



Lateral Stability: Who Owns the Risk?

by J.P. Binard, Precast Systems Engineering LLC, and Glenn Myers, Atkins

A 209-ft-long, 96-in.-deep Florida I-beam being transported from a precast concrete plant. Photo: Durastress.

Prestressed concrete girders are widely used for construction of bridges in the United States, and have been used successfully since their introduction. The girders are generally designed for initial conditions at the transfer of the prestress force and for final conditions with the girder incorporated into the bridge.

One of the features of prestressed concrete girders is that they are fabricated in a manufacturing facility rather than at the project site. Therefore, they must be handled several times and transported prior to erection in their final locations in the bridge. Accidents or near-miss incidents have often been traced to assumptions that are made with a lack of complete control or complete information or awareness of interdependencies of variables regarding what is required to achieve the final positive outcome. In other words, the designer does not know the route or the equipment being used by the contractor and producer.

With newer types of girder sections and advances in materials, designers can now design girders that are significantly longer than those of the past. With the increased length comes an increased risk of lateral instability of the girder during handling or transportation, which can lead to damage or collapse of a girder. While such events are rare, those that have occurred are reminders that lateral stability of girders is an issue that needs to be considered by designers, contractors, and precast manufacturers.

The industry has recognized the need for improved methods for analysis of lateral stability of prestressed concrete girders at each stage of handling and transportation. When such an analysis is

made, it is important that assumptions made by the designer in assessing the lateral stability of a girder and design modifications required to address lateral stability are clearly presented in the contract documents. This alerts the contractor and precast producer to potential issues, and allows them to assess their risks during the bidding process. Behavior of the girder during each of the following stages should be considered:

- transfer of prestress force,
- lifting the girder from the casting bed,
- transportation to the storage yard,
- support conditions in the storage yard,
- transportation to the project site,
- erection at the project site, and
- bracing requirements during the construction of the deck or post-tensioning operations.

Early work done by Mast^{1,2} has now been extended and refined in the recently released publication from PCI: *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*.³ This comprehensive document has established the methods for analysis. This is a step forward in addressing the lateral stability of girders.

A major issue, however, remains to be answered, which is who owns the risk for each of the activities listed above: designer, contractor, owner, or precast producer? There is no consensus and the question remains controversial.

A common issue with many contracts is that there is no assignment of responsibility for stability analysis during each of these construction phases. With this lack of definition, many contractors elect to take responsibility for only the

areas that are clearly within their scope of work and pass the remainder to the precast producer. The primary problem with this approach is related to technical competency, time, and transparency. The procurement procedure typically results in selection of the producer at a late stage in the project. If changes are made to the girder design to accommodate any of the construction phases, they can have significant schedule and coordination impacts.

PCI's *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* offers guidance on how to address each step in the fabrication, delivery, and bridge completion cycle. The document assigns the role of responsible charge to a "stability engineer." This category of engineer is necessary because clear lines of responsibility have yet to be identified. The *AASHTO LRFD Bridge Design Specifications* are unclear: Section 5.5.4.3 states that stability shall be investigated; however, no responsible party is identified. The AASHTO Technical Committee T-10, Concrete Design, is currently considering how to address this matter and provide more explicit direction in the AASHTO LRFD specifications.

It is the opinion of the authors that designers must consider aspects of the construction process within the scope of their work and indicate on the contract plans their assumptions regarding lateral stability that they believe will provide a constructible solution. All modifications to the concepts presented by the designer in the plans are the responsibility of the contractor and producer. The stated assumptions for the transportation vehicle, maximum sweep, and route

extreme characteristics will be an area that the designer will need agency and industry input. The result is less overall risk to the project, less uncertainty during the bidding process, and a collaborative platform where all parties are working under the same set of initial assumptions.

Handling in the Yard

A pivotal aspect of the design of precast, prestressed concrete girders is the concrete strength at time of transfer. Transfer strength requirements have economic implications relating to fabrication turnover time on a casting bed as well as design impacts pertaining to prestress losses, primarily due to creep and camber. The standard of care requires the designer to specify this strength. Techniques such as debonding (sheathing) strands, temporary top strands, and draping or harping (deflecting the position of the center of gravity of the strands downward), are used at transfer of prestress to control stresses. Minimizing the concrete strength at transfer is part of an economical design.

