

Cold Joints in Bridge Structures: From Design Practicality to Structural Behavior

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As the concrete bridge industry continues to evolve, practitioners are increasingly called upon to make decisions that affect the structural performance, durability, constructability, and long-term costs of bridges. Research plays a critical role in informing those decisions, but its value is realized only when findings can be translated into practical applications. As a resource for bridge owners, engineers, contractors, and students, the Concrete Bridge Engineering Institute is committed to connecting the industry with reliable, evidence-based information and educational opportunities that advance the state of practice. In this article, we highlight findings from recent research^{1,2} on cold joints, and, more importantly, the practical lessons that they offer. The investigation, which was conducted at the University of Texas at Austin Ferguson Structural Engineering Laboratory, demonstrates how research can be applied to support informed decision-making and improved outcomes for concrete bridge projects.

Concrete placement is rarely as simple as casting an entire structure in one continuous operation. In bridge engineering, sequential concrete placement is often unavoidable in projects that involve staged construction, massive structural members, complex structural geometries, repair operations, or rehabilitation. **Figure 1** illustrates a common example with a cast-in-place bridge deck placed over a precast concrete panel, which creates an interface between an existing concrete member and a freshly cast component.³ This interface is commonly referred to as a cold joint.

Although cold joints are a familiar part of bridge construction, their behavior



Figure 1. After the deck has been thoroughly wetted and prepared, workers use a screed to level cast-in-place concrete on top of a precast concrete panel.³

can be complex and difficult to quantify. In many cases, the structural integrity of the member depends not only on the strength of the concrete on either side of the cold joint but also on the force transferred across it. Therefore, to design safe and efficient bridges, designers must understand the behavior and load-carrying capacity of cold joints, and the corresponding evaluation approaches.

Previous Research on Cold Joints

Decades of research have contributed to the current understanding of interface shear behavior. Early studies of composite concrete members led to the development of the shear-friction theory,⁴ which considers the resistance provided by friction, externally applied normal forces, and normal forces

generated by reinforcement crossing the interface. Later experimental studies⁵⁻⁷ further refined this concept by considering the contribution of chemical bonding and the role of interface preparation. Those efforts formed the foundation for many of the interface shear provisions used in current design specifications.⁸⁻¹²

Much of the research was on horizontal shear strength of the concrete-to-concrete interface of composite concrete beams.¹³⁻¹⁵ These studies focused on structural members with relatively uniform stress distributions and intentionally avoided regions that cannot be evaluated using sectional analysis. However, as discussed in the Concrete Bridge Technology article in the Fall 2020 issue of *ASPIRE*®, cold joints in actual bridge structures are not

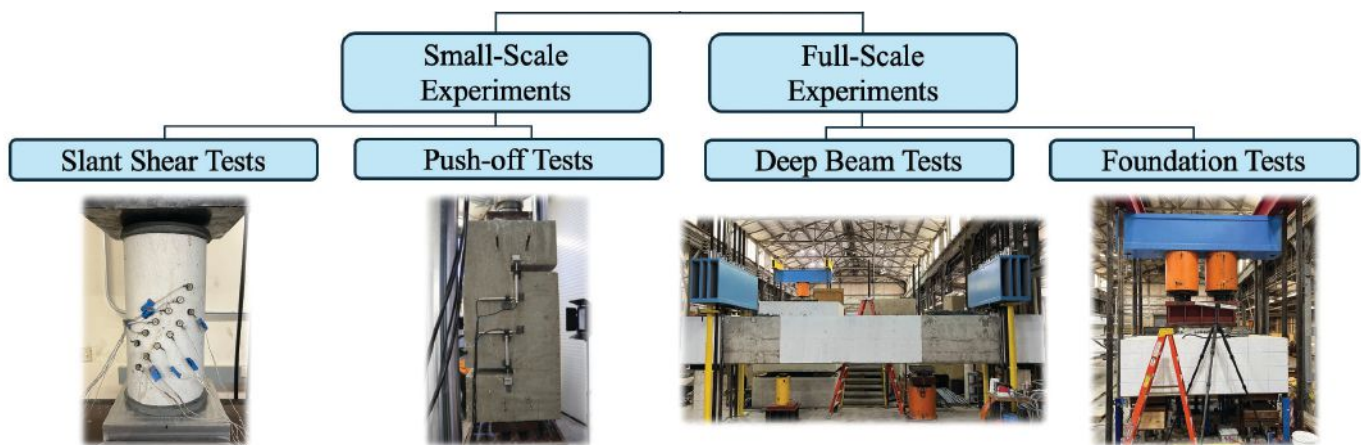


Figure 2. Research road map for Texas Department of Transportation Project 0-7117. Figure: Concrete Bridge Engineering Institute.

