Temporary Top Strands in Prestressed Concrete Girders

by Dr. Krista M. Brown

Extending spans using taller girders, high-performance concrete, and more strands packed into the bottom flange leads to prestressed concrete girders with increased compressive stresses in the bottom fibers and increased tensile stresses in the top fibers at the ends of the girder, as well as the potential for large cambers. In addition, these aspects of current designs can make it challenging to achieve girder stability during handling, shipping, and erection; necessitate debonding of some bottom strands; or require higher concrete strengths at transfer or additional prestressing. Addressing these challenges can become a vicious cycle, which may not have a good solution. In an effort to temper the adverse effects of an increased prestressing force, some designers and precasters make use of temporary strands in the top flange.

What Are Temporary Top Strands?

Temporary top strands are fully tensioned strands that are installed in the top flange of a prestressed concrete girder and are typically only intended to function until the girder is erected and braced. They can be either pretensioned or post-tensioned. If pretensioned, the temporary strands are tensioned at the same time as all other strands, before the concrete is placed. If post-tensioned, the temporary strands are typically post-tensioned after the transfer of prestress of the permanent strands, either while the girder is still on the casting bed or shortly thereafter while the girder is still in the precaster's yard. If pretensioned, the strands are generally bonded for about 10 to 15 ft at each end, and the remaining portion of the strands in the midsection of the girder is debonded, typically with a sleeve. Post-tensioned temporary strands may be unbonded for their full length or bonded at one end.

With either pretensioning or post-tensioning, the temporary top strands are detensioned after the girders are erected and temporarily braced, but before the permanent diaphragms are installed. Pretensioned strands are detensioned using the same process that is used in the plant for permanent strands: One at a time and working in a symmetrical pattern, a strand is heated with a flame to relax (yield) the strand and gradually release the force before individual wires break. The strand is not "cut," even though that term is commonly used.

Post-tensioned temporary strands are used less frequently than pretensioned temporary strands, and the detensioning processes for the post-tensioned strands vary. Sometimes, the force in each post-tensioned temporary strand is backed off using a jack, one at a time in a symmetrical pattern. Because the post-tensioned temporary strands are not bonded, extra care should be given to this process. Another detensioning technique for post-tensioned strands is to provide a slot in the live-end bearing plate and place material behind the plate to create a small void; then, an acetylene torch can be used to relax the strand just ahead of the anchor. Care must be taken to ensure all personnel are clear of both ends of the girder during the detensioning process.[1]

Occasionally, external temporary strands are used to control stresses in girders. This article does not address that option.

What Is the Function of Temporary Top Strands?

The benefits of placing strands in the top flange have been documented.[2–4] They include controlling tensile stresses in the top fiber and compressive stresses in the bottom fiber near girder ends; improving lateral stability of the girder during handling, shipping, and erection; and reducing camber. Secondary benefits can include the ability to use a lower concrete design strength at transfer and reducing the need to debond as many strands in the bottom flange. The downside is that permanent top strands partially offset the desirable effect of compression in the bottom flange for in-service conditions. The best of both worlds is to take advantage of top strands before the bridge deck is placed and have the full advantage of bottom-flange strands and/or harped strands thereafter.

Guidance and Design

Top temporary strands may be included in the engineer of record's original design or added by a precaster at the shop drawing stage (with the approval of the engineer of record) to enhance lateral stability of the girder and/or reduce the concrete stresses or the required concrete strength at transfer.

For temporary top strands, typical design requirements may not apply or may be absent altogether. Article 5.9.4.5 of the *AASHTO LRFD Bridge Design Specifications*[5] briefly addresses temporary top strands. The following items are noteworthy:

- Detensioning shall be shown in the construction sequence.
- The development length of the pretensioned strands shall be determined per Article 5.9.4.3.3 ($\kappa = 2.0$), but no other provisions of debonded strands (Article 5.9.3.3) shall apply to temporary strands.
- The effects of temporary strands must be considered when determining camber and loss of prestress, both before and after the temporary top strands are detensioned.

The first item ensures that the proper instructions will be conveyed to everyone involved in girder fabrication and construction. The second points out that the restrictions on the number of debonded strands in a row and the length of debonding do not apply to temporary top strands. The last item directs the engineer to take the temporary strands into account when determining prestress losses and camber. Also, the commentary recommends that the inside diameter of the debonding sleeve should be 0.18 to

