The AAAP Bridge Deck Concrete Initiative

A partnership of leading concrete producers, admixture and cement companies in the Commonwealth of Pennsylvania under the direction of the PACA Concrete Technical Committee

Pennsylvania Aggregates and Concrete Association

pennsylvania
DEPARTMENT OF TRANSPORTATION

PENNSYLVANIA AGGREGATES AND CONCRETE ASSOCIATION
CONCRETE TECHNICAL COMMITTEE

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Pennsylvania Aggregates and Concrete Association

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Executive Summary

Over the past two years the concrete industry and the Pennsylvania Department of Transportation have had numerous discussions about bridge deck concrete. Throughout these discussions we realized that we share a common goal - to improve bridge deck concrete. We also realized that there is one overriding theme that has broad support throughout PennDOT and among the concrete producers: it is time for an improvement to the existing AAA specification.

To achieve this goal, an extensive research review was conducted and a new mix design specification proposed. The mix was designated AAAP. The name was derived from the required use of a pozzolan or supplemental cementitious material (SCM).

The AAAP Specification used in this study includes:

- 4000 PSI at 28 days Specified Compressive Strength
- A reduced cement factor of 560 minimum lbs/cubic yard
- Rapid Chloride Permeability Limits - 2000 coulombs (either 56 day standard cure or 28 day rapid cure)
- Water / Cementitious Ratio - .45 maximum

The outline of this specification is a combination of a performance and prescriptive specification. The standard measurements of plastic concrete properties, air content, slump, and temperature along with the testing of compressive strength provide a baseline specification. Improved performance is provided by the addition of rapid chloride permeability limits. The requirement for a maximum water / cementitious ratio insures a minimum level of durability as recognized in ACI standards. A revised minimum cementitious content allows for the reduction in paste content, water demand, shrinkage potential and unnecessary excessive strength. In addition, the inclusion of a SCM when used properly will in almost all cases provide improved workability.

An extensive mix design and laboratory testing program was conducted. Materials that are representative and readily available in the Commonwealth of Pennsylvania were selected. Seven mix designs were made, tested, and repeated. The results of the mix design testing showed that this specification produced concrete with an improved resistance to chloride ion penetration along with excellent strength with good plastic properties. The use of SCM also demonstrated a lower and better heat signature as tested with the AdiaCal.

An outreach program was conducted with the PennDOT Districts. The mix design testing program results were shared and the broad topic of bridge deck concrete was discussed. Many good comments and suggestions were received and incorporated into the proposed specification. With the guidance of the PennDOT Districts, ten sample projects were selected to evaluate the effectiveness of AAAP and to insure that it could readily be made across Pennsylvania.

From September 2009 thru October 2010 these ten projects were placed. The placements were evaluated to assess the workability of AAAP. Seven of the ten projects noted an improvement in workability. For each one of these placements a companion load of AAA was batched and comparison tests conducted.

These tests revealed:

- AAAP yielded a reduction in shrinkage of 15 % (390 vs. 460 microstrains at 28 days)

- AAAP demonstrated higher 28 day strengths:
    - AAAP - 5232 psi
    - AAA- 4921 psi

- AAAP demonstrated a slower and more desirable strength gain (28/7 day ratio)
    - AAAP - 1.34
    - AAA - 1.22

Based upon the Laboratory testing program and the field evaluation, AAAP demonstrated that it would add value and benefit to the Commonwealth by providing:

- A reduction in shrinkage potential that would help to reduce cracking.

- A mix with an increase in strength at a lower cement factor.

- Increased resistance to chloride ion penetration and a criterion to measure this for mix design acceptance.

- The mandated use of a Supplementary Cementitious Materials (SCM). Providing concrete that is less permeable and has demonstrated a slower and more desirable strength gain.

- Concrete that has demonstrated an improvement in workability and is easier to finish, allowing contractors to provide a finish that would be more durable and longer lasting.

- Provide a specification that all approved PennDOT producers could make.

Based upon the testing and evaluation program a proposed AAAP specification was drafted.

A formal outreach and implementation program should be conducted. The specification and best practices document should be communicated to the producers and PennDOT Districts through PennDOT/PACA webinars, established or new District Producers meetings, and PACA Concrete Technical Committee meetings (attended by District personnel).

The AAAP initiative represents an unprecedented amount of work and level of cooperation between industry and many individuals at all levels within the Pennsylvania Department of Transportation. We would like to thank all of the PennDOT personnel who worked on this initiative. We recognize their strong desire to improve bridge deck concrete and appreciate their expertise and their contributions to this work. It is also a testament of what can be accomplished by PennDOT and Industry working together.

Introduction

In September of 2008, Industry engaged the Pennsylvania Department of Transportation in a conversation regarding consideration of a bridge deck concrete that would be an improvement to the current AAA specification. Two primary focus areas were targeted to improve performance - reduced shrinkage potential and enhanced permeability characteristics. To accomplish these objectives, Industry undertook the AAAP initiative. AAAP concrete will utilize a reduced cement paste content and require the use of supplementary cementitious materials (SCM). In addition to enhancing performance, a secondary objective was to design a concrete mix that could be readily produced by ready mixed concrete firms across the Commonwealth.

Following the initial discussions with PennDOT, Industry conducted extensive research into the current practice for High Performance Bridge Deck concrete (HPC). A mix design evaluation program was outlined and research conducted to investigate the performance of AAAP made with representative materials (cement, SCM, aggregates, and admixtures) available across Pennsylvania. Based upon those results, a special provision specification was developed with the assistance of PennDOT. The results of the mix design program were shared with all the PennDOT Engineering Districts and trial field projects were selected. Ten projects were placed from September 2009 thru October 2010. Comparison testing between AAAP and AAA was conducted on each of these projects. Shrinkage potential was evaluated based upon the field test results.

Laboratory Mix Design Testing Program

Eight mix designs were made in November of 2008 and repeated in January of 2009. Both sets of mix designs were conducted utilizing the same materials. The materials selected are representative and commonly available across Pennsylvania.
The concrete mixes evaluated contained the following mix properties and supplemental cementitious materials (SCM).

Mix Properties:

- Cementitious content: 580 pounds per cubic yard
- W/C Ratio = 0.45
- Coarse aggregate content = 10.76 ft^3
- Targeted Slump 7" +/- 1"

Mixes Evaluated:

1. Control mix (all cement)
2. 25% Slag
3. 40% Slag
4. 15% Type F Fly Ash
5. 20% Type C Fly Ash
6. 40% Type C Fly Ash
7. 5% Silica Fume
8. Ternary Mix 30% Slag and 20% Type F Fly Ash

Mix Design Properties

The proportions for the mixes are shown in Table 1 and 2

Table 1
Concrete Mixes Evaluated on November 6, 2008

MATERIALS	# 1 Straight Cement	# 2 Slag 25%	# 3 Slag 40%	#4 Class F Ash 15%	# 5 Class C Ash 20%	# 6 Class C Ash 40%	# 7 Silica Fume 5%	# 8 Ternary 50% Cement 30% Slag 20% F Ash
Cement Type I	580	435	348	493	464	348	551	290
Fly Ash Type F				87				115
Fly Ash Type C					116	232		
Slag		145	232					175
Silica Fume							29	
Total Cementitious	580	580	580	580	580	580	580	580
Stone # 57	1756	1756	1756	1756	1756	1756	1756	1756
Sand	1266	1256	1250	1245	1249	1249	1256	1225
Water	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
Water/Cement Ratio	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Water Reducer/Super	3.5	5.0	4.6	3.5	3.5	1.5	4.0	3.0
Retarder	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Air Entraining	0.6	0.8	0.9	0.8	0.6	0.8	0.8	0.6

Table 2
Concrete Mixes Evaluated on January 14, 2009

MATERIALS	# 1 Straight Cement	# 2 Slag 25%	# 3 Slag 40%	#4 Class F Ash 15%	# 5 Class C Ash 20%	# 6 Class C Ash 40%	# 7 Silica Fume 5%	# 8 Ternary 50% Cement 30% Slag 20% F Ash
Cement Type I	580	435	348	493	464	348	551	290
Fly Ash Type F				87				115
Fly Ash Type C					116	232		
Slag		145	232					175
Silica Fume							29	
Total Cementitious	580	580	580	580	580	580	580	580
Stone # 57	1756	1756	1756	1756	1756	1756	1756	1756
Sand	1266	1256	1250	1245	1249	1249	1256	1225
Water	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
Water/Cement Ratio	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Water Reducer/Super	3.5	5.0	4.6	3.5	1.5	3.5	5.5	5.5
Retarder	2.0	2.0	2.0	2.0	2.0	2.0	3.0	2.0
Air Entraining	0.5	0.6	0.6	0.6	0.5	0.6	0.6	0.8

Performance Results

The above mixes were evaluated for slump, air content, concrete temperature, set time and unit weight. Each mix was also tested for compressive strength. Both sets of mixes were evaluated using the Rapid Chloride Permeability Test (RCP) ASTM C1202 / AASHTO T277. Two sets of RCP tests were conducted on each of the mixes. The standard 28 and 56 day as per ASTM C1202 as well as the accelerated curing test developed by Virginia DOT (Ozyilidirim1998). The January 2009 set of mixes were evaluated by both the RCP test and the Chloride Ion Ponding test, AASHTO T259. The heat signature of each mix was established using the AdiaCal® Calorimeter apparatus. The plastic properties and performance results are shown below in Tables 3 and 4, RCP results in Charts 1 and 2, and the AdiaCal® set time results in Charts 3 and 4.

