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Subject: **Final Report (Revised) Fritz Pak's Air Plus, Air-Entraining Admixture – Compliance Verification**
AASHTO M 154-06 Standard Specification for Chemical Admixtures for Concrete
TEC Services Project No: TEC 09-0774
TEC Services Laboratory No: 10-718

Dear Mr. Ojeda:

Testing, Engineering and Consulting Services, Inc. (TEC Services) is pleased to present this report of our compliance verification testing of Fritz Pak's AIR PLUS, an ASTM C 260-06 (*Air-Entraining*) admixture. The sample preparation and testing was performed in accordance with applicable sections of AASHTO M 154-06, ASTM C 260 and documents referenced therein. Material and procedures outlined in AASHTO T 157-06 were used. Our test results indicate that AIR PLUS complies with the requirements in AASHTO M 154 and Table 1 of ASTM C 260. These test results pertain only to the sample tested.

The compliance verification was performed in TEC Services' laboratory in Lawrenceville, Georgia. Concrete batching was performed on three different days in November, 2010. One control mixture and one test mixture containing AIR PLUS were produced each day. All six mixes met the requirements of AASHTO M 154 and ASTM C 260 for fresh concrete properties. A 227 gram sample of AIR PLUS was manufactured and supplied to TEC Services by The Fritz Pak Corporation (Fritz Pak). The control air-entraining agent used was a commercially available vinsol resin admixture, meeting the requirements of AASHTO M 154.

Mixture proportions and our test results 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 supplied by the producers of the AIR PLUS. 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 to 12.

Table 1: Average admixture performance and specification requirements for an Air-Entraining admixture

	AIR PLUS	Specification Requirements
Time of setting, deviation of control		
Initial (hr:min)	-0:08	-1:15 to +1:15
Final (hr:min)	-0:04	-1:15 to +1:15
Compressive strength (percent of control)		
3 days	103	90 (min)
7 days	105	90 (min)
28 days	106	90 (min)
56 days	106	90 (min)
Flexural strength (percent of control)		
3 days	106	90 (min)
7 days	101	90 (min)
28 days	110	90 (min)
56 days	102	90 (min)
Length change (increase over control)	0.001	0.006 (max)
Relative durability factor	100	80 (min)
Bleeding of the net amount of mixing water (%) (percent over control)	-0.1	+2% (max of control)

Table 2: Average mixture proportions, fresh concrete properties, and specification Requirements for an Air-Entraining admixture

Average of Three Separate Tests	Control Mixture	AIR PLUS	Specification Requirements
Cement factor (lb/yd ³)	517	518	517 ± 5
Water (lb/yd ³)	272	267	
Water-cement ratio	0.527	0.515	
Coarse aggregate	1849	1853	
Fine aggregate	1186	1212	
Fine aggregate-total aggregate ratio	0.39	0.40	
Air Plus (oz/cwt)	0.00	0.57	
Vinsol Resin (oz/cwt)	0.60	0.00	
Slump (in.)	4.00	3.50	3 ½ ± ½
Air content (%)	5.6	5.5	± 0.5 of control
Density (lb/ft ³)	141.6	142.5	
Time of setting			
Initial (hr:min)	5:00	4:52	
dev. of control (hr:min)		-0:08	-1:15 to +1:15
Final (hr:min)	6:34	6:30	
dev. of control (hr:min)		-0:04	-1:15 to +1:15
Bleeding of the net amount of mixing water (%)	3.34	3.20	+2% (max of control)

Table 3: Properties of hardened concrete

Test Data (average of three separate tests)	Control Mixture	AIR PLUS
Compressive strength (psi)		
3 days	2580	2650
7 days	3740	3930
28 days	4850	5120
56 days	5330	5640
Flexural strength (psi)		
3 days	435	460
7 days	545	550
28 days	575	635
56 days	635	645
Length change (%)	-0.017	-0.018
Durability factor (%)	84	85

