Precast and Precast, Prestressed Concrete

BRIDGE DESIGN MANUAL

Fourth Edition, First Release, 2023

Fourth Edition, First Release Errata

April 2026

The errata published herein are intended to supplement, revise, or clarify the information provided in the manual. PCI suggests that you mark the changes in your copy so that your manual is as accurate as possible.

As this edition of the manual is used, additional errata may be discovered. You are urged to notify PCI of any potential errata for committee review. You are also encouraged to send any questions or comments to PCI regarding the material in the standard and suggested improvements or clarifications. Please direct your comments to PCI at PCIBridgeManual@pci.org.

Chapter 3

Replace pages 3-35 through 3-38 with the following five pages (3-35 through 3-38a) in their entirety.

Add the following reference to Section 3.10:

Chhetri, S. and Cross, R. 2024. “Experimental Investigation of Multiple-strand Lifting Loops,” *PCI Journal*, Precast/Prestressed Concrete Institute, Chicago, IL. Vol. 69, No. 3 (May- June), pp 74-88. https://doi.org/10.15554/pcij69.3-03

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3.2.4.4.1 Strand Lifting Loops

Prestressing strand lifting loops are widely used due to their high strength and flexibility. Loops can be bent into multiple configurations suited to the intended application. They are also economical because, in many cases, they are made from what would otherwise be "waste" strand such as the tail end of a strand pack or tails cut from a production run. Strand that has been damaged by gripping jaws or pitted with rust should not be used for lifting loops.

3.2.4.4.1.1 Individual-Strand Lifting Loops

The capacity of individual-strand lifting loops is governed by the following:

- Size and grade of the strand
- Configuration of the loop
- Length of embedment into the concrete
- Extension of the loop above the surface of the member
- Edge, side, or end distance
- Diameter of the pin used through the loops during lifting.

Typical lifting loop configurations, which apply to both individual and multi-strand lifting loops, are shown in **Fig. 3.2.4.4.1.1-1**. Loops with straight legs may be used if there is sufficient embedment (**Fig. 3.2.4.4.1.1-1a**). If there is insufficient length for embedment, hooked or broomed legs (where the individual wires are unwrapped) may be used (**Fig. 3.2.4.4.1.1-1a**). The surrounding concrete should be adequately consolidated and reinforced to prevent splitting of the concrete and associated loss of bond.

Some typical lifting loop details are shown in **Fig. 3.2.4.4.1.1-1b**, **3.2.4.4.1.1-1c**, and **3.2.4.4.1.1-1d**. Lifting loops with angled legs, where the legs are not perpendicular to the long axis of the girder, are not common and have not been tested under any load configuration. Mustafa (1974) tested lifting loops embedded at various angles, but the force was inclined and parallel to the direction of embedment.

When a hook is used through a strand lifting loop, the capacity of the loop can significantly decrease if the diameter of the steel lifting device engaging the loop is small (< 2 in.). This is also true of shackles when the diameter of either the bent portion or the pin is small (Chhetri and Cross, 2024).

It is important to remember that the strand used in lifting loops is not stressed. Development length and transfer length equations in the AASHTO LRFD Specifications are based on testing done on stressed strand, where anchorage to the concrete is heavily influenced by the mechanics of initially pretensioned strands as they seek to gain their original size and length after detensioning. These mechanical effects are not present in unstressed strand. Development length and transfer length equations in the AASHTO LRFD Specifications cannot be used to assess the pull-out strength of unstressed strand as used in lifting loops (Mustafa, 1974).

