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Managing Water in the West

Memorandum Number MERL 2011-34

Evaluation of New Concrete Shrinkage Reducing Additive for Glen Elder Dam Spillway Inlet Slab Repair

**Missouri River Basin Project –
Solomon Division – Glen Elder Unit - Kansas
Great Plains Region**



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Glen Elder Dam

Missouri River Basin Project – Solomon Division – Glen Elder Unit - Kansas Great Plains Region

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Introduction

In early spring of 2010, the Materials Engineering and Research Laboratory (MERL), a part of the Technical Service Center (TSC) for the Bureau of Reclamation was approached by representatives of Premier Magnesia, LLC to consider evaluating a new type of concrete shrinkage reducing additive. The product was characterized as being more effective and less costly than currently available technologies.

Their primary interest was in getting the product used for a large placement as a “real” world test. The company had performed extensive proof of concept laboratory work with a well respected firm, and based on results, was very interested in moving forward with their concepts.

Over the next several months, MERL representatives provided some suggestions and recommendations about further testing and evaluations that Premier should perform. Results from those further tests would likely increase the comfort level for someone considering using their product. At the same time, Premier developed some enhancements to their technology that they felt would make it perform even better.

Then, in late winter of this year, MERL staff was contacted by representatives for the Inlet Slab Concrete Repair project that was ongoing at Glen Elder Dam in Kansas. One of the engineers for that project was not happy with the quality of the concrete that was placed. The replacement concrete had numerous restrained shrinkage cracks. His observations indicated that the cracks appeared within one to two weeks after concrete placement.

The decision was made to test the Premier product on two placements at Glen Elder Dam and compare results with similar placements made last year for concrete placed without the additive. This report describes that work and the results from using the new shrinkage reducing product.

Conclusions

1. The concrete made with the Premier Magnesia product had significantly less cracking.
2. One large test placement saw cracking reduced about 90% over a comparable placement made last fall.
3. Two smaller test placements showed no cracking, while the comparable placements from last fall showed considerable cracking.
4. The Premier Magnesia product used at Glen Elder was a combination of two technologies – a liquid component and a dry powder. The product was added manually during batching.
5. About 110 cubic yards of concrete were placed with the Premier Magnesia product.

Discussion

Glen Elder Dam is a zoned earthfill embankment located across the Solomon River in north-central Kansas (Figure 1¹). The spillway (Figure 2) is located at the right abutment of the dam and consists of an excavated earthen inlet channel, a concrete inlet apron (approach slab), a concrete radial gate structure, a downstream chute, a hydraulic jump stilling basin, and an excavated outlet channel.

The gate structure contains twelve 50-foot-wide by 21.76-foot-high radial gates (seated on top of a concrete ogee crest) and eleven 4-foot-wide separating piers. The gate bays between piers are numbered from the left abutment (Bay 1) to the right abutment (Bay 12). Longitudinal joints are located at the center of each bay.

The inlet apron extends across the spillway from the left abutment to the right abutment, directly upstream of the gate structure for a distance of 50 feet. Longitudinal joints divide the inlet apron into a series of 18-inch-thick reinforced concrete slabs which are numbered from the left abutment (Slab 1) to the right abutment (Slab 16). Each slab has a 6-foot-deep, 18-inch-thick buried cutoff at the upstream end and is anchored with #11 bars placed on a 6-foot, 3-inch pattern around the perimeter. These anchors are angled upstream at 30 degrees from vertical with the top of the anchor located downstream of the base and extend vertically 12-feet from the base of the inlet slab into the foundation bedrock. The slabs are typically 40 feet wide so the longitudinal joints between the adjacent panels do not align with the longitudinal gate structure joints except at the spillway centerline.

The invert of the excavated inlet channel upstream of the inlet apron is approximately 1 foot higher than the inlet apron invert which creates a grassy berm upstream of the spillway. As a result, water which is located on top of the inlet apron (either from receding reservoir levels or precipitation) becomes trapped and remains ponded in this area (Figure 2).

The concrete in both the inlet apron and the pier noses/gate structure were exhibiting areas of extensive deterioration. Results of a concrete core testing program [1] showed that the structure was suffering from freeze-thaw damage largely caused by absorptive aggregate. Cracking from freezing and thawing was then promoting alkali-silica reaction. There was also evidence of carbonation which could lead to susceptibility to reinforcement corrosion. Early evaluation of the approach apron of the structure indicated that about 43 percent of the inlet slab area was in need of repair with deterioration measured as deep as 14-inches during the concrete coring program [2]. A plan view (Figure 3) shows which areas were originally thought to be sound concrete and rough estimates of the depth of deterioration in the areas of damaged concrete. However, once repairs were started, the amount of damaged concrete was discovered to be much larger (Figure 4).

The repair consisted of removing deteriorated concrete using hydrodemolition (Figure 5) methods and then placing new concrete back to the existing lines and grades. In most areas, damaged concrete was removed to a depth of about 6-inches, leaving about 12-inches of the original concrete. In some areas, due to the poor quality of the concrete, it was excavated down

¹ Figures are located in Appendix A at the end of this memorandum

to the foundation. In addition, for some areas, no concrete was removed, so full depth areas of existing concrete were left in place (Figure 6).

