Design of Attachments to Concrete with Shear Lugs—A Primer

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Shear lugs are steel elements used to transfer shear forces from a steel base plate into concrete. They consist of rectangular plates or steel shapes composed of plate-like elements that are welded to a steel base plate and either cast directly into concrete or post-installed into a grout-filled blockout (**Fig. 1**).

The American Concrete Institute's *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*[1] introduced provisions for shear-lug design in Section 17.11. These provisions are now referenced in Article 5.13.1 of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*, 10th edition,[2] which permits the use of attachments to concrete with shear lugs. ACI 318-19 Section 17.11 requires two concrete failure modes to be evaluated in shear-lug design:

- **Bearing strength in shear.** This refers to the bearing strength before concrete fracture in front of the shear lug (that is, on a vertical plane). The ACI 318 provisions are based on a uniform bearing stress of $1.7f'_c$ acting over the effective area of the shear lug. Resistance provided by the embedded plate and welded anchors is conservatively neglected in this evaluation.
- **Concrete breakout strength.** This is calculated similarly to how the concrete breakout strength of anchors is determined in ACI 318 Section 17.7.2. The difference is in the determination of the projected area of the failure surface on the side face of the concrete A_{vc}. For shear lugs, A_{vc} is approximated as the rectangular shape that results from projecting 1.5 times the edge distance c_{a1}, both horizontally from the shear lug and vertically from its effective depth (**Fig. 2**).

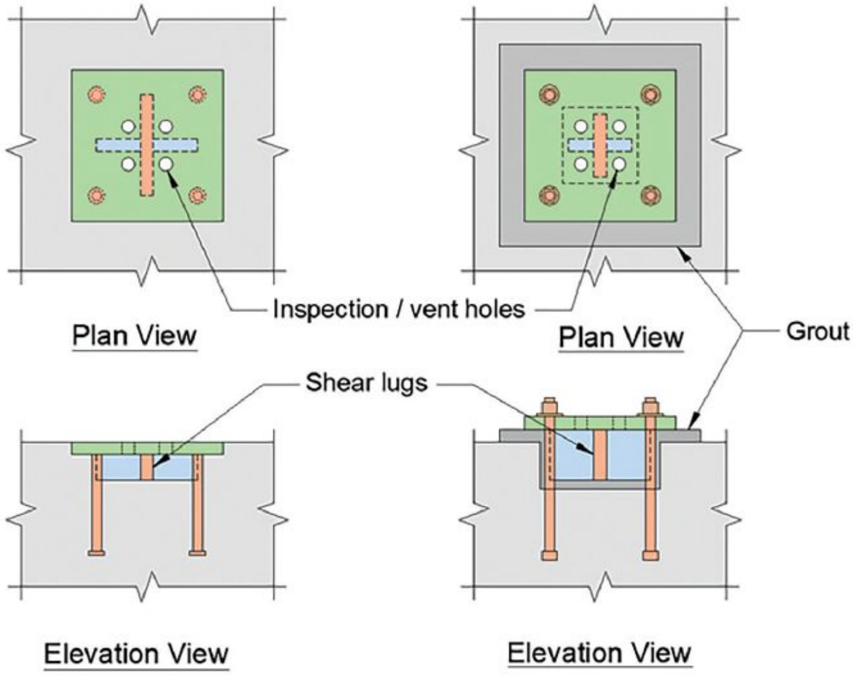

Figure 1. Examples of attachments with shear lugs. The example on the left illustrates a cast-in-place detail, and the example on the right shows a post-installed option. Figure: Adapted from ACI 318-19, Figure 17.11.1.1a.[1]

While these two failure modes are specifically addressed in ACI 318, the steel and weld design of the attachment base plate and shear lugs must also be checked. Additionally, practitioners should note that the ACI 318 provisions use pound units, whereas the AASHTO LRFD specifications use kip units (1 kip = 1000 lb).

In accordance with ACI 318 Section 17.11.1.1.2, a minimum of four anchors that satisfy the anchorage to concrete requirements of Chapter 17 must be welded to the attachment base plate. The anchors provide moment resistance, which prevents pry-out action on the shear lugs.

