout creates a girder with a prefabricated vertical curvature known as precamber. Precamber is the sum of the natural camber due to girder self-weight and eccentricity of the prestressing force plus the curvature built into the formwork (hereafter called formed camber). Precamber is an effective technique for matching the roadway profile grade for girders fabricated with a monolithic deck slab. For superstructures with a cast-in-place (CIP) concrete deck, this technique helps meet challenging vertical clearance requirements and reduces the slab haunch buildup associated with significant vertical curve profiles. **Figure 1** shows a girder fabricated with substantial crest precamber to provide vertical clearance under the span. Girders have also been cast with sag curvatures to match required roadway profile grade.

The Alaska Department of Transportation and Public Facilities has specified precambered prestressed concrete decked bulb-tee (DBT) girders for decades.[1] Construction time frames and access to construction materials in remote locations are limited. As a result, many bridge superstructures are constructed with a kit consisting of prestressed concrete DBT girders, connection steel, welding rods, and grout for the joints. Under these conditions, the girders must be fabricated to match the roadway profile, which requires some level of precamber in most cases. To date, the Washington State Department of Transportation (WSDOT) has made little use of DBT girders, preferring prestressed concrete I-girders with a CIP concrete deck instead. This preferred type of con-

Figure 1. Precambered girder for the South Razor Clam Bridge in Ocean Shores, Wash. Courtesy of Concrete Technology Corp.

struction permits the profile grade to be accommodated in the slab haunch buildup so precamber is not necessary; however, some recent WSDOT projects have highlighted the usefulness of the precambered girder system for prestressed concrete I-girders with a CIP concrete deck.

Precambered precast, prestressed concrete bridge girders offer several advantages over standard (nonprecambered) girders:[2]

- project limits can be shortened
- deeper girders and longer spans can be used while maintaining vertical clearance requirements
- deck haunch concrete dead load and material quantities can be reduced
- aesthetics can be improved

Precast, prestressed concrete decked girders, such as DBT girders, box beams, and slabs, can be precambered upward or downward to match the roadway profile grade. Precambered girders require special fabrication hardware and techniques, additional design effort, and special bearing details, and they may be less stable during handling operations.

This paper highlights the fabrication and design of precambered girders to raise awareness and share technical knowledge about this effective but underused application of precast concrete. This paper considers girders with a symmetric parabolic precamber profile, though girders with varying profiles along their length have also been fabricated. Formed camber for precast concrete spliced girder segments is not considered in this paper.

When to specify precambered girders

The initial fabrication setup for each magnitude of precamber specified for a project is time-consuming, affecting both cost and schedule. Consequently, precamber should only be specified when its use is truly beneficial to the project. As the number of girders with the same design increases, the impact of the initial setup on the unit price decreases. Once the initial setup is complete, girders with the same precamber can be produced at the same rate as traditional girders.

For some applications, such as the bridge shown in Fig. 1, the need for precambered girders is obvious. This is not always the case. Alternative means of achieving the desired result may be less expensive than precambered girders. To select the appropriate solution for a given project, engineers must exercise judgment and should consult with local contractors and precast concrete manufacturers.

For girders cast with a monolithic deck slab, the primary goal of precambering is to have the top of the girder follow the roadway profile. At some bridge sites, this goal can be accomplished by setting the roadway profile to match the girder's natural camber.[3] Alternatively, the girder top flange thickness can be varied to match the profile grade. Either of these alternatives, if feasible for a particular project, may be less expensive than specifying precambered girders.

For prestressed concrete I-girders with a CIP concrete deck, matching the roadway profile is normally achieved by varying the thickness of the slab haunch buildup. For bridge decks with significant vertical curvature, this slab haunch buildup can become excessively thick. If the span consists of only a few girders, it is probably best to proceed with traditional girders and a variable slab haunch buildup. However, if there are many girders in the span, it may be cost-effective to reduce the required haunch material and resulting dead load by using precambered girders. For spans with fixed bearing elevations that require increased vertical clearance, precambered girders are the most attractive option.

The level of precamber that can be achieved will depend on the local precast concrete manufacturer's capabilities and any restrictions for transporting the girder to the site. The amount of precamber is quantified using the precamber ratio, which is defined as the formed camber δ_{fc} divided by the precast concrete girder length L. Girders with precamber ratios δ_{fc}/L of as much as 1/81 have been fabricated and shipped in Washington state. Designers should consult local precast concrete manufacturers to verify limitations. In cases of extreme vertical curvature, it may be advantageous to combine precamber with other techniques such as flange thickening or slab haunch buildup.

Fabrication

Precambered girders are fabricated using a series of straight formwork segments arranged to create a chorded girder profile closely approximating a circular arc or parabola.[4] **Figure 2** shows a schematic arrangement of straight form segments approximating a parabolic curve. When properly fitted, the variation between the shape created by the straight segments and parabolic shape is within 0.25 in. (6.4 mm). Although the girder profile is chorded, the curvature induced by bonded prestressing strands at each individual section along the girder length provides the appearance of a smooth curve in the finished product (Fig. 1).

The straight pretensioned strands in a precambered girder are not truly straight; they follow the formwork, maintaining a constant offset from the bottoms of the forms. Special deviators that are embedded in the cast concrete hold the strands in their intended locations (**Fig. 3**), otherwise they would straighten and bear against the bottom form pan when tensioned. Harped strands are placed in a precambered girder to maintain the desired eccentricity near midspan and at the ends, but the eccentricity throughout the remainder of the girder length varies compared with the eccentricity of the strands for a girder of the same design fabricated with a flat profile. The vertical forces induced by changes in strand direction must be resisted by the formwork or prestressing bed. **Figure 4** shows a typical form setup for precambered girders and a precambered girder that has been lifted after form stripping.