The replacement concrete mixture is shown in Table 1. The nominal maximum size for the course aggregate was ½-inch, and it contained sand sized particles. Because of that, the as-mixed concrete aggregates contained about 50% sand.

Table 1 – Concrete Mixture Proportions

Cement lbs/yd³	Water lbs/yd³	Course Aggregate lbs/yd³	Fine Aggregate lbs/yd³	Air Content %	Other Admixtures
588	265	1240	1736	6	Water Reducing High Range Water Reducing

Using smaller aggregate usually increases the paste content of the concrete, which can exacerbate shrinkage problems. The smaller aggregate size used by batch plants in this area of Kansas is typical, since sources with larger aggregate are not readily available. Obtaining larger aggregate to use for the replacement concrete was deemed too costly and restrictive.

After initial placements were performed in the late summer and fall of 2010, restrained shrinkage cracking was observed in the new concrete (Figure 7). The occurrence of this cracking was not unanticipated, but the number and size was disconcerting.

Trial Placement Program

The client office approached TSC and MERL about finding possible solutions to at least reduce the amount of cracking in the replacement concrete. This request came in at the same time MERL was working with Premier to find a suitable location to evaluate their product. A series of meetings were held with Premier, their lab, MERL, and the client office to work out details for such a trial.

The client office agreed to host the trial. Premier agreed to work with the contractor and the batch plant to ensure that the trials with their product went as smoothly as possible and that concrete delivered to the site would meet the specification requirements. They supplied material for about 110 cubic yards of concrete.

Samples of the concrete making materials used by the batch plant were shipped to Premier’s laboratory for mixture proportioning and testing. Results were sent to this office to ensure that the specified concrete properties were met when using Premier’s additive. Once the mixture was determined to be suitable, placement of the modified mixture was approved.

The trial placements occurred in early May. Initially, 2 areas were approved for trials with the Premier additive – one bay area placement (B7, Figure 8) and one approach slab placement (S10,

Figure 9). For the comparison crack mapping, two similar areas with about the same shape were selected to map cracks (B3, Figure 10 and S3 Figure 11). One bay area placement (B8 and 9, Figures 12, shown after concrete placement) was added to the trial since material was available and the contractor had time to place additional concrete.

A total of about 100 cubic yards of concrete were placed in three separate placements. The first placement was about 70 cubic yards, and the second and third were about 15 yards each.

MERL personnel traveled to the site just prior to the placements to map cracks from comparable placements made the fall before (Figures 13 and 14).

The following day MERL personnel observed the concrete placements of concrete containing the Premier additive. In addition, executives from Premier and personnel from their laboratory were on site during the trial placements. Their lab ensured that the Premier additives were added properly and that concrete met the specified fresh properties before it was placed.

The Premier product was manually added to the mixture by personnel from their lab. Each truck was loaded with about half the concrete batch, then the Premier products, comprised of a liquid component and a dry powder, were added by hand. The rest of the concrete ingredients were added to the truck, it was brought to mixing speed for the appropriate time, and fresh properties were measured (Figure 15). After that, trucks drove to the site, fresh properties were measured again, any adjustments were made as appropriate, and then the concrete was placed using a conveyor system (Figure 16).

The trial placements were complete by early afternoon. In general, difficulties were noted in achieving the specified air content and mixtures free of clumps and balls of poorly mixed material. However, these were likely issues related to batching and mixing and not the Premier additive, since these problems were noted for several other placements.

Three weeks later, personnel from MERL and executives from Premier returned to the site to examine the trial concrete placements. Only the placement for slab 10 (S10) showed any cracking (Figure 17), and that was significantly less than cracking observed in the comparison slab. The cracking in S10 was measured and documented in a drawing. The next day, construction activities at the site were halted due to flooding (Figure 18), and as of the middle of August, the area is still underwater.

Figures 19 and 20 are drawings showing the approximate crack locations and widths of the observed cracks. Since the placement for Bay 8/9 was not in the original plan, a comparable placement from last year was not evaluated. However, there was no cracking observed in that placement. Results show that cracking was either greatly reduced or completely eliminated when cracking was compared between concrete with and without the additive. In addition, surface areas of open cracks were estimated from crack length and opening data. Table 2 shows those comparisons.

Table 2. – Comparison for Crack Data

Placement	Crack Area Opening, in²	Ratio Crack Area to Concrete Area, (ft²/ft²) x10⁻⁵
B3 (without additive)	20.4	39
S3 (without additive)	58.7	26
S10(with additive)	6.5	2.6
B7 (with additive)	0	N/A
B8/9 (with additive)	0	N/A

[1] Memorandum, MERL Report Number MERL-07-16, Report of Findings, Laboratory Evaluation of Concrete Cores - Glen Elder Dam Spillway Inlet Floor Slab - Solomon Division, Pick-Sloan Missouri Basin Program, Kansas, Bureau of Reclamation, Denver, Colorado, June, 2007

[2] Technical Memorandum No. GLE-8130-SA-2007-1: Glen Elder Dam Spillway Inlet Slab Evaluation - Glen Elder Dam - Missouri River Basin Project – Solomon Division – Glen Elder Unit – Kansas - Great Plains Region, Bureau of Reclamation, Denver, Colorado, July 2007.