Table 3
Performance results for November 6, 2008

	# 1 Straight Cement	# 2 Slag 25%	# 3 Slag 40%	#4 Class F Ash 15%	# 5 Class C Ash 20%	# 6 Class C Ash 40%	# 7 Silica Fume 5%	# 8 Ternary 50% Cement 30% Slag 20% F Ash
Slump	6.25"	6.50"	6.75"	6.00"	7.50"	7.50"	6.50"	6.50"
Air Content	7.0%	6.9%	6.5%	7.5%	5.8%	6.2%	7.4%	6.5%
Concrete Temp.	66	65	61	66	65	66	62	64
Ambient Temp	56	56	56	56	58	62	64	64
Actual Unit Weight	142.3	143.2	143.0	141.6	144.0	144.6	141.6	143.4
Calculated Unit Weight	143.1	142.7	142.5	142.37	142.4	141.8	142.7	141.5
COMPRESSIVE STRENGTH RESULTS								
7 Day	4,430	5,252	5,412	4,271	4,598	4,174	4,315	4,704
14 Day	4,952	6,137	6,482	5,155	5,226	5,146	4,757	5,474
28 Day	5,208	6,552	7,030	5,509	5,562	5,863	5,332	6,561
28 Day / 7 Day Ratio	1.18	1.25	1.30	1.29	1.21	1.40	1.24	1.39
RAPID CHLORIDE PERMEABILITY (COULOMBS)								
Standard Cure 28 Day	3,424	1,474	982	2,208	2,942	2,768	2,828	680
Standard Cure 56 Day	3,269	1,258	780	1,502	2,380	1,829	2,549	569
Accelerated Cure 28 Day	3,442	1,341	893	1,411	2,171	1,685	2,441	424
Accelerated Cure 56 Day	2,652	1,026	535	758	1,438	781	2,143	265

Table 4
Performance results for January 14, 2009

	# 1 Straight Cement	# 2 Slag 25%	# 3 Slag 40%	#4 Class F Ash 15%	# 5 Class C Ash 20%	# 6 Class C Ash 40%	# 7 Silica Fume 5%	# 8 Ternary 50% Cement 30% Slag 20% F Ash
Slump	7.25"	7.00"	7.50"	5.25"	8.50"	7.25"	7.00"	7.25"
Air Content	7.8%	7.6%	7.8%	6.0%	6.8%	7.2%	8.1%	8.5%
Concrete Temp.	58	60	60	59	58	60	60	58
Ambient Temp	55	55	55	55	55	55	55	55
Actual Unit Weight	140	139	139	142	141	140	138	138
Calculated Unit Weight	143.1	142.7	142.5	142.3	142.4	141.8	142.7	141.5
COMPRESSIVE STRENGTH RESULTS								
7 Day	4,637	4,577	4,358	5,632	4,438	3,980	4,617	4,199
28 Day	5,489	6,126	6,326	7,439	5,629	5,927	5,649	6,902
28 Day / 7 Day Ratio	1.18	1.34	1.45	1.32	1.27	1.49	1.22	1.64
RAPID CHLORIDE PERMEABILITY (COULOMBS)								
Standard Cure 28 Day "L"	4,200	2,044	1,428	1,280	4,961	2,708	1,963	1,076
Standard Cure 28 Day "G"	4,692	1,994	1,537	1,396	4,857	3,050	1,819	1,170
Standard Cure 56 Day "L"	3,263	1,380	952	913	3,130	1,513	1,303	541
Accelerated Cure 28 Day "L"	4,231	1,870	1,248	1,175	4,498	2,241	1,717	953
Accelerated Cure 56 Day "L"	2,733	1,112	872	640	1,665	933	1,241	356

Chart 1

Rapid Chloride Permeability (RCP) Results for November 6, 2008

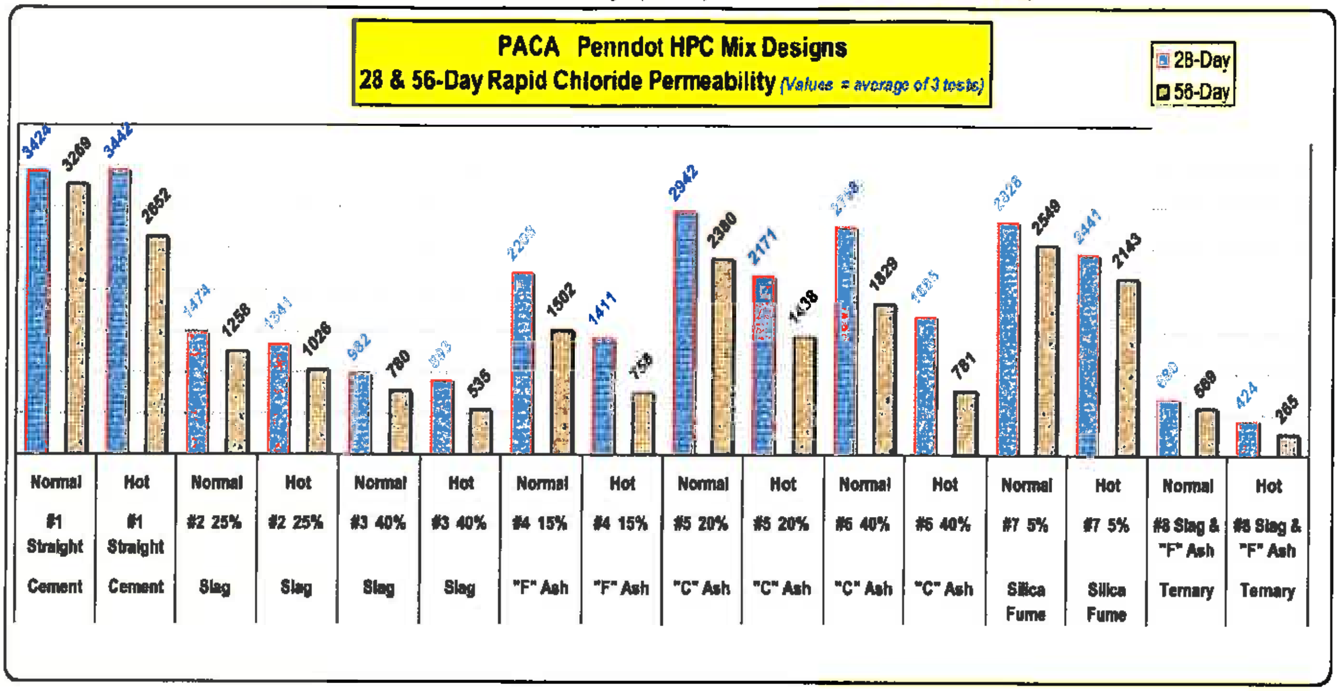
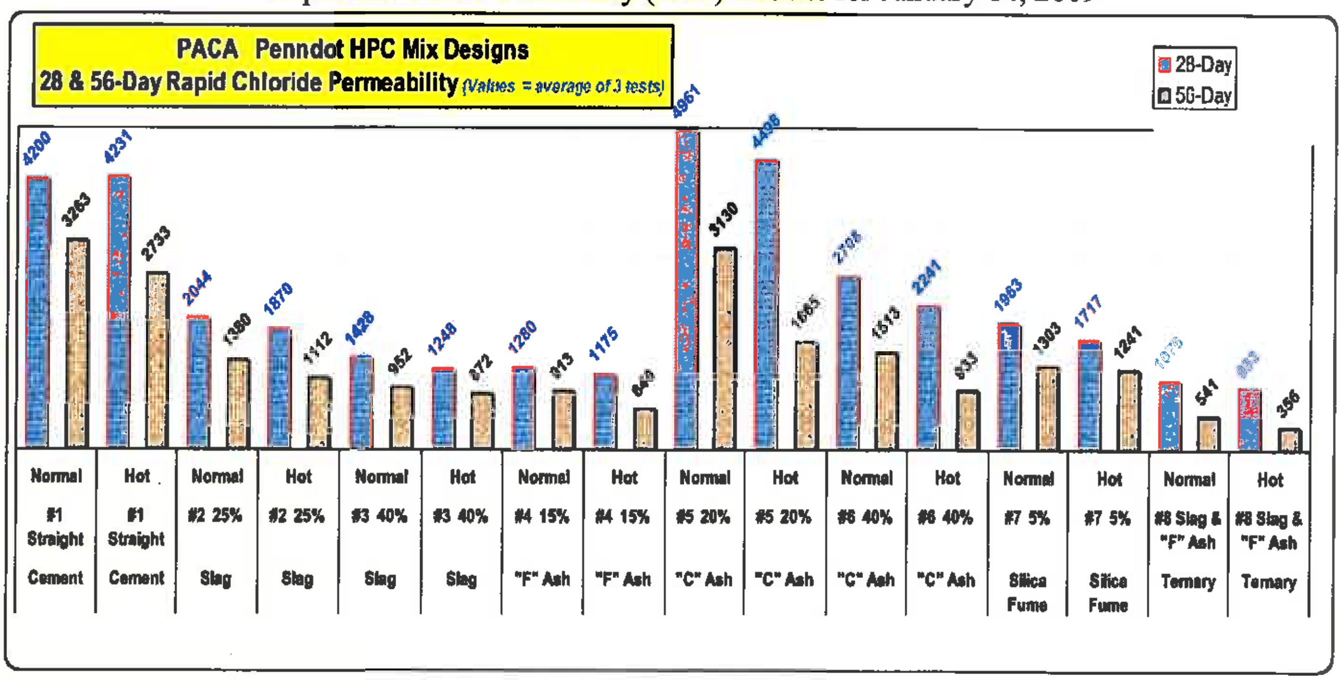


