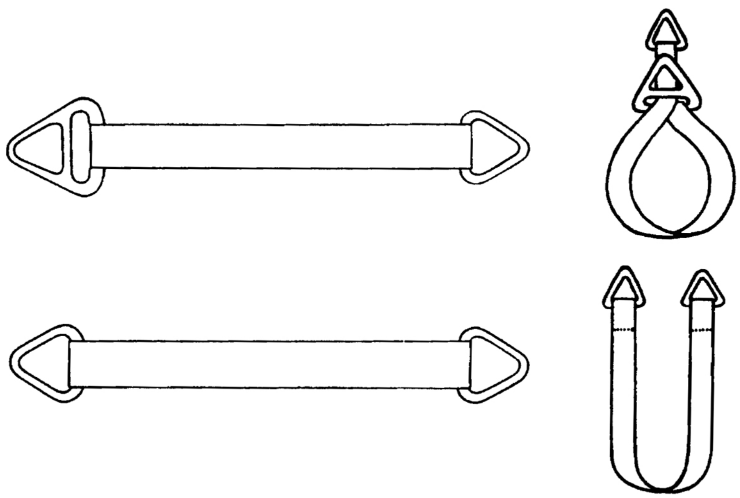
WATER OPERATION AND MAINTENANCE BULLETIN

No. 205 September 2003



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UNITED STATES DEPARTMENT OF THE INTERIOR Bureau of Reclamation

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This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

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For further information about the *Water Operation and Maintenance Bulletin*, contact:

Jerry Fischer, Managing Editor

Bureau of Reclamation

Inspections and Emergency Management Group

Code D-8470

PO Box 25007, Denver, Colorado 80225-0007

Telephone: (303) 445-2748

FAX: (303) 445-6381

Email: jfischer@do.usbr.gov

***Cover photograph**: Two examples of synthetic web slings.*

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EVALUATION OF A POST-HYDRATION CONCRETE HARDENER

Written by Kurt F. von Fay

Introduction

Occasionally, structural concrete fails to reach its design strength due to various reasons, including improper curing, higher than specified water to cement ratio, high air content, or lower cement content. On one recent Federal Highway Administration (FHWA) project, a topical application (SURTREAT TPS-II), purported to strengthen concrete, was applied to improve the strength of the concrete. Non-destructive surface measurements indicated an increase in strength after treatment.

The SURTREAT product used at Frenchman Lake Road Bridges, TPS-II, now called GPHP, is a water-soluble silicate blend. These types of products interact with hydrating Portland cement and increase the calcium silicate hydrate (CSH) at the expense of calcium oxide. Although these types of products are sometimes heavily marketed, treatment with these products is of questionable effectiveness.[1]

The FHWA's experience with these products is limited. More information was needed on the effectiveness of these products to strengthen and improve the quality of the concrete. There is evidence that these types of products improve the surface strength of concrete, but very little is known about strength or other improvements with depth in the concrete.

This application was evaluated to determine the effectiveness of the treatment. For this investigation, concrete cores obtained from treated and untreated concrete at Frenchman Lake Road Bridge were evaluated using several petrographic techniques and some physical properties tests. Funding for this study was provided by FHWA and the Bureau of Reclamation's (Reclamation) Science and Technology program. FHWA provided the majority of the funding.

Conclusions

1. The treated concrete surfaces contain slightly more calcium carbonate and slightly less calcium hydroxide (Portlandite) than untreated concrete, as indicated by x-ray diffraction (XRD) analysis. The greater amount of calcium carbonate may be a result of carbonation or treatment with SURTREAT. No increase in CSH was detected.

[1] Nixon, Randy and Dr. Richard Drisko, "The Fundamentals of Cleaning and Coating Concrete," The Society for Protective Coatings (SSPS), 2001, Chap. 8, pg. 165.

2. The hardened cement paste from the treated surfaces areas exhibits a lighter gray color when specimens are saturated surface dry. On this basis, the depth of penetration appears to average about ¼ of an inch.

3. The treatment appears not to have decreased paste voids.

4. Improvements in concrete quality as a result of the treatment were not observed.

5. Improvement in compressive strength resulting from treatment of the concrete was not evident.

6. Improvement in density of the concrete resulting from treatment of the concrete was not evident.

7. Water absorption of treated concrete, observed during measurements made for specific gravity determinations, seemed to be high.

8. More thorough investigations into the effectiveness of these products seem warranted. These types of products are heavily marketed from time to time, and some manufacturer's claims are hard to substantiate. If these products do, in fact, improve concrete quality, more knowledge about when and where they are appropriate for use would benefit potential users.

Procedure

A two-phase testing program was recently completed, coordinated by the FHWA and performed by Reclamation at their research laboratories located in building 56 at the Denver Federal Center. Phase I was Evaluating Post-Hydration Concrete Hardening Admixtures, and Phase II of the program consisted of Assessing Set Retarding Admixtures. This report contains results of testing for Phase I of the program.

Phase I consisted of evaluating the properties of concrete treated with SURTREAT TPS-II, which was applied to about 1,000 ft^2 of the concrete in the Abutment 1 Breastwall and Abutment 2 Cap at Plumas National Forest, Frenchman Lake Road Bridge, California. The compound was applied to the concrete on May 23 through May 25, 2000, in an attempt to increase the strength of the concrete. Prior to the application of SURTREAT compound, the Abutment 2 cap was treated with a curing compound.

A project report from SURTREAT describing the process for treating the concrete and the mix design of the concrete was provided. Apparently, concrete was placed in the structures around the end of April. Problems with the concrete were noted shortly after placement.

Information about concrete compressive strengths and concrete placement information alerted FHWA that they might have a problem with concrete strengths at the bridge. The concrete was treated near the end of May, and the concrete quality was evaluated by SURTREAT personnel using a rebound hammer near the middle of September.

Cores from the treated and untreated concrete were obtained near the end of June 2002 and shipped to Denver. For comparison purposes, the untreated samples of concrete came from concrete that was reported not to have experienced strength gain problems. Cores arrived in Reclamation's laboratory in early July and were logged and tested.

Several testing programs were considered to evaluate the full impact of SURETREAT on concrete. Among those were:

- Compressive strength tests, with elastic properties.
- Change in freezing and thawing durability with depth.
- Change in chloride ion penetration with depth.
- Petrographic and thin section examinations at different depths, including thin sections, XRD analysis and scanning electron microscope (SEM) examination as needed to investigate the effects of SURTREAT.
- If a companion core can be obtained from the same concrete that was not treated, then a petrographic comparison will be made between treated and untreated concrete.

We also originally planned to test SURTREAT and two or three other similar products on laboratory prepared specimens to more fully test the products in a controlled situation. However, due to time and budget constraints, and the apparent reluctance of the suppliers we contacted of these products to submit samples, no laboratory prepared concrete specimens were evaluated.

In addition, there was insufficient core for freezing and thawing and chloride ion permeability testing, so that testing was not performed. Instead, additional petrographic studies were performed.

A number of physical properties tests and petrographic examinations were performed on submitted samples of concrete from Frenchman Lake Road Bridge. The petrographic examinations comprised the bulk of the work efforts for this program.

Physical Properties Tests

The core log notebook fully describes the recovered concrete cores.

During logging and specimen examination and selection, cores were stored in Reclamation's core layout room (50 percent relative humidity, 73 degrees Fahrenheit (^{o}F) temperature) under moist towels, which were covered with plastic sheeting. Once specimens were selected for testing, they were sawcut from the cores and moved to Reclamation's fog room (100 percent relative humidity, 73 ^{o}F).

