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Discussion: The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders

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Abstract

The research presented in "The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders"1 by Hang Nguyen, John Stanton, Marc Eberhard, and David Chapman in the September–October 2015 issue of PCI Journal is timely and useful. This article is aimed at estimating thermal camber for precast, prestressed concrete beams based on ambient temperature.

Disciplines

Civil Engineering | Geotechnical Engineering | Structural Engineering

Comments

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Discussion

The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders

The research presented in "The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders"[1] by Hang Nguyen, John Stanton, Marc Eberhard, and David Chapman in the September–October 2015 issue of *PCI Journal* is timely and useful. This article is aimed at estimating thermal camber for precast, prestressed concrete beams based on ambient temperature.

Typically, solar radiation, ambient temperature, and wind velocity influence the girder temperature profile, which in turn causes thermal deflection. The influence of solar radiation and wind velocity is collectively represented by the authors using variables A_0 and A_1 in Eq. (19) and (23), respectively.

$$\Delta_{camber} = \frac{\alpha A_0}{h}\left[T_{amb,eff}(t) - T_{min}\right]\frac{L^2}{8} \tag{19}$$

where

Δ_{camber} = camber of girder

α = coefficient of thermal expansion

A_0 = calibration factor

h = depth of the girder

$T_{amb,eff}(t)$ = effective ambient temperature at time t

t = time

T_{min} = minimum air temperature during the 24-hour period

L = length of the girder

$$\Delta_{camber} = \left(\frac{\alpha A_1}{h}\right)\left(\frac{(T_{max} - T_{min})\left\{1 - \cos\left[\frac{(t - t_0)}{24}2\pi\right]\right\}}{2}\right)\left(\frac{L^2}{8}\right) \tag{23}$$

A_1 = calibration factor

T_{max} = maximum air temperature during the 24-hour period

t_0 = reference time for counting thermal camber during a day

These variables are also assumed to account for the differences between the actual concrete temperature profile and assumed linear profile and the actual and assumed thermal coefficient of expansion. The article established 1.31 and 1.28, respectively, for these two variables, by calibrating against measured camber and temperature data (for example, T_{max} and T_{min}).

Although the suggested equations and A_0 and A_1 values appear to accurately represent the data reported in the paper, it appears to have not recognized one critical point. The most influential parameter that affects the girder temperature is solar radiation, which can vary among the four different meteorological seasons.[2] This issue may not be a concern for the West Coast, but it significantly affects the thermal camber in the Midwest and East Coast, as demonstrated in a recent study of girders in Iowa.[3] The data collected as part of the referenced project confirmed that the thermal camber of a precast, prestressed concrete beam in summer can be as much as

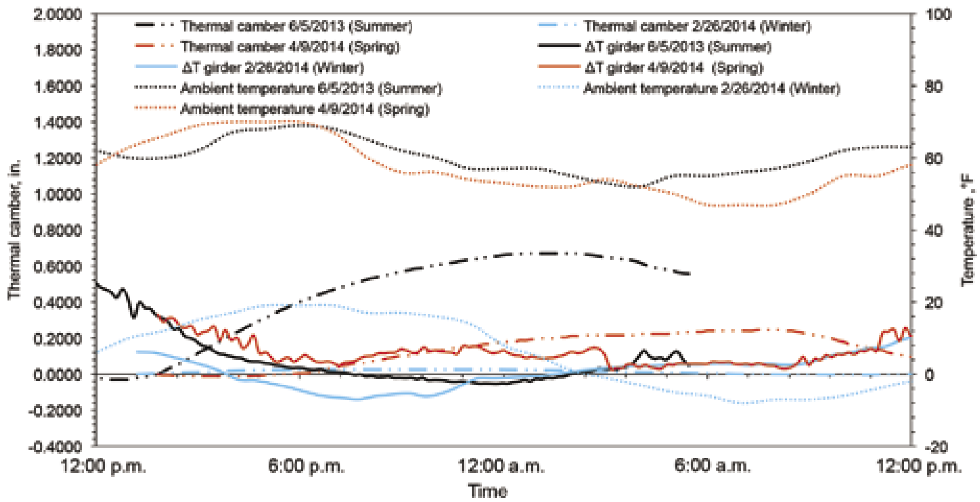

Figure 1. Variation of measured thermal camber, ambient air temperature, and the girder temperature difference between the top and bottom flange surfaces for a BTE145 girder. Note: ΔT = temperature difference over the height of the girder. 1 in. = 25.4 mm; °C = (°F – 32)/1.8.