Chart 2

Rapid Chloride Permeability (RCP) Results for January 14, 2009



90 Day Chloride Ponding Results

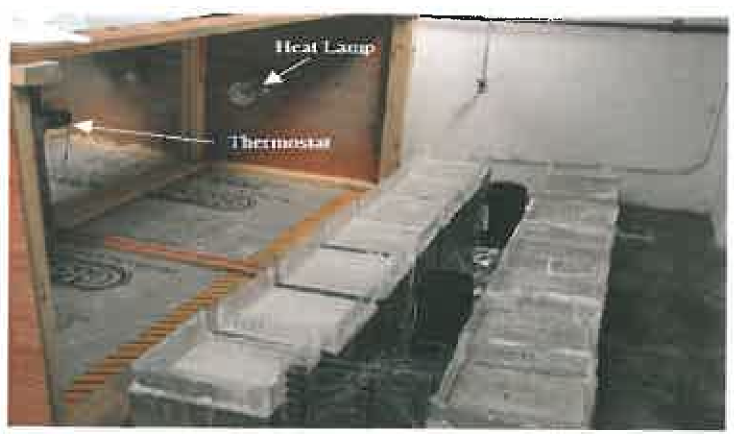
Acid Soluble Chloride

The concrete samples were cured and tested in accordance to AASHTO T-259. The top samples were taken from 1.6 mm (0.0625 in.) to 13 mm (0.5 in.) below the top surface of each slab and the bottom samples were taken from 13 mm (0.5 in.) to 25 mm (1.0 in.) below the top surface of each slab. All of the samples were passed through a 0.300-mm (No. 50) sieve and analyzed in duplicate for their acid soluble chloride contents according to the modified version (re:W.R.Grace) of AASHTO T260. The averages of the duplicate analyses for each of the portions are given in table 5 below.

Table 5
Chloride Ion Penetration and comparison RCP Tests for January 14, 2009 Mixes

Average % Chloride by Weight of Sample								
Sample	1	2	3	4	5	6	7	8
Wet Top	0.309	0.241	0.371	0.21	0.365	0.334	0.319	0.202
Wet Bottom	0.038	0.01	0.009	0.008	0.028	0.01	0.016	0.01
Dry Top	0.009	0.008	0.100	0.008	0.009	0.009	0.010	0.009
Dry Bottom	0.007	0.008	0.009	0.007	0.008	0.008	0.009	0.009
Coulombs	4692	1994	1537	1396	4857	3050	1819	1170
Design Cubic Yard Mass (lbs)	3864	3853	3848	3841	3846	3828	3853	3821
% Cementitious per Yard³	15%	15%	15%	15%	15%	15%	15%	15%
Pounds of Cementitious per Yard³	580	580	580	580	580	580	580	580
CI - % by Mass of Cement	0.25	0.07	0.06	0.05	0.19	0.07	0.11	0.07
Lbs. CI- per CY	1.47	0.39	0.35	0.31	1.08	0.38	0.62	0.38

Typical Ponding Test Apparatus (AASHTO T-259)

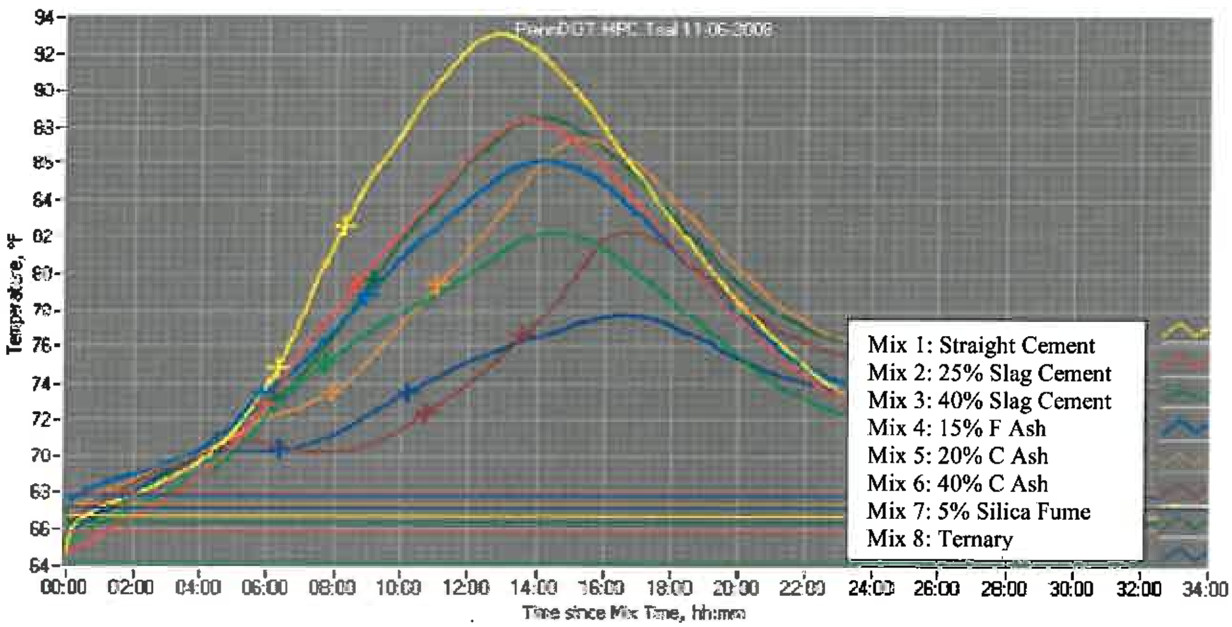


Calorimetry Testing

Calorimetry measures the heat generated from the early hydration reactions of cementitious materials. The heat outflow tracks the hydration reactions of cement, which provides insight into the behavior of concrete in a way that a simple set time or compressive strength test could not. The timing and shape of the temperature curve obtained through calorimetry is an indicator of the heat evolution and relative performance of concrete mixes.

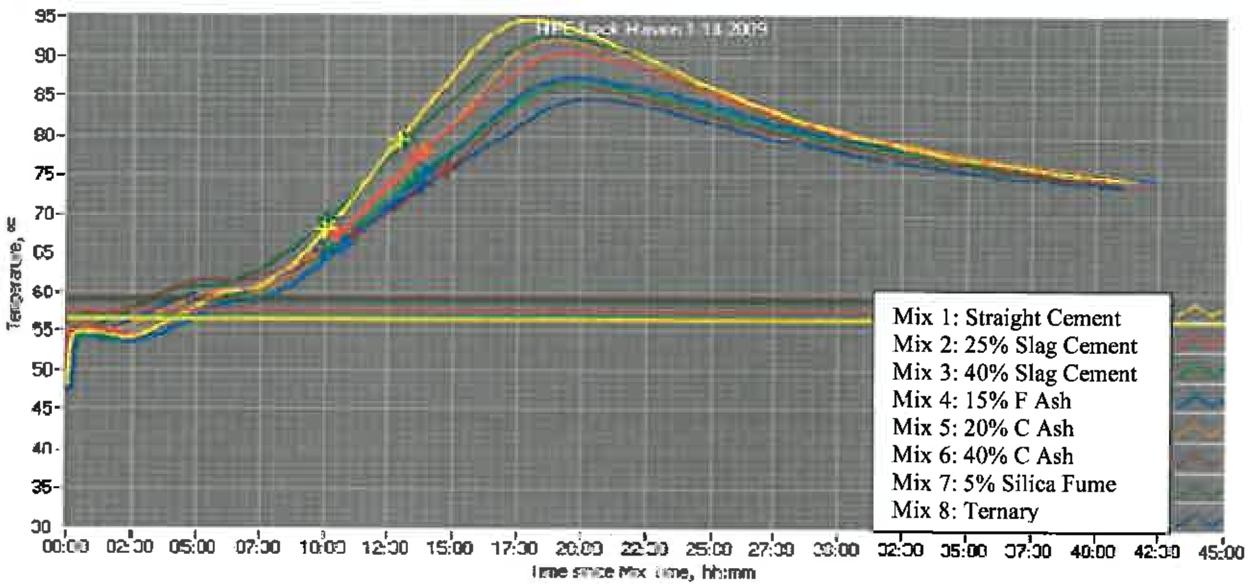
Charts 3 and 4 show the results of the calorimetry testing on the AAAP mix designs.