ACI 318 Section 17.11.1.2 presents an important detailing requirement: Steel base plates must include a minimum 1-in.-diameter hole along each of the long sides of the shear lug. This detail complies with the installation requirements of ACI 318 Section 26.7.2, which require proper consolidation of concrete or grout around the shear lugs to be verified using base plate inspection holes. For a cruciform-shaped shear lug, the commentary to ACI 318 Section 17.11.1.2 recommends four inspection holes, one per quadrant (Fig. 1).

A more in-depth discussion of the shear lug provisions of ACI 318 can be found in the September 2021

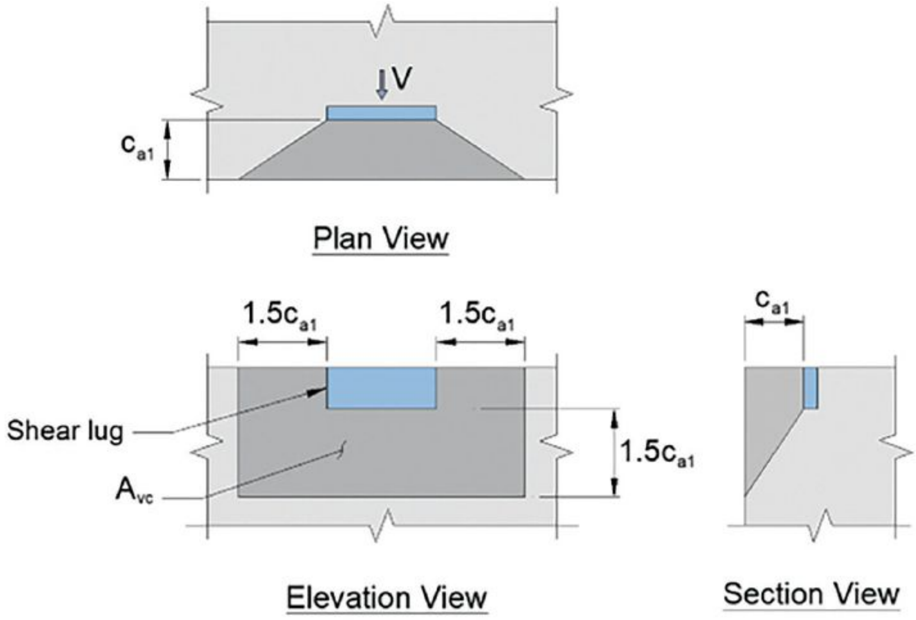

Figure 2. The projected area of the failure surface on the side face of the concrete for a shear lug near an edge. Figure: Adapted from ACI 318-19, Figure R17.11.3.1.[1]

STRUCTURE Magazine article titled "Integrating Shear Lug Design Anchoring-to-Concrete Provisions."[3] For practical guidance, designers can also refer to Anchorage Example 21 in Chapter 15 of the *ACI Reinforced Concrete Design Handbook* (ACI MNL-17).[4] That example illustrates the design of a column base plate subjected to both shear and tension, with shear lug calculations beginning at Step 17d.

The inclusion of shear lug provisions in ACI 318 and their adoption by reference in the AASHTO LRFD specifications represents a significant advancement in codified concrete anchorage design, providing engineers with a valuable tool for addressing shear demands. In bridge construction, shear lugs can be especially effective in enhancing the lateral resistance of bearing assemblies in long-span bridges, particularly in seismic design applications.

References

1. American Concrete Institute (ACI). 2019. *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*. Farmington Hills, MI: ACI.
2. American Association of State Highway and Transportation Officials (AASHTO). 2024. *AASHTO LRFD Bridge Design Specifications*. 10th ed. Washington, DC: AASHTO.
3. Morgan, R. T. 2021. "Integrating Shear Lug Design Anchoring-to-Concrete Provisions." *STRUCTURE Magazine* (September), pp.10–14. https://www.structuremag.org/issues/2021-digital-issues/september-2021.
4. ACI. 2017. ACI *Reinforced Concrete Design Handbook*. ACI MNL-17(21). Farmington Hills, MI: ACI.