Long-Term Performance of Epoxy-Bonded Rebar-Couplers

RESULTS: Although epoxy-bonded rebar-couplers are approved for use by Caltrans in select applications, preliminary tests indicate the epoxy may be vulnerable to moisture-based degradation. Moisture-degraded specimens were tested over sixteen and a half months, and results extrapolated to the service life of the system based on numerical studies. The original failure mode, rebar fracture, still controlled after a 75-year service life at moderate temperature conditions of 23°C.

Why We Pursued This Research
Caltrans has approved a relatively new class of rebar-couplers for limited use. Epoxy-bonded rebar-couplers have several advantages over other types of rebar-couplers; particularly ease of installation. Figure 1 shows a cutaway view of a typical epoxy-bonded rebar-coupler.

In addition to continuing the tests started in the de-selection phase, epoxy-bonded rebar couplers were tested at periodic time intervals of environmental conditioning. Rebar-couplers were tested in accordance with a modified California Test 670. One of the modifications was the use of a long-gauge extensometer to measure slip across the coupler during the test. Lastly, a creep test was developed based on ASTM D1512.

Research Results
Preliminary test results showed significant differences in the moisture-resistance of commercially available ASTM C881 epoxy systems. Figure 2 shows test specimens less than 1 hour after immersion in 60°C (140°F) de-ionized water. The specimens of one epoxy system exhibit extreme sagging under their self-weight, indicating a serious vulnerability to heat and moisture for this system.

What We Did
A preliminary de-selection test was performed on a variety of commercially available epoxy systems to assess their moisture-based degradation behavior. Moisture uptake, tension and Dynamic Mechanical Thermal Analysis (DMTA) testing, at a limited variety of environmental conditions, were performed in the preliminary de-selection test. A longer, primary environmental testing program was performed on two of the most promising epoxy systems selected from the preliminary test; i.e., system A (US Anchor HS-200) and C (CIA Gel 7000). Both systems are Caltrans approved.

Figure 1: Cutaway view of epoxy-bonded rebar-coupler

Figure 2: Sagged epoxy specimens after 1 hour immersion in 60°C (140°F) de-ionized water

The results of the preliminary testing were compared for relative resistance to moisture-based degradation of the six systems. Systems A and C were chosen for inclusion in the primary test program because they appeared to remain most stable when exposed to moisture.
The primary test plan was of longer duration to effectively characterize the moisture-based degradation of the two epoxy systems. Figure 3 shows a set of material tension test stress-strain plots illustrating the decline of stiffness and strength with increasing time in a 60°C (140°F) de-ionized water environment. These results were representative of both systems’ response.

Although the poor performance of the non-optimal epoxy system was evident from coupler ultimate tests, a rebar-coupler creep test was performed to quantify the difference. Since no standard exists for testing rebar-couplers in creep, a standard for creep testing of adhesive anchors, ASTM E1512, was adapted. The test was performed on couplers assembled with System C and System F, for comparison. The test was 42 days in duration and was load-controlled at 40% of rebar ultimate stress. The resulting data, and extrapolation to 600 days, is shown in Figure 5.

Since none of the rebar-coupler test-specimens failed due to the moisture-based degradation of the epoxy system during the test period, a finite element analysis was performed to correlate changing epoxy material properties to changes in rebar-coupler failure mode. Assuming the service life of the coupler consists of being embedded in a 23°C, moist environment for its assumed service life, and then being tested to failure (in tension); one can assume the original system failure mode should remain unchanged after 75 years of service.

**Recommendations**

Recommended changes to California Test 670 include:
(a) the use of a long-gauge extensometer to measure slip; and (b) an adhesive material pre-screening test for epoxy-bonded rebar-couplers to identify the vulnerability of the adhesive to moisture.

Select areas of future research include:
- Repeat rebar-coupler testing on larger bar sizes and at elevated temperatures
- Repeat rebar-coupler creep testing at elevated temperatures
- Incorporate moisture-based epoxy degradation into structural codes and acceptance criteria.

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