Cores were all about 2¾ inches in diameter and about 6 inches long. The concrete core contained numerous voids—more than we would expect to see.

Table 1 shows results from specific gravity, compressive strength, and elastic properties tests performed on specimens obtained from the concrete cores.

Table 1.—Physical properties test results

Core ID	Specific gravity	Compressive strength (lb/in^2)	Modulus of elasticity (x10^6 lb/in^2)	Poisson's ratio
Control 2	2.16	3,750	2.72	.22
Control 3	2.17	3,400	2.46	.21
B9-71, Abut1, Sample 6	2.28	3,600	2.28	.21
#2, Unknown location	2.28	3,200	2.72	.22
B9-72, Abut2, Sample 7	2.25	3,110	2.34	.14
B9-71, Abut1, Sample 4	2.28	2,910	2.02	.12

Specific gravity of the concrete was determined after the specimens were removed from the 100-percent humidity room. Due to the porous nature of the concrete, the specimens were placed in water buckets for about 3 weeks before measurements were made for determining the specific gravity to ensure that the concrete was fully saturated. The control specimens absorbed about 3 percent water, while the treated specimens gained over about 4 percent water, compared to the original dry weight. Lime was added to the water to prevent leaching of calcium hydroxide. Mass measurements were taken over a period of several days until mass gain from water absorption stopped.

For testing, all cores (except B9-71, Abut1, sample 6), were cut to length so that the length to diameter ratio was 2:1. Specimen B9-71, Abut1, sample 6 had a length to diameter ratio of 1.68, and test results were adjusted according to ASTM C-42 "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete." Compressive strength testing was performed according to ASTM C-39 "Compressive Strength of Cylindrical Concrete Specimens." The ends of the compressive strength specimens were capped with a sulfur compound to achieve end tolerances according to USBR 4617, "Capping Cylindrical Concrete Specimens." Testing to determine elastic properties was done according to USBR 4469 "Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression." Data for elastic properties calculations were gathered automatically using electrical resistance strain gauges glued to appropriate locations of the concrete tests specimens.

Specific gravity values are lower than expected for concrete of this type and age. However, these values are in agreement with the number of voids observed in the core, indicating relatively high porosity of the concrete, when compared to normal concrete.

Compressive strengths reported here are about the same to somewhat higher than results reported in the FHWA document. Since the concrete was placed about 2 years before we obtained the samples, some strength gain would be normal and expected. The consequences of drilling the concrete may mask some of the strength gain, since some believe that drilling causes some damage to the concrete cores.

Documentation of rebound testing of the treated concrete provided to FWHA from SURTREAT is substantially higher than test results reported in table 1. That is not unusual or surprising, since rebound hammer test results should not be used to measure actual strength of concrete. Rebound hammer test results are suitable for locating areas of different concrete strength from one area to another.

Modulus of Elasticity values and Poisson's Ratio values for two specimens were lower than expected for quality concrete and reflect the low quality of the concrete tested here.

Rebound hammer testing of the concrete cores was performed according to ASTM C-805 "Rebound Number of Hardened Concrete." Although the procedure calls for doing the tests on 6-inch minimum diameter specimens, we performed the tests in an attempt to determine differences in concrete quality from top to bottom of the concrete cores. However, after numerous attempts on two core samples, the process was halted. It was very difficult getting readings because of the porosity and softness of the core, and, in many cases, the hammer was damaging the concrete and breaking off pieces of the core. Damaged ends were removed before compressive strength testing was conducted.

Petrographic Examination

Several samples were examined petrographically. Examinations were performed to determine the effects of the treatment and, if possible, the depths of treatment.

The examination consisted of megascopic and microscopic evaluations, including SEM, as well as XRD analysis and a few qualitative physical and chemical techniques. The purpose of the examinations was to try and detect differences between treated and untreated concrete.

Visually, the examined core specimens exhibit only slightly lighter gray paste in the top (about ¼ of an inch). This becomes apparent only after immersing the specimens in water and then allowing them to dry to saturated surface-dry condition.

XRD analysis was conducted on four of the selected core specimens, with one sample prepared from the top about ¼ of an inch and one from well below that area. The hardened paste was separated from aggregate as much as practicable for the analysis. In each case, there was a slight enrichment of calcium carbonate ($CaCO_3$), and a corresponding decrease in Portlandite ($Ca(OH)_2$) in the top (treated) portions.

Paste from treated and untreated areas appears similar in all other respects; no trend or difference in void density, configuration, or distribution within a specimen was observed, nor could any morphological or textural feature(s) be detected by petrographic or SEM that could be ascribed to the treatment. No significant difference in elemental composition could be detected using energy dispersive spectroscopy (EDS).

The surfaces treated with SURTREAT were somewhat rough and weathered. Tests for water absorption on these surfaces indicate they are slightly and moderately absorptive but occasionally highly absorptive. The outer surface of the control specimen is only slightly absorptive.

The treated concrete surfaces contain slightly more calcium silicate hydrates and slightly less calcium hydroxide (Portlandite) than untreated concrete, as indicated by XRD analysis. The hardened cement paste from these areas also exhibits a lighter gray color when specimens are saturated surface dry. On this basis, the depth of penetration appears to average about ¼ of an inch. The treatment appears not to have affected detectable paste voids.

If you have any questions about information contained in this article, please contact Kurt von Fay at kvonfay@do.usbr.gov.

ASSESSING SET-EXTENDING ADMIXTURES

Written by Erin Gleason and Kurt von Fay

Introduction

Approximately 10 years ago, chemical admixtures that significantly extend the workability time by delaying the setting time of concrete were introduced to the market. These admixtures are known as "extended set-retarding admixtures" or more commonly, "stabilizers." To date, there are two known manufacturers of this admixture—Master Builders (a division of Degussa Construction Chemicals) and W.R. Grace. Master Builders' (www.masterbuilders.com) stabilizer is called Delvo, and W.R. Grace's (www.wrgrace.com) product is called Recover. Both products fall under the classification for a Type D (Water reducing set retarding) admixture according to ASTM C-494, "Standard Specification for Chemical Admixtures for Concrete."

Although conventionally classified as retarders, these products differ from traditional set retarders due to more complete retarding of the setting of concrete. As opposed to a conventional retarder, which slows down the hydration process, a stabilizer stops hydration for a user-determined period of time—dictated by the dosage of the admixture. One of the benefits claimed by the producers of the admixture is that using the stabilizer allows remote sites to be supplied by central commercial batch plants, without the usual problems associated with long distance hauls. Both the U.S. Corp of Engineers and Master Builders tested Delvo. None of the tests reported by either group reveal any significant performance problems when using Delvo.

The Bureau of Reclamation (Reclamation) and the Federal Highway Administration (FHWA) both have limited experience with this product. Questions have come up regarding several projects where the stabilizer has been used. More information is needed on batching, reliability of the extended set time, and modified finishing methods and curing requirements (if any).

Conclusions

1. Both Delvo and Recover extend the setting time of concrete. Larger doses of set extenders extended the setting time even more. Increases in setting time were large compared with increases in dosage. At higher doses, the Recover set extender caused very long extension times, over twice those of the corresponding Delvo mixtures at both temperatures of 70 °F and 95 °F. The relationship between time of set and stabilizer dosage is exponential.

2. Both admixtures caused significant fluctuations in air content during the extended set time. At higher doses of the set extenders, air content rose substantially. At higher doses, the Recover caused larger increases in air content than corresponding doses of Delvo. At room temperature, these high air contents did not return to original levels.

3. Results of the 28-day compressive strengths were consistently higher for the mixtures at 95 degrees Fahrenheit (^{o}F) than the mixtures at 70 ^{o}F. Figure 11 in Reclamation's Concrete Manual, 8th Edition, shows that specimens made at higher temperatures have higher strengths initially but then lower strengths at 28 days. None of the specimens follow this trend.

