

June 17, 2021

Mrs. Katheryn L. Malusky
AASHTO
444 N. Capitol St. N.W., Suite 249
Washington D.C. 20001

Phone: (202) 624-5815
Email: Kmalusky@ashto.org

Subject: **Final Report for Fritz-Pak Delay Set, Compliance Verification for Type D Admixture
AASHTO M194-13 (2017) Standard Specification for Chemical Admixtures for Concrete
TEC Services Project No: TEC 13-1026
TEC Services Laboratory No: 20-502
NTPEP ID: CADD-2020-01-014**

Dear Mrs. Malusky:

SGS TEC Services, Inc. (TEC Services) is an AASHTO R18, ANS/ISO/IEC 17025:2017 and Army Corps of Engineers accredited laboratory. TEC Services is pleased to present this report of our compliance verification testing of Fritz-Pak Delay Set, an ASTM C494-16 Standard Specification for Chemical Admixtures for Concrete, Type D (Water Reducing & Retarding) admixture. Our services were performed in accordance with our service agreement date August 30, 2013.

Sample preparation and testing was performed in accordance with applicable sections of AASHTO M194-13 (2017) Standard Specifications for Chemical Admixtures for Concrete, ASTM C494 and documents referenced therein. Material and procedures outlined in AASHTO M194 were used. Based on our results to date, Fritz-Pak Delay Set complies with the requirements in AASHTO M194 and Table 1 of ASTM C494. These test results pertain only to the samples tested.

The compliance verification was performed by TEC Services in Lawrenceville, Georgia. Concrete batching was performed on three different days in May and June of 2020. One control mixture and one test mixture containing Fritz-Pak Delay Set, both meeting the requirements of AASHTO M194 and ASTM C494 for fresh concrete properties, were produced each day. A 1-gallon sample of Fritz-Pak Delay Set was supplied to TEC Services by Fritz-Pak Corporation. The air-entraining agent used in this testing was a vinsol resin, meeting the requirements of AASHTO M154-12(2016) Standard Specification for Air-Entraining Admixtures for Concrete.

Testing of the concrete's plastic properties, time of setting, compressive strengths, flexural strengths, length change, and freeze thaw resistance were performed by TEC Services. Mixture proportions and results of our testing are given in Tables 1 to 3. Information and test data on fine and coarse aggregates are listed in Tables 4 to 6. Table 7 contains information on Fritz-Pak Delay Set. Product information and test data on the Type I cement is included in Table 8. Test results for each of the six batches prepared for this report are included in Tables 9 thru 12.

Table 1: Fritz-Pak Delay Set performance and ASTM C494 requirements for a Type D admixture

| Test Results | Fritz-Pak Delay Set | Specification Requirements |
|---|---------------------|----------------------------|
| Water content (percent of control) | 93 | 95 (max) |
| Time of setting, deviation of control | | |
| Initial (hr:min) | 1:29 | +1:00 to +3:30 |
| Final (hr:min) | 1:20 | +3:30 (max) |
| Compressive strength (percent of control) | | |
| 3 days | 110 | 110 (min) |
| 7 days | 112 | 110 (min) |
| 28 days | 110 | 110, 120* (min) |
| 56 days | 111 | n/a |
| 90 days | 106 | 117* (min) |
| 6 months | 106 | 100, 113* (min) |
| 1 year | 109 | 100 (min) |
| Flexural strength (percent of control) | | |
| 3 days | 104 | 100 (min) |
| 7 days | 101 | 100 (min) |
| 28 days | 100 | 100 (min) |
| 56 days | 103 | 100 (min) |
| Length change (increase over control) | -0.001 | 0.010 (max) |
| Relative durability factor | 108 | 80 (min) |

