Sweep in Precast, Prestressed Concrete Bridge Girders—Part III

by Dr. Bruce W. Russell, Oklahoma State University

This article is the third and final article in a series focusing on sweep, or lateral bowing, in prestressed concrete bridge girders. The first article focused on potential causes of sweep and provided recommendations for actions that can be taken at the prestressing plant to mitigate its effects (see the Spring 2019 issue of *ASPIRE*®). The second article concentrated on the lifting, transportation, and erection of girders with sweep (see the Fall 2019 issue of *ASPIRE*). This article focuses on effects that girders with sweep will have on long-term stresses, strength, and other performance criteria. Also, the effects of attempting to partially straighten a girder to bring it within tolerance are examined. By the time you reach the article's conclusion, you may agree with me that sweep in prestressed concrete girders that is within, or in some cases beyond, the published tolerance may not have significant adverse effects on the long-term performance of a bridge.

Table 1. Girder Design Details for Example

Girder Design:	Bruce W. Russell, PhD, PE	
Length:	130.5 ft	
Type of Girder:	PCI-AASHTO BT-72	
A =	767	in.^{2}
h =	72.0	in.
c_b =	36.6	in.
c_t =	35.4	in.
I_{xx} =	545,113	in.^{4}
I_{yy} =	37,543	in.^{4}
J = torsional inertia =	6673	in.^{4}
w_b =	0.799	kip/ft
f'_c =	10.0	ksi
E_c =	5760	ksi
Width of bottom flange	26	in.
Width of top flange	42	in.
N =	38	0.6-in.-diameter Gr. 270 ASTM A416, low-relaxation strands
Strand eccentricity =	29.02	in.
Δ_{camber} =	2.72	in.↑ estimated at time of handling and includes girder self-weight

Design Example Illustrating Sweep's Effects

To provide an example for discussion, a PCI–American Association of State Highway and Transportation Officials (AASHTO) bulb-tee BT-72 girder with a span length L of 130 ft 6 in. and a girder spacing of 7 ft 2 in. is used. **Table 1** presents the girder cross-section and material properties as well as other design information. For purposes of discussion in this article, one of the girders is assumed to exhibit a midspan sweep f of 1.631 in., which is equal to the PCI recommended sweep tolerance f_{tol} of ⅛ in. per 10 ft of length.[1] Other cases are considered where the sweep varies from zero to twice the PCI tolerance.

In this article, four cases are considered:
- The effects of sweep after girder erection but prior to deck slab placement
- The effects of sweep during deck slab placement

Figure 1. Schematic plan and elevation of girder with sweep showing vertical reactions, torsional restraint at bearings from bracing or other means, and flexural moment at midspan for self-weight only. Note: For illustration purposes sweep is exaggerated. All figures: Dr. Bruce Russell.