Appendix A

Figures

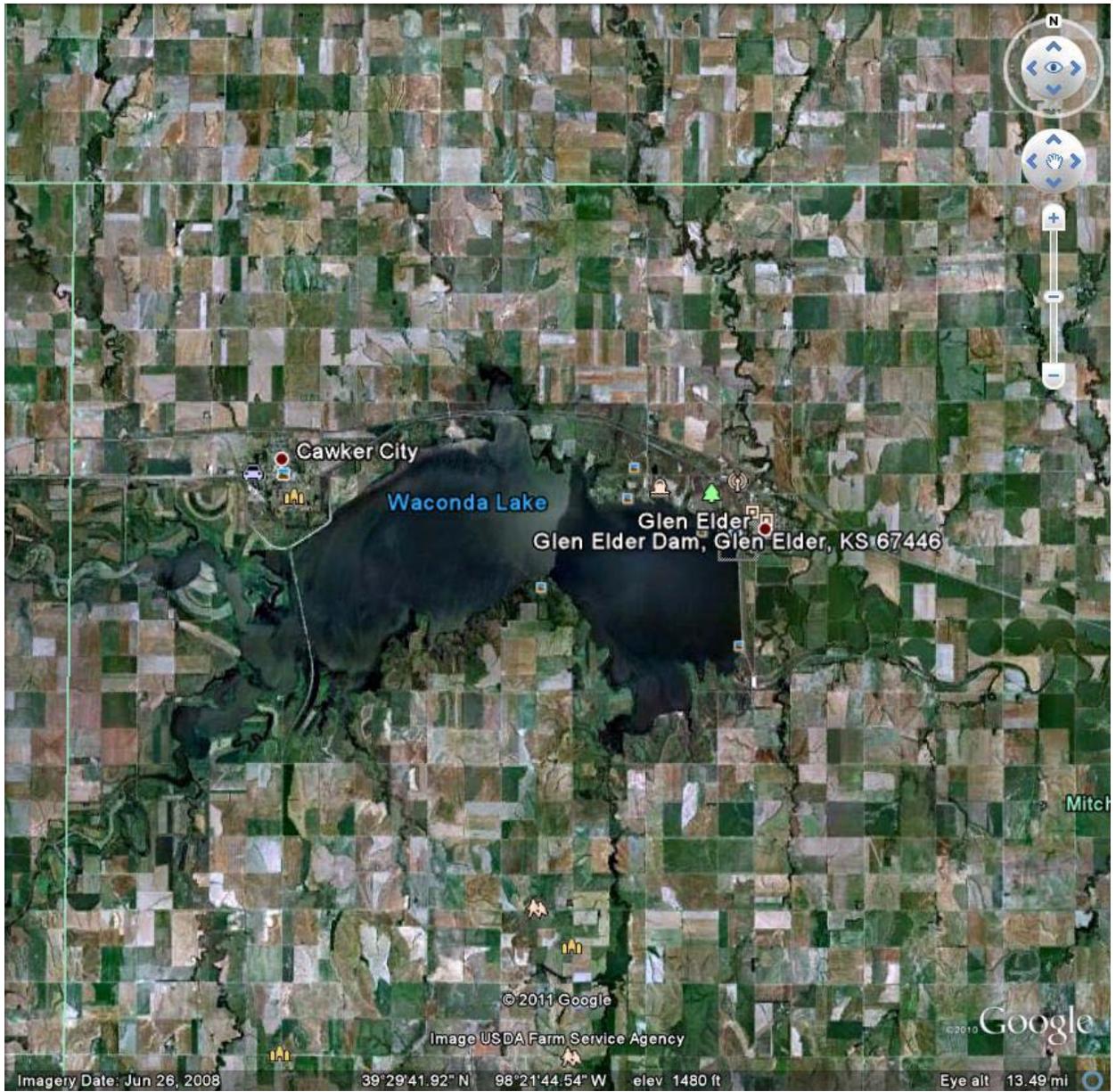
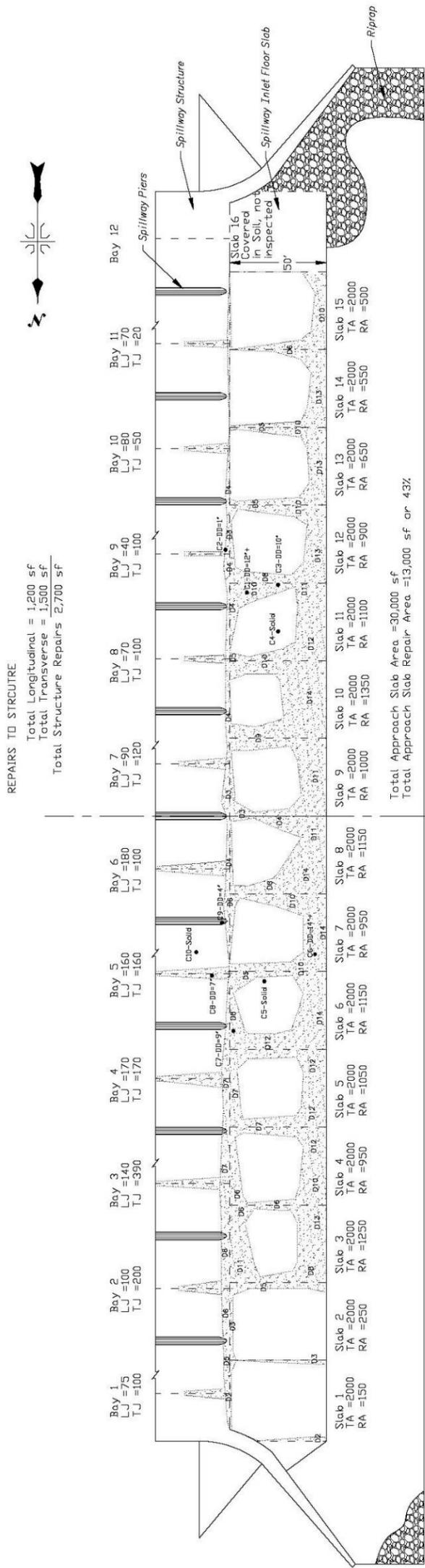