Chart 3
AdiaCal® Heat Evolution Results
11/06/08



Peak Heat Evolution from Greatest to Least:				
Rank	Mix ID	Cement Materials	Elapsed Time	Temp. °F
1	Mix #1	Straight Cement	13:00 hr	93.00 °F
2	Mix #7	5% Silica Fume	14:30 hr	88.50 °F
3	Mix #2	25% Slag Cement	13:45 hr	88.50 °F
4	Mix #5	20% C Ash	15:15 hr	87.50 °F
5	Mix #4	15% F Ash	14:25 hr	86.00 °F
6	Mix #6	40% C Ash	17:00 hr	82.50 °F
7	Mix #3	40% Slag Cement	14:75 hr	82.25 °F
8	Mix #8	Ternary	16:45 hr	77.50 °F

Chart 4
AdiaCal® Heat Evolution Results
1/14/09



Peak Heat Evolution from Greatest to Least:				
Rank	Mix ID	Cement Materials	Elapsed Time	Temp. °F
1	Mix #1	Straight Cement	18:00 hr	94.50 °F
2	Mix #7	5% Silica Fume	19:00 hr	93.00 °F
3	Mix #5	20% C Ash	19:00 hr	92.50 °F
4	Mix #2	25% Slag Cement	19:30 hr	90.75 °F
5	Mix #4	15% F Ash	19:45 hr	87.50 °F
6	Mix #6	40% C Ash	18:45 hr	87.00 °F
7	Mix #3	40% Slag Cement	20:00 hr	87.00 °F
8	Mix #8	Ternary	20:00 Hr	84.75 °F

Summary of Mix Design Testing

The mixes developed excellent strength when evaluated at air contents and slumps that would be necessary for field production.

The 28 day strength of all the mixes (excluding mix 1 control) ranged from:

- 5,330 - 7,030 psi (Nov 08)
- 5,649- 6,902 psi (Jan 09)

In both sets of design trials each mix that incorporated a SCM produced higher strengths than the control mix which contained cement only. The control mix produced strengths of 5,209 and 5,489 psi in November and January, respectively.

The range of the plastic properties measured were:

Slump:	6.0" – 7.5" (Nov 08)	Air Content:	5.8% - 7.4%	(Nov 08)
	7.0" – 8.5" (Jan 09)		6.8% - 8.5%	(Jan 09)

The use of supplemental cementitious materials (SCM) produced a substantial improvement in the durability characteristics measured by the RCP and Ponding Tests.

November 2008 Designs

5 of 7 mixes with SCM had values below 2000 coulombs at 56 days or 28 days of accelerated curing. The values ranged from:

- 569 – 2549 coulombs at 56 days
- 424 – 2441 coulombs at 28 days accelerated curing

The control mix had values of 3,269 and 2,652 coulombs at 56 days and 28 days accelerated curing, respectively.

January 2009 Designs

6 of 7 mixes with SCM had values below 2000 coulombs at 56 days; 5 of 7 mixes had values below 2000 coulombs at 28 days of accelerated curing.

The values ranged from:

- 541 – 3130 coulombs at 56 days
- 953 – 4498 coulombs at 28 days accelerated curing

The control mix had values of 3,263 and 4,231 coulombs at 56 days and 28 days accelerated curing, respectively.

The control mix exhibited higher RCP test results in all but one of the 14 tests with the exception of the 28 day accelerated results for mix 5 (Jan 09).

Table 6 shows the ranges for classifying concrete based on the results of the RCP tests.

Table 6

Rapid Chloride Permeability AASHTO T277 / ASTM C1202 Result Interpretation Table	
Charge Passed Coulombs	**Chloride Permeability**
> 4000	High
2000 -4000	Moderate
1000 -2000	Low
100 -1000	Very Low
< 100	Negligible

Chloride Ion Ponding Tests

Two criteria have been established to evaluate the quantity of chloride ions which penetrate the concrete as measured by the ponding test. They are the amount of chloride ions as expressed in lbs per cubic yard and chloride ions as a percentage of cementitious material in the concrete.

All of the mixes that contained a SCM had values below the threshold limit of 1.2 lbs of chloride ions per cubic yard.

The values ranged from .28 to .62 lbs/yd^3

The control mix had a value of 1.47 lbs/yd^3

5 of 7 mixes had values of chloride ions less than 0.1% the cementitious content.

The values ranged from:

- 0.007 - 0.009 dry bottom
- 0.008 - 0.028 wet bottom

The control mix had values of .007 dry bottom and .038 wet bottom.

Table 7 shows the chloride ion limits based on the recommendation of ACI 222R

Table 7

ACI 222R Table 3.1 - Chloride limits for new construction

Category	Chloride limit for new construction (% by mass of cement)		
	Test method		
	Acid-soluble	water-soluble	
	ASTM C 1152	ASTM C 1218	Soxhlet*
Prestressed concrete	0.08	0.06	0.06
Reinforced concrete in wet conditions	0.10	0.08	0.08
Reinforced concrete in dry conditions	0.20	0.15	0.15

*The Soxhlet test method is described in ACI 222.1

The mixes with SCM demonstrated an improvement on heat signature and strength gain as measured by the Adiacal results and the 28/7 day ratio.

The AdiaCal results show that all the mixes containing a SCM displayed a lower overall heat signature. An additional desirable characteristic was that the maximum heat was generated at a later time than the control mixes. The lower overall heat evolution of the mixes containing SCM's indicates a lesser potential for thermal cracking. (Wang etal 2007)

Heat evolution is a function of w/c, cement chemistry, type and quantity per cubic yard. AAAP has a lower minimum cement requirement and therefore should have a lower peak heat value than current AAA mixes with similar replacement percentages. This should translate to a reduced potential for thermal cracking.

The mixes that contained a SCM showed a significant increase in the 28/7 day strength ratio.
The 28/7 ratio ranged from:

- 1.24 – 1.39 (Nov 08)
- 1.22 – 1.64 (Jan 09)

The control mix had values of 1.18 in both sets of trials.

Comments and Suggestions from District Meetings

During late 2009 and early 2010, representatives from the Pennsylvania Aggregates and Concrete Association (PACA) Concrete Technical Committee and Industry conducted meetings with Bridge and Materials personnel in 10 PennDOT Engineering Districts. The purpose of the meetings was to review and discuss the report that was generated as a result of the aforementioned laboratory testing program and a Special Provision that had been written for AAAP concrete.

The Districts were also asked to identify any projects that may be candidates for AAAP field work. Ten projects were selected statewide with the support of PennDOT BQAD and BOCM. These meetings also provided an opportunity to engage numerous district personnel in the broad subject of bridge deck concrete. These discussions yielded consensus that the current AAA specification could and should be improved. Other suggestions and comments are listed below:

- Establish correct minimum structural strengths (Sec. 704, Table A) and the minimum compressive strengths (Sec. 110, Table A). These would need to be established for calculating PWL's and disposition/payment when dealing with low strength concrete (Sec. 110.10). Should the minimum structural F'c be 3,750 psi and the absolute min. strength (F'cs, Sec. 110, Table A) be 3,500 psi?

- The current over-design in Bulletin 5 is 1,000 psi. Should the AAAP special provision lower this to 500 psi? This would help us in the direction that this specification is headed for lowering cement factors etc…

- Should the minimum cement factor be lowered to 6 bags, 564 lbs, instead of 580?

- Lower 7 day strength requirement to (3,000 psi?); however, this would take some modification of the current Sec. 1001 specifications for loading, cure times, etc…

- There were several comments supporting the requirement for 14 day wet cure.

- Several districts expressed support for the inclusion of ternary mixes into the specification.

- Blended aggregates should be allowed.

- Based on the required testing with RCP's/ microstrains, should the special provision waive the 28 day/ 7 day strength requirement of 1.33 as currently required in Sec. 1001? I believe it should be waived and not be required.

Field Evaluation Program

Beginning in September of 2009 and concluding in October of 2010 ten (10) AAAP projects were placed. These projects are listed in Table 8 below.

Table 8
AAAP Projects

Project	Concrete Producer	Contractor	District	Placement Date
SR 2008	Rock Hill Materials	Clearwater Construction	5	9/2/2009
SR 3011	Meadeville Redi Mix	Shingledecker's Welding	1	6/10/2010
SR 472	New Holland Concrete	Eastern Highway Specialists	8	7/8/2010
SR 955	Austin Servall	Shingledecker's Welding	1	8/3/2010
SR 2070	Kinsley Materials	Deblin Inc.	8	8/17/2010
SR 2014	New Enterprise Stone & Lime	Francis J. Palo Inc.	9	8/17/2010
SR 8	J.J. Kennedy	Mekis Construction	10	8/24/2010
SR 2038	Rahns Construction Materials	J.D. Eckman, Inc.	6	10/7/2010
SR 3011	Ligonier Stone & Lime	Russell Standard	10	10/13/2010

Summary of Field Testing Results

Tests were conducted on each AAAP placement and included slump, air content, and temperature. Test cylinders were made and tested at 7, 14, 28, and 56 days. These tests were conducted at the concrete batch plants, witnessed by PennDOT personnel, and were conducted in addition to the normal jobsite acceptance and quality control tests.

The average of the test results for these projects were:

AAAP Results

Slump	Air Content	Temperature	7 day	14 day*	28 day	56 day*
5.6"	7.4%	69 F	4287	4938	5916	6372

*The 14 day result is the average of 8 tests, the 56 day result is the average of 7 tests

The range of the test results for AAAP were:

Slump	Air Content	Temperature
4.5" – 6.5"	6.0% – 9.8%	61°– 76° F

Compressive strength test results:

7 day 3175 psi - 5250 psi
14 day 4112* psi - 5943 psi
28 day 5236 psi - 7045 psi
56 day 5394 psi - 7980 psi
*12 day result

An important part of the field evaluation program was to determine the performance of AAAP when produced to meet the requirements mandated for bridge deck construction in the field. The results show these mixes produced excellent strength at the slump and air content required for field acceptance and placement. The average 28 day strength of 5916 psi is 48% higher than the required strength of 4000 psi.