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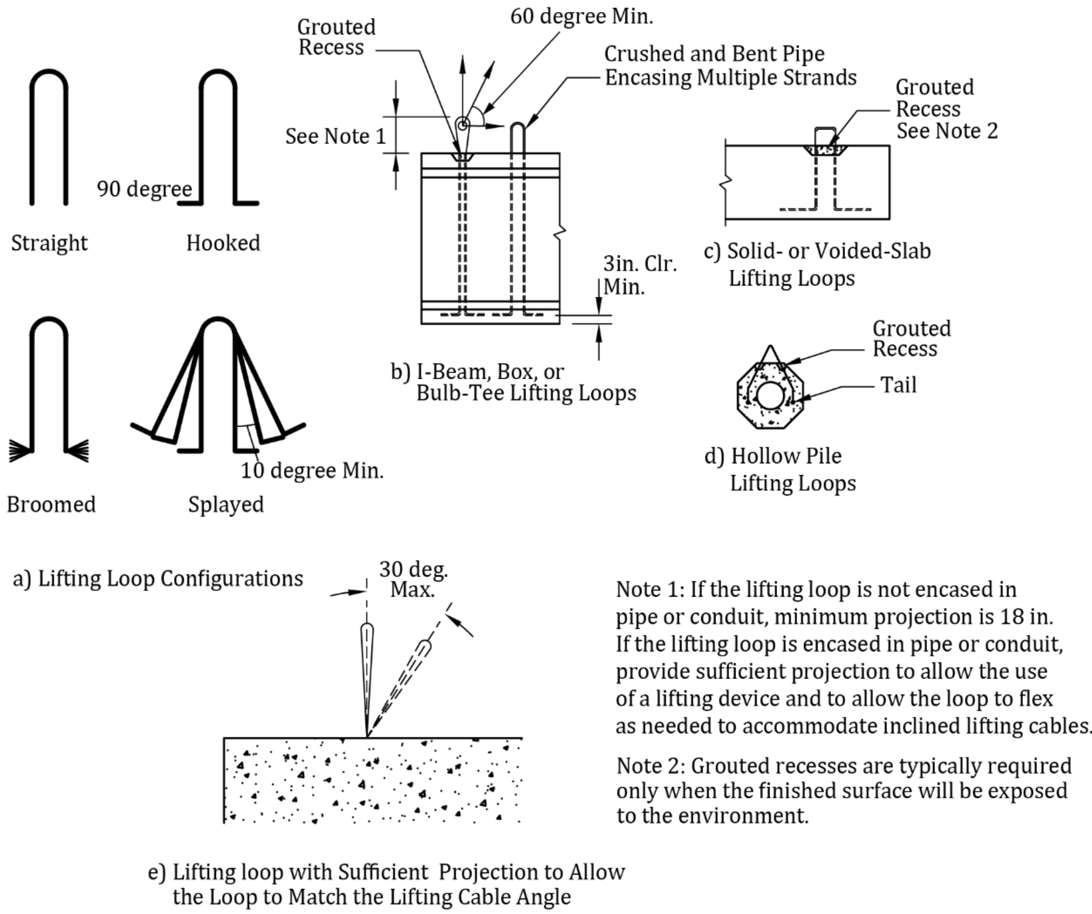
Figure 3.2.4.4.1.1-1
Typical Configurations for Individual and Multi-strand Lifting Loops



The *PCI Design Handbook* (MNL 120-17) provides limited guidance on the safe working load of lifting loops using 0.5-in.-diameter strand. Chhetri, et al. (2021); Chhetri (2023); Chhetri and Cross (2024) extended this work to 0.6-in.-diameter strand. Based on the guidance previously given in the *PCI Design Handbook* (MNL-120-17) and the additional works cited, the following recommendations are made for lifting loops made of prestressing strand with an ultimate strength of 270 ksi:

a. For straight lifting loops (Fig. 3.2.4.4.1.1-1a), the term "embedment length" is the distance from the concrete surface to the bottom of the lifting loop. For hooked lifting loops (Fig. 3.2.4.4.1.1-1a), the term "embedment length" does not include the length of hooks and the term "total embedded length" includes the distance from the concrete surface to the bottom of the lifting loop and the length of the hooks. Testing for 0.6 in. diameter lifting loops was performed on lifting loops with a 6 in. extension on the hooked ends.

b. The factor of safety is taken as 4 for lifting loops made of conventional strand.

c. The concrete strength must be a minimum of 3,000 psi at the time of handling.

d. Each leg of the lifting loop should have a minimum embedment length of 24 in. If there is insufficient embedment length for a straight loop, the ends of the loops must be hooked at a 90-degree angle or "broomed" legs (individual wires unwrapped and splayed) can be used (**Fig. 3.2.4.4.1.1-1a**). Even if there is sufficient embedment, using hooked legs is good practice unless congestion in the area prevents it.

e. When lifting, a shackle pin, bent portion of the shackle, or hook with a diameter of at least 4 times the strand diameter must be used. The diameter of the pin used to bend the strands should be at least 4 times the strand diameter but not less than 2 in.

f. For flanged members, lifting loops should be anchored into the bottom flange.