   We do not have an explanation for the control specimens not conforming to Figure 11. For the mixtures with the stabilizer, reasons for higher strength at higher mixing temperatures may be due to the stabilizing admixture extending the properties found in compressive strength early on (i.e., extending the high-early strength found in concrete made at high temperatures beyond the typical 7-day period). Another possible reason that the 28-day compressive strengths were higher at the higher temperature is that the stabilizer has a positive effect on strength at higher temperatures. Further investigation is necessary to determine the cause of this phenomenon with any degree of certainty.

4. For the 70 ^{o}F temperature specimens, the 28-day compressive strengths of the concrete with higher doses of set extenders tended to be lower than the control specimen. This can at least be partly explained by higher air content in concrete with higher doses of set extenders.

5. For the 95 ^{o}F temperature specimen, the 28-day compressive strength of concrete with higher doses of set extenders was higher than, or about the same as the strength of, the 95 ^{o}F control specimens. At higher temperatures, the increase in air content did not have as large an impact on compressive strength as it did on concretes mixed at lower temperatures. A petrographic examination is necessary to study the air void system. Changes in the air void system may help to explain why the high air content at the higher admixture dosages did not appear to have a negative impact on compressive strengths of specimens having lower densities.

6. In general, all specimens did very well with respect to freeze-thaw durability. Reclamation's criteria for durable concrete is that a specimen must go through at least 500 freeze-thaw cycles and lose no more than 25 percent of its mass. All specimens tested easily met this criteria; none lost more than 1 percent of its mass after 500 cycles.

7. The specimens mixed at 95 °F show better results for freeze-thaw durability than those mixed at 70 °F. This can be attributed to the fact that the average compressive strength was higher for the 95 °F specimens than the 70 °F specimens.

8. Set extenders seem to be an attractive alternative to other methods for delivery concrete with long haul times if issues with changing air content can be resolved.

9. Table 1 summarizes the amount of time a prescribed dose of either admixture extends the time of the final set (information derived from table 7).

Table 1.—Extended set times

Admixture	Dosage (oz/100 lb c + p)	Temperature (°F)	Time set extended (past control) Hours	Minutes
Delvo	3	70	1	37
Recover	3	70	1	28
Delvo	6	70	4	59
Recover	6	70	10	34
Delvo	9	70	7	47
Recover	9	70	26	52
Delvo	3	95	2	1
Recover	3	95	3	58
Delvo	6	95	4	42
Recover	6	95	16	57
Delvo	9	95	15	10
Recover	9	95	43	59

Test Program

This report contains a description of Phase II of a two-phase testing program developed by the FHWA. Phase I of the program was evaluating post-hydration concrete hardening admixtures, and Phase II was the assessment of set-extending admixtures. All testing for Phase II was performed by Reclamation at their Materials Engineering and Research Laboratories (MERL). This program was jointly funded by FHWA and Reclamation's Science and Technology (S&T) Program. FHWA provided the majority of the funding. Phase I of the program is reported in a separate document.

Phase II consisted of preparing concrete using both the admixtures in accordance with FHWA specification FP-96, Section 552 for Structural Concrete, Class A(AE), Table 552-1 (Appendix). The three variables examined in the program were mixing temperature, admixture dosage, and the brand of admixture (Delvo or Recover).

A total of 12 mixtures were made using 3 different admixture dosages and at 2 different temperatures, 70 °F and 95 °F. Two control batches (no stabilizer added) were also made (one for each temperature) in addition to the 12 mixtures. All 14 mixes were made using the saturated surface dry (SSD) proportions listed in table 2.

Table 2.—SSD mixture proportions – quantities per cubic yard

Component	Mass (lbs)	Volume (ft^3)
Air		1.62
Water	270	4.33
Cement	614	3.12
Pozzolan	0	0.00
Sand	1,225	7.53
Coarse aggregate (#4 to 1 inch)	1,724	10.40
Total	3,833	27.00

Daravair, an air-entraining admixture (AEA) manufactured by Master Builders, was added to each mixture at a quantity of 3 oz per 100 lb of cementitious material. Since the addition of most admixtures generally has the effect of increasing the air content of mixtures, AEA dosages usually vary in proportion to admixture dosages. This testing program maintained the 3 oz proportion of AEA for all mixtures so that the degree of effect the admixtures had on the air content could be determined. The three stabilizer dosages at each temperature were 3 oz, 6 oz, and 9 oz per 100 lb of cementitious material.

Mixing

The concrete was mixed in accordance with ASTM C-192, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory," and fresh properties—slump, unit weight, air content (gravimetric and pressure methods), and temperature—were tested and determined in accordance with the corresponding ASTM test methods. Table 3 lists the ASTM test method used to determine each fresh property.

Table 3

Fresh property	Test method	ASTM designation
Slump	Standard test method for slump of hydraulic-cement concrete	C-143
Unit weight	Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete	C-138
Pressure air	Standard test method for air content of freshly mixed concrete by the pressure method	C-231
Gravimetric air	Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete	C-138
Temperature	Standard test method for temperature of freshly mixed Portland cement concrete	C-1064

All seven 70 ^{o}F mixtures were mixed and the fresh properties tested in the central mixing room at MERL. The seven 95 ^{o}F mixtures were mixed and fresh properties tested in one of MERL's environmental chambers, which was set to 95 ^{o}F. The constituents of the concrete were placed in temperature conditions corresponding to the mixture, for a minimum time of 24 hours before testing to ensure the desired mixing temperatures.

After the concrete was mixed, the fresh properties were tested and the concrete was put back into the mixer, and the stabilizer was then added. The concrete was then mixed for an additional 3 minutes, and fresh properties were again measured. To determine the long-term effects the stabilizers had on the fresh properties of the concrete, each batch of concrete was left in the mixer for 3 hours, when fresh properties were tested for a third time. The mixer was covered with a damp towel for the duration of the 3 hours. Every 15 minutes over the course of the 3 hours, the mixer was turned on for 60 seconds. This process was intended to simulate the mixing action of a concrete truck on a long haul.

Specimens

After the final testing of the fresh properties, specimens were cast (control specimens were cast immediately after the initial fresh property measurements). Six cylindrical specimens having the dimensions of 6 inches in diameter by 12 inches long, along with three cylindrical specimens, 3 inches in diameter and 6 inches long, were cast in accordance with ASTM C-192. The cylinder specimens from each mixture were then cured in MERL's 100 percent humidity (fog) room until the date they were to be tested. The specimens were tested according to the schedule and method shown in table 4.

Table 4

Specimen	Test method	Test designation	Quantity	Test age
6 x 12 cylinder	Standard test method for compressive strength of cylindrical concrete specimens	ASTM C-39	3	7 days
6 x 12 cylinder	Standard test method for compressive strength of cylindrical concrete specimens	ASTM C-39	3	28 days
3 x 6 cylinder	Resistance of concrete to rapid freezing and thawing	USBR 4666	3	28 days (start)

The remaining concrete from each batch was screened over a #4 sieve (conforming to ASTM E-11, "Standard Specification for Wire Cloth and Sieves for Testing Purposes") and placed in four containers conforming to ASTM C-403, "Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance." Three of the specimens were tested for time of set according to ASTM C-403. A thermocouple was placed in the fourth specimen and was attached to a data logger to record the temperature change of the setting concrete. The temperature was logged to try to correlate the temperature rise due to the heat of hydration to the setting time of the mixture.