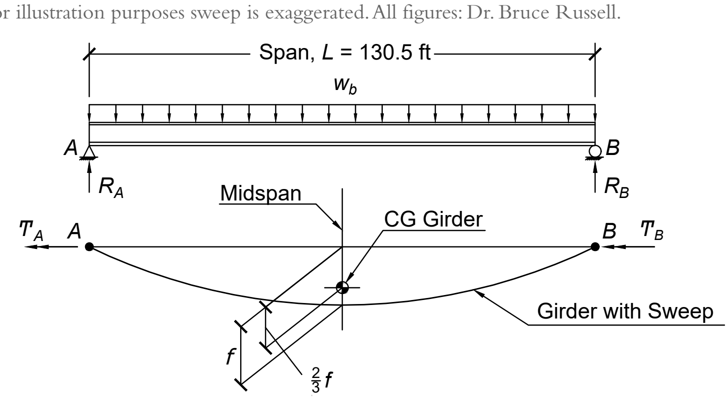


FIGURE 1a. SCHEMATIC ELEVATION AND PLAN VIEWS

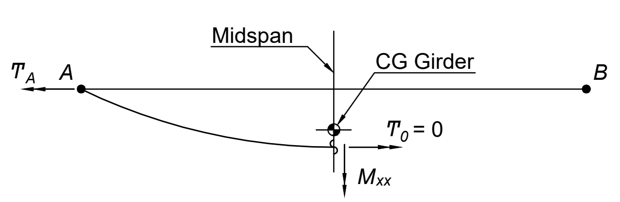


FIGURE 1b. MECHANICS AT MIDSPAN, PLAN VIEW

Table 2. Effects of Sweep on Girder After Erection, Prior to Deck Slab Placement

Sweep f	Sweep at Midspan f, in.	CG of Girder from Centerline of Bearings $\frac{2}{3}f$, in.	Torsional Restraint Required at Bearing T_A, kip-ft	Equivalent Eccentricity at Bearing $e_T = T_A / R_A$, in.	Stable? (Yes or No)	Torsional Deformation at Midspan ϕ, rad	Maximum Torsional Stress τ, ksi
0.0	0.00	0.00	0.00	0.00	Yes	0.0000	0.000
0.5 f_{tol}	0.82	0.54	2.36	0.54	Yes	0.0009	0.017
1.0 f_{tol}	1.63	1.09	4.72	1.09	Yes	0.0018	0.034
1.5 f_{tol}	2.45	1.63	7.09	1.63	Yes	0.0027	0.052
2.0 f_{tol}	3.26	2.18	9.45	2.18	Yes	0.0036	0.069

Notes:
1. Calculations are based on a BT-72 girder with length L = 130.5 ft. Vertical reaction at bearing R_A = 52.13 kip for all cases.
2. Sweep tolerance f_{tol} = 1.631 in. is computed from a PCI standard practice[1] where sweep tolerance is ⅛ in. per 10 ft of length.

- The effects of sweep in the completed composite bridge superstructure during service (primarily live loads)
- The effects of reducing sweep in the girder after erection but prior to deck slab placement

Effects of Sweep After Girder Erection, Prior to Deck Slab Placement

For illustration purposes, this discussion focuses on the forces, stresses, and deformations in the example girder with sweep that are caused by self-weight. **Figure 1a** shows a schematic plan view of a girder with sweep as it rests on its bearings. The girder spans 130.5 ft from center to center of the bearings with a sweep f equal to 1.631 in. Note that the center of mass (CG) of the girder is located at ⅔f from a line connecting the centerlines of the bearings, which are assumed to be centered under the girder ends. The eccentricity of the girder's CG creates an imbalance of the girder's self-weight w_b, which must be resisted by torsional restraint T_A and T_B at the bearings. The restraint may be provided by the bearings alone or additionally by end bracing, which is commonly installed as soon as the girders are erected. The torsional restraint required at each support is computed by the following equation:

$$T_A = T_B = \frac{w_b L}{2} \times \frac{2f}{3} = \frac{w_b L}{3} \times f$$
$$= \frac{(0.799 \text{ kip/ft})(130.5 \text{ ft})}{3}$$
$$\times \frac{(1.631 \text{ in.})}{12 \text{ in./ft}} = 4.72 \text{ kip-ft}$$

Table 2 reports the calculation results for varying amounts of sweep.

At midspan, the torsional moment T_0 is zero, both horizontal (transverse) and vertical shears are zero, and the out-of-plane bending moment M_{yy} (not shown) is also taken as zero (**Fig. 1b**). Note that regardless of sweep, the vertical reaction at the supports is constant, R_A = R_B = 52.13 kip. The bending moment at midspan about the girder's strong axis M_{xx} also remains constant:

$$M_{xx} = \frac{w_b L^2}{8} = \frac{(0.799 \text{ kip/ft})(130.5 \text{ ft})^2}{8}$$
$$= 1700.9 \text{ kip-ft}$$

Girder sweep causes both torsional deformation, or twist, and shear stresses. Maximum torsional rotation θ occurs at midspan, whereas the maximum torsional shear stress τ occurs at the ends of the girder. Table 2 lists the values for rotations and stresses as a function of sweep. Calculation of these values, which is not shown here, uses the St. Venant's torsional inertia J given in Table 1. The value of J for this example was based on thin-walled theory and is conservative. Computation of torsional rotations and accompanying stresses is typically not performed in bridge design except for curved beams.