Figure 1. – Location of Glen Elder Dam



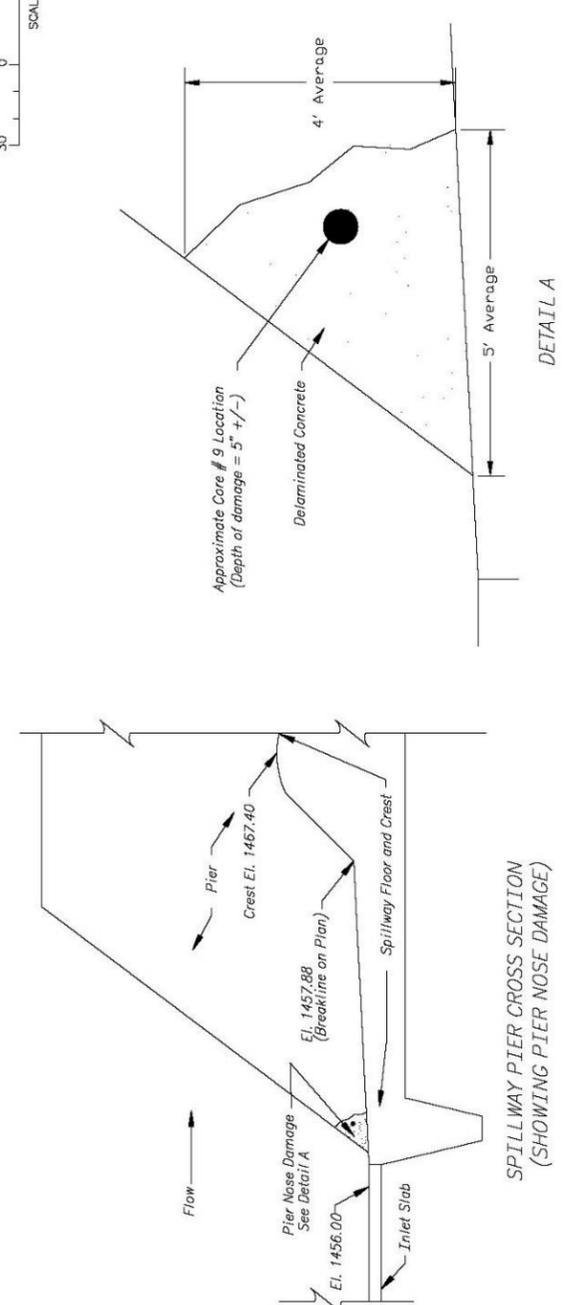
Figure 2. – View of approach area of spillway. The soil berm trapped water on the apron, leading to deterioration of the concrete.

DELINEATION OF DAMAGED CONCRETE SPILLWAY INLET FLOOR SLAB, PIERS AND UPSTREAM STRUCTURE GLEN ELDER DAM



Flow
 Spillway
PLAN

SCALE OF FEET
 30 0 30 60 90



LEGEND
 LJ = Longitudinal Joint Repair Area
 TJ = Transverse Joint Repair Area
 TA = Total Area
 RA = Repair Area
 C1-DD=12+ → Core 1 - Deteriorated Depth = 12'
 04 → Estimated Repair Depth in this area
 Shaded Areas Represent Damaged Concrete

Figure 1. – Early estimate of damaged concrete.