In order to obtain a practical comparison to existing AAA mix designs a companion load of AAA was batched and tested on each placement. Each of these were tested for plastic properties, shrinkage specimens molded, and companion test cylinders were made on eight of the ten projects.

A comparison of average values of the AAAP and AAA for only those samples with corresponding companion samples is shown on Table 9 below.

Table 9
Field Test Values AAAP versus AAA

Average Values	**AAAP**	**AAA**
Slump	5.6"	5.8"
Air Content	7.4%	7.2%
Temperature	69° F	71° F
7 Day Strength psi	3915	4403
14 Day Strength psi	3787*	3784*
28 Day Strength psi	5232	4921
56 Day Strength psi	5373*	5367*
28/7 Day Ratio	1.34	1.22

*14 and 56 day result are the averages of 6 comparison tests

These results show close correlation to the plastic properties of these mixes; however, the strength curve is significantly different. The AAAP had lower 7 day strength and higher 28 day strengths. This is reflected in the increase in the 28/7 day ratio of AAAP which is 1.34 as compared to 1.22 for AAA. The 7 day strength of AAAP was almost 500 psi lower than AAA. The 56 day strengths were very close.

Another significant result is that AAAP showed an average increase in 28 day strength of 311 psi or 6.3%. This occurred even though the average cementitious factor is reduced by 73 pounds per cubic yard and the average water/cement ratio was increased from .410 to .422.

A significant reduction in paste content was demonstrated in these projects as shown in table 10 below.

Table 10

Average of Ten Projects	AAAP	AAA
Paste Content (percentage)	26.4	29.1
Cementitious Factor lbs/yd^3	671	599
Water / Cementitious Ratio	.410	.422

Rapid Chloride Permeability (RCP) tests ASTM C1201 were conducted on these mixes used in these ten projects as part of the mix design approval process. The average 56 day RCP value for the ten projects was 1115 Coulombs. Comparison RCP tests were available for six out of the ten projects. AAAP demonstrated a reduction in RCP values for the projects with companion samples.

The 56 day RCP values were:

- AAAP 943 Coulombs
- AAA 1151 Coulombs

There were two projects scheduled to be built using AAAP in District 4. The initial mix designs did not meet the RCP limits. A second set of mix designs was made with RCP results just above the 2000 Coulomb requirement. Additional mix designs where then made. Eventually two suppliers were able to produce designs that met all the requirements; however, in order not to delay the scheduled projects while waiting for test results the decision was made to use AAA on those decks. Valuable information was learned from these mix designs. These producers and their suppliers now have a much better understanding as to the effect that aggregate type, cement factors, and type of and quantity of SCM have on a mix's ability to meet the RCP requirements. These producers are now able to supply concrete that meets the AAAP specification.

The performance of ternary mixes was demonstrated in the mix design testing program and the need confirmed during the field testing program. There are areas of Pennsylvania such as those in District 4 where the quality of available aggregate is such that the use of ternary mixes would be required or may be the most prudent method available to achieve the required RCP values.

All of the test results are included in Appendix A.

Summary of Field Observations

A representative of the PACA Concrete Technical Committee attended all but one of the placements. Placing and finishing operations were observed and the comments of contractors and inspectors captured. A placement inspection report form was used to evaluate these projects on a consistent basis. Care was taken to capture the comments and observations of the finishers.

Based on comments from the field personnel seven of the ten projects reported an improvement in workability and ease of finish as compared to AAA. Three of the projects reported the mix as sticky or similar to AAA. The placement inspection forms for each of these projects are included in Appendix A.

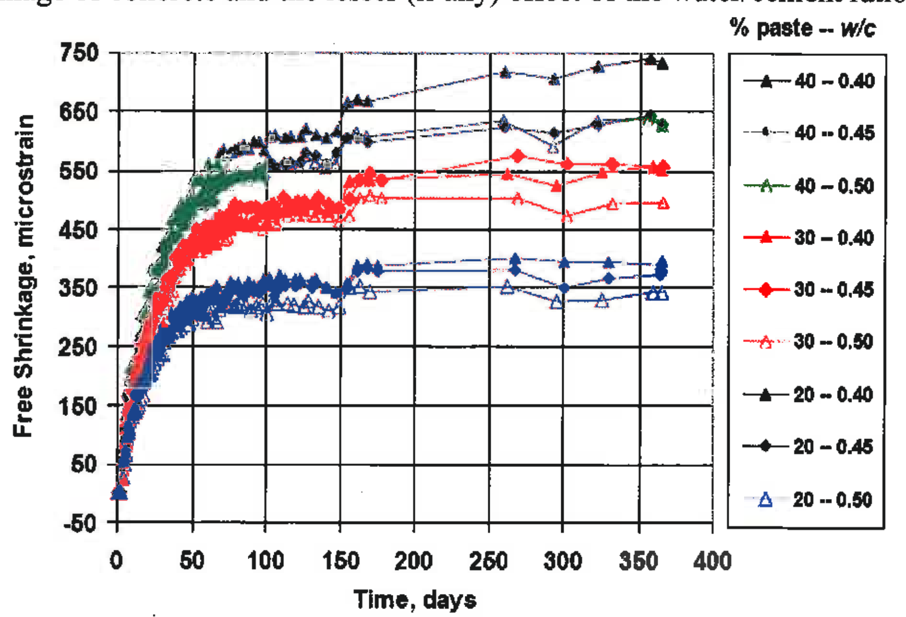
Evaluation of Shrinkage Characteristics

Cracks in bridge decks provide easy access for chloride ions to begin the corrosion process. The resulting loss in service life of bridge decks is a significant cost to the Commonwealth of Pennsylvania. The material properties of concrete are only one of four groups of factors that contribute to bridge deck cracking. The others include environmental or site conditions, construction techniques, and design details.

A decrease in the shrinkage potential of bridge deck concrete and resulting reduction in cracking would improve the service life of bridges. AAAP has the ability to provide a reduction in shrinkage potential over the existing AAA specification. A theoretical estimate of shrinkage reduction was evaluated using guidelines established by the American Concrete Institute (ACI) and the Portland Cement Association (PCA). On each of the ten AAAP projects shrinkage tests specimens were cast and evaluated for both the AAAP and the AAA companion batches.

There are a number of factors that affect the drying shrinkage of concrete including the materials, construction procedures, and environmental conditions. It has been a common approach for many decades to limit shrinkage by reducing the most controllable factor in a concrete mixture, water content (Design and Control of Concrete Mixtures PCA 1980). It is easy to understand how many specifications would then take this approach and limit w/c ratio in hopes of reducing shrinkage.

Recent research specific to bridge deck cracking has evaluated shrinkage in terms of paste content and corresponding aggregate content. This research has shown that the shrinkage is largely controlled by paste content (volume of cementitious material and water) and not directly by water content (Deshpande Darwin Browning 2007, Lindquist Darwin Browning 2008). Figure 1 below shows the effect of the paste content on shrinkage of concrete and the lesser (if any) effect of the water/cement ratio



Free shrinkage plotted versus time through 365 days for concrete containing nominal paste contents between 20 and 40% with w/c ratios ranging from 0.40 to 0.50 [Adapted from Deshpande et al. (2007)]. (Lindquist Darwin Browning 2008)

The above reference and other research conducted as part of Construction of Crack-Free Bridge Decks Transportation Pooled Fund Study TPF-5(051) and earlier work looked to set a target on paste content to reduce bridge deck cracks. A maximum paste content of 27 percent was chosen as a target value (Schmitt & Darwin 1999, Lindquist Darwin Browning 2008).

The paste content of AAAP and AAA at their minimum cementitious content and maximum water cement ratio are*:

AAAP	AAA
25.8 %	28.5 %

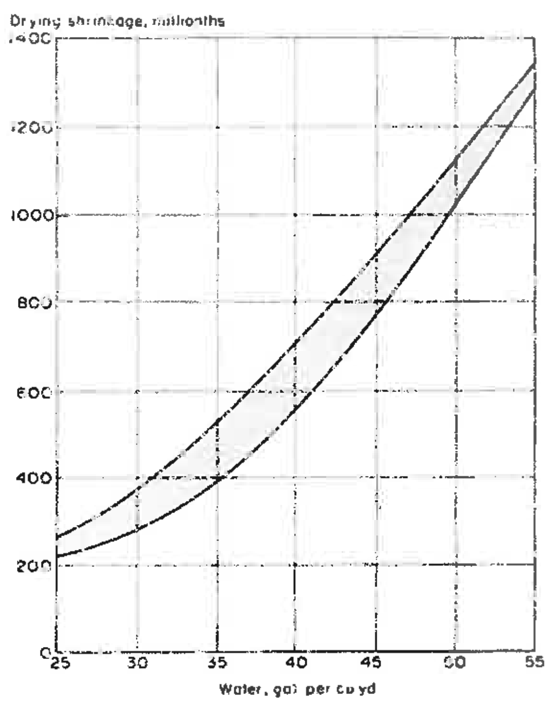
*based on total cementitious being 30% GGBFS by weight, avg from 2010 PACA survey 31%

Estimate of Reduction in Shrinkage

The reduction of shrinkage potential from AAAP as compared to AAA was estimated using PCA and ACI guidelines.