Results

Fresh Properties

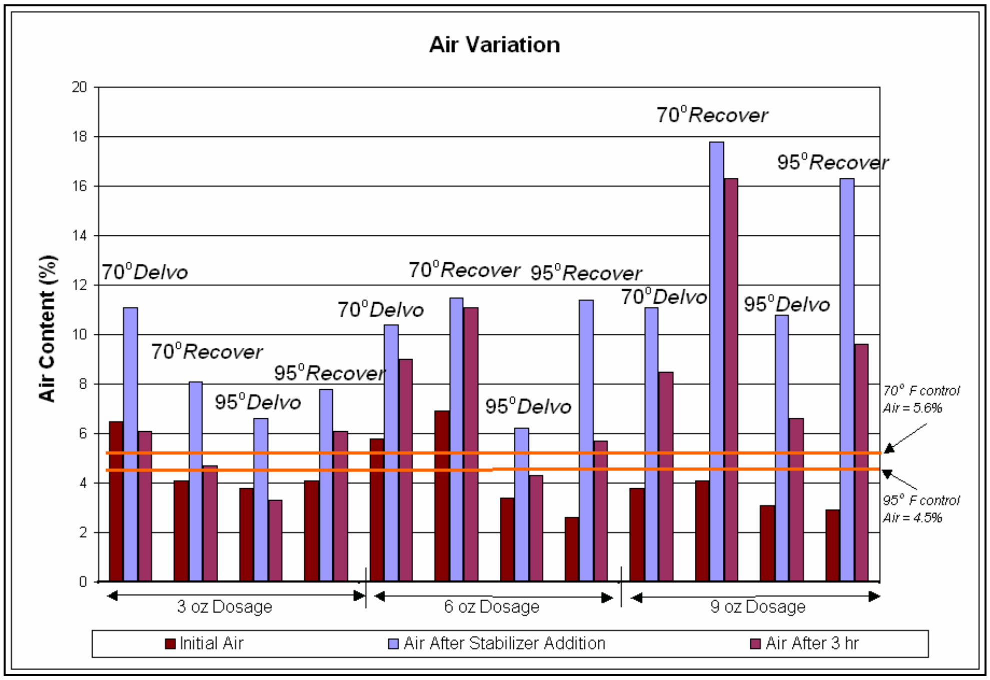
Table 5 shows the results for all measured fresh properties. For each mixture (with the exception of the two control mixtures), fresh properties were measured and recorded three times: (1) after initial mixing, (2) immediately after the addition of the stabilizer, and (3) 3 hours after the addition of the stabilizer.

Graphs 1 and 2 show the rise and fall of air content and slump, respectively, for the three times fresh properties were tested. Reviewing graphs 1 and 2 , it is apparent that the air content increased sharply (above 10 percent) when using 6 oz and 9 oz doses of either admixture (one exception is with 6 oz Delvo at 95 ^{o}F). This is especially problematic with the Recover admixture at 70 ^{o}F, since the air content does not go back to its original level in either instance. In general, the trends in the slump can be correlated with air content with the exception of the 9 oz Recover mixtures; this may be due to the excessively high air contents at 9 oz dosages of Recover (over 16 percent) making the mixture perform in an unpredictable manner.

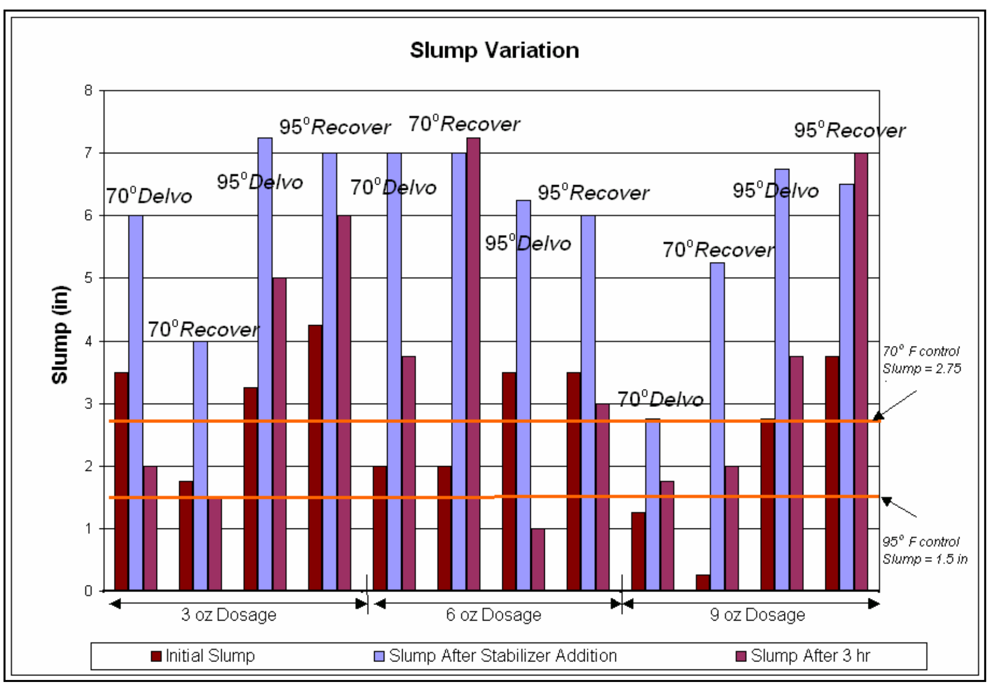
Table 5

Fresh Properties summary							
Mix	***Mixing Temperature oF***	***Date/Time***	***Slump in***	***Temp oF***	***Density lb/ft^3***	***Pressure Air %***	***Gravimetric Air %***
control	**70**	**07/02/02 12:00**	**2.75**	**73**	**142.60**	**6**	**5.6**
		07/04/02 10:30	3.50	69	141.20	6.9	6.5
		07/04/02 10:45	6.00	69	134.20	12.5	11.1
3oz Delvo	70	07/04/02 13:15	2.00	71	141.76	6.5	6.1
		07/02/02 13:30	1.75	73	144.90	5.3	4.1
		07/02/02 13:45	4.00	73	138.87	9.5	8.1
3oz Recover	70	07/02/02 16:30	1.50	73	143.93	5.6	4.7
		07/04/02 12:45	3.25	71	142.20	6.5	5.8
		07/04/02 13:00	7.25	71	135.25	11.5	10.4
6oz Delvo	70	07/04/02 16:00	5.00	74	137.42	9.5	9
		07/04/02 15:30	4.25	70	140.68	6.8	6.9
		07/04/02 15:45	7.00	70	133.64	12.9	11.5
6oz Recover	70	07/04/02 18:45	6.00	74	134.32	12	11.1
		7/17/02 13:25	2.00	74	145.30	5.1	3.8
		7/17/02 13:45	7.00	72.5	134.32	11.5	11.1
9oz Delvo	70	7/17/02 16:45	3.75	72.5	138.14	9.75	8.5
		7/17/02 14:45	2.00	74	144.86	5	4.1
		7/17/02 15:20	7.00	73	124.16	16	17.8
9oz Recover	70	7/17/02 18:30	7.25	71.5	126.41	16.75	16.3
control	**95**	**08/01/02 15:15**	**1.50**	**93**	**144.29**	**5.9**	**4.5**
		7/26/02 8:40	3.50	95.7	145.30	4.3	3.8
		7/26/02 8:55	6.25	93	141.08	7.2	6.6
3oz Delvo	95	7/26/02 11:45	1.00	96.4	146.10	3.5	3.3
		7/26/02 7:55	3.50	95	144.90	4.5	4.1
		7/26/02 8:10	6.00	89	139.27	9	7.8
3oz Recover	95	7/26/02 11:15	3.00	90	141.88	6.9	6.1
		08/01/02 09:45	1.25	95	145.90	4.1	3.4
		08/01/02 10:00	2.75	92	141.68	7.4	6.2
6oz Delvo	95	08/01/02 13:00	1.75	89	144.49	5.5	4.3
		08/01/02 11:00	0.25	93	147.11	4.2	2.6
		08/01/02 11:15	5.25	90	133.84	12.5	11.4
6oz Recover	95	08/01/02 14:15	2.00	88	142.48	6.9	5.7
		7/25/02 09:40:00	2.75	92	146.30	3.5	3.1
		7/25/02 10:00:00	6.75	90.5	134.65	10	10.8
9oz Delvo	95	7/25/02 13:15:00	3.75	90	141.08	7.2	6.6
		7/25/02 08:50:00	3.75	95	146.70	3.3	2.9
		7/25/02 09:15:00	6.50	91	126.41	16.5	16.3
9oz Recover	95	7/25/02 12:30:00	7.00	90	136.45	10.5	9.6