g. A vertical safe working load for monostrand lifting loops with hooked ends at least 6 in. long, with an embedment length of least 24 in. but less than 36 in. can be determined by assuming a bond stress of 100 psi along the total embedded length of the strand, including the hook. This safe working load provides a factor of safety of 4 relative to the average test result; (Chhetri et al. 2021). The surface area of strand per leg is calculated as follows:

$$A = \frac{4}{3}\pi L d \qquad \text{(Eq. 3.2.4.4.1-2)}$$

where

A = surface area

L = total embedded length of one leg (includes the vertical leg and the hooked leg)

d = nominal strand diameter

Care is advised when using this equation for embedment lengths greater than 36 in. with at least 6-in. hooked ends because no tests were performed beyond that embedment length. In the limited tests that were performed for a 36 in. embedment with 6-in. hooked ends, failure was by rupture of the strand in the bend of the loop, and it is expected that deeper embedment would not produce higher capacity.

h. For 0.5-in.-diameter strand embedded without hooked ends at least 24 in. the safe working load of a single loop is 10 kips.

i. For 0.6-in.-diameter strand without hooked ends, with an embedment length of 24 in. the safe working load of a single loop is 12 kips. For 0.6-in.-diameter strand without hooked ends with an embedment lengths between 32 in. and 42 in., the safe working load of a single loop is 16 kips. Safe working load values may be interpolated between 24 in. and 32 in. Data show that for 0.6 in. diameter strand, without hooked ends, embedded up to 42 in., failure is by pull-out. There is no data on the capacity or mode of failure for embedment lengths beyond 42 in. (Chhetri et al., 2021).

j. Data from research suggests that strand embedded in normal weight or lightweight concrete made with softer aggregates may have a lower pull-out strength (Chhetri, et al., 2021, including appendix by Logan). Data on the effect of aggregate hardness on pull-out capacity is limited; however, fabricators should be aware that concrete with softer aggregates may exhibit reduced pull-out capacities.

k. Stainless steel strand should not be used for lifting loops because it is less ductile. If conventional strand cannot be used due to corrosion concerns, it is recommended that the factor of safety of stainless steel lifting loops be increased from 4 to 6.

Note that the recommendations given above are based on testing on lifting loops made of individual 0.5- or 0.6-in.-diameter strand were generally conducted for vertical loads. Kuchma and Hart (2009) studied the capacity of loops lifted with angled cables at both 45^{o} from horizontal and 60^{o} from horizontal in 11 in. and 17 in. deck beams, but this is the only data available on lifting with angled cables.

No data on testing lifting loops made of composite strand or epoxy-coated strand are available.

3.2.4.4.1.2 Multiple-Strand Lifting Loops

For multiple-strand lifting loops, the recommendations for individual-strand loops apply along with additional considerations. The primary additional requirement is that each individual loop in a multiple-strand set must project as equally as possible from the concrete. Also, a straight pin must be used through multiple loops so that each individual loop carries its share of the load. A hook or bent portion of a shackle should not be used through multiple-strand loops. Legs of individual loops can be splayed (**Fig. 3.2.4.4.1.1-1a**) to promote bond with the concrete. Unless test data is available, the following multipliers are recommended for multiple-strand loops: 1.7 for double-strand loops and 2.2 for triple-strand loops (PCI, 2017). For the specific case of 0.6-inch diameter lifting loops with hooked ends, minimum shackle pin diameter equal to 4(0.6”) = 2.4 in. and an embedment of at least 36 inches, multipliers of 1.9, 2.8, and 3.3 could be used for double, triple and quadruple strand cases. Thus, for 0.6 in. strand with hooked ends and an embedment length of 36 inches, the safe lifting loads are: 21 kips for a single strand, 40 kips for two strands, 58 kips for three strands and 69 kips for four strands with a 2.4 in. diameter or greater shackle pin.

