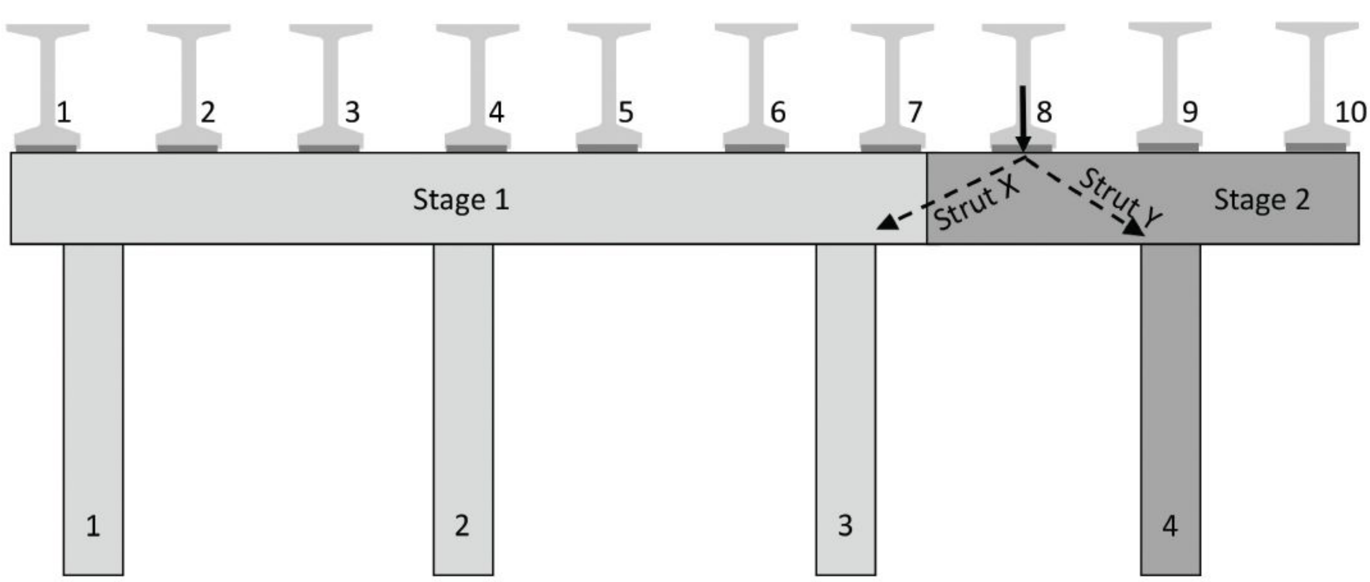
Strength of Structures with Struts Crossing Cold Joints—Beginning the Discussion

by Dr. Oguzhan Bayrak, University of Texas at Austin

This article addresses some of the challenges that arise in calculating the capacities of reinforced concrete structural components constructed in multiple phases and, hence, possessing cold joints. Staged construction, roadway expansion projects, and retrofitting old substructure components for increased load demands necessitate constructing new structural elements connected to the older components. To better define this concept, let us focus on the two examples shown in **Fig. 1** and **2**.

Figure 1 shows the staged construction of a multicolumn bent. The entire bent cap shown in this figure can be classified as a D-region, or a region of discontinuity, because loads introduced by each beam line and those from the supporting columns create disturbed regions. Such regions of discontinuity are to be designed in compliance with the strut-and-tie modeling (STM) provisions in Article 5.8 of the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*.[1] Figure 1 shows seven beam lines supported on three columns that are constructed as part of the first phase. The need to expand the roadway supported on this multicolumn bent necessitates adding three beam lines and an additional column, which is supported on a separate foundation (foundations are not shown in Fig. 1 for simplicity). Each beam line introduces concentrated loads at the location of the bearing pads shown supporting the bottom flanges of the beams. Focusing on beam line 8, it can be observed that the load introduced into the bent cap by this beam line must flow into columns 3 and 4 through struts X and Y. Analysis of strut Y, per the AASHTO LRFD specifications, is straightforward because struts are checked at the strut-to-node interface. Strut X, on the other hand, crosses a cold joint on its path to column 3. Shear friction of this strut must be checked in accordance with the commentary of Article 5.8.2.2 in the AASHTO LRFD specifications: "Where a strut passes through a cold joint in the member, the joint should be investigated to determine that it has sufficient shear-friction capacity." The actual geometry of the strut at the interface can be conservatively assumed to be equal to the width of the strut at the location where it frames into a nodal region. More specifically, averaging the width of both ends of strut X and assuming that compression does not spread through the depth of the cap would provide a conservative, well-justified solution. Research is ongoing to determine more

Figure 1. Multicolumn bent constructed in two phases shows a strut crossing a cold joint. All Figures: Dr. Oguzhan Bayrak.



refined and appropriately conservative approaches for analysis of a strut crossing a cold joint. The geometry, in conjunction with the intensity of the axial load in the strut, will drive the necessity to provide a shear key or roughened surface at the cold joint. This necessity is determined by analyzing the demand on and the capacity of the cold joint for transferring the load.

A similar, albeit more complex, scenario is presented in Fig. 2. This figure depicts the retrofit of a bridge foundation to accommodate additional loads. The original footing is supported on four drilled shafts (DS 1 through 4 in Fig. 2). Increased column loads, which are anticipated to be transferred through the footing, necessitate the installation of 10 additional drilled shafts and the expansion of the original footing (retrofit shown in dark gray in Fig. 2). Similar to the example discussed in Fig. 1, struts will form between the column and the new drilled shafts as compression fields form in the footing. Each one of these new struts will cross a cold joint, and therefore shear friction capacities of those struts must be checked. Once again, it is possible to determine the geometry of the struts crossing the cold joint, determine the capacity and demand, and make decisions on roughening the surfaces of the original footing or providing shear keys to enable the force transfer across the cold joint.

For the examples presented in Fig. 1 and 2, the interface shear resistance must be checked using the provisions of AASHTO LRFD specifications Articles 5.7.4.3 and 5.7.4.4.

Current design provisions in the AASHTO LRFD specifications do not directly address this issue. In an effort to emphasize the importance of this capacity calculation, AASHTO Technical Committee T-10 Concrete Design is currently considering clarifying or modifying the mandatory language in the AASHTO LRFD specifications and providing additional commentary. Once those deliberations are finalized and a formal vote is taken, our team at *ASPIRE*® will provide a detailed explanation of any upcoming changes developed and adopted by the AASHTO Committee on Bridges and Structures.

In conclusion, recognizing the issue, current related activities, and the number of questions being raised on this topic, the intent of this article is to draw the attention of our readers to this technical issue, the applicable provisions of the AASHTO LRFD specifications, and the ongoing consideration of additional design provisions to address it.

Reference

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*, 9th ed. Washington, DC: AASHTO.

Figure 2. Structural retrofit of an existing footing supported by drilled shafts that requires a larger footing and more drilled shafts to accommodate increased column loads (plan view).