Immediately after the prestressing force is transferred to the girder, the product must be lifted and moved to allow the casting bed to be set up for the next casting. The support conditions assumed in design are altered during this handling as the girder is moved from the bed (end support) to hanging from lifting loops to sitting on dunnage (at locations that may vary from design bearing locations), while the concrete is still at this early strength. These changes in support conditions may influence the design strength required at transfer.

Lifting the girder or moving it from the bed to storage with travel lifts or by other means imparts a dynamic force, whereby the self-weight of the product is effectively decreased or increased. This dynamic force commonly makes the storage load case less critical, as long as the lift points are also the dunnage locations and the dunnage is placed on a level surface capable of providing adequate bearing resistance.

Stability during Lifting

Lifting the girder from the haul vehicle to erect it in the bridge typically does not control the design. The concrete strength at this time is higher and the

prestress losses have reduced the effective prestress in the girder. Dynamic forces are also typically less than in the precast yard because a stationary crane is generally used.

The initial and final lifting stages described previously contain a lateral-stability component. Lift points may be considered a compromise of stress and stability in longer-span products. Equilibrium of the precast, prestressed concrete girder, as originally published by Mast and developed further in PCI's Recommended Practice, is a function of several items, including span length, overhang beyond lift points, stiffness of the product, and estimated sweep based on maximum tolerances in accordance with PCI's *Tolerance Manual for Precast and Prestressed Concrete Construction* (MNL-135). The concepts of equilibrium are then used to establish allowable lifting locations for stress conditions at both transfer and erection. Thus, at a minimum, initial design computations should address lifting as it pertains to lateral stability and stress for a functional design.

Stability in Transportation

Transportation is a more elusive matter. The equipment for hauling long-span bridge girders is specialized and varies by region and by hauler. Furthermore, terrain challenges vary from project to project. Both Mast and the PCI Recommended Practice provide a method of evaluation that can be considered for the safe and successful transportation of these components.

It is very likely that this set of minimum criteria will be altered by contractor or precast producer in the shop drawing and submittal phase. The original assumptions in the design phase can serve as a benchmark for the appropriate standard of care that the girder is transportable under a certain set of assumptions and a preferred hauling route. Publications and proprietary software provide the necessary guidance to establish the upper and lower bounds of acceptability for this condition.

Stability at the Project Site

After the girder has been handled and stored properly, and successfully shipped and erected at the project site, the remaining task is providing adequate



Forms for deck paving and rail for paving equipment create eccentric loading on exterior girder. Photo: Atkins.

bracing and checking the exterior girders for torsion from the deck overhang and paving equipment. Skews make this more complicated, but in general this step is already within the scope of work of the contractor to vet their on-site scheme for safe and successful completion of the bridge. Occasionally unique conditions may be analyzed by the designer in advance to provide a comprehensive overview of all limit states that may impact the original design.

Conclusion

All parties are responsible for the safe execution of construction and the quality of a structure. It is often forgotten that design and construction are iterative processes during which we continually home in on the final, successful solution by a myriad of steps involving collaboration, communication, and execution. Lateral stability is no different and may be the most important parameter for future projects as our industry continues to evolve and adapt to greater challenges in construction.

To promote awareness of lateral-stability issues and communication among all parties, PCI is developing a spreadsheet tool for lateral-stability computations based on the *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*.

References

1. Mast, Robert F. 1989. "Lateral Stability of Long Prestressed Concrete Beams Part 1." *PCI Journal* 34 (1): 34-53.
2. Mast, Robert F. 1993. "Lateral Stability of Long Prestressed Concrete Beams Part 2." *PCI Journal* 38 (1): 70-88.
3. PCI Bridge Committee. 2016. *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*. CB-02-16. 1st ed. Chicago, IL: PCI. 