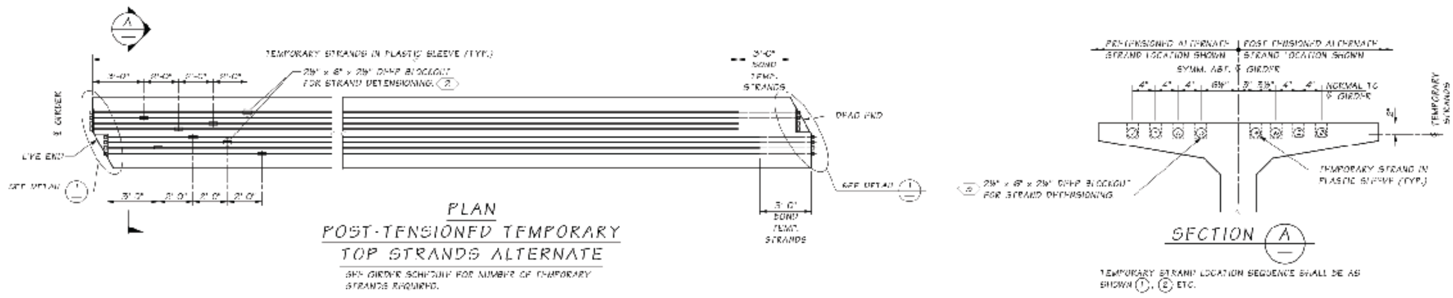

Figure 1. Excerpt from Washington State Department of Transportation standard details for pretensioned and post-tensioned temporary top strands. All Figures: Washington State Department of Transportation.

0.25 in. larger than the strand diameter; timing of detensioning (after bracing but before permanent diaphragms); and treatment of access pockets to prevent water accumulation and subsequent freezing.

While some state departments of transportation may mention in their bridge design manuals or specifications that temporary top strands are either allowed or not permitted, Washington State Department of Transportation (WSDOT) gives specific directions, details, and example calculations for temporary top strands.[6,7] **Figure 1** shows WSDOT standard details for pretensioned and post-tensioned temporary top strands, and **Fig. 2** illustrates the change in camber that occurs when the temporary strands are detensioned after erection. The WSDOT *Bridge Design Manual (LRFD)*[6] includes a prestressed concrete girder design example that shows calculations for prestress loss, camber, and camber growth associated with temporary top strands. The WSDOT bridge design software *PGSuper*™ also has the ability to make these calculations. For construction, WSDOT requires that the detensioning process be included in the construction sequence. WSDOT also specifies that temporary top strands be tensioned to $0.75f_{pu}$, where f_{pu} is the specified ultimate tensile strength of the prestressing strand. For other agencies and owners, the temporary strands are tensioned to the stress that is required for the specific design application, up to the $0.75f_{pu}$ maximum.

The reduction in camber due to temporary top strands is not fully regained after detensioning those strands because additional prestress losses have occurred and the concrete has gained strength. Furthermore, if the initial camber is smaller, so is the camber growth. However, if the temporary top strands were not considered in the original design and the camber is less than originally predicted, the reduced camber could lead to changes in material quantities or vertical profile for a bridge. An increase in the haunch depth (the concrete between the top of the girder and the bottom of the deck), especially for girders with wide top flanges, would increase the dead load, which would affect the demand at service and strength limit states. If a prestresser recognizes the need for temporary top strands early in the project, the contractor can be notified of the expected change in camber so adjustments can be made to bearing seat elevations to accommodate the reduced camber.

Why Is There Reluctance to Use Temporary Top Strands?

Temporary top strands in prestressed concrete girders have been used for at least 10 years. As mentioned earlier, they reduce concrete stresses at the ends of girders and also camber. Their use can allow the precaster or designer to move lifting points inward to improve girder stability during handling, shipping, and erection, and they may help reduce design concrete strength at transfer.[1] With all of these benefits, why aren't temporary top strands used more often? Reluctance by some contractors, precasters, engineers, and owners may be explained by a lack of experience, misconceptions about detensioning the strands, limits on prestressing bed capacity, the need for additional planning, or the possible shift of design responsibility when temporary top strands are not included in the original design.

A common misconception is that detensioning in the field is unsafe. Tensioning or detensioning of strands should never be taken lightly, but with proper training and procedures, the process for detensioning pretensioned strands is no different on a jobsite than in a precaster's yard. As mentioned earlier, the strand is not "cut"; rather, an access pocket is provided for each temporary strand and each strand is detensioned gradually by heating with a flame (torch). Remember, each strand is in a sleeve that is encased by concrete; it is unlikely that a detensioned strand could harm a worker.

Another misconception is that upon detensioning, the strand will "buck" the worker off the girder. However, there have been no such reported cases, the mass of a girder makes this highly unlikely, and the typical safety measures would protect a worker from such a scenario.

In a few cases, cracking of the top flange has occurred during the post-tensioning process or during the detensioning process for pretensioned strands. Documented cases are not available, but such damage is likely the result of poor detensioning practices or insufficient pretensioning or post-tensioning anchorage reinforcement (see the AASHTO LRFD specifications, Articles 5.9.4.4 and 5.9.5.6, respectively). Cracking in the top flange can also be caused by ice forming in the access pocket or along the unbonded length of strand. Precautions to protect the pocket from accumulating water and freezing, and patching the void immediately after detensioning should suffice. For this reason, WSDOT prefers to place the pocket toward the end of the girder on the downhill side and to leave the foam in the access pocket to prevent water entry until detensioning. Some agencies prefer to place the pocket at the center of the beam.