*Provisional Requirement

Table 2: Mixture proportions, fresh concrete properties, and ASTM C494 requirements for a Type D admixture

| Average of Three Separate Tests | Control Mixture | Fritz-Pak Delay Set | Specification Requirements |
|--------------------------------------|-----------------|---------------------|----------------------------|
| Cement factor (lb/yd ³) | 515 | 516 | 517 ± 5 |
| Water (lb/yd ³) | 279 | 260 | |
| Water-cement ratio | 0.540 | 0.504 | |
| Coarse aggregate | 1845 | 1848 | |
| Fine aggregate | 1171 | 1222 | |
| Fine aggregate-total aggregate ratio | 0.39 | 0.398 | |
| Fritz-Pak Delay Set (% of cement) | 0.00 | 0.181 | |
| Vinsol Resin (oz/cwt) | 0.75 | 0.72 | |
| Slump (in.) | 4.00 | 3.25 | 3 ½ ± ½ |
| Air content (%) | 5.8 | 5.6 | 5-7 (± 0.5 of control) |
| Density (lb/ft ³) | 141.1 | 142.4 | |
| Time of setting | | | |
| Initial (hr:min) | 5:20 | 6:49 | |
| dev. of control (hr:min) | | 1:29 | +1:00 (min) to +3:30 (max) |
| Final (hr:min) | 7:05 | 8:25 | |
| dev. of control (hr:min) | | 1:20 | +3:30 max |

Table 3: Properties of hardened concrete

| | Control Mixture | Fritz-Pak Delay Set |
|-----------------------------------|-----------------|---------------------|
| Compressive strength (psi) | | |
| 3 days | 2910 | 3210 |
| 7 days | 3340 | 3750 |
| 28 days | 4060 | 4480 |
| 56 days | 3990 | 4440 |
| 90 days | 4450 | 4700 |
| 6 months | 4360 | 4620 |
| 1 year | 4180 | 4550 |
| Flexural strength (psi) | | |
| 3 days | 560 | 580 |
| 7 days | 615 | 620 |
| 28 days | 670 | 670 |
| 56 days | 670 | 690 |
| Length change (%) | -0.016 | -0.015 |
| Durability factor (%) | 90 | 96 |

Table 4: Properties of fine and coarse aggregates

| Aggregate Information | Fine aggregate | Coarse aggregate |
|---------------------------------|-----------------------|------------------|
| Manufacturer | Lambert Sand, Shorter | Vulcan, Lithonia |
| Aggregate Type | Natural sand | Crushed Granite |
| Specific Gravity _{SSD} | 2.64 | 2.62 |
| Absorption (%) | 0.58 | 0.50 |

Table 5: Gradation of fine aggregate and ASTM C494 requirements

| Sieve | Percent passing | |
|------------------|-----------------|-----------------------------|
| | Fine Aggregate | Specifications Requirements |
| No. 4 (4.75 mm) | 100 | 95 to 100 |
| No. 8 (2.36 mm) | 74 | 80 to 100 |
| No. 50 (300 μm) | 16 | 5 to 30 |
| No. 100 (150 μm) | 4 | 0 to 10 |

Table 6: Gradation of coarse aggregate and ASTM C494 requirements

| Sieve | Percent passing | |
|-------------------|------------------|-----------------------------|
| | Coarse Aggregate | Specifications Requirements |
| 1.5 in. (37.5 mm) | 100 | 100 |
| 1.0 in. (25.4 mm) | 98 | 95 to 100 |
| 0.5 in. (12.5 mm) | 32 | 25 to 60 |
| No. 4 (4.75 mm) | 6 | 0 to 10 |
| No. 8 (2.36 mm) | 4 | 0 to 5 |

Table 7: Admixture information

| Information | Admixture Information |
|---|-----------------------|
| Brand Name | Fritz-Pak Delay Set |
| Manufacturer | Fritz-Pak Corporation |
| Lot Size | 2000 lbs |
| Solids content (%) | 92.986 |
| pH | 4.27 |
| Chloride Content (% per BS EN 480-10:2009) | 0.0221 |