Table 4: Properties of fine and coarse aggregates

	Fine aggregate	Coarse aggregate
Manufacturer	Martin Marietta, Shorter	Vulcan, Lithonia
Aggregate type	Natural sand	Crushed Granite
Specific gravity _{SSD}	2.60	2.63
Absorption (%)	0.35	0.70

Table 5: Gradation of fine aggregate and ASTM C 494 requirements

Sieve	Percent passing	
	Fine aggregate	Specifications Requirements
No. 4 (4.75 mm)	100	100
No. 16 (2.36 mm)	75	65 to 75
No. 50 (300 µm)	15	12 to 20
No. 100 (150 µm)	2	2 to 5

Table 6: Gradation of coarse aggregate and ASTM C 494 requirements

Sieve	Percent passing	
	Coarse aggregate	Specifications Requirements
1.5 in. (37.5 mm)	100	100
1.0 in. (25.4 mm)	99	95 to 100
0.5 in. (12.5 mm)	41	25 to 60
No. 4 (4.75 mm)	4	0 to 10
No. 8 (2.36 mm)	2	0 to 5

Table 7: Admixture information

	Air-entraining admixture
Brand name	AIR PLUS
Manufacturer	Fritz Pak Corporation
Lot Number	112210-AirPlus

*IR Scan proved by Fritz-Pak is attached to this report

Table 8: Cement information and test data

ASTM C 150 Type I cement			
Brand name		Cemex Portland Type I	
Manufacturer		Cemex Cement Company	
<i>Chemical analyses by mass (%)</i>			
Silicon dioxide (SiO ₂)	20.6	Titanium dioxide (TiO ₂)	0.36
Aluminum oxide (Al ₂ O ₃)	5.0	Phosphorus pentoxide (P ₂ O ₅)	0.07
Iron oxide (Fe ₂ O ₃)	3.9	Manganic oxide (Mn ₂ O ₃)	0.06
Calcium oxide (CaO)	64.6	Strontium oxide (SrO)	0.07
Magnesium oxide (MgO)	1.0	Barium oxide (BaO)	0.01
Sodium oxide (Na ₂ O)	0.30	Loss on ignition (950°C)	0.9
Potassium oxide (K ₂ O)	0.35	Insoluble residue	0.19
Sulfur trioxide (SO ₃)	3.0	Alkalies as Na ₂ O	0.31
<i>Calculated potential compounds as per ASTM C 150-05 (%)</i>			
Tricalcium silicate (C ₃ S)	59	Tricalcium aluminate (C ₃ A)	7
Dicalcium silicate (C ₂ S)	14	Tetracalcium aluminoferrite (C ₄ AF)	12
<i>Physical Testing and Results</i>			
Fineness Specific Surface (Blaine)	374 m ² /Kg	Air Content (%)	5.9
Setting Times (Vicat)	Initial	Autoclave Expansion (%)	-0.07
	Final		
	105 minutes		
	185 minutes		
Compressive 3 Day Strength (psi)	3450	Compressive 7 Day Strength (psi)	4720
% Expansion @ 3.4% SO ₃ (C1038)	0.002		

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)	517	516	517	517
Water (lb/yd ³)	273	272	271	272
Water-cement ratio	0.528	0.528	0.525	0.527
Coarse aggregate (lb/yd ³)	1851	1845	1850	1849
Fine aggregate (lb/yd ³)	1171	1190	1197	1186
Fine aggregate-total aggregate ratio	0.39	0.39	0.39	0.39
Air Plus (oz/cwt)	0.00	0.00	0.00	0.00
Vinsol Resin (oz/cwt)	0.65	0.59	0.55	0.60
Slump (in.)	4.00	4.00	4.00	4.00
Air content (%)	5.7	5.6	5.5	5.6
Density (lb/ft ³)	141.2	141.6	142.0	141.6
Time of setting				
Initial (hr:min)	5:08	5:01	4:51	5:00
Final (hr:min)	6:47	6:28	6:29	6:34
Bleed Water (%)	3.73	3.53	2.77	3.34