always located in such simple regions. Cold joints may occur near the supports, other regions where concentrated loads may be applied, the anchorage zones, or the connections. These locations, defined as the disturbed regions (D-regions), are characterized by the highly nonlinear and localized stress field, rendering the plane-sections-remain-plane assumption underlying sectional analysis invalid.

This distinction raises important questions for bridge engineers: How does a cold joint behave when it is intersected by localized compressive or tensile stress fields? How should the effective resisting area of the interface be defined when forces are not uniformly distributed? Are conventional interface shear equations applicable when the cold joint is part of a complicated load transfer system?

Recent Advancements

Texas Department of Transportation Project 0-7117¹ was developed to address the questions posed in the previous paragraph, and to advance the understanding of cold joints in D-regions of reinforced concrete members. The project combined a nationwide survey, small-scale component experiments, full-scale structural experiments, analytical modeling, and numerical simulation (Fig. 2). Rather than treating cold joints only as isolated material interfaces, the investigators examined how the cold joints interact with the overall load-transfer mechanism.

The first step was to understand standardized current practice. The

research team conducted a nationwide survey of representatives from departments of transportation about construction practices, interface treatment, reinforcement detailing, and design concerns related to cold joints. The survey responses indicate that although cold joints are common in bridge construction, guidance on design details for cold joints in D-regions is limited and agencies take a variety of approaches to construction when cold joints are encountered in D-regions.

The research then moved from practice-based observations to laboratory testing. Investigators conducted a series of slant shear tests and push-off tests to quantify the influence of key variables on cold-joint behavior. The results showed that interface roughness is one of the most influential parameters for cold-joint behavior. Roughened interfaces (Fig. 3 [left]) generally provided greater resistance than smooth interfaces (Fig. 3 [right]), a finding that confirms the importance of surface preparation in construction. From a practical construction perspective, the experimental observations and the wide variety of roughening methods identified in the survey raise several important questions that need to be investigated further: How should roughness amplitude be measured? How should interface condition be specified and standardized? What roughening procedures are appropriate for various interface geometries and structural demands? Future efforts to standardize roughening procedures and measure reliable roughness



Figure 3. Different levels of interface roughness: intentionally roughened interface on the left and form-finished interface on the right.¹

characteristics are expected to improve both design consistency and construction quality.

After the small-scale component experiments, the project expanded to full-scale structural experiments. Deep beams and drilled-shaft footing caps were tested to investigate how cold joints interact within members governed by nonlinear and nonuniform stress distribution. The full-scale tests demonstrated that the location and orientation of a cold joint relative to the internal stress field can substantially influence the structural response. When the cold joint intersects the critical load-transfer path, interface slip or opening may influence the redistribution of forces and the capacity of the components, potentially resulting in cold-joint

controlled failure before the strength of the remaining portion of the structure is fully mobilized (**Fig. 4**). These experiments provided direct evidence that cold joints should not be evaluated only as isolated interfaces. Instead, their behavior must be considered together with the load path and adjacent components within the structural system.

Based on the small-scale and full-scale experimental results, the researchers proposed a design approach that incorporates cold-joint behavior into the strut-and-tie method. The approach evaluates the interface shear demand along the portion of the cold joint engaged by the internal load path (**Fig. 5**). By combining interface shear calculations with the compressive and tensile stress fields represented in the strut-and-tie model, the proposed method provides a practical way to account for the interaction between cold joints and other structural components in D-regions.