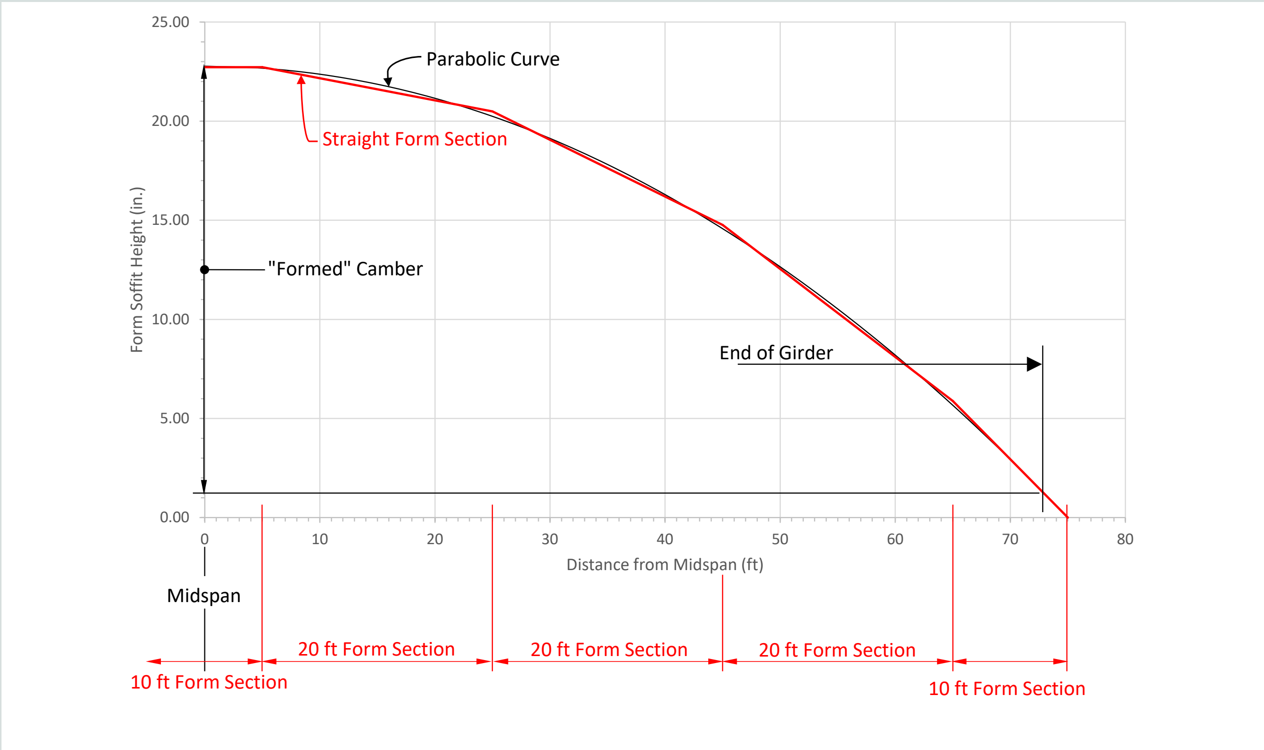

Figure 2. Straight form section fit of parabolic formed camber profile. Note: 1 in. = 25.4 mm; 1 ft = 0.305 m.

Figure 3. Straight strand deviator plate in precambered girder.

Figure 4. Stripping a precambered girder from the form.

Design

Precambered girders are initially designed in the same manner as any other standard precast, prestressed concrete bridge girder. This initial design provides a baseline for further analysis in the precambered configuration. In particular, the natural camber of the baseline design is estimated and compared with the required final camber to determine the amount of formed camber needed. Additional analysis after the baseline design may involve the following:

- determining pretensioned strand eccentricity for the precambered girder
- adjusting design calculations and natural camber estimates to account for the nonlinear variation of pretensioned strand eccentricity with respect to the center of gravity of the girder cross section
- reducing the slab haunch buildup and dead load for precambered I-girders with a CIP concrete deck
- adjusting the design to account for resisting the vertical reaction at "straight" strand deviators internally
- providing special consideration for bearing connection details
- accounting for the reduced handling and shipping stability and increased corresponding stresses caused by crest precamber

Pretensioned strand eccentricity

The center of gravity of a precambered girder closely approximates a parabolic arc. Straight pretensioned strands follow the same profile, so their eccentricity from the center of gravity of the cross section is constant, as shown in the following equation.

$$e_s = y_b - y_s$$

where

e_s = eccentricity of straight strands

y_b = distance from bottom of girder to center of gravity of gross girder section

y_s = distance from bottom of girder to straight strands

The same is not true of harped strands, whose eccentricity varies nonlinearly with respect to the center of gravity of the girder. **Figures 5** and **6** illustrate this nonlinear variation in eccentricity for crest- and sag-formed camber profiles,