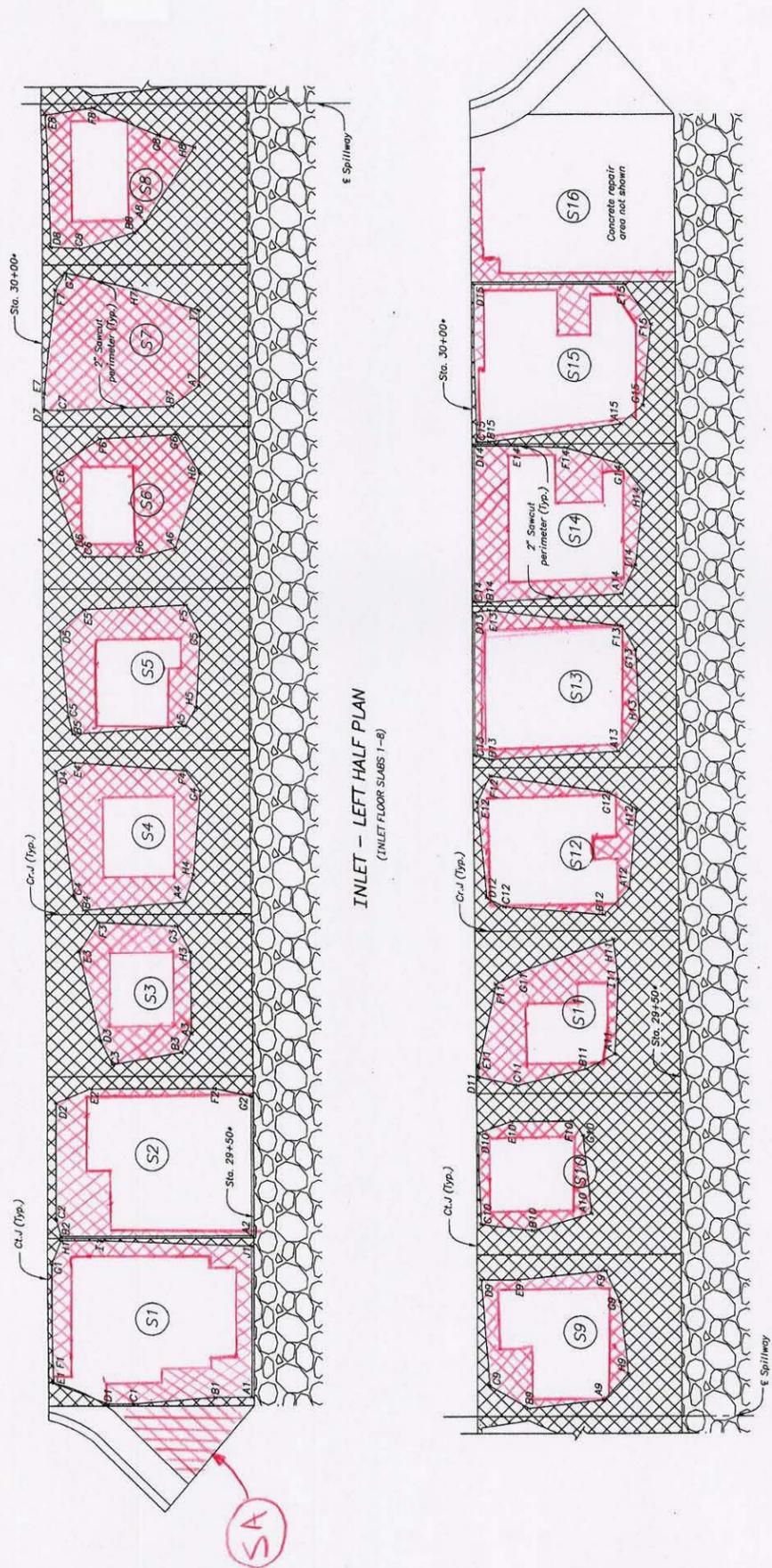


Figure 4. – Revised area of concrete damage.