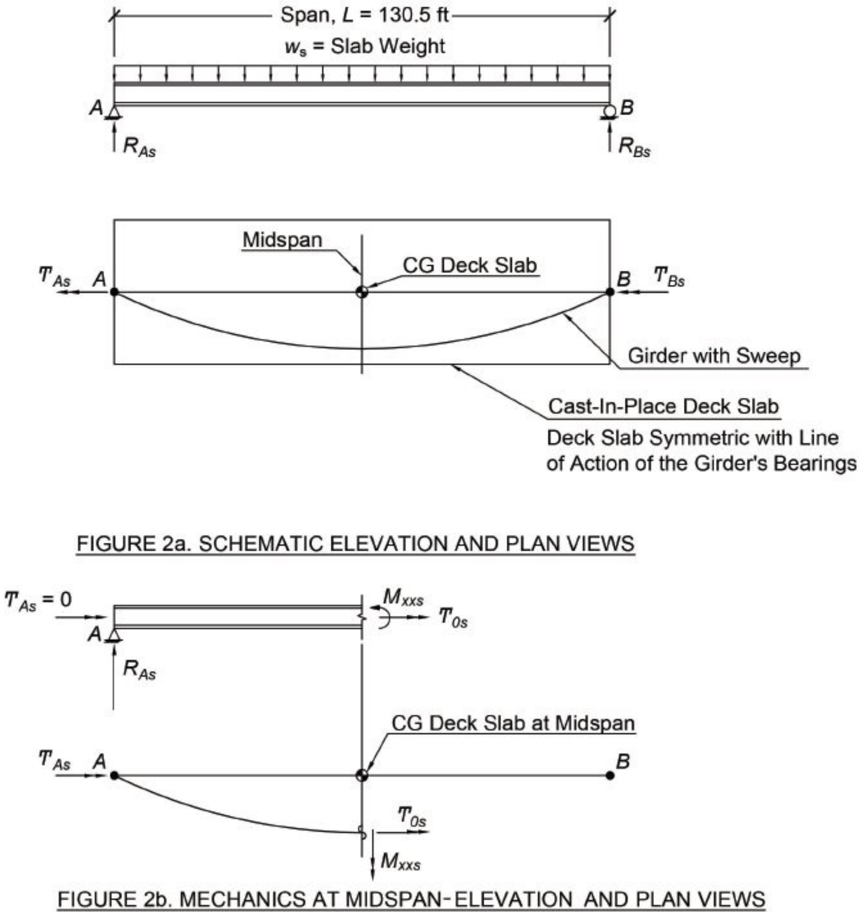
For the example case, with sweep equal to the sweep tolerance, the angular deformation at midspan is 0.0018 rad (about 0.10 degree). This angular deformation at midspan results in a lateral deflection of the top fiber of about $\frac{1}{16}$ in., which would be nearly imperceptible. The maximum torsional shear stress for this same case is 34 psi, which would appear to be a small enough increment to not cause principal tensile stress cracking or raise any serviceability concerns. Even with sweep equal to twice the tolerance in the example girder, torsional stress is only about 70 psi. Overall, the numbers in this simplified example demonstrate that cracking or other serviceability problems due to the effects of self-weight and sweep alone are unlikely.

Table 2 also shows the result of the computation of whether sweep in the example girder is likely to cause the girder to overturn on its bearings. The eccentricity of the equivalent couple from the torsional effects is easily calculated by dividing the torque T_A by the vertical reaction R_A. In this approach, the girder can be considered stable for cases where the eccentricity of the torsional moment is located within the middle third of the bearing, which ensures that the full width of the bearing remains in compression. The width of the BT-72 bottom flange is 26 in. A typical bearing pad width for this beam would be 22.5 in., which accounts for the ¾ in. bottom chamfers and a 1 in. offset on each side of the girder; therefore, the middle third extends to $\frac{22.5 \text{ in.}}{6} = 3.75 \text{ in.}$ on each side of the centerline of bearing. If the girder sweep f equals 1.631 in., the calculation for the eccentricity of the torsional moment is:

$$e_T = \frac{T_A}{R_A} = \frac{(4.72 \text{ kip-ft})(12 \text{in./ft})}{52.13 \text{ kip}}$$
$$= 1.09 \text{ in.} \leq 3.75 \text{ in.} \checkmark \text{ OK}$$