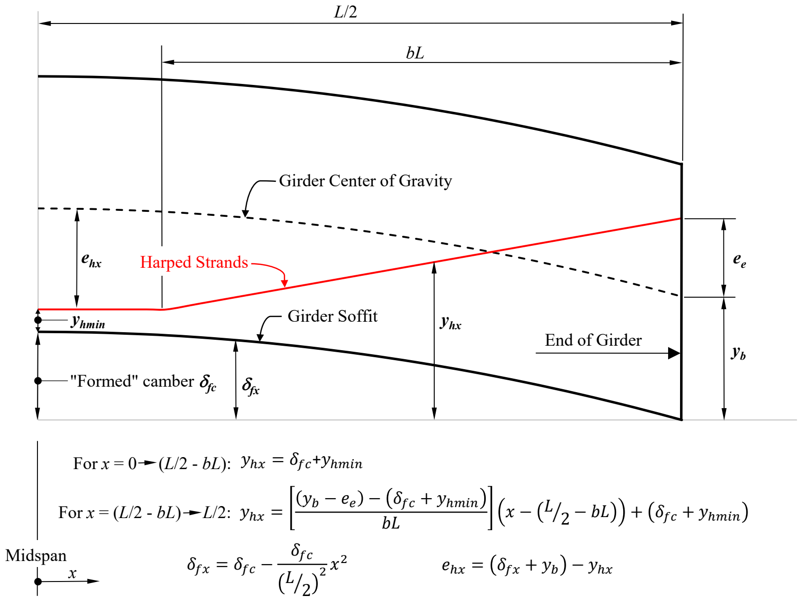

Figure 5. Harped strand eccentricity of crest-formed camber profile for half girder length. Note: Eccentricity of harped strands at the girder ends is negative when harped strands are above the girder center of gravity. b = fraction of girder length from end of girder to nearest harp point; e_e = eccentricity of harped strands at the girder ends; e_{hx} = eccentricity of harped strands at a section x; L = length of precast concrete girder; x = horizontal distance from designated point of origin to section under consideration; x = horizontal distance from designated point of origin to section under consideration; y_b = distance from bottom of girder to center of gravity of gross girder section; y_{hmin} = minimum distance from bottom of girder to center of gravity of harped strands; y_{hx} = elevation of harped strands from lowest girder soffit elevation at a section x; δ_{fc} = maximum value of formed camber; δ_{fx} = formed camber at a section x.

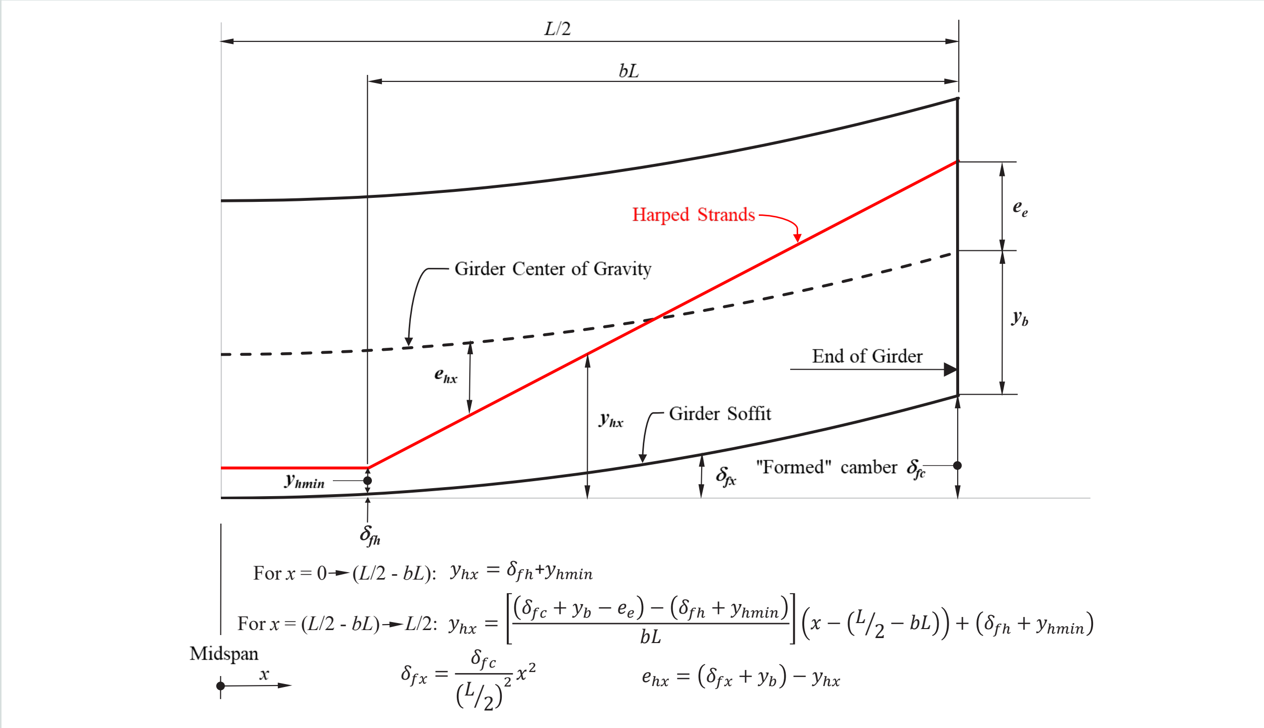

Figure 6. Harped strand eccentricity of sag-formed camber profile for half girder length. Note: Eccentricity of harped strands at the girder ends is negative when harped strands are above girder center of gravity. b = fraction of girder length from end of girder to nearest harp point; e_e = eccentricity of harped strands at the girder ends; e_{hx} = eccentricity of harped strands at a section x; L = length of precast concrete girder; x = horizontal distance from designated point of origin to section under consideration; x = horizontal distance from designated point of origin to section under consideration; y_b = distance from bottom of girder to center of gravity of gross girder section; y_{hmin} = minimum distance from bottom of girder to center of gravity of harped strands; y_{hx} = elevation of harped strands from lowest girder soffit elevation at a section x; δ_{fc} = maximum value of formed camber; δ_{fh} = formed camber at harp point; δ_{fx} = formed camber at a section x.