0.74 in. (18.8 mm) whereas the corresponding value in winter is almost zero, though the difference between the maximum and minimum ambient temperatures is comparable. This highlights the impact of solar radiation on the girder temperature. Capturing this phenomenon using A_0 and A_1 and the ambient temperature as approached in the paper[1] may not produce accurate camber in different seasons. This aspect is further explained in Fig. 1 using a standard Iowa Department of Transportation prestressed BTE145 girder with a length of 145 ft (44.2 m) and height of 63 in. (1600 mm).

Figure 1 shows thermal camber measured for a BTE145 girder over several hours in three different seasons and the girder temperature difference between the top and bottom flange surfaces. Also shown in this figure is the ambient temperature for the three cases. A summary of the maximum camber values is presented in Table 1 with those predicted using Eq. (19) with three different A_0 values: 1.31, 0.66, and 1.97. This includes the suggested A_0 as well as ±50% variation on A_0 to account for the scatter reported for this variable in the article by Nguyen et al.[1] Based on the information presented in Fig. 1 and Table 1, the following observations can be made:

- With appropriate consideration of time lag, the thermal camber is more reflective of the girder temperature difference than the ambient temperature difference, and the correlation between the girder temperature difference and the ambient temperature difference is generally not good. The main parameter that separates these two temperature differ-

Table 1. Maximum measured and predicted thermal camber within one day for a BTE145 girder in different seasons and critical temperatures

Season	Measured $T_{max} - T_{min}$, °F	Measured maximum ΔT girder, °F	Measured maximum thermal camber,* in.	Estimated maximum thermal camber using Eq. (19), in.		
				A_0 = 1.31	A_0 = 0.66	A_0 = 1.97
Summer	13	29	0.74	0.53	0.27	0.80
Winter	30	11	0.04	1.30	0.65	1.95
Spring	38	17	0.25	1.64	0.82	2.47

Note: A_0 = calibration factor; T_{max} = maximum air temperature during the 24-hour period; T_{min} = minimum air temperature during the 24-hour period; ΔT = temperature difference over the height of the girder. 1 in. = 25.4 mm; °C = (°F – 32)/1.8.

*Source: Data from Honarvar, Sritharan, Rouse, and Meeker (under review).

ences is solar radiation, and this is most intense in summer and least intense in winter. A more realistic thermal camber estimate may be obtained using the girder temperature difference, which can be estimated using seasonal measurements available for a given region as demonstrated by Honarvar et al.[2]

- A fairly good agreement between the measured and calculated maximum thermal camber is seen for the summer in Table 1, while poor correlations are observed for the spring and winter days. The use of the suggested A_0 captures the influence of solar radiation for summer within the expected scatter.
- The suggested A_0 value is generally inappropriate for calculating the camber in winter, spring, and fall in regions where solar radiation changes throughout the year. Consequently, Eq. (19) will significantly overestimate the thermal camber for these seasons.

The thermal cambers were also calculated using Eq. (23) and are compared with the measured cambers and those obtained from Eq. (19) for the same BTE145 girder in Table 2. Equation (23), which has the same deficiency in capturing the impact of seasonal effects because it also estimates the thermal camber based on the ambient temperature, provides estimates that are comparable to those obtained from Eq. (19). However, the predicted thermal camber in Fig. 11 and 12 in the paper[1] includes negative values, though Eq. (23) suggests that thermal camber will always be positive since $T_{max} \geq T_{min}$. It may be useful to clarify what reference camber was used as the datum to obtain the change in thermal camber reported in these figures.

Table 2. Maximum measured and predicted thermal camber within one day for a BTE145 girder in different seasons

Season	Measured maximum thermal camber,* in.	Estimated maximum thermal camber, in.	
		Eq. (19)† with A_0 = 1.31	Eq. (23)† with A_1 = 1.28
Summer	0.74	0.53	0.55
Winter	0.04	1.30	1.26
Spring	0.25	1.64	1.60

Note: A_0 = calibration factor; A_1 = calibration factor. 1 in. = 25.4 mm; °C = (°F – 32)/1.8.
* Data from Honarvar, Sritharan, Rouse, and Meeker (under review).
† Data from Nguyen, H., J. Stanton, M. Eberhard, and D. Chapman (2015).

