Wind Load on Bridges during Construction

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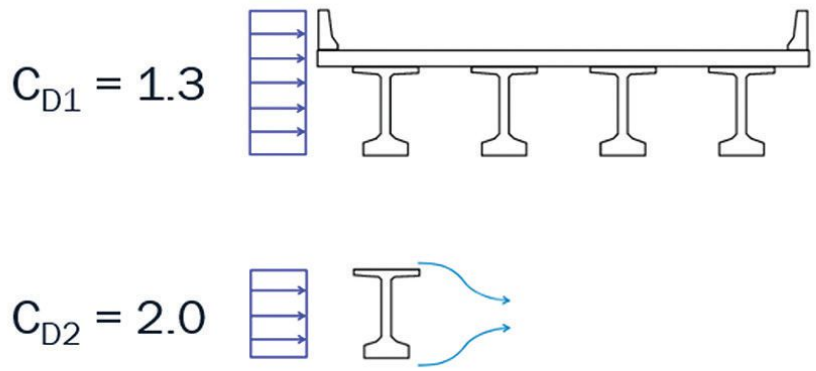


Figure 1. Due to airflow around the bare girder, the base drag coefficient C_D on a bare precast concrete girder is greater than on a completed bridge, even though the completed bridge has a larger area exposed to wind. Figure: Parsons.

The effects of wind on a bridge vary throughout the life of the structure. There is variability in wind speed and direction; additionally, the size and shape of the structure continually change during construction. These variables drastically affect wind loading. As a bridge is constructed, girders are added, exposed wind area increases, and drag coefficients change until the deck is placed. It is important to consider these changing conditions during the design phase to reduce potential issues during construction.

Brief History Lesson

The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] provides guidance for wind loads applied on the completed bridge structure, but it does not consider wind load applied during construction. Although the return period is much shorter during construction, the wind-load effects on the partially completed structure are significantly different than those on the completed bridge and may control portions of the bridge design.

Before 2017, there was no specific guidance for wind loads on bridges during construction, so erection engineers relied on their best judgment for erection analysis. The first edition of the AASHTO *Guide Specifications for Wind Loads on Bridges during Construction*[2] was published in 2017 to address wind loads during the construction phase until the deck is placed. The guide specifications provide comprehensive guidance during bridge construction and introduce three new concepts for the temporary condition: revised drag coefficients, drag modification factors based on girder position, and active versus inactive work zones.

The AASHTO Guide Specifications for Wind Loads on Bridges during Construction *introduced*

- revised base drag coefficients for bare girders versus the completed bridge,
- drag modification factors on undecked, multiple-girder systems, and
- definitions of active and inactive work zones.

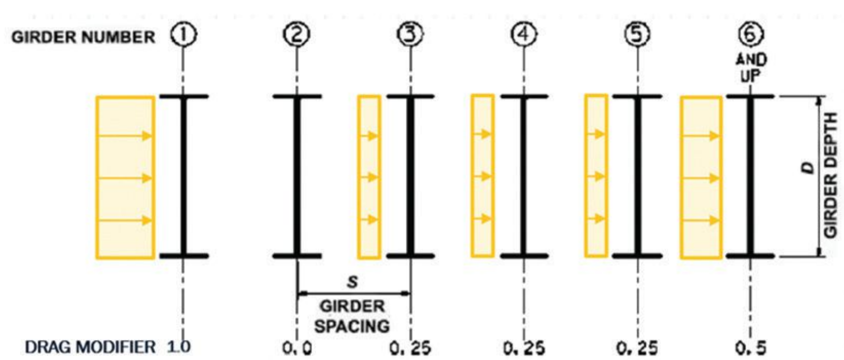
Base Drag Coefficients for Bare Girders

For bridge design, the AASHTO LRFD specifications provide a drag coefficient of 1.3 for the completed bridge to be applied to the exposed area from the bottom of the lowest girder to the top of the barrier. However, the AASHTO guide specifications for wind loads during construction specify drag coefficients that are significantly higher for girders before the deck is placed (for example, 2.0 for a bare precast concrete I-girder and 2.2 for a bare steel I-girder). The increased base drag coefficient is a result of the air's ability to flow around the bare girder, which is prevented once the deck is placed (**Fig. 1**).

Drag Modifier on Undecked, Multiple-Girder Systems

In multiple-girder systems, a modifier is applied to the base drag coefficient

Figure 2. Drag modifiers for leeward girders with spacing-to-depth ratios less than 3, which are common for most bridges. Figure: Modified from Fig. C4.2.1-1 in the American Association of State Highway and Transportation Officials' Guide Specifications for Wind Loads on Bridges during Construction.[2]



C_D depending on the girder spacing-to-depth ratio and the position of the girder in the system (**Fig. 2**). The combined drag coefficient on the system is the product of the base drag coefficient multiplied by the sum of the individual girder drag modifiers (C_D × sum of drag modifiers). The combined drag coefficient is 2.0 with one or two girders erected but increases to 4.5 with six girders erected. **Table 1** shows that the combined drag on the system continues to increase as more girders are added. Typically, the worst-case loading for an individual girder exists with only one girder erected but the highest total wind load on the system occurs when all girders in the cross section are erected.

Active versus Inactive Work Zones

The AASHTO guide specifications for wind loads provide explicit definitions of *active* and *inactive* work zones with distinctly different wind speeds. The work zone is active when workers are on site with erection in progress and subjected to 20-mph winds. The work zone is inactive at all other times, including "time between work shifts," and is subjected to 75-mph winds (the AASHTO guide specifications' 115-mph reference wind speed reduced by a duration factor) for most typical bridges in the United States.