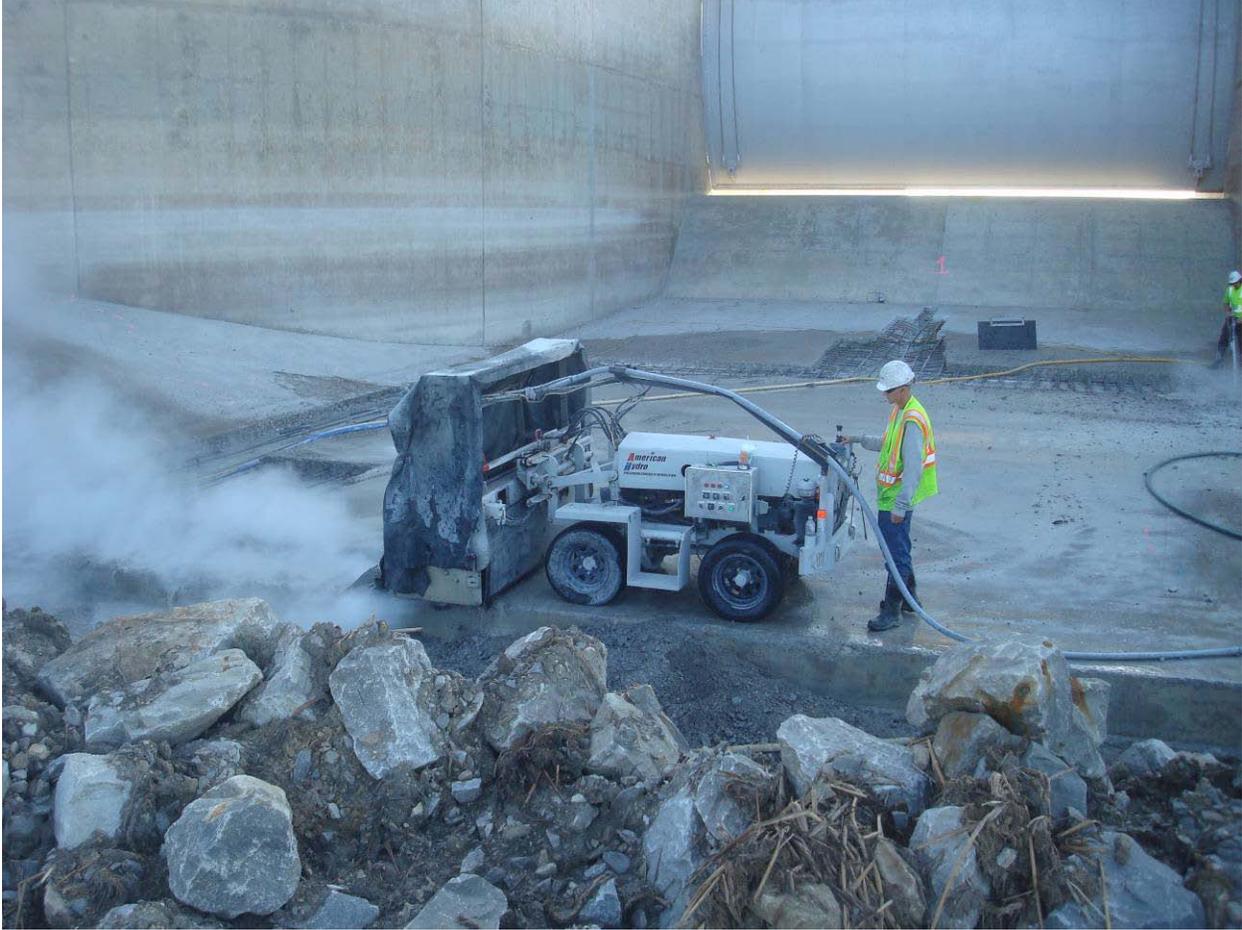


Figure 5. – Hydrodemolition of damaged concrete



Figure 6. – Example of concrete removal with some original concrete remaining.



Figure 7. – View of shrinkage cracking first observed within one to two weeks of concrete placement.



Figure 8. Bay 7 ready for trial concrete placement using concrete containing the Premier Magnesia additive.



Figure 9. – Slab 10 ready for trial concrete placement using concrete containing the Premier Magnesia additive.



Figure 10. – Slab 3 placement made with concrete without the Premier Magnesia additive.



Figure 11. – Bay 7 placement made with concrete without the Premier Magnesia additive.



Figure 12. – Placement B8/9 made with concrete containing the Premier Magnesia additive.



Figure 13. – Typical shrinkage cracking that was measured and mapped.



Figure 14. – Measuring crack openings.



Figure 15. – Measuring fresh properties of the concrete after addition of the Premier Magnesia additive.



Figure 16. – Placement of the trial concrete.

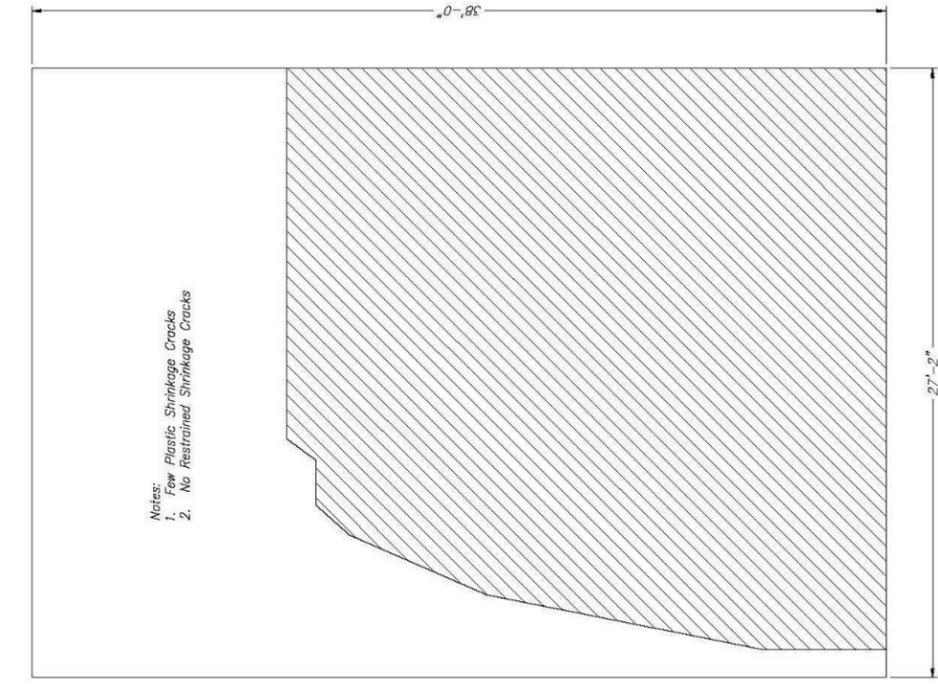


Figure 17. – Slab 10 repair made with the trial concrete.