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References

1. Nguyen, H., J. Stanton, M. Eberhard, and D. Chapman. 2015. "The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders." *PCI Journal* 60 (5): 48–63.
2. Honarvar, E., S. Sritharan, J. M. Rouse, and W. Q. Meeker. "Precast Pretensioned Concrete Beams: Incorporation of Thermal Effects into Camber and Stress Analyses." Under review, *Engineering Structures Journal*.
3. Honarvar, E., J. Nervig, W. He, S. Sritharan, and J. M. Rouse. 2015. "Improving the Accuracy of Camber Predictions for Precast Pretensioned Concrete Beams." Final report for Iowa Highway Research Board project TR-625. Ames, Iowa: Iowa Department of Transportation.

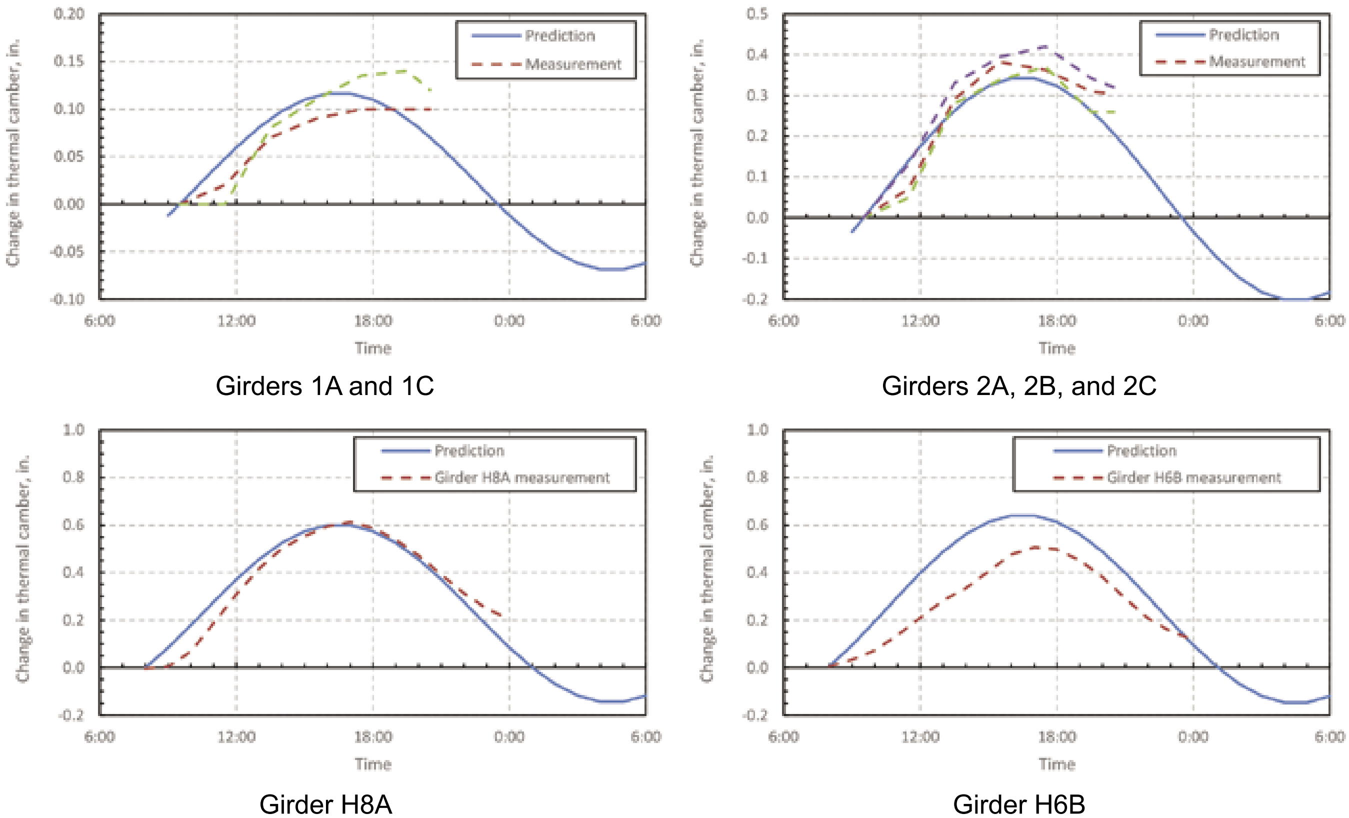


Figure 11. Comparison of measured and calculated thermal camber changes for Washington State girders. Note: 1 in. = 25.4 mm.