Graph 1



Graph 2



Physical Properties of the Hardened Concrete

To meet end tolerances to test the compressive strength of the cylinders specified in ASTM C-39, the ends of the cylinder were capped according to ASTM C- 617, "Standard Practice for Capping Cylindrical Concrete Specimens." Elastic properties (Modulus of Elasticity and Poisson's Ratio) were measured using four strain gages per specimen, mounted with epoxy. Two of the gages were mounted axially, and two were mounted laterally. The strain gages were placed vertically at the midpoint of the specimen and circumferentially 180^{o} apart.

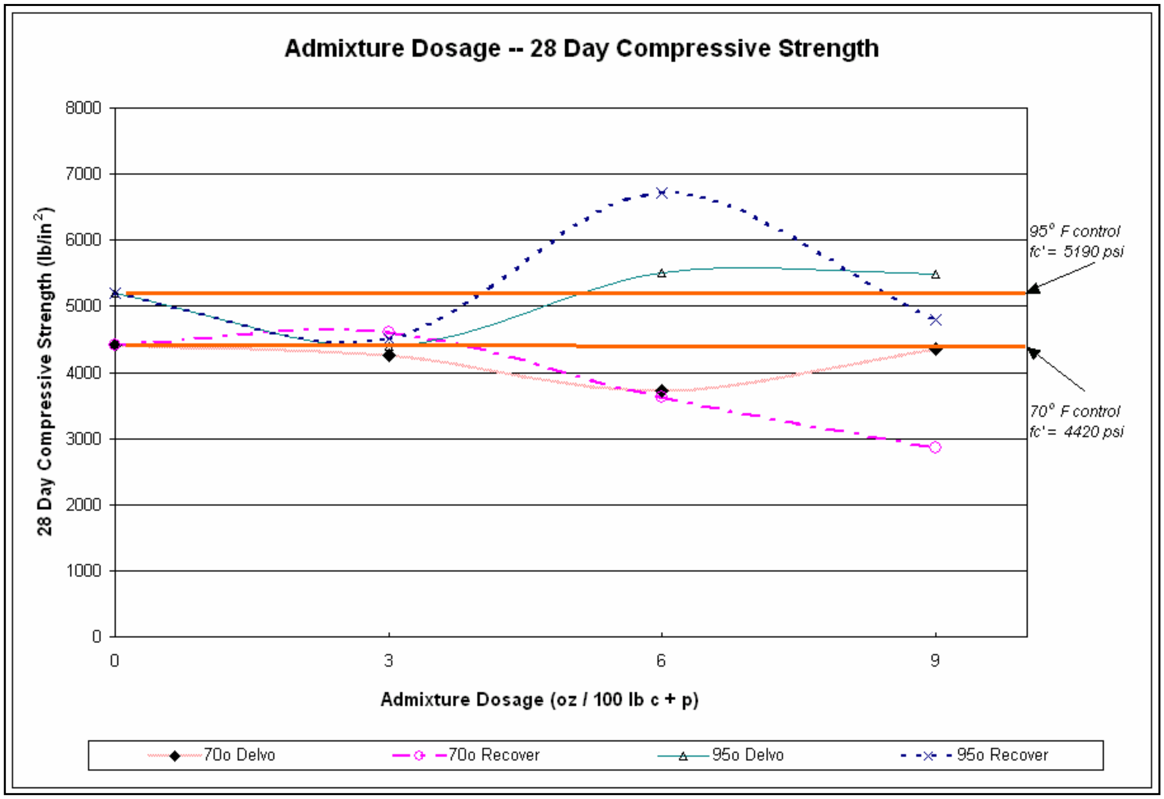
The results of the compressive strength tests (averaged from the three cylinders) at 7 days and at 28 days for all the mixtures are shown in table 6. The low specific gravity on both the 9 oz Recover and 6 oz Recover at the 70 ^{o}F mixing temperature are indicative of the hit air content. One of the major problems with the air content rising so high, especially without dropping back down, is that the large amount of voids greatly reduces the compressive strength.

Table 6

Physical Properties of Hardened Concrete Summary						
Mix	*Temperature* ^{o}F	*7-day Strength* lb/in^2	*28-day Strength* lb/in^2	*Density* lb/ft^3	*Modulus of Elasticity* lb/in^2	*Poisson's Ratio* in/in
control	**70**	**3530**	**4420**	**144.6**	**3.29**	**0.19**
3oz Delvo	70	3640	4260	143.9	3.28	0.19
3oz Recover	70	3840	4600	146.0	3.45	0.19
6oz Delvo	70	3080	3720	139.6	3.07	0.20
6oz Recover	70	3040	3620	135.4	3.29	0.21
9oz Delvo	70	3270	4350	140.2	3.22	0.19
9oz Recover	70	2130	2860	131.0	2.63	0.19
control	**95**	**4020**	**5190**	**147.7**	**3.43**	**0.20**
3oz Delvo	95	3440	4390	148.3	3.28	0.18
3oz Recover	95	3630	4500	144.4	3.34	0.20
6oz Delvo	95	4370	5500	145.0	3.54	0.20
6oz Recover	95	4990	6720	148.3	3.79	0.19
9oz Delvo	95	4200	5480	144.1	3.45	0.21
9oz Recover	95	3510	4790	140.4	3.19	0.19

Graph 3 shows the compressive strength at 28 days plotted against the admixture dosage for both stabilizers. Interestingly enough, the 6 oz dosage of the either admixture seems to have more effect on compressive strength at both temperatures than either the 3 oz or the 9 oz dosages as shown in graph 3. The specimens mixed at 95 ^{o}F have higher compressive strengths than those mixed at 70 ^{o}F. The average 28-day compressive strength for the 70 ^{o}F

