CRACKED BEAM/PONDING TESTS

ASTM G109 – Standard Test Method for Determining Effects of Chemical Admixtures on Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments

This protocol is widely accepted to determine and rank SCMs, inhibiting admixtures and exotic rebar materials of steel in concrete samples. It is performed and provided to meet and exceed the relevant areas of ***ASTM C1582 - Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Concrete Reinforcing Steel in Concrete and ASTM C494, Type S Admixture – Standard Specification for Chemical Admixtures for Concrete and ASTM C494, Type S Admixture.*** *We modified our protocol to reflect the most realistic construction conditions and by NOT using any electrical charge (current flow) between the two layers of rebar. Instead, we rely on the previous Half Cell readings (provided under separate copy) to illustrate concrete's "resistivity" and/or "transportability" of chloride ions through concrete and "de-passivity" of reinforcement steel.*

The only performance portion of these tests, is a final autopsy to subjectively judge the amount of corrosion product formed relative to the same mix design with various admixtures and SCM options.

Cracked Beam/Ponding protocol is such –

To expedite the process (while eliminating microcell current) and show rapid chloride corrosion, we utilized a roughly 20% sodium chloride ponding solution (instead of 3-5% solution).

The specimens were created to accommodate this Cracked Beam/Ponding protocol and the previous ASTM C876 protocol, and include:

The Mix Design tested; and six industry accepted variations are below –

<u>0.45 w/c Ratio, with a 4" (+/- 1") Slump</u>

28-Day comp. strengths @ 28 days = 5,300 psi

Cement; Type II & V – 658 lbs.

Water – 300.4 lbs. (36 gallons)

1" Agg. (#4) – 1392 lbs.

3/8" Agg. (#8) – 310 lbs.

Washed Con Sand – 1393 lbs.

WR-91, Type A water reducer – 26.32 ounces/yd^3

Air – 1%, 149.8 lbs./ft^3 Plastic Weight, 4045 lbs., 27.0 ft^3

(Aggregate Gradations available upon request)

Specimen X – crystalline growth mix; newer product marketing by Xypex on the west coast. A dry, concentrated dry powder (cement delivery with treated silicates) added at 1.25% of cement weight (this product replaces the previous 2.5% by weight commercial product) = 8.225 lbs. per cu. yard.

Specimen D – calcium nitrite mix; popular admixture with min. 30% calcium nitrites = 5.5 gallons per cu. yard.

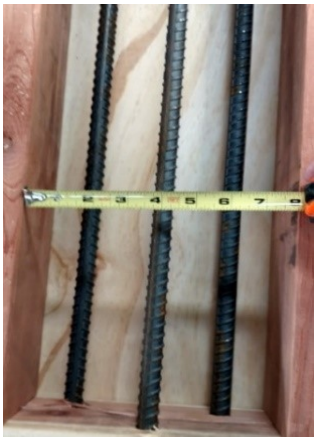
Specimen F – 20% fly ash (Class C) mix; a direct replacement of 20% (131.6 lbs.) replacement of cement.

Specimen V – Vapor Lock 40/40 mix; 10 ounces per hundred lbs. of cement = 65.8 ozs. per cu. yard.

Specimens VL – Vapor Lock 40/40 + lightweight sand mix; 10 ounces per hundred weight of cement, with 22% replacement of fine aggregate (sand) with lightweight sand provided by Arcosa Lightweight, Southern California source = 278.6 lbs. of lightweight sand.

Specimen C – Plain Control; straight mix, above.

Using "off-the-shelf" #4 rebar (1/2", not cleaned or conditioned in any way), positioned into a standard triangle pattern, with the top bar having exactly 1" of concrete cover. Forms are standard 2" x 6" wood and fastened at each corner with two screws. *No form release/oils were used. Specimen size was a nominal 5.5" deep, 24" long, and 8" wide (this gives a 3:1 geometry that would also promote a mid-point crack).



The 1” of concrete cover was compromised (to simulate an acceptable crack) with a 0.030” (1/32”) metal shim, left mid-point on the top rebar for 4 hours and then removed.



Mixes were placed into the specimens, vibrated in two spots with a stinger, screeded with a wood float, then hit with a mag float, and finally a steel edger. *There was no ability to use a power trowel, which should be taken into consideration. After the beams were cast, that evening a 3-mil black poly was laid over the specimens and weighted down with wet sand for 7 days to provide a “wet cure”.

After seven days of common curing (wet cure), the specimens were stripped of forms and air dried for 24 hours. At Day 9, four-inch-high plexi-glass reservoirs were adhered to the surfaces with silicon; 6” wide and 16” long. This was to produce ponding at roughly half the surface area of the specimens.

At Day 10 a 20% salt solution was added to an approximate depth of 1” for each specimen. The tap water was heated to approximately 120 degrees Fahrenheit. 20% (by weight) fine salt crystals are added and agitated/stirred for approximately 5-7 minutes. It is thought that the increase in water temperature would allow for the highest saturation levels possible.

Salt water was added every Monday morning at 8am. Specimens were out in the open and have semi to direct sun on them, with full thermal night and day cycles. With April weather in Southern California, they were getting about a 30 to 35-degree swing in temperature; which held constant throughout the year. Wind and rain are sporadic. Monday mornings, a new 20% salt solution is added to a depth of 1" for each specimen. Some weeks, it took all week to evaporate (April, May) and later in the year it took a day and half to evaporate (July, August). Once a month, the inside of the reservoirs were rinsed out with water to remove the salt build-up and their order was rearranged once on the raised bench during the protocol. The reservoirs were repaired once after the first month as well; additional silicone was added to the corners and joints to fix leaks.

After 20 weeks of the ponding protocol, specimens were stripped of their plexi-glass reservoirs, cleaned with water and air-dried for 24 hours. *The two Vapor Lock specimens were more difficult to strip and clean the silicon adhesive off the surface.

Day before autopsy; Physical corrosion product evident on the Control specimen, with "hot spots" on the calcium nitrite specimen ponding surfaces.

The conclusion of this protocol is to perform a destructive autopsy; cutting on top and below the top rebar for two, equal halves. Split specimens were laid out in the open for 48 hours (Southern California in September) to allow oxygen and slight evening moisture to highlight corrosive product; end encroachment and mid-point (compromised) areas are of most importance.

Specimen X – crystalline growth

Specimen D – calcium nitrite

Specimen F – fly ash

Specimen V – Vapor Lock admixture

Specimen C – Plain, Control