Even for the scenario in which sweep is twice the tolerance, Table 2 shows that the girder is stable when resting on its supports. Even if the girder has no sweep, bracing each end of each girder with blocking or other devices is recommended to prevent tipping and overturning of the girder in the event of wind or other lateral loads that may be applied to the girder during construction. Temporary bracing represents good practice, even if the structural computations suggest that the girder is stable. Depending on the length of the girder, midspan or multiple-point bracing may be necessary during construction. Guidance is provided in the PCI *Recommended Practice for*

Figure 2. Schematic plan and elevation of girder with sweep showing vertical reactions, torsional restraint at bearings from bracing or other means, and flexural moment at midspan for the weight of fresh concrete at completion of deck slab placement. Note: For illustration purposes sweep is exaggerated.



Lateral Stability of Precast, Prestressed Concrete Bridge Girders.[2]

Effects of Girder Sweep During Deck Slab Placement

This part of the discussion focuses on the stresses and deformations that occur within the example bridge girder with sweep as it supports the deck slab's fresh concrete weight. Construction loads, including workers, formwork, and other equipment, especially on exterior girders, should be included in a detailed analysis, but they are ignored here for simplicity of discussion. Note that stresses and deformations caused by self-weight on a girder with sweep exist prior to deck slab construction. It is assumed that girders are sufficiently braced at the time of deck slab placement.

The results of the following approximate analysis may be surprising to some. As shown in **Fig. 2**, which presents both plan and elevation views of the bridge girder with sweep supporting the weight of fresh concrete for a cast-in-place deck slab, the weight of the fresh concrete deck slab on the bridge girder with sweep does not produce torsional stresses or deformations at girder ends, if the deck is placed the full length of the girder in a single placement. (Phased construction or partial deck placement is a different situation and must receive due consideration.) For this analysis, the 8-in.-thick deck slab is assumed to be symmetrically placed about the line of action between the girder's bearings.

Figure 2a shows the arc of the centerline of the girder with sweep and the line of action between the girder's bearings. The CG of the deck slab is located directly over the line of action; therefore, there is no torsional moment at the girder ends. However, the girder will experience torsion at midspan due to the eccentricity of the deck load.

Figure 2b provides both elevation and plan views of the girder with sweep from the support to midspan. To calculate the deflection and stresses for the fresh weight of the deck slab concrete for a girder with sweep, we use the same calculations used for a straight girder (without sweep). Accordingly, there are no out-of-plane moments, no out-of-plane shears, and no torsion at the girder ends caused by the self-weight of the deck slab. It is important to analyze the effect of out-of-tolerance sweep on exterior girders. Overhanging formwork or a concrete finishing machine may place loads on an exterior girder that could possibly exceed in-service conditions.

Effects of Girder Sweep in the Completed Composite Bridge Superstructure

For this discussion, only the live loads are considered because dead loads applied to the composite section tend to be small compared to live loads. In this example, the service live load moment on an interior girder is 1621.6 kip-ft.

Note that for an interior girder, the live load moment and shear are also applied on the line of action between the bearings, and the horizontal eccentricity of the girder sweep does not produce torsional effects in the composite cross section. The analysis for the composite cross section is similar to that shown in Fig. 2 for addressing the effects the fresh concrete weight of the slab.

