Updates to Lifting Loops: Provisions and Research

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Prestressing strand (ASTM A416[1]) is commonly used as lifting loops to transport precast concrete components from the casting yard to the project site. The prestressing strand is mechanically bent and the ends are embedded into the concrete to create loops that project out of the concrete surface and allow attachments for rigging (**Fig. 1**). The loops can be embedded with straight ends, bent ends, or broomed (flared) ends. This type of lifting device is readily available and economical, and if it is properly designed and detailed, it can achieve sufficient strength and ductility under lifting loads.

In a survey conducted in April 2019 of 35 PCI-certified precast concrete producers,[2] 95% of the participants reported that they use the safe lifting loads provided in the *PCI Design Handbook*[3] to determine their lifting-loop configurations, and 38% indicated that they had conducted their own in-house testing. The *PCI Design Handbook* and the *PCI Bridge Design Manual*[4] have long been the standard sources of guidance for safe lifting-loop practices.

Research on lifting loops is limited, and understanding in this area has been based primarily on work published in 1974,[5] as well as some short-embedment testing published in 2009.[6] None of that work included studies on lifting loops formed from 0.6-in.-diameter prestressing strand. Recognizing a need for more understanding and guidance on lifting-loop behavior, PCI funded an experimental testing program at the University of Cincinnati through the 2019 PCI Dennis R. Mertz Fellowship, as well as an extensive follow-up study to determine the safe lifting loads for 0.6-in.-diameter strand loops under vertical loads.[7,8] Inclined loading (that is, the lifting loops at an angle less than 90 degrees with respect to horizontal) was not studied in this project, but previous research provided some data on inclined load capacities.[5,6]

Updates to the *PCI Bridge Design Manual*

The fourth edition of the *PCI Bridge Design Manual*, which was released in 2023, has adopted some of the findings from the University of Cincinnati work. However, these findings could not be incorporated into the forthcoming ninth edition of the *PCI Design Handbook* in time for its publication. The primary recommendations and updates to Section 3.2.4.4.1 of the *PCI Bridge Design Manual* are as follows:

- *The factor of safety is taken as 4 for lifting loops made of conventional strand* (270-ksi ultimate strength). This is consistent with the eighth edition of the *PCI Design Handbook*.
- *The concrete strength must be a minimum of 3000 psi at the time of handling*.
- *A safe working load for a 0.6-in.-diameter single-strand loop embedded at least 24 in. is 12 kips*. Previously there was no guidance for this strand diameter.
- *A safe working load for a 0.5-in.-diameter single-strand loop embedded at least 24 in. is 10 kips*. This is consistent with the eighth edition of the *PCI Design Handbook*.
- *The use of shackles is recommended to ensure even loading of the loops in multiple-strand lifting-loop conditions. A hook or bent portion of a shackle should not be used through multiple-strand loops*. Experimental results showed a reduction in strength of at least 12% when a hook lifting device, as opposed to a straight pin shackle, is used.[8]
- *The need to crush the pipe sleeves before bending the strands of multiple-strand lifting loops is emphasized*. Sleeves fabricated from conduit or pipe are commonly used around multiple strands in a loop to keep the individual strands together and at relatively the same elevation. Locating each strand of a multiple-strand lifting loop at the same elevation is crucial to ensure even loading of the loop; failure to do so could result in progressive and premature failure of the loop.[8] **Figure 2** shows that simply bending the strands within the sleeve is not adequate to ensure even loading of the strands. The sleeve must be crushed

Figure 1. A lifting loop of conventional strand is embedded before concrete placement. Photo: University of Cincinnati.

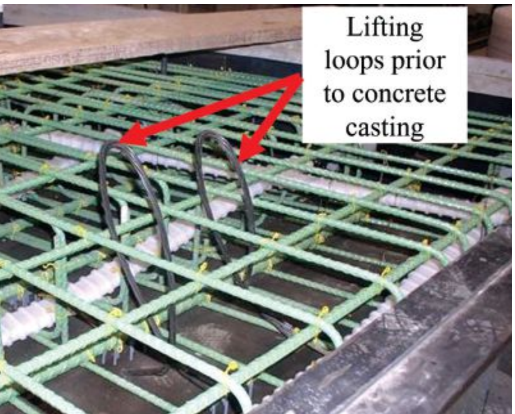

Figure 2. Comparison of multiple-strand loops with crushed and uncrushed pipe sleeves. Uncrushed pipe sleeves do not adequately keep the individual strands together and at the same elevation. Photo: Prestress Services Inc.

Figure 3. Researchers observed that failure modes varied depending on the configuration of the lifting loops. From left to right, the photos show pullout, strand rupture, and side-face blowout failure modes. Photos: University of Cincinnati.

before bending, otherwise, a consistent elevation of each strand loop cannot be maintained.

- *Mohs hardness of aggregates influences lifting-loop pullout strengths*. While soft, coarse aggregate with a low Mohs hardness (less than 3.8) was not specifically tested in the University of Cinncinati work, that type of aggregate has been shown to produce lower bond strengths than harder aggregates. The designer is cautioned to consider the bond quality of the strand being used, as well as the Mohs hardness of the aggregate, to determine whether more-conservative values of lifting-loop capacities are warranted.
- *Stainless steel strand should not be used for lifting loops because it is less ductile than conventional strand*. In cases where conventional strand cannot be used due to corrosion concerns, the factor of safety of stainless steel lifting loops should be increased from 4 to 6.

Potential Forthcoming Changes to the *PCI Bridge Design Manual*

There is a desire from the bridge community to include a safe working load for lifting loops with embedments of 36 in. or more, which is not currently in the *PCI Bridge Design Manual*. Loops with 24-in. embedments primarily fail in pullout (**Fig. 3**), where the bond between the prestressing strand and the loop is not strong enough and the strand pulls out of the concrete. This issue dictated the safe lifting loads; however, most precast concrete bridge girders are deep components that would enable longer embedments.

The University of Cinncinati investigators studied loops with 36-in. embedments and 6-in. bent legs and found that the strength of these loops were largely controlled by the rupture strength of the strand (Fig. 3).[8] In other words, by using deeper embedments, pullout could be precluded and the strength of the loop could be increased significantly. Results from this study proposed a 21-kip safe lifting load with the deeper 36-in. embedment. This proposal may not apply if the distance from the strand to the edge of the concrete component is small enough (less than 3 in.) to cause side-face blowout (Fig. 3). Note that the current *PCI Bridge Design Manual* does not specify a safe lifting load for deeper embedments, although it does permit the user to presume a uniform bond stress of 100 psi, which equates to approximately 21 kips for a 36-in. embedment with 6-in. bent legs.

The University of Cincinnati investigators also found that multipliers of 1.9 and 2.8 could be used for double- and triple-strand configurations,[8] compared with the current recommendations of 1.7 and 2.2, respectively.[3,4] It is presumed that the current recommendations were based on shorter embedments where pullout or side-face blowout would control the loop capacity. For deeper embedments, where concrete failures are precluded, the multipliers of double- and triple-strand configurations were shown to align more closely with the number of strands in the loop (that is, 2 and 3, respectively). Tests of quadruple-strand configurations resulted in a multiplier of 3.3 because side-face blowout began to control. Lifting-loop designs for bridge components with deep embedments may be able to take advantage of these increased multipliers. The current edition of the *PCI Bridge Design Manual* does not include any modifications to the original multipliers, but this issue will be considered, along with safe lifting loads, for a forthcoming addendum to the manual.

References

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