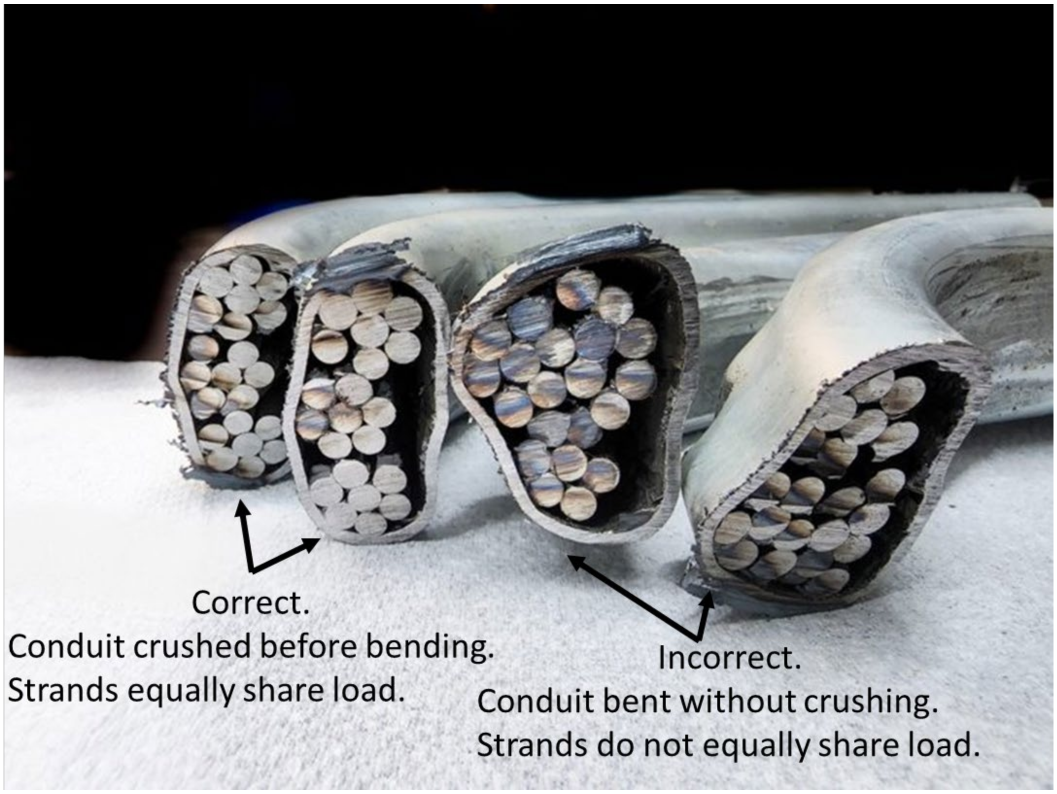
There is insufficient data to make a recommendation for 0.6-inch strand loops with more than 4 strands. (Chhetri and Cross, 2024). Up to five 0.5-in.-diameter strands have been successfully used in such multiple-strand loops.

The following two methods of holding the individual strands of multiple-strand loops at reasonably equal projections have been successfully used:

- Placing the strands in a conduit or pipe, then crushing the conduit or pipe as flat as practical in a plane perpendicular to the radius of the loop bend. The crushed conduit or pipe is then bent into the desired shape of the loop. The crushing of the conduit or pipe helps to ensure that the individual strands remain aligned and share load equally, when compared to strands inserted into a conduit or pipe and bent without crushing (**Fig. 3.2.4.4.1.1-2**). Since the strands are held level by the crushed pipe, the loops need only project a distance sufficient to comfortably accommodate the straight pin used for lifting. There is no known testing of such loops with straps at angles other than 90^{o}, so all lifts should be vertical. Testing has only been performed for the use of 4 strands or fewer in loops lifted vertically.
- When individual loops are projected without the restraint of a crushed conduit or pipe, they should be fabricated as identically as possible and projected equally a minimum of 18 in. from the top surface. The extended projection provides an ability for the individual loops to “stretch” and equalize the loads to each loop. When configured with the proper projection and angle limitation as shown in **Fig. 3.2.4.4.1.1-1e**, angled straps may be used for lifting. Moustafa (1974) provides test data for 0.5-in.-diameter strand loops loaded at an angle, and for the consistent fabrication and installation of such loops.

The Washington State Department of Transportation (WSDOT) Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT, 2023) Section 6-02.3(25)L1 provides some alternative recommendations for the use of single and multi-strand lifting loops. The reference is provided here as additional information.

Fig. 3.2.4.4.1.1-2 – Correct and Incorrect Methods of Crushing Conduit for Multiple Strand Lifting Loops



3.2.4.4.2 Other Lifting Embedments

Bolts used for lifting perform much the same as headed studs. Embedment must be sufficient to prevent concrete shear cone failure, and edge distance must be considered when it encroaches on the shear cone.

A wide range of common proprietary lifting devices also are available. For bridge applications, these are normally limited to precast concrete products that are relatively thin and light such as precast concrete wing walls, barriers, and soundwalls. When the lifting device is in an exposed place in the structure, it is common to cover the device with a patch for durability reasons. The ability to provide a patch with sufficient durability for the demands of bridge applications can influence the selection of the lifting device.