The primary effects caused by girder sweep when considering an individual girder with composite deck slab section for traditional longitudinal bending stress analysis are that the composite cross section becomes asymmetric near midspan, and the principal axes are not precisely vertical and horizontal. As the principal axes rotate, this also creates bending moments about both of the principal axes. However, the applied live load bending moment (1621.6 kip-ft)—which is produced by the vector addition of the two moments about the principal axes—does not change. For the case considered with sweep equal to the sweep tolerance, the rotation of the principal axes is about –0.024 rad (less than –2 degrees), which produces additional lateral moment and stress of 38.54 kip-ft and 19 psi, respectively. Therefore, the total bending stress due to live load only at the bottom of the prestressed concrete girder is 0.942 ksi (tension), which is about 2% greater than the 0.923 ksi bending stress in the cross section without sweep. This analysis demonstrates that the effects of girder sweep on the completed system for this bridge are very small.

The analysis just discussed assumes that the isolated girder and deck slab section can deflect laterally and rotate to generate bending moments in the lateral direction. When a single girder and its composite deck slab are considered, the lateral deformation remains very small—on the order 0.065 in. at midspan for the example case. However, one must recognize that any lateral deformation from the composite section of a single girder with sweep will be resisted by the whole system of girders, presumably without sweep, that are connected by the composite deck slab. Therefore, the effects on the girder when considered in the composite cross section will be further reduced from what was previously computed, and there will be virtually no lateral deformations, and therefore no stresses, in the superstructure system related to the girder with sweep.

Having considered the effect of sweep on the girder in the composite section, we will now turn to consider the effects of girder sweep on the deck slab design, which will be shown to be small. Using the example bridge, if it is assumed that the span of the deck slab increases from 65 in. (7 ft 2 in. spacing minus one-fourth of the flange width on each side) to 66.6 in. due to sweep at midspan equal to the tolerance, bending stresses in the slab due to a single point load will increase by about 2.5%.

In this simplified example, the effects of girder sweep on the stresses, serviceability, and strength in the completed bridge have been shown to be small when the girder is considered to be independent from the rest of the bridge. However, these minor effects due to asymmetry are restrained by the rest of the bridge because the composite deck ties together all girders, preventing independent girder rotation. In other words, the effects of a girder with sweep on the completed bridge are small enough that the owner should be reasonably assured that girder sweep within tolerance does not cause a significant change of the stresses and deformations due to live load in the completed structure.

What about exterior girders with sweep? Exterior girders are not generally balanced in the slab loads that they resist, so the unbalanced load from sweep would be evaluated using standard procedures.

Effects of Reducing Sweep After Girder Erection

The preceding sections show that sweep within tolerance, and in some cases even greater than tolerance, has a small effect on stresses and deformations in the prestressed concrete girder and the completed bridge. Therefore, after a girder is erected, it is generally not necessary, nor desirable, to attempt to reduce a sweep that is within, or possibly even greater than, the recommended tolerance.

The owner or engineer may wish to consider reducing the amount of sweep in a girder if the sweep exceeds tolerance. A girder with sweep should be "straightened" only to the extent that the sweep is reduced to within tolerance. For example, a girder that has a sweep of twice the sweep tolerance $2f_{tol}$ could be straightened to reduce the sweep to f_{tol}. The contractor, in consultation with an engineer and the owner, may consider straightening an out-of-tolerance girder because of concerns about deck formwork fit-up or final acceptance of the finished structure.

The first step should be to analyze the girder after erection and in the finished structure, similar to the analyses in the preceding sections, to determine whether out-of-tolerance sweep will have detrimental effects on the bridge or if the effects are small enough to be acceptable to the owner and engineer. If the analyses indicate that straightening seems advisable, a straightening plan can be developed and an analysis performed that considers the entire system that will be engaged as the force is applied to push or pull the girder with sweep into tolerance. The contractor will require engineering services to safely carry out any type of straightening scheme, as straightening a girder requires significant engineering, planning, and bracing of all affected bridge elements. Most straightening schemes will produce lateral bending and torsion in all girders involved. Although it may be possible to design a straightening method that does not twist the girders, applying such a method will further complicate the straightening operation and require more hardware, effort, and engineering expertise.