respectively. For a girder with harped strands, the resultant eccentricity of all pretensioned strands at any section along the girder length is

$$e_{psx} = \frac{\left(A_{ss}e_s + A_{hs}e_{hx}\right)}{\left(A_{ss} + A_{hs}\right)}$$

where

e_{psx} = eccentricity of all strands at a section x

A_{ss} = area of straight strands

A_{hs} = area of harped strands

e_{hx} = eccentricity of the harped strands at a section x

x = horizontal distance from designated point of origin to section under consideration

Baseline design calculation adjustments

The baseline design calculations should be adjusted to check the effects of the nonlinear eccentricity profile of the precambered configuration. For example, harped strands in crest precambered girders are at a shallower angle with respect to a horizontal axis than in standard girders. The resulting vertical component of the prestressing force is reduced in precambered girders compared with the baseline design, thereby reducing its contribution to shear capacity. Alternatively, harped strands in girders with sag precamber have a steeper slope with respect to a horizontal axis than a standard girder, increasing their contribution to shear capacity. The adjusted strand eccentricities, discussed previously, are used to check the design stresses, flexural and shear strength, and other considerations.

Natural camber

Historically, the camber calculated for the baseline design has reflected the actual natural component of precamber reasonably well. Because the straight strands are bonded with constant eccentricity, they create the same curvature at each section. The integration of these curvatures along the girder length results in an equation for the initial natural camber that is the same as for the baseline design. Again, the same is not strictly true for the harped strands, but the theoretical difference is small (see the appendix).

The amount of formed camber required is based on an estimate of long-term natural camber. Both WSDOT and Concrete Technology Corp. use in-house software to reliably estimate an upper bound of long-term girder camber. To reflect the inherent variability of camber, WSDOT specifies a range of long-term camber with the upper bound of camber calculated at 120 days D_{120} and the lower bound taken as 50% of the camber calculated at 40 days D_{40}.

Figure 7 shows a plot of measured natural camber for the South Razor Clam Bridge in Ocean Shores, Wash. (pictured in Fig. 1), along with the calculated upper and lower bounds. The measured natural camber was determined by subtracting the formed camber from the measured actual camber, and the values are roughly centered between the two limits. The primary purpose of precamber for this project was to provide a minimum vertical clearance under the span. In this case, the lower bound of natural camber was used to estimate the minimum amount of formed camber needed. The lower bound was also used to calculate the maximum dead load due to slab haunch buildup at midspan. The upper bound of natural camber was used to ensure that a minimum slab haunch buildup thickness was provided at midspan to prevent the tops of the girders from protruding into the deck.

Temporary top strands are sometimes needed to alleviate excessive tensile stresses in the top flange of the girder during handling or shipping. Holding pretensioned temporary top strands at a constant offset from the top surface of the girder is not practical. For this reason, temporary top strand tendons are installed in ducts at a constant offset from the top surface of the girder and post-tensioned after the girder is fabricated. Depending on the stability requirements, tensioning can be performed immediately before lifting the girder from the casting bed, after initial lifting at the beginning of storage, or immediately prior to hauling.[5]

Post-tensioned top strands reduce the girder camber and slightly reduce the long-term creep growth of camber due to a reduction in compressive stress in the bottom of the girder. Once the girder is erected and the temporary top strands are cut, some rebound of camber will occur; however, because the girder has aged since the temporary top strands were tensioned, the magnitude of this rebound will generally not recover all the camber that was lost.

A rational estimate of the camber lost due to post-tensioned temporary top strands can be made by estimating a baseline camber including the temporary top strands, calculating the anticipated rebound at an assumed age when the temporary top strands will be cut, and comparing the results with the original baseline design. The effects of post-tensioned temporary top strands are expected to be small.

Slab haunch buildup

Precambered girders can closely follow crest and sag vertical curve profiles (**Fig. 8**). This reduces the slab haunch buildup thickness, dead weight, and material costs.

Slab haunch buildup is computed using standard methods by including formed camber in the total camber. When specifying the haunch dimension for a precambered girder, designers should account for the variation in the time-dependent component of natural camber as previously discussed.