Table 10: Properties of hardened concrete from three control test batches

	Control 1	Control 2	Control 3	Average			
Compressive strength (psi)							
3 days	2270	2590	2890	2580			
7 days	3460	3530	4220	3740			
28 days	4220	4640	5700	4850			
56 days	5110	4900	5970	5330			
Flexural strength (psi)							
3 days	415	475	415	435			
7 days	505	520	605	545			
28 days	540	545	640	575			
56 days	555	645	700	635			
Length change (%)	-0.016	-0.02	-0.015	-0.017			
Durability Factor (%)	82	84	87	84			
Approximate Total Cycles Completed	Fundamental Transverse Frequency, kHz			Relative Dynamic Modulus, percent			Average
	Control 1	Control 2	Control 3	Control 1	Control 2	Control 3	
0 cycles	2.070	2.109	2.090	NA	NA	NA	NA
27 cycles	1.914	1.953	1.973	85	86	89	87
68 cycles	1.914	1.953	1.973	85	86	89	87
109 cycles	1.895	1.953	1.973	84	86	89	86
172 cycles	1.895	1.953	1.973	84	86	89	86
220 cycles	1.895	1.934	1.953	84	84	87	85
278 cycles	1.875	1.934	1.953	82	84	87	84
304 cycles	1.875	1.934	1.953	82	84	87	84

Table 11: Yield adjusted mixture proportions, fresh concrete properties, and time of set for three test batches containing AIR PLUS

	Test 1	Test 2	Test 3	Average
Cement factor (lb/yd ³)	519	519	516	518
Water (lb/yd ³)	267	267	266	267
Water-cement ratio	0.515	0.515	0.515	0.515
Coarse aggregate (lb/yd ³)	1856	1856	1846	1853
Fine aggregate (lb/yd ³)	1214	1214	1207	1212
Fine aggregate-total aggregate ratio	0.40	0.40	0.40	0.40
Air Plus (oz/cwt)	0.55	0.58	0.58	0.57
Vinsol Resin (oz/cwt)	0.00	0.00	0.00	0.00
Slump (in.)	4.00	3.25	3.00	3.50
Air content (%)	5.5	5.5	5.6	5.5
Density (lb/ft ³)	142.8	142.8	142.0	142.5
Time of setting				
Initial (hr:min)	4:18	4:58	5:20	4:52
Final (hr:min)	5:48	6:37	7:07	6:30
Bleed Water (%)	3.69	3.52	2.40	3.20

Table 12: Properties of hardened concrete from three batches containing AIR PLUS

	Test 1	Test 2	Test 3	Average			
Compressive strength (psi)							
3 days	2480	2780	2690	2650			
7 days	3510	3620	4670	3930			
28 days	5020	4840	5490	5120			
56 days	5360	5550	6010	5640			
Flexural strength (psi)							
3 days	455	465	465	460			
7 days	530	575	550	550			
28 days	585	655	670	635			
56 days	595	675	665	645			
Length change (%)	-0.018	-0.021	-0.014	-0.018			
Durability Factor (%)	84	84	86	85			
Approximate Total Cycles Completed	Fundamental Transverse Frequency, kHz			Relative Dynamic Modulus, percent			Average
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	
0 cycles	2.109	2.109	2.129	NA	NA	NA	NA
27 cycles	1.953	1.953	1.992	86	86	88	86
68 cycles	1.953	1.953	1.992	86	86	88	86
109 cycles	1.953	1.953	1.992	86	86	88	86
172 cycles	1.953	1.953	1.992	86	86	88	86
220 cycles	1.953	1.934	1.973	86	84	86	85
278 cycles	1.953	1.934	1.973	86	84	86	85
304 cycles	1.934	1.934	1.973	84	84	86	85

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.



Anne Miller
Project Manager



Shawn P. McCormick
Laboratory Manager

Attachment: IR Scan of Air Plus

IR Scan of Air Plus provided by Fritz-Pak