Figure 13-9 Design and Control of Concrete Mixtures 13 th ed. PCA (Figure 2 below) shows the relationship between drying shrinkage and water content. Using this figure and evaluating AAAP and AAA at their minimum cement factors and maximum water cement ratios predicts a reduction in drying shrinkage of 58 microstrains. This corresponds to a reduction of approximately 15 %.

Figure 2



Relationship of total water content and drying shrinkage. A large number of mixtures with various proportions is represented within the area of the band curves. Drying shrinkage increases with increasing water contents. 1 gal = 8.34 lb of water.

Figure 2.3 of ACI 209.1R (Figure 3 below) shows the influence of w/c, cement content, and water content on shrinkage. Using this figure and evaluating AAAP and AAA as above a reduction in shrinkage of 68 microstrains is estimated. This corresponds to a reduction in shrinkage of approximately 15 %.

Figure 3
ACI 209.1R

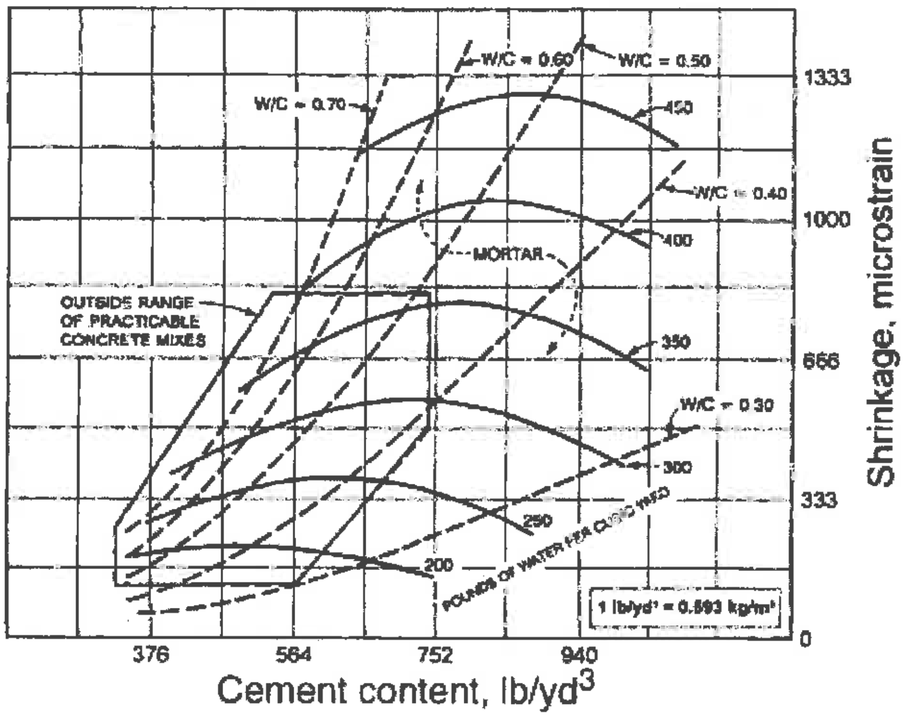


Fig. 2.3—Influence of w/c, cement content, and water content on long-term shrinkage (Blanks et al. 1940). For any given cement content, a line is drawn vertically to intersect the line of w/c. A line is drawn horizontally to determine the drying shrinkage.

An estimate in the reduction of shrinkage due to the increase in aggregate content can be calculated using equation 2-31 of ACI 209R.

The AAAP and AAA mixes at their minimum cementitious factors yield approximate aggregate volumes of 68.2% and 65.5%, respectively. Evaluating these mixes using equation 2-31 yields a reduction in shrinkage of approximately 3.0 %.

While the above values are not totally independent the total potential for reduction in shrinkage from AAA to AAAP can be estimated to be between 15 and 18%.

Shrinkage Tests from Field Projects

On each of the ten field projects shrinkage specimens were made on the AAAP concrete and the companion AAA. These specimens were tested in accordance with ASTM C157. The values of the 28 day shrinkage results are listed on Table 11.

Table 11
28 Day Shrinkage Values
(in percent of length change)

Project	AAAP	AAA	Difference
SR 2008	-0.020	-0.019	- 0.001
SR 3011	-0.033	-0.047	0.014
SR 472	-0.010	-0.013	0.003
SR 955	-0.125	-0.173	0.048
SR 2070	-0.021	-0.022	0.001
SR 2014	-0.048	-0.041	-0.007
SR 8	-0.022	-0.027	0.005
SR 2038	-0.024	-0.040	0.016
SR 3011	-0.045	-0.038	-0.007
SR 322	-0.041	-0.038	-0.003
Average	***-0.039***	***-0.046***	***0.007***

The average of the values for these ten projects are:

- AAAP - 0.039 % or 390 microstrains
- AAA - 0.046 % or 460 microstrains

The results of these ten projects show an average reduction in 28 day shrinkage of 70 microstrains or 15%.

The value of the reduction in shrinkage comparing AAAP to AAA ranged from 0.048% to -0.007% (480 to -70 microstrains).

Six out of the ten projects showed a reduction in shrinkage. On the six projects where AAAP exhibited less shrinkage than AAA the difference ranged from 0.001% to 0.048% (10 to 480 microstrains). On the four projects where AAAP exhibited more shrinkage than AAA the difference ranged from 0.001% to 0.007% (10 to 70 microstrains).

Across all the projects the shrinkage values of AAAP ranged from -0.010% to -0.125% (100 to 1250 microstrains). The shrinkage values of AAA ranged from -0.013% to -0.173% (130 to 1730 microstrains).

On nine out of the ten projects the shrinkage values reported for AAAP and AAA were below the widely used benchmark of 500 microstrains.

AAAP showed the greatest reduction in shrinkage 0.048% (480 microstrains) on the project where the shrinkage was the greatest (SR 955).

The above tests were conducted in accordance with ASTM C157 which calls for the samples to be wet cured for 28 days and then tested. It is not uncommon to see specifications where shrinkage tests are conducted on samples that are wet cured for only 7 or 14 days. This curing period has a very significant effect on shrinkage results and has been the subject of much research. Shorter curing periods will in most cases show higher shrinkage values (Deshpande Darwin Browning 2007). For this investigation the 28 day wet cure was chosen because of its adherence to ASTM C157 and also because it should yield the most conservative estimate of the difference in shrinkage of AAAP versus AAA.

A laboratory mix design testing program was conducted to compare the shrinkage of AAAP and AAA at their minimum cementitious contents and AAA at a statewide average cementitious content. There was a probable measuring error in the baseline reading of some of the samples and the results were very erratic. These tests are being repeated at the time of publication of this report.

Summary of Shrinkage Results

The predicted reduction of shrinkage in bridge deck concrete was confirmed by the ten field projects. This value was estimated to be between 10 and 15 percent of total shrinkage and a 15 percent reduction in 56 day shrinkage was observed. This is in very close agreement given the sensitive nature of the test methods and the many variables which may affect the results.

There are numerous factors which affect the measured shrinkage on concrete. Not the least of which is the length of initial curing of the specimens. The measured 15 % reduction in shrinkage was observed using the 28 day wet cure method. This method should yield the most conservative estimate of difference in shrinkage potential of AAAP versus AAA.

Nine out of the ten comparison tests showed low shrinkage values for both the AAAP and the existing AAA designs. This should be attributed to the quality of the specifications and methods already in place. AAAP demonstrated an improvement to these practices on the majority of these projects. On the four projects where the AAAP did not shrink less than AAA the difference was minimal.

An important consideration in application of the AAAP specification is that the reduction in shrinkage potential from the use of AAAP versus the existing AAA specification would come primarily from a reduction in paste content and the accompanying increase in aggregate content.

Conclusion and Proposed Specification

The intent of this initiative was to develop a mix that was an improvement to the existing AAA specification and to evaluate its performance. An extensive laboratory testing and field testing program was conducted. The work performed during this initiative demonstrates that AAAP provides superior performance to AAA concrete, which should translate into reduced maintenance and longer service life to bridge decks. The criteria in which AAAP demonstrated improvement over AAA were:

1. A reduction in shrinkage potential that would help to reduce cracking.
2. Provides bridge deck concrete with an increase in strength at a lower cement factor.
3. Provides minimum values for resistance to chloride ion penetration and a criterion to measure this for mix design acceptance.
4. Mandates the judicious use of Supplementary Cementitious Materials (SCM). They provide concrete that is less permeable and has demonstrated a slower and more desirable strength gain.
5. Provides concrete that has demonstrated an improvement in workability and is easier to finish. This would allow contractors to provide a finish that would be more durable and longer lasting.
6. Provide a specification that all approved PennDOT producers should be able to produce across the Commonwealth.

The increase in performance, due to the mix design enhancements of AAAP concrete, demonstrated in this program is consistent with the results documented in similar research that has been conducted across the transportation construction industry.

Proposed Specification

Based upon the increase in performance, the potential improvement in service life, and added value; it is proposed that AAA concrete be replaced with AAAP concrete produced in accordance with the following specification. Simultaneous with the release of this document, the Department has circulated a Clearance Transmittal stipulating the use of AAAP concrete as a replacement for AAA concrete.

Class AAAP Cement Concrete
1001.1 Description
Furnish Class AAAP Cement Concrete for structure S -27760 in accordance with Section 704, except as noted below.

704.1 General-

(a) Description Furnish Class AAAP cement concrete according to the requirements of Table A. Cement concrete is a mixture of Portland cement, pozzolan, fine aggregate, coarse aggregate, water and air-entraining admixture with or without water reducing or admixture.