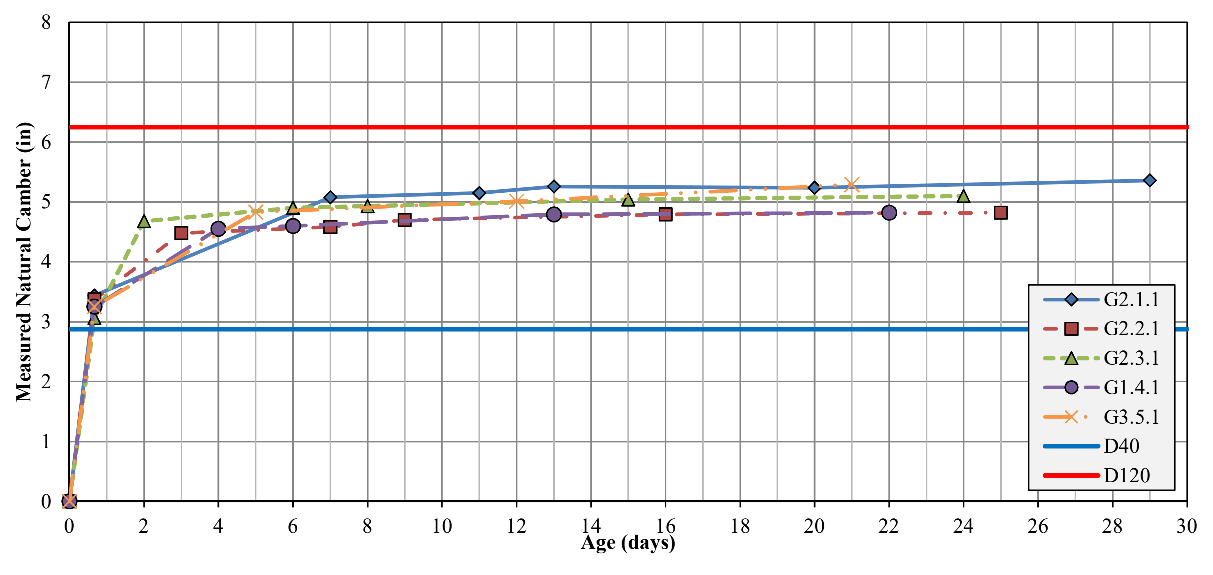

Figure 7. Measured natural cambers for the South Razor Clam Bridge in Ocean Shores, Wash. Note: Designations G2.1.1, G2.2.1, and so forth denote individual girder mark numbers on the project. D_{40} = half of the estimated natural long-term camber at 40 days; D_{120} = estimated natural long-term camber at 120 days. 1 in. = 25.4 mm.

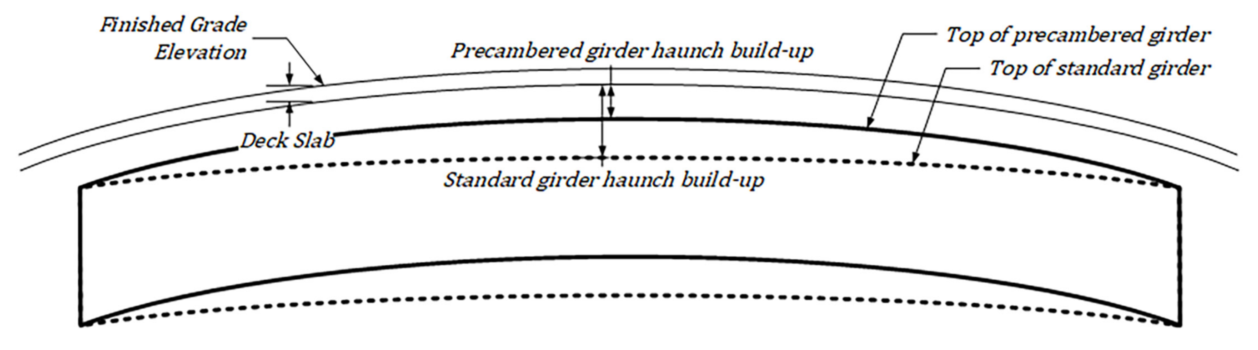

Figure 8. Comparison of slab haunch buildup for standard and precambered girders.

Straight strand deviator reactions

Concentrated downward reactions occur at the straight strand deviator plates for form setups with crest precamber. Once the concrete has cured and the stress is transferred from the pretensioned strands to the concrete, the bonded strands induce compression in the bottom flange and a vertical downward reaction on the deviator plates. Most precambered girders manufactured to date have not included additional anchorage or supplemental reinforcement to resist this force because bond and friction generated by the clamping effect of the precompression force is sufficient to resist the downward reactions. This is the case for the deviator plate shown in Figure 3. However, it is conservative to assume that the vertical component of the reaction must be accommodated in the girder design. This assumption requires vertical reinforcement in addition to the standard confinement and shear reinforcement. The vertical reinforcement can be sized based on the reaction at the deviator plate divided by an allowable stress of 30 ksi (210 MPa). Welding the vertical reinforcement to the plate and extending it into the web a minimum length equal to the reinforcing bar development length anchors the deviator plate to the girder. Alternatively, other anchorage methods and strut-and-tie models can be used to size and detail this anchorage reinforcement.

Bearings

Precamber creates a significant angle between the bottom of the girder and a level bearing surface. Bearing assemblies must accommodate the girder end slope due to roadway grade and a slope of $4\delta_{pc}/L$ due to precamber, where δ_{pc} is the total precamber including natural and formed camber. Article 14.8.2 of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[6] requires a tapered plate when the inclination of the underside of the girder to the horizontal exceeds 0.01 rad. **Figure 9** presents a schematic of a typical bearing assembly with a tapered plate.

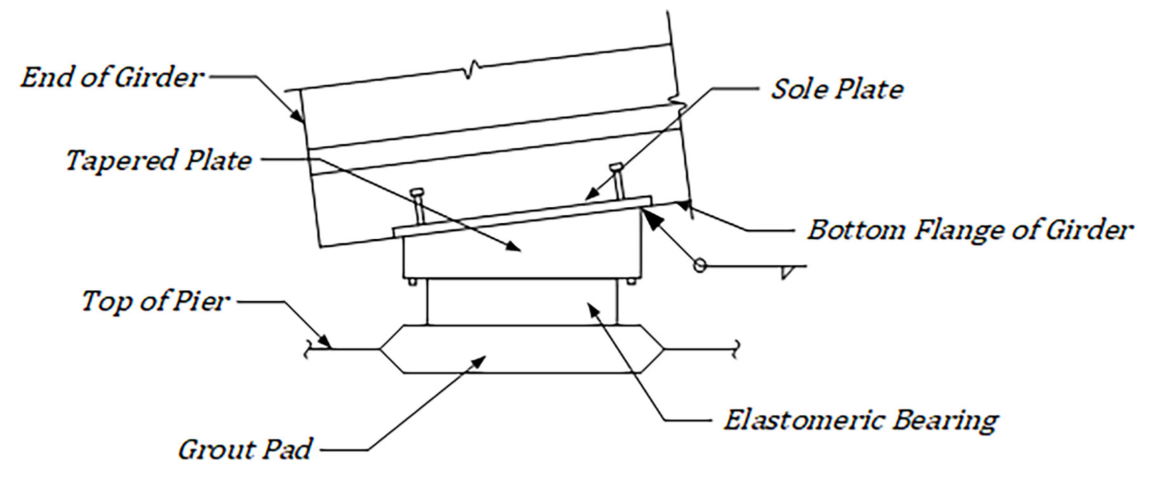

Figure 9. Schematic of a typical bearing assembly.