There are many possible schemes for straightening girders, and the means and methods of straightening are beyond the scope of this article. However, for the sake of this discussion, we will explore how one girder can be straightened by pushing or pulling from two adjacent girders by using diagonal bracing elements connected to the adjacent girders near their supports. **Figure 3** illustrates one possible concept for straightening a single girder using two adjacent girders for bracing. Of course, all three girders will experience lateral forces, deformations, and possibly torsion. The forces required to straighten one girder are significant, and an engineer must design or review the detailing required for attachments and hardware, as well as the effect of the straightening activity on the adjacent girders.

When straightening a girder, one method is to apply a lateral point load at midspan. The horizontal force required to "straighten" the girder can be calculated using a basic, classic mechanics formula. If our example girder has a midspan sweep of $2f_{tol}$ equal to 3.26 in., then the horizontal force F_H required to straighten the girder to within the sweep tolerance of 1.63 in., with the change in sweep taken as Δf, is:

$$F_H = \frac{48EI_{yy}}{L^3} \times \Delta f$$

$$= \frac{48(5760 \text{ ksi})(37{,}543 \text{ in.}^4)}{(130.5 \text{ ft})^3(1728 \text{ in.}^3/\text{ft}^3)}$$

$$\times (3.62 \text{ in.} - 1.63 \text{ in.}) = 4.42 \text{ kip}$$

This calculation assumes the force is applied at the centroid of the girder cross section. It also assumes that permanent end diaphragms have not yet been placed so the ends of the girder are free to rotate in the horizontal plane but are braced against overturning.

Table 3 lists F_H for reducing varying amounts of sweep. As expected, F_H increases in proportion to the amount of "straightening" that is desired. Table 3 also shows the out-of-plane

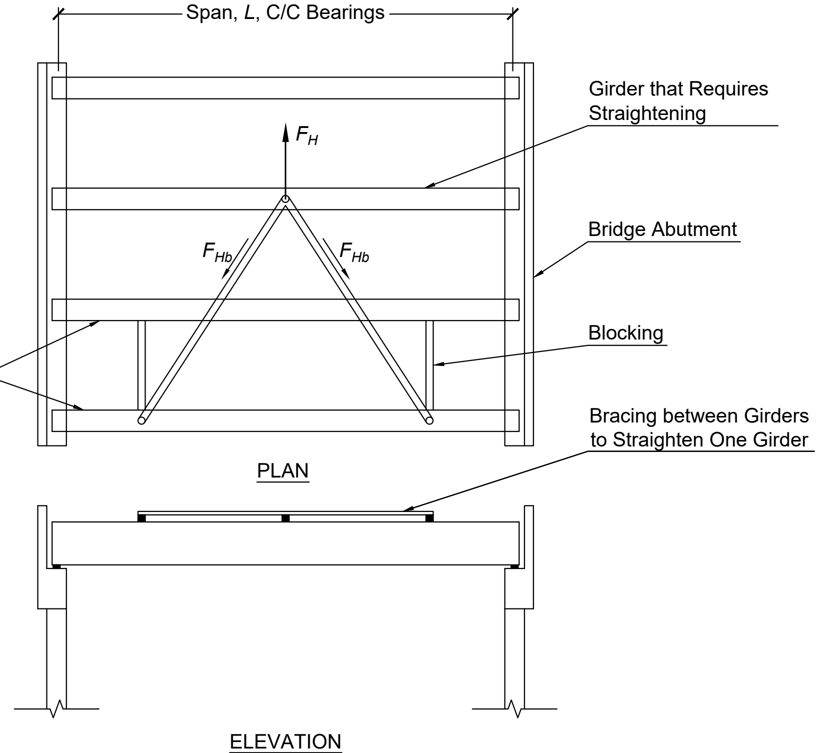


Figure 3. Schematic for possible scheme to straighten one girder in a four-girder span. Lateral girder bracing is required for stability at supports. Note: For illustration purposes girder spacing is exaggerated with respect to the girder span.