Graph 3



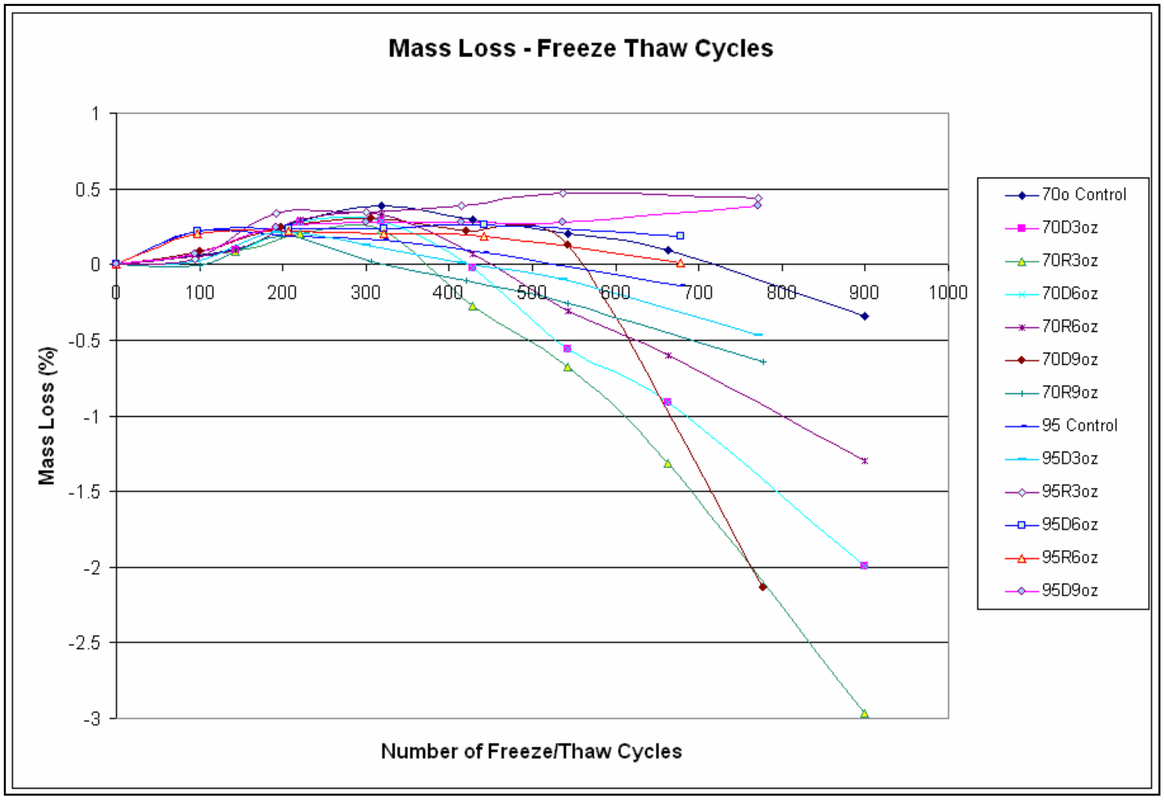
specimens was 3,880 lb/in^2 (maximum of 4,600 lb/in^2, minimum of 2,860 lb/in^2), while the average 28-day compressive strength for the 95 ^{o}F specimens was 5,220 lb/in^2 (maximum of 6,720 lb/in^2, minimum of 4,390 lb/in^2).

Another interesting observation that can be seen in this graph is that, as a general rule, the stabilizer seems to have a strengthening effect with the 95 ^{o}F mixtures while it seems to have the opposite effect with the 70 ^{o}F mixtures.

Freeze/Thaw Tests

Graph 4 shows the results of the freeze-thaw tests for all specimens. In general, all specimens did very well with respect to freeze-thaw durability. Reclamation's criteria for durable concrete is that a specimen must go through at least 500 freeze-thaw cycles and lose no more than 25 percent of its mass. All specimens tested easily met this criteria; none lost more than 1 percent of its mass after 500 cycles.

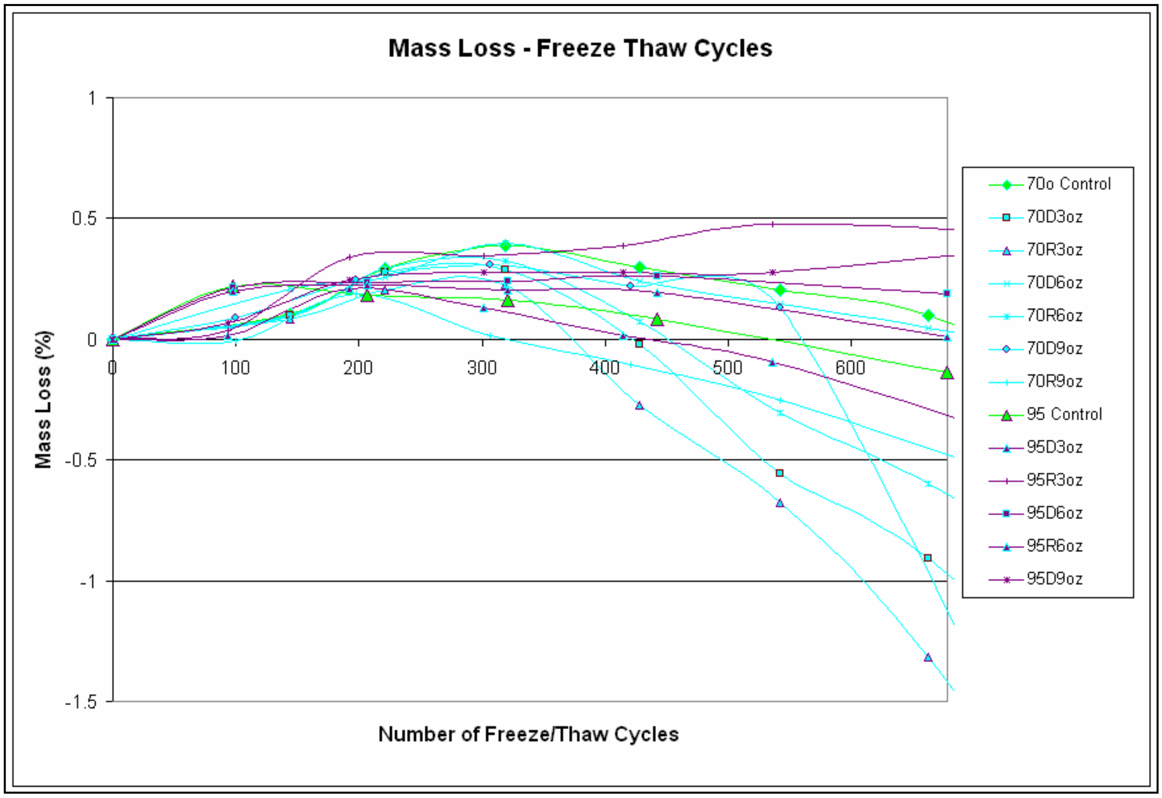
Graph 4



Graph 5 highlights the differences between the 95 °F mixtures, the 70 °F mixtures, and the controls. The specimens mixed at 95 °F show better results for freeze thaw durability than those mixed at 70 °F. This can be attributed to the fact that the average compressive strength was higher for the 95 °F specimens than the 70 °F specimens. The average 28-day compressive strength for the 70 °F specimens was 3,880 lb/in^2 (maximum of 4,600 lb/in^2, minimum of 2,860 lb/in^2), while the average 28-day compressive strength for the 95 °F specimens was 5,220 lb/in^2 (maximum of 6,720 lb/in^2, minimum of 4,390 lb/in^2).

This phenomenon of better freeze-thaw durability and higher strengths at the higher mixing temperature suggests that at higher temperatures the stabilizer adds to the quality of the concrete. As shown in Figure 11 in Reclamation's Concrete Manual, 8th Edition, specimens made at higher temperatures had higher strengths initially but then lower strengths at 28 days. Without explanation, the control specimens do not follow this trend.

Graph 5



Time of Set/Temperature Rise

Table 7 compares temperature rise to setting time. The second to last column in table 7 shows that there were three mixtures where the mixture did not set up between the times the temperature first began to rise (onset of the heat of hydration) and the time the temperature peaked during the heat of hydration. The exceptions to this are all at the higher (9 oz) admixture dosages.

Graph 6 compares the admixture dosage to the time of final set, which corresponds to a penetration resistance of 4,000 lb/in^2 for both stabilizers.