Figure 10. Precambered girder being prepared for transport to the Interurban Trail Pedestrian Bridge jobsite. Courtesy of Concrete Technology Corp.

Handling and shipping

Handling of precambered precast, prestressed concrete bridge girders is a serious concern. Crest precamber raises the girder's center of gravity, increasing lateral bending stress and the girder's susceptibility to rollover during handling operations.

Care must be taken when selecting lift locations for precambered girders. Stability is improved when lift points are moved inward from the ends of the girder. However, using lift points closer to midspan reduces the dead-load moments that typically balance the prestressing force. This leads to increased top-flange tensile stresses and bottom-flange compressive stresses, and that in turn increases the minimum concrete strength required for handling. Rigid lifting devices may be used to raise the roll axis of the girder and improve stability.

The location of a girder's center of gravity and its effect on stability must be carefully considered for girder transport. **Figure 10** shows a precambered girder being prepared for hauling. Crest precamber increases the center-of-gravity elevation above the haul vehicle's roll center, reducing stability.

Because the profile of a crest precambered girder is curved, the ends of the girder are lower than the support locations. This may cause the ends to interfere with the hauling equipment. Moving the support locations inward from the ends of the girder increases stability but exacerbates interference problems. Blocking may be used to raise the girder at support locations to eliminate girder-truck conflicts, but doing so raises the girder's center of gravity and reduces its stability. Blocking may also contribute to over-height issues along the haul route.

PCI has published recommended practices to address girder stability concerns.[7] The effect of precamber is not explicitly addressed in these recommendations, but can be accommodated in the analytical procedures by substituting precamber (formed camber plus natural camber) for natural camber.

Table 1. Precambered bridge projects in Washington state

Bridge	Girder length L, ft	Formed camber δ_{fc}, in.	δ_{fc}/L
Tonquin Avenue Bridge	146.0	21.5	1/81
South Razor Clam Bridge	118.8	17.3	1/83
Interurban Trail Pedestrian Bridge*	167.5	22.3	1/90
State Route 519 Royal Brougham Bridge	123.5	13.4	1/111
South Lander Bridge	114.0	10.3	1/134
Marshall Avenue Bridge*	137.5	10.5	1/157
Burlington Northern Bridge	186.8	13.0	1/172
NW Dogwood Street Bridge*	93.1	5.6	1/199
State Route 167 Eighth Street Bridge	180.7	3.0	1/723
Skagit River Bridge*	163.1	-4.4	-1/447

Note: 1 in. = 25.4 mm; 1 ft = 0.305 m.

*Denotes bridges using decked bulb-tee girders. All others used a cast-in-place deck.

Projects

Several projects using precambered girders have been successfully constructed in Washington state (**Table 1**). Modest to significant precamber, ranging from *L*/723 to *L*/81, has been used in these projects.

The Interurban Trail Pedestrian Bridge (**Fig. 11**) was constructed for the City of Tukwila in 2002 with approximately 2.0 ft (0.61 m) of precamber, which is the largest amount of precamber constructed in Washington state to date.

The State Route 519 Royal Brougham Bridge (**Fig. 12**) constructed between the stadiums that house the Seattle Mariners and Seattle Seahawks was precambered primarily to provide vertical clearance to the railroad tracks beneath the structure; however, the profile grade also had to accommodate Americans with Disabilities Act standards for access to an adjacent parking structure, putting a cap on the amount of precamber that could be used. To fit this tight window of camber variation, contingency plans were developed to provide bearing shims or to move girders with higher cambers to locations in the span that were less sensitive to the vertical curve geome-

Figure 11. Completed Interurban Trail Pedestrian Bridge. Courtesy of Concrete Technology Corp.