Table A (English)
Cement Concrete Criteria
(Replace the existing table with that shown below)

Class of Concrete	Use	Cement Factor(3)(5)(9) (lbs/cu. yd.)		Maximum Water Cement Ratio6 (lbs/lbs)	Minimum Mix(2) Design Compressive Strength (psi)			Proportions Coarse(1) Aggregate Solid Volume (cu. ft./cu. yd.)	8-Day Structural Design Compressive Strength (psi)
					Days				
		Min.	Max.		3	7	28		
AAAP	Bridge Deck	560	752	0.45	---	TBD	4,000	—	TBD

Required addition of Supplementary Cementitious Material (SCM):
(9) Cement factor must include one of the following as a replacement for a portion of the cement:
Ground Granulated Blast Furnace Slag (GGBFS) (Grade 100 or higher).............................25% (min)
Fly Ash (Type F)..15% (min)
(for flyash minimum cement content = 510 lb/cy)
Silica Fume..5% - 10%
Three of the above SCM may be used on one mix (Tri-blends) as long as one of the SCM meet the above minimum percentage of replacement.

(c) Design Basis.

2. Cement Factor.

Replace the second paragraph as follows:

Portland cement must be replaced with pozzolan (fly ash, ground granulated blast furnace slag, or silica fume) weighing as much or more than the Portland cement replaced.

4. Mix Design Acceptance.

Replace the third paragraph as follows:

Additional criteria for acceptance:

Rapid chloride permeability (AASHTO T-277) 2000 coulombs at 56 days. To be performed by an accredited laboratory.

(f) Mixing Conditions.

3.c Portland Cement-Pozzolan Combinations

Delete the last paragraph

Proposed Implementation and Outreach Program

To insure the best possible implementation of AAAP, we propose an education and information outreach program be conducted. A suggested program would include:

1. Produce a best practices document to help producers and PennDOT district officials make and approve AAAP designs that would yield the best results.

2. Conduct a formal outreach program. The specification and best practices document should be communicated to the producers and PennDOT District through PennDOT/PACA webinars, established or new District Producers meetings, and PACA Concrete Technical committee meetings (attended by District personnel).

3. Utilize the structure and guidance of the PennDOT/APC Bridge Committee to reach all the involved PennDOT personnel, designers, and contractors.

4. Use the established APC District Meetings to communicate the AAAP specification and best practices document.

5. Data collection and analysis of future projects continue in order to promote the continuous improvement of AAAP concrete.

Acknowledgements

The AAAP initiative represents an unprecedented amount of work and level of cooperation between industry and many individuals at all levels within the Pennsylvania Department of Transportation. We would like to thank all of the PennDOT personnel who worked on this initiative. We recognize their strong desire to improve bridge deck concrete and appreciate their expertise and their contributions to this endeavor. It is also a testament of what can be accomplished by PennDOT and Industry working together.

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Appendix A Field Evaluation Data and Observations

Field Evaluation Data – SR 2008

SR 2008 September 2, 2009 (District 5)

	AAAP	AAA
Slump (inches)	6	5.5
Air Content (%)	6.7	6.8
Temperature (F)	73	71
Compressive Strength (psi)		
7 Day	5250	6340
14 Day	5943	6606
28 Day	7045	6805
56 Day	7980	7540
Cementitious Content	588	695
W/C Ratio	0.4	0.42
56 Day RCP (Coulombs)	351	
Shrinkage Value (-)		
7 Day	0.011	0.011
14 Day	0.014	0.013
28 Day	0.020	0.019
56 Day	0.025	0.022

AAAP Deck Placement and Condition Report
SR 2008 September 2, 2009

Project: SR 2008

Contractor: Clearwater Construction

Supplier: Rock Hill Materials

Placement Date: September 2, 2009
Yards Placed: 87
Placement Start Time: 3:30 am   Placement Completion Time: 7:30 am

Weather

Start	Temp 54	Wind Speed < 5	Rel. Humidity 89%
Finish	Temp 51	Wind Speed < 5	Rel. Humidity 92%

Cloud Cover: Clear
Other Weather Remarks - Foggy

All plant test results		Slump	Air Content	Temp
	AAAP	6"	6.7%	73
	AAA	5.5"	6.8%	71

Placement Observations: Short span on low volume two lane road.

Finishing Methods: Bidwell with metal pan drag, bullfloated then tined.

Comments: (contractor supervisor) "A little sticky, fought to close."

Field Evaluation Data – SR 3011

SR 3011 June 10, 2010 (District 1)

	AAAP	AAA
Slump (inches)	6.5	7.75
Air Content (%)	6	7.1
Temperature (F)	61	n/a
Compressive Strength (psi)		
7 Day	4173	3820
14 Day	5128	4319
28 Day	6543	4510
56 Day		
Cementitious Content	611	682
W/C Ratio	0.41	0.41
56 Day RCP (Coulombs)	1422	n/a
Shrinkage Value (-)		
7 Day	0.020	0.026
14 Day	0.025	0.036
28 Day	0.033	0.047
56 Day	0.035	0.054

AAAP Deck Placement and Condition Report
SR 3011 June 10, 2010

Project: SR 3011 Albion District 1

Contractor: Shingledecker's Welding

Supplier: Meadville Redi-Mix Concrete, Inc.

Placement Date: 6/10/10
Yards Placed: 64
Placement Start Time: 7:40 am Placement Completion Time: 11:30

Weather: Sunny - mild

Start Temp	64	Wind Speed	<5	Rel. Humidity	84
Finish Temp	71	Wind Speed	<5	Rel. Humidity	61

Cloud Cover: Clear

All plant test results (Air, Slump, & Temp): N/A

Placement Observations: Placement went very well, experienced crew, no delays.

Finishing Observations: Was very easy to close, used bridge machine and pan drag only, not bullfloated, tined.

Comments: (contractor supervisor) "Good mix – finished well", (finishers) "Easy to work, not sticky, closed very easily", (field inspectors) "Looked very good", (DME) "Liked the mix", (QA) "Material and deck looked good".

Field Evaluation Data – SR 472

SR 472 July 8, 2010 (District 8)

	AAAP	AAA
Slump (inches)	6	6
Air Content (%)	7.8	6.6
Temperature (F)	70	70
Compressive Strength (psi)		
7 Day	4897	5137
14 Day		
28 Day	5553	5986
56 Day (63 Day)	6039	6313
Cementitious Content	630	658
W/C Ratio	0.39	0.41
56 Day RCP (Coulombs)	725	712
Shrinkage Value (-)		
7 Day	(+)0.001	0.002
14 Day	0.003	0.010
28 Day	0.010	0.013
56 Day	0.013	0.019

AAAP Deck Placement and Condition Report
SR 472 July 8, 2010

Project: SR 472

Contractor: Eastern Highway Specialists

Supplier: New Holland Concrete

Placement Date: July 8, 2010
Yards Placed: 60
Placement Start Time: 1:30 am   Placement Completion Time: 4:35 am

Weather

Start	Temp 79	Wind Speed none	Rel. Humidity 74
Finish	Temp 76	Wind Speed none	Rel. Humidity 89

Cloud Cover: Clear
Other Weather Remarks: Extremely hot the day before and after.

All plant test results (Air, Slump, & Temp)

1	6.5%	8.5"	57 F	.43 w/c	rejected at plant
2.	7.3%	7.5"	60F	.39 w/c	
3.	8.5%	5.25"	63F	.39 w/c	
4.	7.9%	6.5"	72F	.39 w/c	
5.	6.5%	4"	73F	.39 w/c	
6.	7.8%	6"	70F	.39 w/c	

All AAAP vs AAA comparison tests results.
Load 6 above AAAP
AAA 6.6% 6" 70F .39 w/c

Placement Observations: Placement crew a little green, finishers experienced.

Finishing Observations: Used bridge machine with pan drag, fresno then tined, closing nicely, not much worked required, tined and placed burlap very quickly (marred surface).

Comments:(contractor supervisor - Brian Ferris) – "Looked good", (finisher - Larry Evans) "Closing very well not much work to do" (finisher – Gary) "Much less sticky not like peanut butter" (field inspectors - Scott Berg and Ed Baker) "Like the look of the mix", (QA - Brad Auker and Terry Kohler) "Material looked good".

Field Evaluation Data – SR 955

SR 955 August 3, 2010 (District 1)

	AAAP	AAA
Slump (inches)	5.25	5.25
Air Content (%)	7.4	7.4
Temperature (F)	75	0.75
Compressive Strength (psi)		
7 Day	4529	4427
14 Day	5619	5243
28 Day	6038	5559
56 Day	6774	6442
Cementitious Content	611	683
W/C Ratio	0.43	0.41
56 Day RCP (Coulombs)	1105	n/a
Shrinkage Value (-)		
7 Day	0.110	0.159
14 Day	0.115	0.162
28 Day	0.125	0.173
56 Day	0.128	0.184

AAAP Deck Placement and Condition Report
SR 955 August 3, 2010

Project: SR 955

Contractor: Shingledecker Welding

Supplier: Austin Servall

Placement Date: August 3, 2010

Yards Placed: 60

Placement Start Time: 7:00 am Placement Completion Time: 10:00 am

Weather

Start	Temp	78	Wind Speed	11 mph	Rel. Humidity	86%
Finish	Temp	82	Wind Speed	11 mph	Rel. Humidity	86%

Cloud Cover: Overcast, rain (12:00 PM -1:00 PM)

All plant test results – N/A

All AAAP vs AAA comparison tests results – N/A

Placement Observations: Due to plant comparison testing placement finished when we arrived.