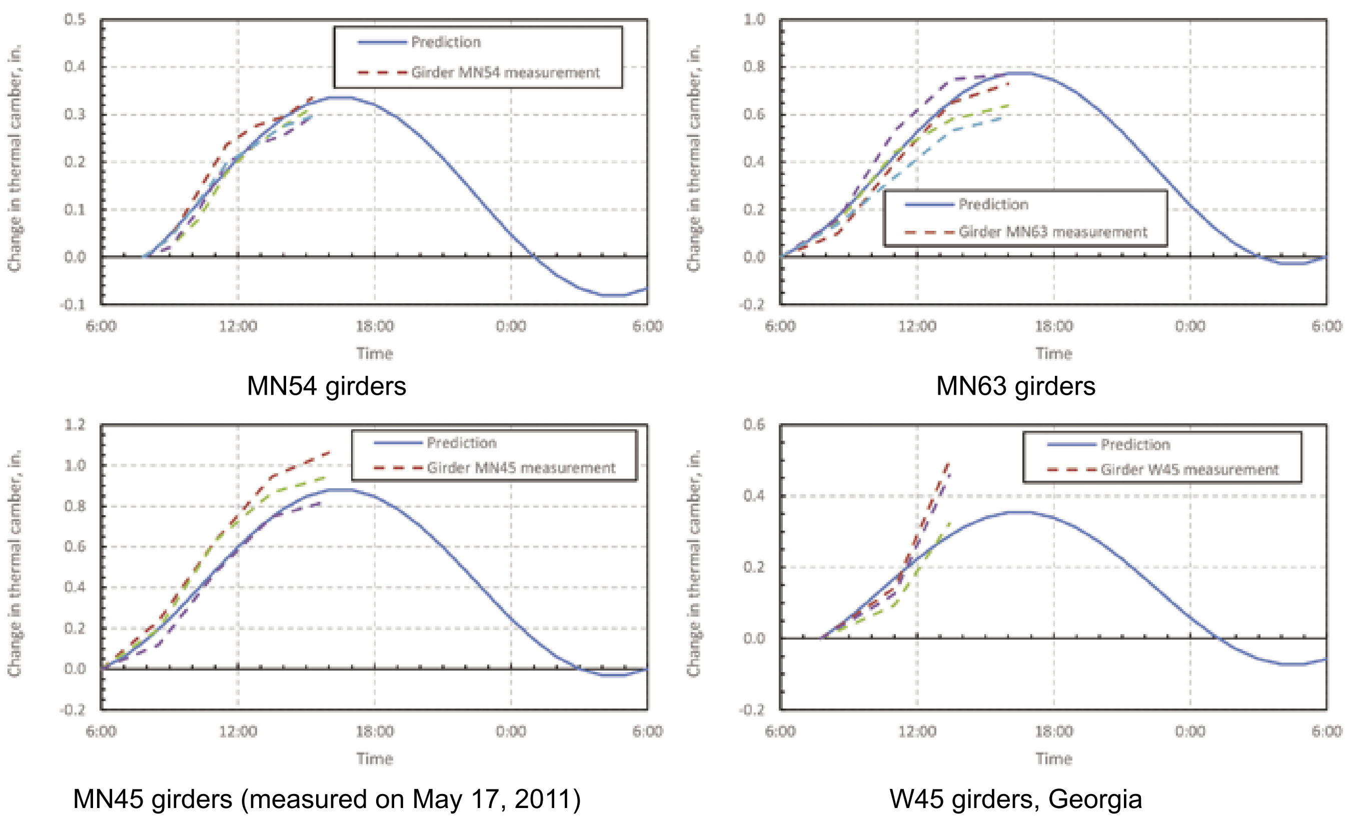
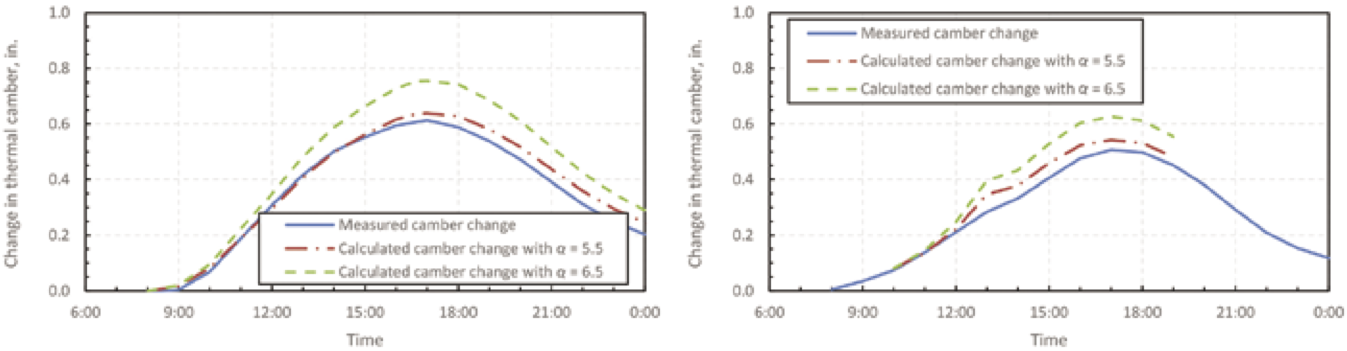