Table 8: Cement information and test data

| ASTM C 150 Type I/II cement | | | |
|--|-----------------------------|---|------|
| Brand name | Portland Type I/II | | |
| Manufacturer | Coosa Cement, Ragland Plant | | |
| <i>Chemical Analyses by Mass (%)</i> | | | |
| Silicon dioxide (SiO ₂) | 20.6 | Sulfur trioxide (SO ₃) | 2.8 |
| Aluminum oxide (Al ₂ O ₃) | 4.7 | Loss on ignition (950°C) | 2.8 |
| Iron oxide (Fe ₂ O ₃) | 3.11 | Insoluble residue | n/a |
| Calcium oxide (CaO) | 62.0 | Alkalies as Na ₂ O | 0.59 |
| Magnesium oxide (MgO) | 2.75 | | |
| <i>Calculated Potential Compounds as per ASTM C 150-05 (%)</i> | | | |
| Tricalcium silicate (C ₃ S) | 52 | Tricalcium aluminate (C ₃ A) | 7 |
| Dicalcium silicate (C ₂ S) | 20 | Tetracalcium aluminoferrite (C ₄ AF) | 9 |
| <i>Physical Testing and Results</i> | | | |
| Fineness Specific Surface (Blaine) | 436 m ² /Kg | Air Content (%) | 7 |
| Setting Times (Vicat) Initial | 147 minutes | Autoclave Expansion (%) | 0.00 |
| Compressive 3 Day Strength (psi) | 3410 | Compressive 7 Day Strength (psi) | 4080 |
| C1038 Expansion @ 3.3% SO ₃ (%) | 0.014 | False Set (%) | 53 |

Table 9: Yield adjusted mixture proportions, fresh concrete properties, and time of set for three control batches

| | Control 1 | Control 2 | Control 3 | Average |
|--|------------------|------------------|------------------|----------------|
| Cement factor (lb/yd ³) | 516 | 514 | 516 | 515 |
| Water (lb/yd ³) | 279 | 278 | 279 | 279 |
| Water-cement ratio | 0.540 | 0.540 | 0.540 | 0.540 |
| Coarse aggregate (lb/yd ³) | 1847 | 1840 | 1847 | 1845 |
| Fine aggregate (lb/yd ³) | 1173 | 1168 | 1173 | 1171 |
| Fine aggregate-total aggregate ratio | 0.388 | 0.388 | 0.388 | 0.388 |
| Fritz-Pak Delay Set, (% of cement) | 0.00 | 0.00 | 0.00 | 0.00 |
| Vinsol Resin (oz/cwt) | 0.75 | 0.75 | 0.75 | 0.75 |
| Slump (in.) | 4.00 | 3.75 | 4.00 | 4.00 |
| Air content (%) | 5.6 | 6.1 | 5.6 | 5.8 |
| Density (lb/ft ³) | 141.3 | 140.7 | 141.3 | 141.1 |
| Time of setting | | | | |
| Initial (hr:min) | 5:23 | 5:21 | 5:17 | 5:20 |
| Final (hr:min) | 7:09 | 7:00 | 7:05 | 7:05 |

Table 10: Yield adjusted mixture proportions, fresh concrete properties, and time of set for three test batches containing Fritz-Pak Delay Set

| | Test 1 | Test 2 | Test 3 | Average |
|--|---------------|---------------|---------------|----------------|
| Cement factor (lb/yd ³) | 517 | 516 | 517 | 516 |
| Water (lb/yd ³) | 260 | 260 | 260 | 260 |
| Water-cement ratio | 0.504 | 0.504 | 0.504 | 0.504 |
| Coarse aggregate (lb/yd ³) | 1848 | 1846 | 1848 | 1848 |
| Fine aggregate (lb/yd ³) | 1222 | 1221 | 1222 | 1222 |
| Fine aggregate-total aggregate ratio | 0.398 | 0.398 | 0.398 | 0.398 |
| Fritz-Pak Delay Set (% of cement) | 0.181 | 0.181 | 0.181 | 0.181 |
| Vinsol Resin (oz/cwt) | 0.72 | 0.72 | 0.72 | 0.72 |
| Slump (in.) | 3.00 | 3.50 | 3.50 | 3.25 |
| Air content (%) | 5.6 | 5.7 | 5.6 | 5.6 |
| Density (lb/ft ³) | 142.5 | 142.3 | 142.5 | 142.4 |
| Time of setting | | | | |
| Initial (hr:min) | 6:40 | 7:06 | 6:42 | 6:49 |
| Final (hr:min) | 8:24 | 8:43 | 8:09 | 8:25 |