Graph 7 shows setting times for each admixture.

It is apparent that at both temperatures, Recover extends the time of set longer than Delvo—over twice as long at the high dosages. In analyzing the best-fit trend lines using graph 6, we found that the relationship between admixture dosage and time to final set is exponential.

Table 7

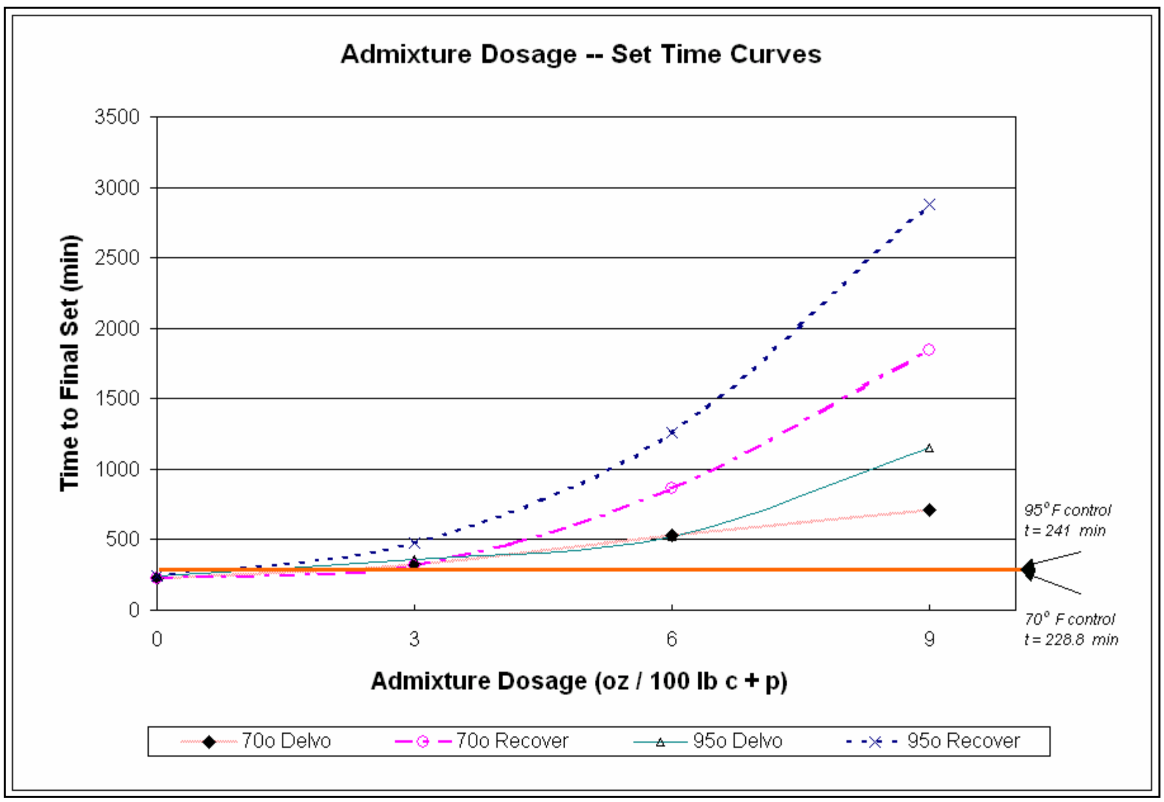
Time of Set Summary						
Mix	***Temperature °F***	***Temp Rise Start min***	***Time to Peak Temp min***	***Time to Final Set min***	***Temp Rise/Set***	***Peak Temp °F***
control	70	75	480	229	Between*	115.3
3oz Delvo	70	218	668	327	Between*	84
3oz Recover	70	185	540	317	Between*	113.2
6oz Delvo	70	878	758	528	Between*	83.1
6oz Recover	70	446	1106	863	Between*	81.8
9oz Delvo	70	265	850	707	Between*	86.7
9oz Recover	70	265	790	1841	Before**	86.7
control	95	135	450	241	Between*	105.4
3oz Delvo	95	240	555	362	Between*	105.4
3oz Recover	95	320	665	479	Between*	103.3
6oz Delvo	95	300	645	523	Between*	107.2
6oz Recover	95	1160	1345	1258	Between*	109.1
9oz Delvo	95	695	1070	1151	Before**	109.2
9oz Recover	95	2945	3410	2880	After***	112.7

* *Beteween indicates setting time is between initial temperature rise and peak temperature*

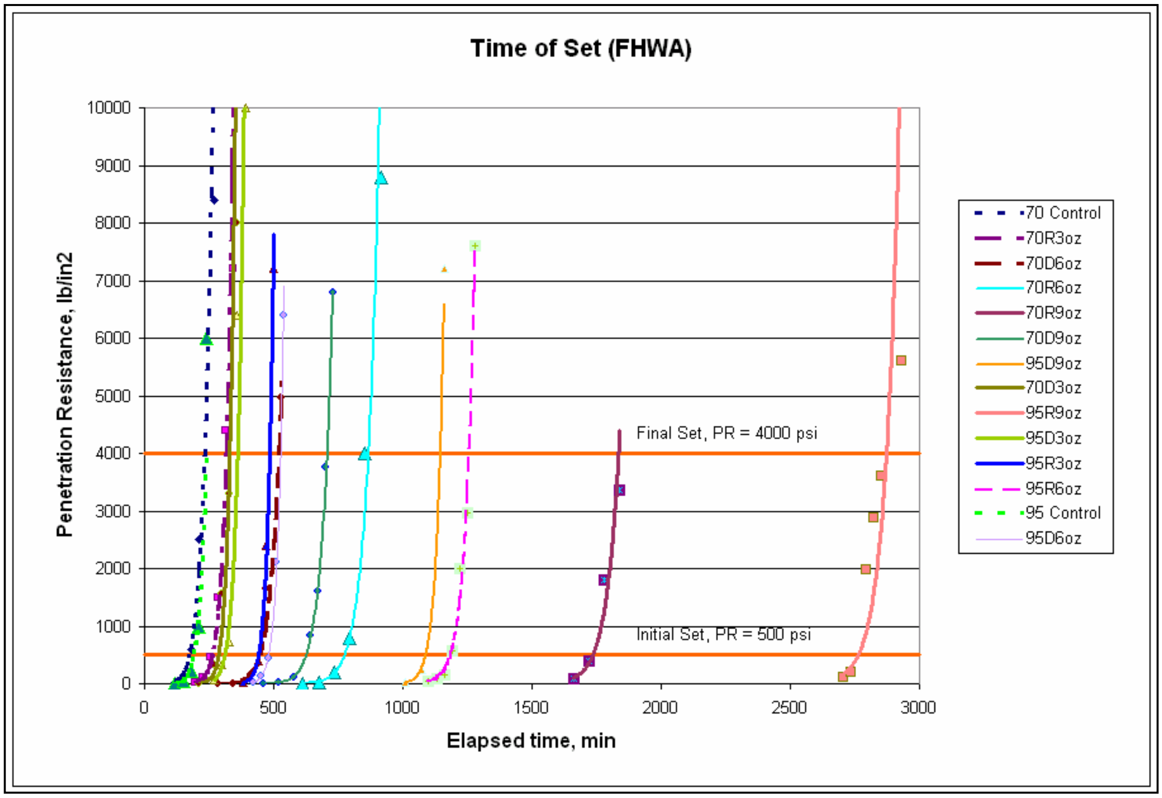
** *Before indicates the temperature peaks before the final set*

*** *After indicates the temperature peaks after the final set*

Graph 6



Graph 7



This indicates that it is possible to expect that by adding a higher dosage of the admixture, the set is extended for a much longer time, according to the specific trend line equation. The scenario in which adding a little bit more stabilizer is expected to extend the set the longest is at 95° using Recover, and the scenario in which the set time extension is expected to be the least sensitive is at 70° using the Delvo. More testing is necessary to see if this is indeed the case and what the top limit for admixture dosage is before the concrete never sets.

