Pretensioning Strand Profiles: Harped or Straight

by Dr. Maher Tadros, eConstruct

Pretensioning is a common method of prestressing in the United States. It requires the use and set-up of a prestressing bed, normally in an off-site plant. The strands are tensioned in the bed between stressing heads. When concrete reaches adequate strength, the strands are detensioned, thus transferring the prestressing force from the prestressing bed to the concrete product.

A large amount of prestressing gives the midspan of a flexural member a large reserve capacity to resist gravity loads. In order to control flexural stresses at the member ends, where the stresses from the girder weight are less, some of the prestressing effects near the member ends must be reduced. Due to the nature of pretensioning, the tensioned strands must follow a series of straight lines. The two commonly used methods of stress control are harping and debonding.

Commercial harping device. Photo: Concrete Industries Inc.

End of debonding tube sealed with duct tape to the strand. Photo: Standard Concrete Products.

Harped Strands

The word "harped" is synonymous with the words "draped" and "deflected." Commercial hold-down devices may be used to drape the strands. The strands typically pass through rollers at a spacing of 2 by 2 in. In the Northwest, the strand group passes as a bundle through a tube and is then spread out into a 2- by 2-in. spacing pattern at the end of the member. In both types, the hold-down device is anchored to the bed pallet using threaded rods. When the prestress is ready to be transferred, the rods are cut before the rest of the detensioning proceeds. The designer should be aware of the limitations of the production facilities near the bridge location, in relation to the amount and location of the hold-down force.

The pretensioning arrangement for the 205-ft-long, 100-in.-deep Alaskan Way Viaduct girders in Seattle, Wash., had 46 straight and 26 harped strands in the bottom of the girder. The harped strands were held down in five bundles consisting of four sets of six strands each and two strands, that were spread out into a 2- by 2-in. spacing at the girder ends. Each girder also had eight temporary top flange strands that helped control the top fiber stresses at time of prestress transfer and member camber making a total of eighty 0.6-in.-diameter strands. In Washington State, it is a common practice to drape about one third of the total number of bottom strands. The top strands also aided in the stability of the long, slender girders during handling and shipping. They were bonded only in the end 10 ft. They were cut after the girders were erected and braced and before the intermediate diaphragms were cast.

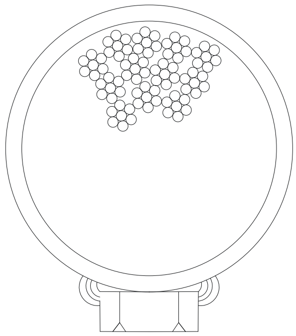
A 205-ft-long girder used for the Alaskan Way Viaduct using bundled harped strands. Photo: Concrete Technology Corporation.

A 191-ft-long bridge girder used for the Cody Avenue Bridge in Okaloosa County, Fla., which used a straight strand profile during production. Photo: Dura-Stress Inc.

Advocates of harping indicate the desire to preserve the prestressing level throughout the member length.

Straight Strands

This process is a simpler one as it does not involve harping. For it to work, however, some of the strands at the members ends may be required to be "debonded," also known as "shielded" or "blanketed." Strand debonding is done by enclosing the strands in plastic sleeves. Slit sleeves have been used in the past to allow the sleeves to be placed on the strands after the strands have been tensioned and anchored.



Example of tube for bundling of strands at the harp point. Figure: *PCI Bridge Design Manual*.

A preferred solution is to use a full tube to ensure no concrete paste leaks into the space between the tube and the strands, causing unintentional bonding. In addition, some producers tape the end of the tube to the strand.

There are specific requirements for debonding given in the AASHTO *LRFD Bridge Design Specifications*. These call for a maximum debonding of 25% of the total number of strands, but no more than 40% debonded in any given row. These requirements are followed by most agencies. There are reports of 50% debonding in box beams and as much as 75% debonding in some U-shaped beams. In some European countries, for example Spain, there is no limit on the amount of strand debonding. In the United States, the interest in debonding has resulted in an ongoing National Cooperative Highway Research Program project to determine debonding limits and recommend auxiliary reinforcement details. For the time being, the AASHTO provisions have served designers well.

An example of an I-girder with all straight strands is one of the girders for the Cody Avenue Bridge in Okaloosa County, Fla. The details of this girder were provided by the precaster, Dura-Stress of Leesburg, Fla. The girder had a record length of 191 ft at the time it was produced. The 8-ft-deep Florida I-beam had sixty-nine 0.6-in.-diameter bottom strands, six 0.6-in.-diameter fully tensioned top strands, and four 3/8-in.-diameter partially tensioned top strands. The six large top strands were debonded in the middle 131 ft of the girder, and later cut to enhance the service load capacity. Of the 69 bottom strands, 18 were debonded at the ends to ensure that the concrete stresses at the time of detensioning were not exceeded.

Advocates of straight strand profiles emphasize the advantages of their production simplicity and reduced risk.

Advantages

Advocates of strand harping indicate the desire to preserve the prestressing level throughout the member length, and on having a strand profile that resembles that of the gravity load moment diagram. In addition, the amount of shear reinforcement is reduced by preserving the full prestressing force near member ends and by the vertical component of the prestressing force created through harping.

Advocates of straight strand profiles emphasize the advantages of their production simplicity and reduced risk. No harping hardware is required. Calculation of strand tensioning amount and sequence are relatively simple. Straight strand profiles allow for a smaller gap between girder ends during production. This may improve bed utilization and reduce strand waste in multi-girder beds.

Example Comparison

For a direct comparison, an example bridge girder design is illustrated assuming a 102-in. deep girder, a girder spacing of 9 ft, concrete strengths at prestress transfer and at service of 6.5 and 10.0 ksi, respectively, an 8-in.-thick, composite cast-in-place concrete deck with 4.5 ksi compressive strength, and the AASHTO *LRFD Specifications* apply without any modification. Given the results shown in the table, the differences in results between the two stress-control methods are insignificant. A

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Dr. Maher Tadros is principal with eConstruct, Omaha, Neb.

Comparison of harped versus straight strand design

Property		Harped Strand	Straight Strand
Straight full-length bonded bottom strands	No.	50	52
Draped strands	No.	18	0
Debonded bottom strands	No.	0	18
Total bottom strands at midspan	No.	68	70
Top strands	No.	6	6
Effective depth	d_v, in.	80	88
Required shear demand at 7 ft from support	V_u, kips	-556	556
Required nominal shear resistance	V_n, kips	618	618
Concrete shear capacity	V_c, kips	167	183
Vertical component of prestress	V_p, kips	49	0
Capacity to be resisted by stirrups	V_s, kips	402	435
Required stirrups	A_s	2#5@19.2 in.	2#5@19.2 in.

Table: eConstruct