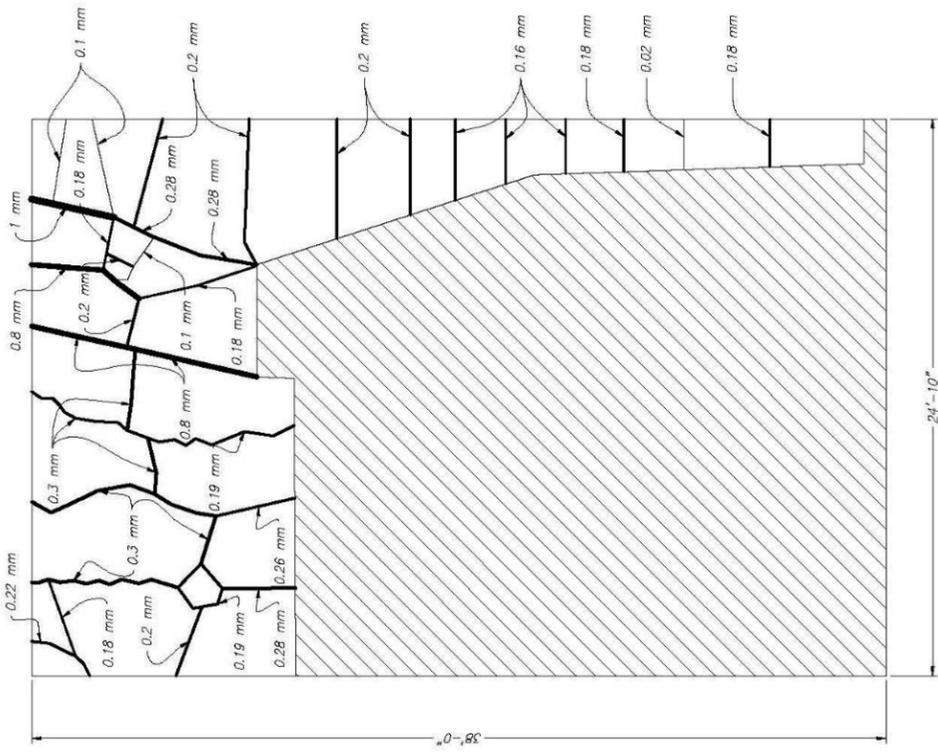


Figure 18. – Approach apron under water after flooding.

Figure 19. - Comparison of bay placements made with and without the shrinkage reducing additive.