Examples

Figure 3 illustrates how wind loads vary as construction progresses for a typical bridge with eight precast concrete girders. The top portion of the figure shows the wind load after all girders are erected but before the deck formwork. The bottom portion of the figure shows the wind load after the deck and barrier are cast. **Table 2** presents a comparison of the design values for this example bridge. Although the overall structure depth is greater and the wind speed is higher for the completed bridge, the accumulation of drag modifiers on the undecked leeward girders imposes significantly more wind load on the undecked girder-only system.

This example shows that the wind load can be significantly higher during construction than for the remaining duration of the structure's life. In addition, there is a greater risk for girder instability during the construction stage without the deck to brace the compression flange.

Table 1. Examples of system drag coefficients

Number of girders erected	Base drag coefficient	Sum of drag modifiers	Combined drag coefficient on the system
1	2.0	1.0	2.0
2	2.0	1.0	2.0
4	2.0	1.5	3.0
6	2.0	2.25	4.5
8	2.0	3.25	6.5
10	2.0	4.25	8.5

Recommendations

Wind loads during bridge construction should be considered during design. Although the contractor makes final decisions on the girder erection sequence, bridge designers should check critical stages of erection using realistic assumptions to ensure that girders have adequate strength during the intermediate construction phases. If a girder requires strengthening, such as increased flange width or the introduction of top-flange prestressing strands, the designer is the best-suited professional to incorporate these elements into the design. Because such changes may influence the behavior of the in-service structure, these types of decisions should not be left to the contractor or the erection engineer. After the girders have been cast, there are limited options to minimize the impacts of wind loads.

Typical cross bracing between girders helps distribute the wind load among all girders but does not improve the lateral capacity of individual girders (**Fig. 4**). Cross bracing should not be confused with plan bracing (**Fig. 5**). Although plan bracing increases the lateral strength of the bare-girder system, it is rarely used for precast concrete girder bridges.

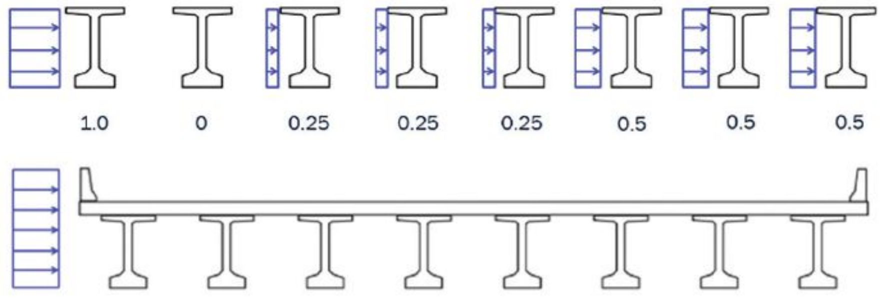


Figure 3. Comparison of wind loads on a girder-only system versus the completed bridge. Figure: Parsons.

Table 2. Comparison of wind load for an example bridge during construction and in the completed condition

	Undecked girder-only system	Completed bridge
Wind speed, mph	115 (inactive work zone)	115 (design)
Duration factor (undecked for 1–6 weeks)	0.65	1.0
Wind speed × duration factor, mph	75	115
Base drag coefficient	2.0 (on fascia girder)	1.3
Base wind pressure, lb/ft^2	28.6	44.0
Sum of drag modifiers of erected girders (see Fig. 3)	3.25	Not applicable
Total lateral wind pressure, lb/ft^2	28.6 × 3.25 ≐ 93.0	44.0
Structure depth, ft	8.5	13
Total wind load on structure, lb/ft	790	572

Figure 4. Typical wood cross bracing helps distribute wind load to all girders but does not provide additional strength to individual girders. Photo: Kicking Horse Canyon Constructors.

> ### *Deck formwork reduces wind loads by:*
>
> - Disrupting airflow around the girders, thus reducing the base drag coefficient
> - Eliminating drag on leeward girders

Conclusion

Deck formwork significantly reduces the wind load by disrupting the airflow around the girders (which lowers the base drag coefficient) and also eliminates drag on all leeward girders. Even if a diligent contractor installs deck formwork immediately following girder erection, the AASHTO guide specifications for wind loads still require the inactive wind load to be considered during the time between shifts until deck formwork is complete.

Wind loads on an undecked girder system are significant. Instead of spending the time, effort, and expense to resist high wind loads during construction of every bridge, it may be prudent to implement a risk-based system that evaluates how damaged girders would affect the surrounding area. For example, failure of girders erected over a frequently traveled highway would cause much more damage and disruption than a comparable failure at a rural, offline bridge crossing a stream. The current guidance in the AASHTO guide specifications for wind loads does not make a distinction between these types of bridges during construction.

The addition of another work zone category between active and inactive is worth considering. The most critical wind-exposure time frame occurs between girder erection and deck forming, but this time could be as little as one week for precast concrete bridges. It is easy to reasonably predict the threat of severe weather within a relatively short time frame following erection (for example, 7 to 10 days). Project teams use forecasts to determine if weather conditions are suitable to cast and cure concrete, but this concept is not used for wind loads. Allowing owners and contractors to use weather forecasts to place reasonable limits on near-term wind speeds may benefit both parties.

It is important for owners, designers, and contractors to understand how the wind load changes as bridges are built. The AASHTO guide specifications for wind loads provide design provisions for wind loads during bridge construction, but minor changes to those provisions could provide time and cost savings with a negligible increase in risk.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications.* 9th ed. Washington, DC: AASHTO.
2. AASHTO. 2017. *Guide Specifications for Wind Loads on Bridges during Construction*. Washington, DC: AASHTO.

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Figure 5. Typical cross bracing layout (left). Plan bracing (right) is uncommon in precast concrete girder bridges. Figure: Parsons.