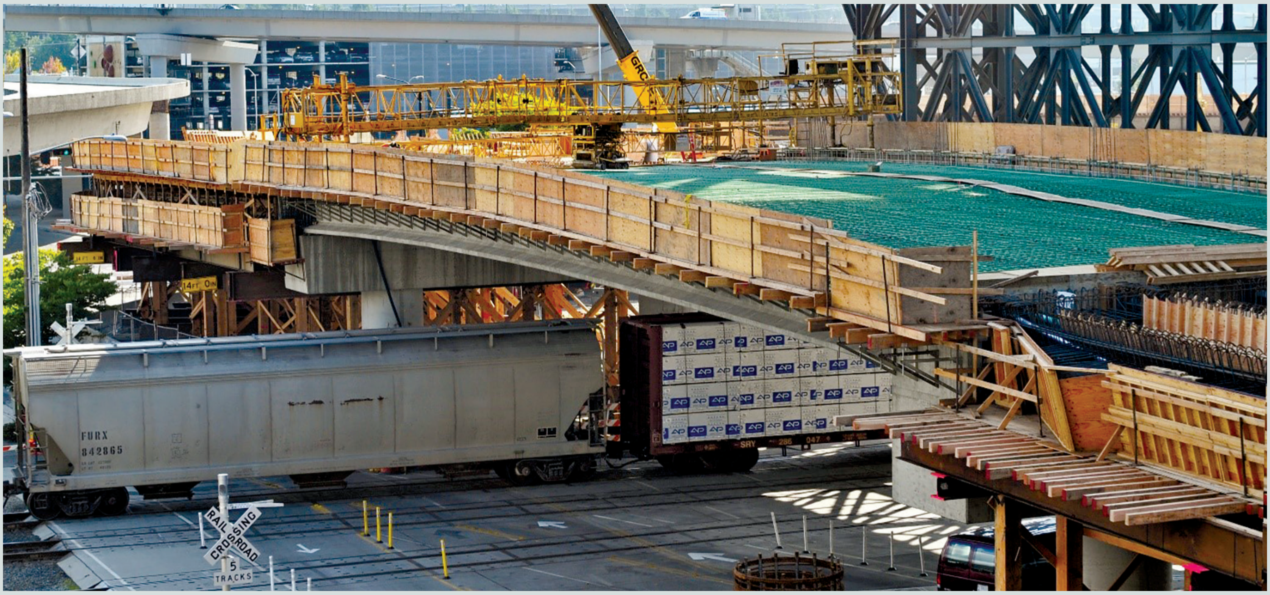

Figure 12. State Route 519 Royal Brougham Bridge girders precambered to provide vertical clearance for railroad tracks beneath the structure. Courtesy of Concrete Technology Corp.

Figure 13. Marshall Avenue Bridge with variable precamber in the main span. Courtesy of Concrete Technology Corp.

try. Ultimately, all girders fit within the intended window of camber, and the bridge was successfully completed without using a contingency plan.

The Marshall Avenue Bridge (**Fig. 13**) spans Port of Tacoma Road and adjacent railroad tracks, with vertical clearance being the primary concern. The profile grade for the main span over the roadway was designed with a straight profile grade for the half span nearest the abutment and a crest curve for the half span near the interior pier. This dictated reverse curvature in the formwork, with a sag-formed camber profile used for half of the span to compensate for natural camber and result in a straight profile and a crest-formed camber used in the other half of the span to result in the crest curve profile. This reverse curvature was successfully accomplished, once again demonstrating the versatility that precast, prestressed concrete can provide.

Design tools

WSDOT recently updated its software programs PGSuper, for pretensioned concrete girders, and PGStable, for general precast concrete girder stability analysis, to include precamber effects. PGSuper and PGStable are part of the BridgeLink suite of tools available from WSDOT at http://www.wsdot.wa.gov/eesc/bridge/software.

Conclusion

Precamber has been successfully used in the fabrication and design of precast concrete bridge girders. It is an effective technique to match roadway profile grade for decked girder bridges and meet challenging vertical clearance requirements and reduce haunch buildup dead load for superstructures with CIP decks. The following conclusions are made:

- Fabrication and design of precambered girders is somewhat more challenging but not significantly different from that of standard girders.
- Technical knowledge for fabrication and design of precambered girders has been shared to raise awareness of an underused application of precast concrete.
- Computer software tools are readily available, removing barriers to designing precambered girders.

When considering precambered girders, engineers should evaluate restrictions for transporting girders and consult with local precast concrete manufacturers to determine their capacity to produce such a product.

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Notation

A_{hs} = area of harped strands

A_{ss} = area of straight strands

b = fraction of girder length from end of girder to nearest harp point

D_{40} = estimated natural long-term camber at 40 days

D_{120} = estimated natural long-term camber at 120 days

e_e = eccentricity of harped strands at the girder ends

e_h = eccentricity of harped strands at the harp points

e_{hx} = eccentricity of the harped strands at a section x

e_{psx} = eccentricity of all strands at a section x

e_s = eccentricity of straight strands

E = modulus of elasticity of concrete at transfer of prestress

I = major axis moment of inertia of girder cross section

k = coefficient representing effect of nonlinear harped strand eccentricity on camber

L = length of precast concrete girder

M = moment induced by eccentricity of prestressing force

P_h = harped strand precompression force at transfer of prestress

x = horizontal distance from designated point of origin to section under consideration

y = vertical deflection of a point on the girder

y_b = distance from bottom of girder to center of gravity of gross girder section

y_{hmin} = minimum distance from bottom of girder to center of gravity of harped strands

y_{hx} = elevation of harped strands from lowest girder soffit elevation at a section x

y_s = distance from bottom of girder to straight strands

δ_{fc} = maximum value of formed camber

δ_{fh} = formed camber at harp point

δ_{fx} = formed camber at a section x

δ_{pc} = total precamber including natural and formed camber

δ_{hs} = midspan camber due to harped strands

Appendix: Effect of precamber on harped strand prestress deflection

Girder deflection due to prestressing force is found by solving the differential equation $EI\dfrac{d^2y}{dx^2} = M\left(x\right)$

where

E = modulus of elasticity of concrete at transfer of prestress

I = major axis moment of inertia of girder cross section

y = vertical deflection of a point on the girder

x = horizontal distance from designated point of origin to section under consideration

M = moment induced by eccentricity of prestressing force

The eccentricity of harped strands in a precambered girder is the distance between the centers of gravity of the strands and the girder as defined in Fig. 5 and 6. Because of the formed camber, harped strand eccentricity varies nonlinearly with respect to the girder center of gravity. The midspan deflection due to prestressing force for girders with harped strands is

$$\Delta_{hs} = \iint -\frac{P_h e_{hx}}{EI}\,dx\,dx = \frac{P_h\left(e_e - e_h\right)\left(3-4b^2\right)L^2}{24EI}$$