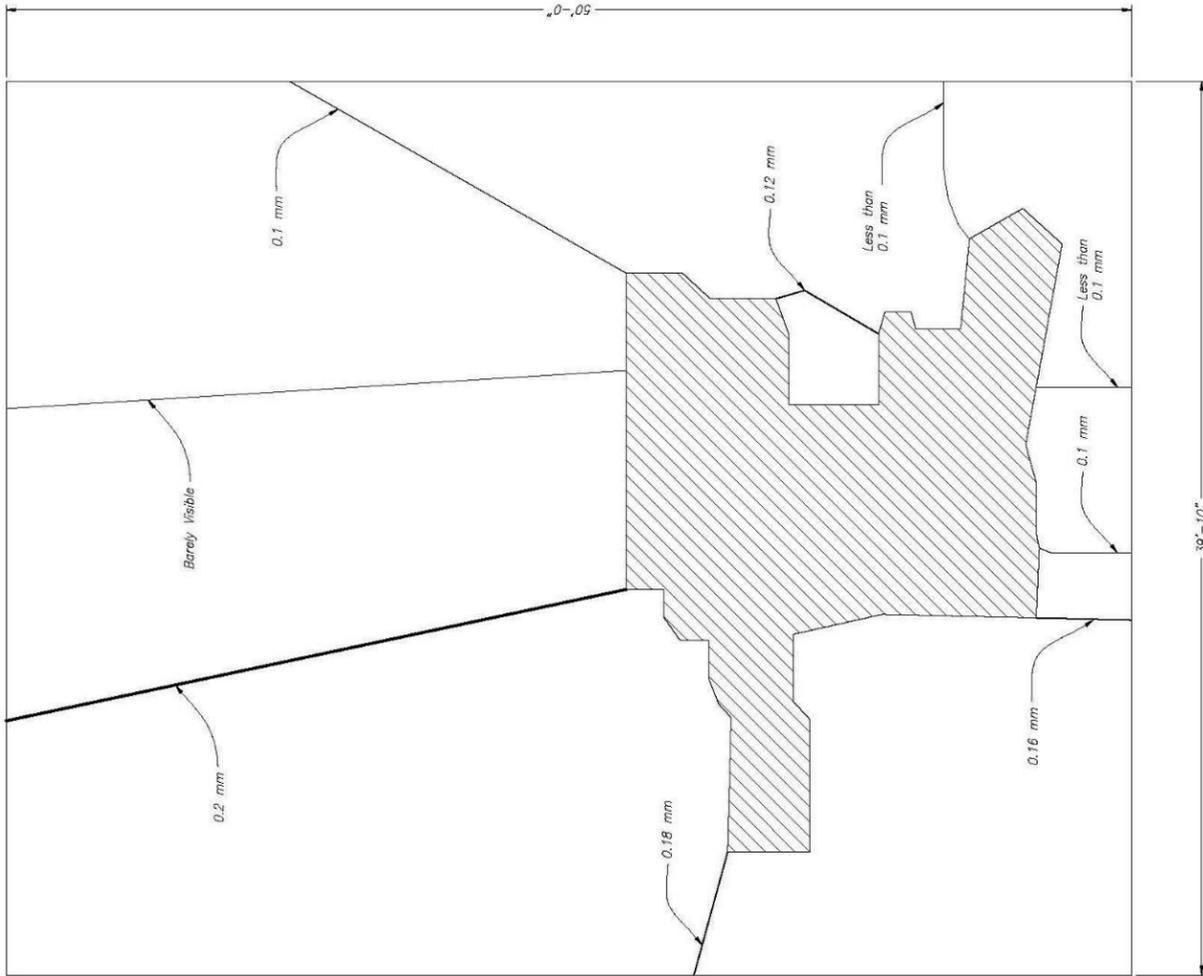


BAY 7 — WITH ADDITIVE

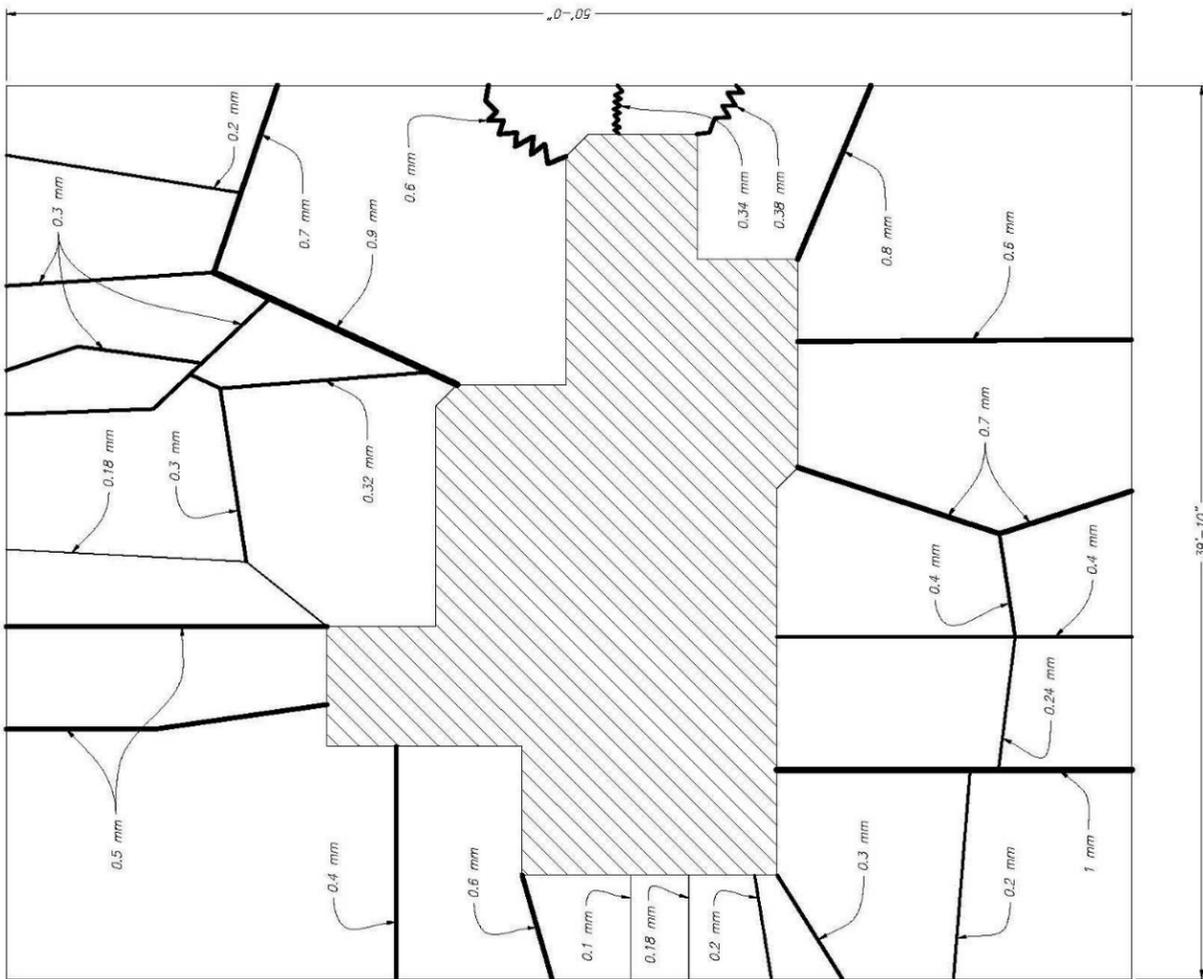


BAY 3 — WITHOUT ADDITIVE

Figure 20 – Comparison of slab placements for concrete placements made with and without the shrinkage reducing additive.



SLAB 10 – WITH ADDITIVE



SLAB 3 – WITHOUT ADDITIVE