bending moment and the related bending stress that result from the straightening force being applied at the centroid of the girder cross section. These bending stresses about the weak axis are computed at the extreme top corner of the BT-72 top flange, which is 42 in. wide, and are in addition to stresses that already exist in the girder. For the example case, the lateral bending moment is 143.8 kip-ft and the additional stress at the corner of the top flange is 0.966 ksi.

$$f_t = \frac{M_{yy}c}{I_{yy}} = \frac{(143.8 \text{ kip-ft})(21 \text{ in.})(12 \text{ in./ft})}{(37{,}543 \text{ in.}^4)} = 0.966 \text{ ksi}$$

Table 3 compares this additional stress to the modulus of rupture (MOR) f_r for the girder concrete. The MOR is given by the formula $f_r = 0.24\sqrt{f'_c} = 0.24\sqrt{10 \text{ ksi}} = 0.759$ ksi. In the example case, the additional lateral bending stress at the outer edge of the top flange would be 0.966 ksi, which would exceed the MOR if there were no preexisting compressive stress in the top flange. These calculations show that the effort to straighten the girder could result in flexural cracking at the edge of the top flange if the precompression at this location is less than the difference between the two stresses, or 0.207 ksi. Table 3 reports the additional bending stresses at the extreme fiber as a result of various amounts of straightening. Total compressive stresses must also be considered.

One should note that if straightening is attempted after the end diaphragms have been placed, and rotation of the girder in the horizontal plane is prevented at the end diaphragms, the force required to straighten the same amount of sweep will increase fourfold, which in this case will be nearly 18 kip. The resulting moment, and therefore the added stresses in the girder, will double. For these reasons, cracking of the girder is more likely if straightening attempts are made after end diaphragms are placed.

When F_H is applied at the top of the girder, torsion and torsional stresses will be imposed on the bridge girders. As shown in Table 3, if the sweep correction is 1.63 in. and F_H is applied to the top flange, the imposed torsional moment will be 13.23 kip-ft and shear stresses will be in the range of 100 psi; these results are greater than the torsional restraining moments and stresses created by the

Table 3. Effects of Reducing Sweep by Applying Lateral Force F_H to Girder at Midspan

Amount of Sweep Reduction, Δf	Amount of Sweep Reduction at Midspan Δf, in.	Horizontal Force Required at Midspan F_H, kip	Moment about Weak Axis M_{yy}, kip-ft	Change in Stress at Extreme Top Fiber f_t, ksi	Change in Stress Greater than MOR ($0.24\sqrt{f'_c}$)? (Yes or No)	Torsional Restraint Required at Bearing T_A, kip-ft	Maximum Torsional Stress τ, ksi
0.0	0.00	0.00	0.00	0.000	No	0.00	0.000
0.5 f_{tol}	0.82	2.20	71.92	0.483	No	6.61	0.048
1.0 f_{tol}	1.63	4.41	143.84	0.966	Yes	13.23	0.096
1.5 f_{tol}	2.45	6.61	215.76	1.448	Yes	19.84	0.145
2.0 f_{tol}	3.26	8.82	287.69	1.931	Yes	26.45	0.193

Notes:
1. Calculations are based on a BT-72 girder with length L = 130.5 ft.
2. Sweep tolerance f_{tol} = 1.631 in. is computed from a PCI standard practice[1] where sweep tolerance is 1/8 in. per 10 ft of length.
3. Calculations assume that the horizontal force F_H is applied at the centroid of the girder cross section.
4. MOR = $0.24\sqrt{f'_c} = 0.24\sqrt{10 \text{ ksi}} = 0.759$ ksi

girder's self-weight with an initial sweep of $2f_{tol}$. Although the horizontal forces could be applied to both the top and bottom of the girders to avoid torsion, that is a jobsite decision and beyond the scope of this article.

All things considered, the computations for this example girder indicate that attempts to straighten a girder with sweep will require significant engineering analyses, planning, and the application of a force that may cause cracking in the girder being straightened. The straightening scheme would also affect the girders that are being used in the bracing system; these effects would need to be considered but have not been explored in this analysis. The owner and the engineer may wish to consider accepting a girder with out-of-tolerance sweep, particularly when, as demonstrated by the earlier discussion of this example, long-term implications for the bridge performance may not be significant. Changes to the slab formwork system may need to be considered to accommodate a girder with sweep beyond tolerance, but it is anticipated that these changes would be simpler than undertaking any straightening measures.