Some say that the change in camber upon detensioning temporary top strands cannot be adequately predicted. This

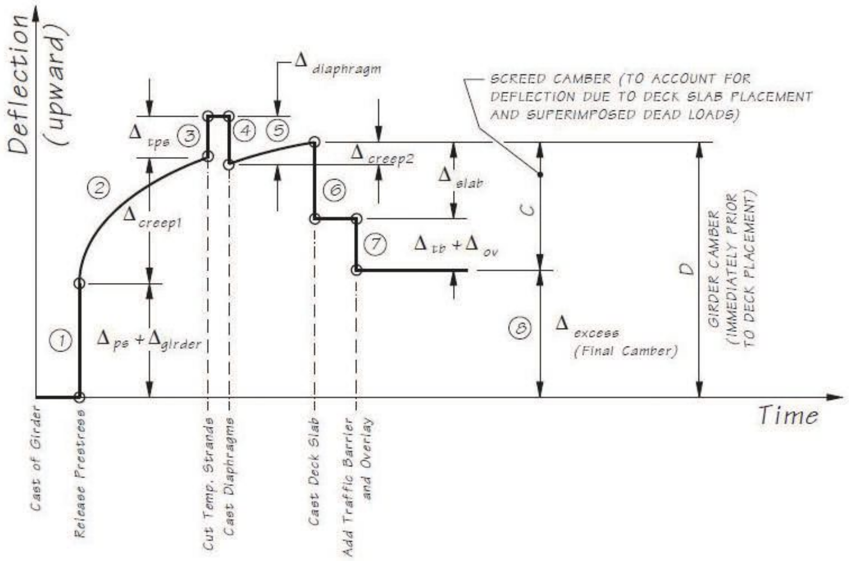

Figure 2. Schematic midspan deflection diagram from Washington Department of Transportation's *Bridge Design Manual (LRFD)*.[6] Step 3 shows the upward change in deflection due to detensioning of temporary top strands, Δ_{tps}. Step 4 is the downward deflection due to the placement of diaphragms. Camber growth between steps 3 and 4 is not obvious, but it must be considered during girder design.

is a basic calculation, and all camber predictions have variability. However, it is important, and often required, to determine the prestress losses both before and after detensioning of the temporary top strands so that camber and camber growth due to creep are appropriately considered.

One item that could prevent installation of pretensioned temporary top strands is a precaster's equipment. Some girders are very tall, and a precaster might not have the casting bed capacity to tension at that height, or the bed might not be long enough to redirect the strands to a lower tensioning height.

Conclusion

Installing temporary top strands in a prestressed concrete girder is not a panacea, but it is certainly a useful tool to control stresses and camber, and to improve girder stability during handling, shipping, and erection. Although the concept is simple, appropriate procedures must be used for each step in design, fabrication, and detensioning. Even if the strands are only installed to gain time to allow additional prestress losses to occur or concrete strength to increase, thus moderating concrete stresses, there may be implications for the final girder design. As always, communication among all parties—the owner, engineer of record, contractor, and precaster—is the key.

References

1. Precast/Prestressed Concrete Institute (PCI) Girder Stability Subcommittee. 2016. *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders*. CB-02-16-E. Chicago, IL: PCI. https://doi.org/10.15554/CB-02-16.
2. Russell, B. W. 2018. "Using Fully Bonded Top Strands in Pretensioned Concrete Bridge Girders." *ASPIRE* 12 (3): 26–28.
3. Jayaseelan, H., and B. W. Russell. 2019. "Reducing Cambers and Prestress Losses by Including Fully Tensioned Top Prestressing Strands and Mild Reinforcing Steel." *PCI Journal* 64 (3): 29–46. https://doi.org/10.1 554/pcij64.3-05.
4. Brice, R., B. Khaleghi, and S. J. Seguirant. 2009. "Design Optimization for Fabrication of Pretensioned Concrete Bridge Girders: An Example Problem." *PCI Journal* 54 (4): 73–111. https://doi.org/10.15554/pcij.09012009.73.111.
5. American Association of State and Highway Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.
6. Washington State Department of Transportation (WSDOT). 2020. *Bridge Design Manual (LRFD)*. M 23-50.20. Olympia, WA: WSDOT https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/manuals/bridge-design-manual-lrfd.
7. WSDOT. 2022. *Standard Specifications for Road, Bridge, and Municipal Construction*. M 41-10. Olympia, WA: WSDOT https://www.wsdot.wa.gov/publications/manuals/fulltext/M41-10/SS.pdf.

External temporary top strands ensured the lateral stability needed to safely ship and erect a 203 ft girder in Utah (for details, see the Creative Concrete Constuction article in the Summer 2019 issue of *ASPIRE*®). Photo: Forterra Structural Precast.