Table 11: Properties of hardened concrete from three control test batches

| | Control 1 | | Control 2 | | Control 3 | | Average |
|------------------------------------|---------------------------------------|-----------|-----------|---|-----------|-----------|---------------|
| Compressive strength (psi) | | | | | | | |
| 3 days | 2870 | | 2970 | | 2900 | | 2910 |
| 7 days | 3550 | | 3240 | | 3230 | | 3340 |
| 28 days | 4220 | | 3960 | | 4010 | | 4060 |
| 56 days | 3520 | | 4420 | | 4020 | | 3990 |
| 90 days | 4480 | | 4260 | | 4600 | | 4450 |
| 6 months | 4520 | | 4350 | | 4200 | | 4360 |
| 1 year | 4380 | | 4140 | | 4010 | | 4180 |
| Flexural strength (psi) | | | | | | | |
| 3 days | 550 | | 570 | | 555 | | 560 |
| 7 days | 635 | | 610 | | 600 | | 615 |
| 28 days | 660 | | 670 | | 675 | | 670 |
| 56 days | 685 | | 660 | | 665 | | 670 |
| Length change (%) | -0.011 | | -0.017 | | -0.019 | | -0.016 |
| Durability Factor (%) | 89 | | 90 | | 90 | | 90 |
| Approximate Total Cycles Completed | Fundamental Transverse Frequency, kHz | | | Relative Dynamic Modulus, (%) Average of 2 Beams per Mix | | | Average |
| | Control 1 | Control 2 | Control 3 | Control 1 | Control 2 | Control 3 | |
| 0 cycles | 1.992 | 1.953 | 1.855 | NA | NA | NA | NA |
| 32 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 66 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 96 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 128 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 162 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 192 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 220 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 253 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 287 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |
| 300 cycles | 1.875 | 1.855 | 1.755 | 89 | 90 | 90 | 90 |

Table 12: Properties of hardened concrete from three batches containing Fritz-Pak Delay Set

| | Test 1 | Test 2 | Test 3 | Average | | | |
|------------------------------------|---------------------------------------|--------|--------|--|--------|--------|---------|
| Compressive strength (psi) | | | | | | | |
| 3 days | 3160 | 3270 | 3190 | 3210 | | | |
| 7 days | 3920 | 3780 | 3540 | 3750 | | | |
| 28 days | 4650 | 4360 | 4430 | 4480 | | | |
| 56 days | 4550 | 4340 | 4430 | 4440 | | | |
| 90 days | 4830 | 4370 | 4890 | 4700 | | | |
| 6 months | 4810 | 4350 | 4760 | 4640 | | | |
| 1 year | 4650 | 4360 | 4650 | 4550 | | | |
| Flexural strength (psi) | | | | | | | |
| 3 days | 585 | 585 | 565 | 580 | | | |
| 7 days | 650 | 600 | 610 | 620 | | | |
| 28 days | 665 | 670 | 675 | 670 | | | |
| 56 days | 715 | 650 | 700 | 690 | | | |
| Length change (%) | -0.014 | -0.017 | -0.015 | -0.015 | | | |
| Durability Factor (%) | 89 | 100 | 100 | 96 | | | |
| Approximate Total Cycles Completed | Fundamental Transverse Frequency, kHz | | | Relative Dynamic Modulus, (%) Average of 2 Beams per Mix | | | Average |
| | Test 1 | Test 2 | Test 3 | Test 1 | Test 2 | Test 3 | |
| 0 cycles | 1.993 | 1.817 | 1.836 | NA | NA | NA | NA |
| 32 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 66 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 96 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 128 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 162 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 192 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 220 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 253 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 287 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |
| 300 cycles | 1.875 | 1.817 | 1.836 | 89 | 100 | 100 | 96 |

We appreciate the opportunity to provide our services to you on this project. Should you have any questions or comments regarding this report, please feel free to contact us at your convenience.

Sincerely,

Testing, Engineering, & Consulting Services, Inc.

Kimberly Pleasant
 Laboratory Administrator

Shawn P. McCormick
 Laboratory Principal