Summarizing the Effects of Sweep in Bridge Construction and in Service

Torsional moments, stresses, and deformations are produced for girders with sweep by the girder self-weight when it is set on the bearings. However, in the example we are discussing, the effects are relatively small, and one may therefore reasonably assume that the owner, engineer, and contractor can ignore the effects of girder sweep. The computations outlined in the discussion and summarized in the tables also clearly show that the effects of sweep do not have large impacts on the structure or the structural mechanics of the bridge during deck slab placement or after the deck slab concrete hardens and the girders become composite with the concrete bridge deck slab.

Sweep of any amount does create the need for torsional restraint at the bearings, but that restraint occurs naturally when considering the self-weight of the girder resting on its bearings. More restraint can be provided by installing bracing at girder ends.

Computations in this article demonstrate the inherent stability of girders with and without sweep. Even so, the conditions for stability must be examined for each individual case; the methods of computation provided in this article may be applied. It is the conclusion of this author that girders with sweep within tolerance can be safety erected on their bearings without any special consideration for girder sweep beyond the temporary bracing that is typically recommended at each end of each girder regardless of sweep.

This article also discusses the forces, stresses, and deformations produced when attempts to "straighten" a girder with sweep are made. Girder straightening is not recommended for girders with sweep that is within tolerance, and it may not be necessary for girders with even greater sweep. When girder straightening is desired to bring a girder's sweep within tolerance, horizontal forces are required to push or pull a girder into alignment, with bracing required against one or more adjacent girders. Three things are apparent from the computations: First, there is significant risk that the straightening attempts could cause cracking. Second, a specialty engineer must design or review the methods and details necessary for straightening to help ensure the practicality and safety of the process. Third, the straightening attempts are likely to produce torsion, torsional stresses, and lateral bending stresses in the girders that may be large enough to crack the girder(s).

It is the conclusion of this author that girders with sweep within tolerance can be safety erected on their bearings without any special consideration for girder sweep beyond the temporary bracing that is typically recommended at each end of each girder regardless of sweep.

This author has concluded that efforts to straighten a girder with sweep are most likely counterproductive to the long-term serviceability of the bridge girder and the bridge itself, and therefore recommends acceptance of girders with reasonable amounts of sweep.

Concluding Remarks

In conclusion of this three-part series, I would like to make a few additional remarks.

The causes of girder sweep are myriad and may reflect other problems or issues within the fabrication of the precast, prestressed concrete bridge girder. In those cases, the tolerance for sweep in prestressed concrete girders may play a role in the overall quality control and quality assurance programs for the production of bridge girders. These issues are discussed in Part I of this series. Additionally, the storage, handling, and transportation of prestressed concrete girders may be further complicated by girders that exhibit sweep, but the problems are manageable. These topics were covered in Parts I and II. Finally, and perhaps most importantly, the analysis described in this final article shows that constructing a bridge with a girder that exhibits a reasonable amount of sweep has little or no impact on the serviceability or strength of the bridge. Therefore, this author's conclusion is that the owner and engineer should consider allowing girders that exhibit reasonable sweep to be incorporated into a bridge. In other words, if a bridge girder with sweep beyond tolerance has been analyzed to ensure that all criteria for stability, strength, and serviceability are met, it can be transported and erected. I believe it is both expedient and reasonable for the owner and engineer to accept that girder, make no attempt to straighten it, and continue with construction.

EDITOR'S NOTE

There is an Errata for Part II published in the Fall 2019 ASPIRE included on page 3 of this issue.

(see page 3)

References

1. Precast/Prestressed Concrete Institute (PCI). 1999. *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*, 4th ed. (MNL-116-99). Chicago, IL: PCI.
2. PCI. 2016. *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*. (CB-02-16). Chicago, IL: PCI.