Figure 12. Comparison of measured and calculated thermal camber changes for Minnesota State and Georgia State girders. Note: 1 in. = 25.4 mm.



Girder H8A

Girder H6B

Figure 6. Comparison of calculated and measured thermal cambers. Note: 1 in. = 25.4 mm.

Authors' response

The authors would like to thank Sri Sritharan and Ebadollah Honarvar for their insightful comments on our paper.[1]

The primary point that they raise is that the effects of solar radiation are not included in the models presented in the original paper and that they have been overlooked.

The first observation is correct; the models do not account for the effects of solar radiation. However, these effects were not overlooked. Rather, they were disregarded in the interests of keeping the model simple and making it dependent only on input data that are readily available. That decision implies a choice between a relatively accurate model that requires data that may or not be available and one that can provide an approximate prediction with easily available information. Such trade-offs occur in many modeling efforts.

For example, the discussers point out that better correlation with camber can be obtained if the girder temperatures are used. We agree, and we also found good correlation between measured cambers and those predicted from the internal temperatures when the latter were available. Figure 6 in the paper shows an example. However, the question arises of what to do if the internal girder temperatures are not available, and that is what the approximate models are intended to address. It is not clear how the discussers obtain girder temperatures from "seasonal measurements for a given region as demonstrated by Honarvar et al.[2]" because that paper was not available at the time of publication. If there is an easy way of developing accurate thermal profiles for a girder from meteorological information, we would welcome its use because it would certainly improve the models' predictions.

The models could likely be rendered more accurate if different values for the calibration constants A_0 and A_1 were adopted for different seasons (and possibly different regions or states), but such changes would come at the expense of simplicity.

The discussers further point out that the proposed models work better in the summer, when solar radiation is high. This is to be expected because the data against which they were calibrated comes largely from summer months. This, in turn, is to be expected because construction tends to be concentrated in the summer months. That is convenient in that it means that the approximate models will be most applicable during the time when most construction happens because the importance of camber is greatest during construction before the deck is cast.

Last, the discussers seek clarification on the datum for temperature in Fig. 11 and 12 because some values in those figures are negative. The figures show temperature change, rather than absolute temperature, so there is no datum. The values shown are relative to the temperature at the start of reading.

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References

1. Nguyen, H., J. Stanton, M. Eberhard, and D. Chapman. 2015. "The Effect of Temperature Variations on the Camber of Precast, Prestressed Concrete Girders." *PCI Journal* 60 (5): 48–63.
2. Honarvar, E., S. Sritharan, J. M. Rouse, and W. Q. Meeker. 2015. "Precast Pretensioned Concrete Beams: Incorporation of Thermal Effects into Camber and Stress Analyses." Under review, *Engineering Structures Journal*.

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