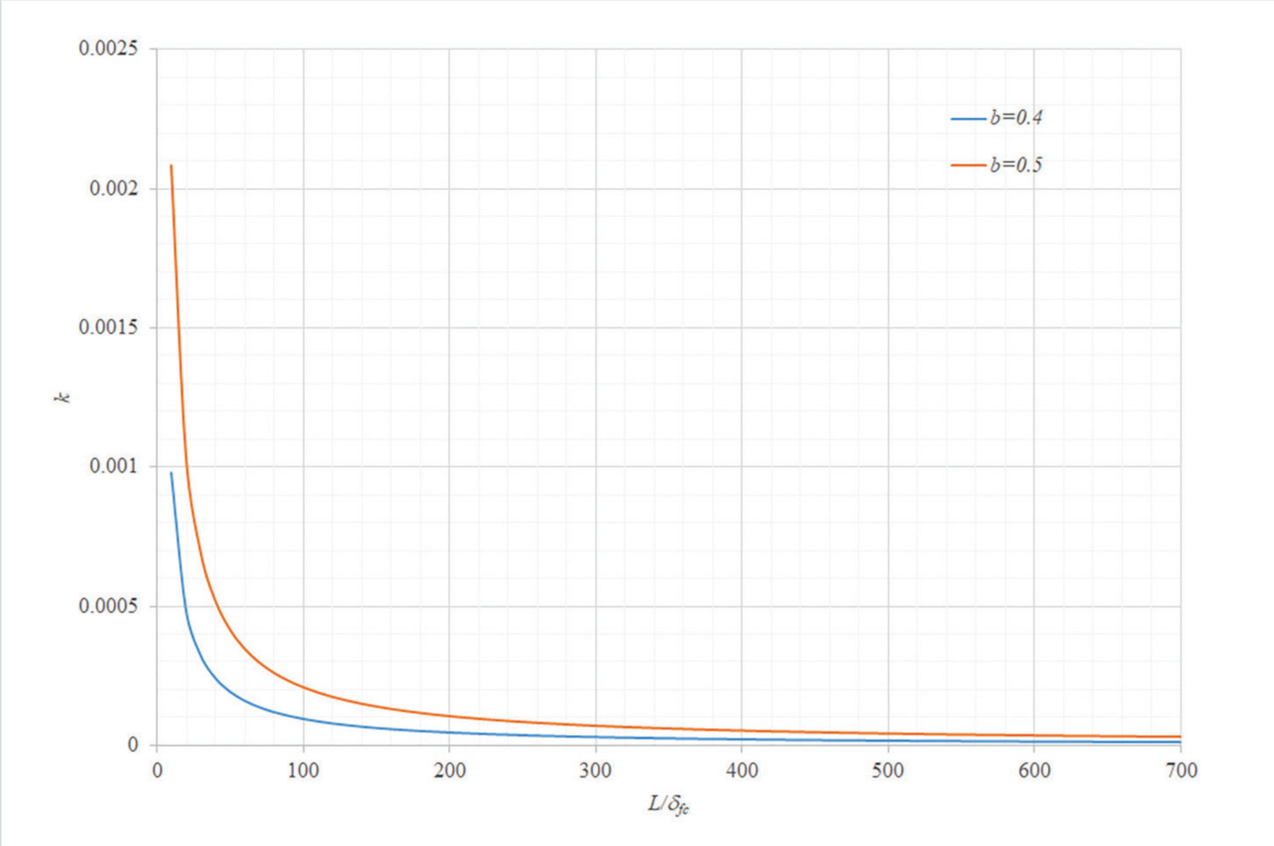

Figure A.1. shows the coefficient *k* from Eq. (A.2) for a wide range of girder length-to-formed camber ratios with harp points at 40% and 50% of the girder length. Even in the most extreme cases, the effect of formed camber on the deflection attributed to harped strands is insignificant.

$$+\frac{P_h e_e L^2}{8EI}+\frac{P_h \delta_{fc}\left(5-8b\left(1-b\right)\left(3-4b^2\right)\right)L^2}{48EI} \qquad \text{(A.1)}$$

where

Δ_{hs} = midspan camber due to harped strands

P_h = harped strand precompression force at transfer of prestress

e_{hx} = eccentricity of the harped strands at a section x

e_e = eccentricity of harped strands at the girder ends

e_h = eccentricity of harped strands at the harp points

b = fraction of girder length from end of girder to nearest harp point

L = length of precast concrete girder

δ_{fc} = maximum value of formed camber

The first two terms in Eq. (A.1) are the deflection due to prestressing force for a standard girder, and the last term accounts for the nonlinear variation in eccentricity associated with the formed camber in a precambered girder. Eq. (A.2) expresses the third term from Eq. (A.1) as a function of harp point location b and girder length–to–formed camber ratio L/δ_{fc} (**Fig. A.1**).

$$\frac{\delta_{fc}}{L}\times\frac{\left(5-8b\left(1-b\right)\left(3-4b^2\right)\right)}{48}\times\frac{P_h L^3}{EI}=k\frac{P_h L^3}{EI} \qquad \text{(A.2)}$$

where

k = coefficient representing effect of nonlinear harped strand eccentricity on camber

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Abstract

Building an intentional vertical curve into a precast concrete girder formwork system and the prestressing strand layout creates a girder with a prefabricated vertical curvature known as precamber. Precamber is an effective technique for matching the roadway profile grade for girders fabricated with a monolithic deck slab. For superstructures with a cast-in-place concrete deck, this technique helps meet challenging vertical clearance requirements and reduces the slab haunch buildup associated with significant vertical curve profiles. This paper highlights the fabrication and design of precambered girders to raise awareness and share technical knowledge about this effective but underused application of precast concrete.

Keywords

AASHTO, fabrication, camber, lateral stability, load- and resistance-factor design, LRFD, precamber, strength, Washington State Department of Transportation, WSDOT.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

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