If you have any questions about information contained in this article, please contact Erin Gleason at egleason@do.usbr.gov or Kurt von Fay at kvonfay@do.usbr.gov.

SYNTHETIC WEB SLINGS AND CRITICAL LIFT PLANS

The purpose of this article is to inform Bureau of Reclamation (Reclamation) personnel of the limitations of synthetic slings and to call attention to the requirement of critical lift plans in the latest version of the Reclamation Safety and Health Standards.

Executive Summary

A recent incident at a Reclamation facility where a load was dropped when two synthetic slings failed has called attention to the limitations of synthetic slings. The failure of the slings was due to the slings being pulled across a sharp corner at a sharp angle with inadequate padding. There were no injuries, but there was damage to equipment. Proper inspection and operating techniques, as well as implementation of critical lift plans, will ensure safe operation when using synthetic web slings.

Background

Synthetic slings have been used extensively throughout Reclamation for a number of years. They are lightweight and do not damage the surface of the item being lifted. If used properly, they are an acceptable replacement for wire rope slings for many applications. The main limitation of synthetic slings is they can be cut rather easily if pulled across a sharp corner without adequate padding. They are also prone to abrasive damage if repeatedly used to lift rough-surfaced objects. Most sling manufacturers offer wear pads to protect against abrasion and, to some extent, help pad the sling material when lifting on corners. These pads may be sewn on the edge or the face, or they may be moveable sleeves that can be slid along the sling to the point needing protection. Pieces of rubber tire can also be used to pad the sling. Where practical, machined pieces of steel, pipe, or other metal can be used to increase the radius of the corner.

There are instances, such as the recent incident, where the corner is too sharp or there is not sufficient room to place adequate padding to protect synthetic slings. In these cases, either wire rope slings should be used or the rigging procedure should be modified to eliminate pulling the sling over the sharp corner. It should be noted that even wire rope slings require adequate padding.

Inspection of Synthetic Web Slings (ASME B30.9C – 1994; RSHS, Section 18)

Synthetic webbing slings, like any rigging equipment, should be visually inspected before each use. Regulations regarding slings are covered by 29CFR1910.184. The following are visual defects that require the sling be removed from service:

1. Acid or caustic burns
2. Melting or charring of any part of the surface
3. Snags, punctures, tears, or cuts
4. Broken or worn stitches
5. Wear or elongation exceeding the amount recommended by the manufacturer
6. Distortion of fitting
7. Knots in any part
8. Missing or illegible sling identification tag

Some synthetic slings are also supplied with visual indicators such as different colored threads in the webbing that will show as the sling wears. There are some slings with outer covers that make the inspection of the interior fibers impossible. These slings can be provided with overload telltales that will be pulled into the cover if the sling is overloaded or fiber optic systems that will not allow light to pass through if there is damage to the core.

Operation of Synthetic Web Slings (ASME B30.9C – 1994)

1. Slings having suitable characteristics for the type of load, hitch, and environment shall be selected in accordance with the appropriate table.

2. The weight of the load shall be within the rated load of the sling.

3. Slings shall be shortened, lengthened, or adjusted only by methods approved by the sling manufacturer.

4. Slings shall not be shortened or lengthened by knotting.

5. Sharp corners in contact with the sling should be padded with material of sufficient strength to minimize damage to the sling.

6. Portions of the human body should be kept from between the sling and the load and from between the sling and the crane hook or hoist hook.

7. Personnel should stand clear of the suspended load.

8. Personnel shall not ride the sling.

9. Shock loading should be avoided.

10. Slings should not be pulled from under a load when the load is resting on the sling.

11. Slings should be stored in a cool, dry, and dark place to prevent environmental damage from moisture, sunlight, etc.

12. Twisting and kinking the legs shall be avoided.

13. Loads applied to the hook should be centered in the base (bowl) of the hook to prevent point loading on the hook.

14. During lifting, with or without a load, personnel shall be alert for possible snagging.

15. In a basket hitch, the load should be balanced to prevent slippage.

16. The sling's legs should contain or support the load from the sides above the center of gravity when using a basket hitch.

17. Slings should be long enough so that the rated load is adequate when the angle of the legs is taken into consideration.

18. Slings should not be dragged on the floor over an abrasive material.

19. In a choker hitch, slings shall be long enough so the choker fitting chokes on the webbing and never on the other fittings.

20. Nylon and polyester slings shall not be used at temperatures in excess of 194 degrees Fahrenheit (^{o}F) or at a temperature below -40 ^{o}F.

21. When excessive exposure to sunlight or ultraviolet light is experienced by nylon or polyester web slings, the sling manufacturer should be consulted for recommended inspection procedures.

Requirements for Critical Lifts

Reclamation Safety and Health Standards Section 19.6 describes requirements for critical lifts. In this section, critical lifts are defined as: (1) lifts made when the load weight is

75 percent or more of the rated capacity of the crane or hoisting device, (2) lifts made with more than one crane, (3) hoisting personnel with a crane, (4) any lift that the crane or hoist operator believes is critical.

Before any critical lift is made, a written critical lift plan must be prepared. The lift supervisor (i.e., the person designated to supervise the planning and execution of all lifts) must prepare the critical lift plan in coordination with the crane/hoisting equipment operator and rigger. All personnel involved in any way with the lift should review and sign the critical lift plan. The plan must include the following information:

- Exact size and weight of the load, including all crane and rigging components that add to the weight. Include the manufacturer's maximum load limits for the complete range of the lift.

- Exact information about the sequence of events and procedures, including equipment positioning, height of the lift, load radius, and boom length and angles, where applicable.

- Rigging plans with lift points, procedures, and hardware requirements.

- Conditions and procedures under which the lifting operation is to be stopped.

- Coordination and communications procedures.

- Names of lift supervisor, hoisting equipment operator, rigger, and other personnel with key roles in the operation.

- For tandem lifts, general information on the hoisting equipment, including make, model, operating speeds, and other information to ensure the equipment is compatible.

- For mobile cranes, ground conditions and other information needed to ensure a level, stable foundation with sufficient bearing capacity for the lift supports of the hoisting equipment, including outrigger, crawler track, and support mat design calculations.

For further information, please contact Bill McStraw at (303) 445-2294 or Roger Cline at (303) 445-2293.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Jerry Fischer, Technical Service Center, ATTN: D-8470, PO Box 25007, Denver, Colorado 80225-0007; (303) 445-2748, FAX (303) 445-6381; email: jfischer@do.usbr.gov

Vicki Hoffman, Pacific Northwest Region, ATTN: PN-3234, 1150 North Curtis Road, Boise, Idaho 83706-1234; (208) 378-5335, FAX (208) 378-5305

Steve Herbst, Mid-Pacific Region, ATTN: MP-430, 2800 Cottage Way, Sacramento, California 95825-1898; (916) 978-5228, FAX (916) 978-5290

Albert Graves, Lower Colorado Region, ATTN: BCOO-4846, PO Box 61470, Boulder City, Nevada 89006-1470; (702) 293-8163, FAX (702) 293-8042

Don Wintch, Upper Colorado Region, ATTN: UC-258, PO Box 11568, Salt Lake City, Utah 84147-0568; (801) 524-3307, FAX (801) 524-5499

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, Montana 59107-6900; (406) 247-7630, FAX (406) 247-7898