For practicing engineers, this step is important. The strut-and-tie method is already widely used for the design of D-regions in concrete bridge structures, and integrating cold-joint evaluation into this framework allows engineers to analyze the interface based on the load-transfer mechanism, rather than calculating the interface capacity as a separate design check. This approach is particularly valuable for bridge components with construction joints that may be subjected to localized force transfer, such as precast concrete segments in balanced-cantilever segmental bridges and composite members with cast-in-place decks

placed over precast, prestressed concrete girders. The approach also provides an experimentally validated tool for evaluating structural components that contain unintentionally created cold joints. This tool can help engineers assess structural capacity without resorting to costly demolition and reconstruction. Beyond new construction, the framework supports the assessment of rehabilitation projects in which new concrete is added to existing structures, such as footing cap enlargements or structure widening (**Fig. 6**), where forces must be transferred across newly created interfaces. Even when the contribution of interface resistance is not explicitly considered in design, it is essential that designers understand the load-transfer mechanism across cold joints so they can evaluate the long-term safety, serviceability, and performance of repaired or expanded structures (see the “Future Provisions” sidebar).

Closing Remarks

Cold joints are an unavoidable part of bridge construction, repair, and rehabilitation. As bridge systems become more complex and as existing infrastructure continues to age, engineers will increasingly encounter situations where new and existing concrete must work together as one structural system. A better understanding of cold-joint behavior will help ensure that these interfaces are designed and constructed with the same level of confidence as the rest of the structure.

The research project presented herein reminds us that structural performance depends not only on individual materials or isolated design checks but also

Future Provisions

A standardized design approach and procedure were included in the final project report for Texas Department of Transportation Project 0-7117,¹ providing a practical template for design applications. The authors are currently developing and preparing the proposed recommendations for submission to the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures for consideration in future provisions in the *AASHTO LRFD Bridge Design Specifications*. Meanwhile, the authors are actively applying the proposed approach to practical design examples to demonstrate its implementation in three-dimensional and multipanel strut-and-tie models.

on the systematic response and the relationship of various components. By studying these interfaces through experiments, design models, and advanced analysis, the bridge engineering community can continue to improve the safety, efficiency, and resilience of concrete bridge structures.

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Figure 4. Failure of deep beams with cold joints intersecting the load transfer path.¹



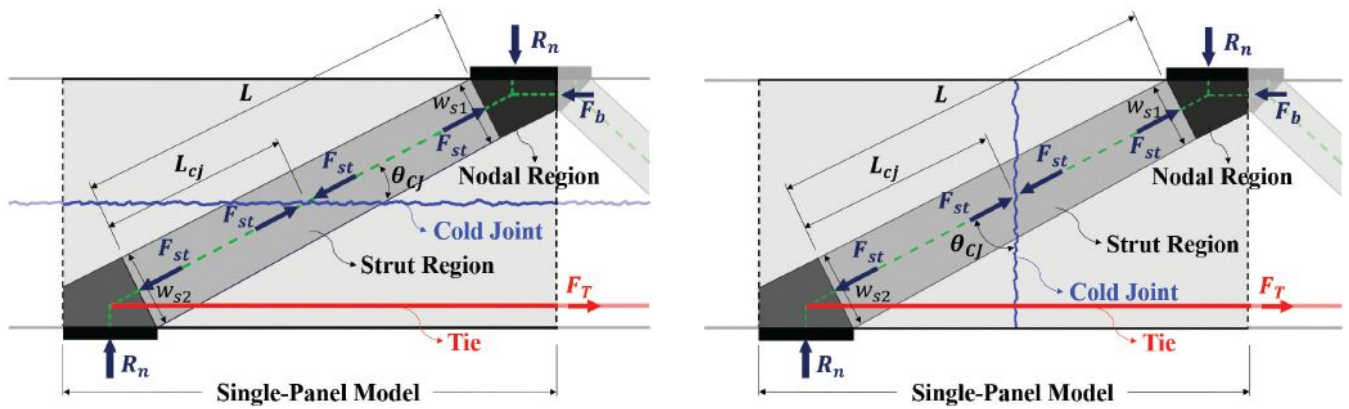


Figure 5. Strut-and-tie model (STM) with cold joints intersecting the load path in different orientations. On the left, the cold joint is not intersected by STM ties. On the right, the cold joint is intersected by STM ties.¹

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Figure 6. Example of bridge widening where forces are transferred across newly created interfaces. Photo: Concrete Bridge Engineering Institute.

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