Texas A&M Transportation Institute

PROJECT SUMMARY

Texas Department of Transportation

0-5722: Lap Splice and Development Length Performance in ASR and/or DEF Damaged Concrete Elements

Background

The chemical constituents in the cement and aggregates play a key role in the durability of concrete structures. High alkali contents in cement, especially Type III cement, when used with reactive siliceous aggregates (which are prominent in Texas) in the presence of moisture can result in alkali-silica reaction (ASR). ASR can lead to the formation of expansive by-products, which in turn can lead to cracking of the concrete. Concrete cracking from ASR can lead to other deterioration processes, such as delayed ettringite formation (DEF) and corrosion, which can further reduce the capacity of the structure. Most cases of *premature concrete deterioration* within the Texas Department of Transportation (TxDOT) bridge inventory have been identified or at least suspected to be primarily from ASR. An area of concern for TxDOT is the structural performance of column splice regions with varying levels of premature concrete deterioration due to ASR and DEF.

What the Researchers Did

The experimental testing program consisted of the design, construction, curing, exposure, and structural load testing of 16 large-scale column specimens with a critical lap splice region under varying degrees of premature concrete deterioration due to ASR/DEF. Two of these specimens (control) were stored in the climate-controlled structural laboratory without supplemental water, which basically eliminated ASR and DEF. The other 14 large-scale specimens were constructed, preloaded to simulate gravity load conditions, and then stored outdoors and exposed to wet-dry cycles using supplemental water via a sprinkler system. Data were recorded for concrete core internal expansion and surface expansion measurements in all specimens throughout the exposure program. Of the 16 specimens, two control specimens without any ASR/DEF deterioration and four groups of two specimens with varying stages of ASR and up to at least early-stage DEF were structurally load-tested. Six additional specimens are being stored indefinitely at the outdoor exposure site.

To complement the experimental program, an analytical model was developed based on flexure theory to characterize the force-deformation behavior of the specimens. In splice regions, the reinforcing steel was assumed to develop tensile resistance linearly from zero at the end of the bar to the yield strength at the code-calculated development length of the bar (no bond-slip deterioration). In addition, a step-by-step flexural stiffness approach was used for sections beyond first cracking of the concrete.

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What They Found

Researchers found the following:

- All exposed specimens successfully developed ASR/DEF deterioration, described as up to late-stage ASR and at least early-stage DEF.
- The transverse concrete surface strains were about 10 times larger than the longitudinal surface strains, and the average surface strains calculated by summing the crack widths between fixed points were about 50 percent of the surface strains calculated by measuring the distance between the same points.
- Compared to the response of the control specimens, specimens exhibiting primarily ASR (and up to some DEF) had similar initial stiffness and behavior up to first cracking, had about a 25 to 35 percent increase in post-cracking stiffness up to yielding, had about a 5 to 15 percent increase in yield strength, and showed no overall detrimental structural effects.
- The increase in stiffness and strength can be explained by the resulting ASR volumetric expansion of the concrete that engaged the transverse steel for better confinement of the core concrete, and engaged the supplemental post-tensioning and column longitudinal steel to generate additional axial compression.
- The step-by-step flexural stiffness modeling approach with no bond-slip deterioration accurately replicated the experimentally measured force-deformation behavior. For the non-control specimens, the analytical model better correlated with the experimental behavior when the level of axial loading was increased to account for the ASR concrete expansion.

What This Means

Although results indicate that late-stage ASR and at least some early-stage DEF did not significantly influence the performance of the specimen lap splice regions under concentric axial loading, care should be taken when applying these results and findings to other structural applications. The lap splice length in the specimens tested was overdesigned per TxDOT standards for the bar size being used, and less conservative designs may exhibit different behavior. The splice region in the specimens tested also had a single full-column hoop at a typical 12-inch (0.3-m) spacing that provided sufficient confinement of the concrete core region. In concrete members without proper confining steel or proper longitudinal steel, special monitoring of developing crack patterns and crack widths should take place in assessing the structural capability. Long-term deterioration may also result in different structural performance.

In structures influenced by premature concrete deterioration, monitoring of developing crack patterns and crack widths should be recorded and carefully studied. When crack widths exceed those typical for in-service structures and when cracking patterns become identifiable, petrography analysis of concrete cores taken from the structure should be performed to identify the developing concrete expansion mechanism. In addition, the provided reinforcement should be carefully identified and assessed for strength and confinement of the concrete core region.

For More Information

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