UNIVERSITY of HOUSTON

PROJECT SUMMARY

Texas Department of Transportation

0-6914: Non-contact Splices at Drilled Shaft to Bridge Column Interface

Background

This research project conducted an experimental and analytical investigation on the behavior of non-contact lap splices at geometrically dissimilar bridge column to drilled shaft connections with regards to non-contact lap splice distance, lap splice length, and amount of transverse reinforcement in the non-contact lap splice zone. Design provisions of existing regulations, especially the AASHTO Load and Resistance Factor Design (LRFD) provisions, were evaluated through the experimental program. This project provides guidelines for the design of non-contact lap splices in the non-circular column to circular drilled shaft connections to ensure the structural safety, construction economy, and applicability of this bridge substructure type.

What the Researchers Did

The researchers performed the following tasks:

- Construction and testing of eleven large-scale column-drilled shaft specimens with regards to non-contact lap splice distances between the spliced bars, lap splice lengths, and amount of transverse reinforcement in the non-contact lap splice zone in the non-circular columns.
- Analysis of the applied load, displacement, strains in the reinforcing bars, and crack pattern data, comparing the specimens' performance to the critical parameters.
- Three-dimensional (3D) finite element analyses (FEA) of the test specimens, comparing the finite element simulated results with the test outcomes, and of the full-scale representative structure with regards to lap splice lengths.
- Thorough parametric study of the critical parameters using the validated FEA models, investigating the effects of each critical parameter.

What They Found

The researchers observed that the specimens with larger non-contact lap splice distance generally exhibited lower lateral stiffness and lower capacity. The test results showed that non-contact lap splices constructed with splice lengths equaling standard lap splice length as per the AASHTO LRFD code (2014, 2015, and 2016) plus the non-contact lap splice distance were effective in developing yielding and strain hardening of the spliced bars, provided that the transverse reinforcements were designed according to the guidelines proposed in this study. The parametric study results demonstrated that the larger the lap splice distance, the greater the contribution of the longer lap splice length in increasing the lateral stiffness of the specimens designed with non-contact lap splices.

Note that the transverse reinforcement in the column and the drilled shaft near the column-drilled shaft interface exhibited the highest tensile stress within the non-contact lap splice zone. The tensile stresses in the transverse reinforcement located away from the interface were significantly lower than those near the interface. For a non-contact lap splice distance of up to 6 inches, the transverse reinforcement near the column-drilled shaft interface in the non-circular columns exhibited yielding after the dowel bars had yielded. On the other hand, for a non-contact lap splice distance greater than 6 inches, the transverse reinforcement near the column-drilled shaft interface in non-circular columns exhibited yielding before the dowel bars had yielded. Therefore, the non-contact

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distance between the spliced bars in non-circular columns connected to circular drilled shafts should not exceed 6 inches.

The increase of non-contact lap splice distance yielded significant inclined cracks and splitting cracks in the non-contact lap splice zone. The angle of inclined cracks increased along with the non-contact splice distance. Also, a significant opening at the column-drilled shaft interface increased along with the non-contact splice distance. Further, the serviceability of such structures could be adversely affected by atmospheric conditions, creating long-term maintenance issues.

The parametric analysis indicated that the global response—i.e., the load vs. lateral displacement relationships of the specimens—was not significantly influenced by the increased amount of transverse reinforcement in the non-contact lap splice zone of the column. However, the column ties in the specimens with a higher amount of transverse reinforcement exhibited smaller stresses at the service load and ultimate load levels.

What This Means

Based on the experimental and analytical investigation, the following design recommendations are provided.

The non-contact lap splice length, l_{ns}, in the non-circular column to circular drilled shaft connections should be equal to the standard lap splice length, l_s, as per the AASHTO LRFD code (2016) plus the non-contact lap splice distance, *s*, as per WSDOT-TRAC Report WA-RD 417.1 (1997), as shown: $l_{ns} = l_s + s$.

Following this recommendation will ensure the development of yielding and strain hardening of the spliced bars, provided that the requirements for the transverse reinforcement in the non-contact lap splice zone of the column and the drilled shaft are satisfied as per the recommendations provided by this study.

The AASHTO LRFD BDS Interim Revisions (2016) publication provides several modification factors to increase l_d in Article 5.11.2.1.2, or to decrease l_d in Article 5.11.2.1.3. One of the modification factors accounts for the effect of transverse reinforcement provided around the spliced bars. This modification factor, λ_{rc} (reinforcement confinement factor), is used to decrease l_d in Article 5.11.2.1.3. However, it is not recommended to reduce the calculated lap splice length as per the AASHTO LRFD Interim Revisions (2016) by the reinforcement confinement factor λ_{rc}, because the results from the FEA of the Bent 17 column-drilled shaft connection have shown that the lap splice length could be reduced to such an extent due to the reinforcement confinement factor λ_{rc} that the tensile damage due to the splitting cracks along the spliced bars would be quite extensive despite providing the required amount of transverse reinforcement in the column and the drilled shaft.

As in the case of non-contact lap splice distances greater than 6 inches, where the transverse reinforcement near the column-drilled shaft interface in non-circular columns exhibited yielding before the yielding of the dowel bars, the non-contact lap splice distance in non-circular columns connected to circular drilled shafts should not exceed 6 inches.

The transverse reinforcement in non-circular columns connected to circular drilled shafts should be designed as per the behavior model proposed by Maksoud (2012) as given by Equation 1. This recommendation will ensure sufficient bond strength development of non-contact lap splices and will prevent sudden brittle anchorage failure of the column-drilled shaft connections.

$$S_{tr} = (n_{tr} A_{tr} f_{ytr} l_s)/(A_{Tl} f_{ul}) \qquad \text{Eq. 1}$$

where, S_{tr} = spacing of column transverse reinforcement (in.); n_{tr} = number of legs of column transverse reinforcement; A_{tr} = area of column transverse reinforcement (in.^{2}); f_{ytr} = specified minimum yield strength of column transverse reinforcement (ksi); l_s = standard required splice length (in.); A_{Tl} = total area of longitudinal reinforcement in tension (in.^{2}); f_{ul} = ultimate strength of longitudinal reinforcement (ksi).

For More Information

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