Comments: Contractor supervisor, PennDOT Materials, and QA were all pleased with workability and results.

Field Evaluation Data – SR 2070

SR 2070 August 17 & 25, 2010 (District 8)

	AAAP	AAA
Slump (inches)	6.5	6
Air Content (%)	8.8	8.5
Temperature (F)	76	77
Compressive Strength (psi)		
7 Day	4165	4466
14 Day	4590	4988
28 Day	5633	5349
56 Day	5607	5810
Cementitious Content	611	688
W/C Ratio	0.43	0.41
56 Day RCP (Coulombs)	1106	884
Shrinkage Value (-)		
7 Day	0.005	0.006
14 Day	0.011	0.012
28 Day	0.021	0.022
56 Day	0.029	0.030

AAAP Deck Placement and Condition Report
SR 2070 August 17, 2010

Project: SR 2070

Contractor: Deblin, Inc.

Supplier: Kinsley Materials

Placement Date: August 17, 2010
Yards Placed: Placement Start Time: 9:00 pm Placement Completion Time:
Placement cut short producer ran out of slag
Placement delayed 2 hours till air temp below 80F

Weather

Start	Temp 79	Wind Speed none	Rel. Humidity 66
Finish	Temp	Wind Speed	Rel. Humidity

Cloud Cover: Clear

All plant test results (Slump, Air Content,& Temp)

Load 1	6.5"	9.5%	74F	.43 w/c
Load 2	6.5"	9.5%	76F	.43 w/c
Load 3	6.5"	9.8%	76F	.43 w/c
Load 4	6.5"	8.8%	76F	.43 w/c

Two loads rejected due to low slump

All AAAP vs AAA comparison tests results
AAAP – load 4 above
AAA 6" 8.5% 77F

Placement Observations: Very experienced placement crew

Finishing Observations: Bridge Machine with pan drag and burlap drag, bullfloated then tined, very good workability, closed very easily

Comments: (contractor supervisors - Bill, Tom) "Mix looked good, nice finish", (finishers - Roy, Joe) "Very easy to work, closed great", (field inspector - Ken (D8)) "Finish looks good", (field inspectors - Ryan, Jay, Tom (TW)) "Concrete looks good", (QA – Linda) "Concrete and finish look very good".

Field Evaluation Data – SR 2014

SR 2014 August 17, 2010 (District 9)

	AAAP	AAA
Slump (inches)	5	5.75
Air Content (%)	9.8	6.8
Temperature (F)	75	76
Compressive Strength (psi)		
7 Day	4227	3538
14 Day	4599	4174
28 Day	5271	4563
56 Day (57 Day)	5394	5058
Cementitious Content	600	635
W/C Ratio	0.42	0.41
56 Day RCP (Coulombs)	1048	803
Shrinkage Value (-)		
7 Day	0.028	0.015
14 Day	0.036	0.026
28 Day	0.048	0.041
56 Day (57 Day)	0.058	0.045

AAAP Deck Placement and Condition Report
SR 2014 August 16, 2010

Project: ECMS#21782 SR: 2014

Contractor: Francis J. Palo, Inc.

Supplier: New Enterprise Stone & Lime Co., Inc.-Roaring Spring Plant

Placement Date: 8/16/10 (Monday)
Yards Placed: 40.0 yd3
Placement Start Time: 9:30AM Placement Completion Time: Approx. 12:00PM

Weather: HHH

Start: hazy	Temp 76F	Wind Speed 3 mph	Rel. Humidity 89%
Finish: humid	Temp 85F	Wind Speed 10 mph	Rel. Humidity 74%

Cloud Cover:
Other Weather Remarks:

All plant test results (Air, Slump, & Temp) – N/A

All AAAP vs AAA comparison tests results – N/A

Placement Observations: Contractor wanted to place the whole deck in one continuous placement. Placed the negative moment. Rejected one load for high temperature, took the ice up to 50lbs/yard.

Finishing Observations: Pumped well, made pump correction (dropped coarse aggregate 4.5%) per ACI 211 6.3.6.1. Bidwell with pan drag, 3-4 passes with float, random tyning.

Comments: (contractor supervisor -Doug (Palo)) "looks good, was borderline with temperature", (finishers) "Not THAT bad as long as it closes up and doesn't tear", (field inspector - Gene Miller, LR Kimball consultants) "Pumps real good, a little warmer than desired", (DME - Kevin Gnegy (D9)) "All of the mix design data looks good (RCP and Shrinkage, Shrinkage lower in AAA-P)".

QA: No appearance

Follow up: Condition survey at approximate opening date - Looks good other than the random cracking. Walked the entire deck and record observations - There are obviously some cracks parallel over the pier, some other ones are parallel to the beams, a few intersect. Would have been interesting if the contractor was allowed to pour one continuous placement.

Additional follow up: Will look at again in the spring to see if there is any scaling or spalling. Repeat the above at 6 – 9 months (spring following construction). Look for cracking, scaling, wear and any other notable observations.

Field Evaluation Data – SR 8

SR 8 August 24, 2010 (District 10)

	AAAP	AAA
Slump (inches)	5.5	6
Air Content (%)	6.6	7.8
Temperature (F)	70	68
Compressive Strength (psi)		
7 Day (1)	4459	n/a
14 Day	5124	n/a
28 Day	5743	n/a
56 Day	n/a	n/a
Cementitious Content	600	658
W/C Ratio	0.43	0.41
56 Day RCP (Coulombs)	1443	1664 (2)
Shrinkage Value (-)		
7 Day	0.003	0.005
14 Day	0.014	0.019
28 Day	0.022	0.027
56 Day	0.036	0.034

1. 7 & 14 day field AT, 28 day field QC
2. Average of two tests

AAAP Deck Placement Report
SR 8 August 24, 2010

Project: SR 8 Butler County

Contractor: Mekis Construction

Supplier: J.J. Kennedy, Inc.

Placement Date: 08/14/2010
Yards Placed: 110
Placement Start Time: 3:30 am Placement Completion Time: 7:30 am

Weather

Start	Temp 60	Wind Speed < 5 mph	Rel. Humidity 94 %
Finish	Temp 72	Wind Speed 5 -8 mph	Rel. Humidity 88 %

Cloud Cover: Cloudy

All plant test results (Air, Slump, & Temp) – N/A

All AAAP vs AAA comparison tests results

AAAP:	Slump 5.5"	Air content 6.6 %	Temp 70 F
AAA:	Slump 6.0"	Air content 7.8 %	Temp 68 F

Placement Observations: N/A

Finishing Observations: Bidwell with rollers and drag

Comments: No complainants from contractor or field inspectors

Field Evaluation Data – SR 2038

SR 2038 October 7, 2010 (District 6)

	AAAP	AAA
Slump (inches)	4.5	5
Air Content (%)	7.8	7.8
Temperature (F)	62	66
Compressive Strength (psi)		
7 Day	4507	4639
14 Day	n/a	n/a
28 Day	5771	5591
56 Day	5819	6409
Cementitious Content	580	705
W/C Ratio	0.45	0.4
56 Day RCP (Coulombs)	740	2154
Shrinkage Value (-)		
7 Day	0.003	0.015
14 Day	0.014	0.027
28 Day	0.024	0.040
56 Day	0.037	0.055

AAAP Deck Placement and Condition Report
SR 2038 Oct 7, 2010

Project: SR 2038

Contractor: J.D. Eckman

Supplier: Rahns Construction Materials

Placement Date: October 7, 2010
Yards Placed: 37 & 38
Placement Start Time: 6:30 am Placement Completion Time: 1:15 pm
Two separate placements with break to move equipment

Weather

Start	Temp 48	Wind Speed 7	Rel. Humidity 100
Finish	Temp 66	Wind Speed 14	Rel. Humidity 54

Cloud Cover: Partly cloudy
Other Weather Remarks: Wind picked up about the same time as moving from west side to east side.

All plant test results (Slump, Air Content,& Temp) – N/A

All AAAP vs AAA comparison tests results

AAAP	4.5"	7.8%	62F
AAA	5.0"	7.8%	62F

Placement Observations: Good experienced crew, first load wet – a moderate amount of bleed water noted, long narrow placements (outside lanes only).

Finishing Observations: Bridge Machine with pan drag, darby, 10' straight edge then tyned. Closed very nicely, a lot of hand work performed.

Comments: (contractor supervisor – Mike) "Good mix", (finisher – Scott) "Closing easily", (field inspectors - Mike, Mike, Kelly)"First load on high side of slump range".

Field Evaluation Data – SR 3011

SR 3011 October 13, 2010 (District 10)

	AAAP	AAA
Slump (inches)	5.25	5.25
Air Content (%)	7.2	7.5
Temperature (F)	63	68
Compressive Strength (psi)		
7 Day	3491	4019
14 Day (13 Day)	4390	4969
28 Day	5236	5878
56 Day	n/a	n/a
Cementitious Content	580	635
W/C Ratio	0.43	0.41
56 Day RCP (Coulombs)	1539	1842
Shrinkage Value (-)		
7 Day	0.019	0.014
14 Day	0.033	0.024
28 Day	0.045	0.038
56 Day	0.061	0.051

AAAP Deck Placement and Condition Report
SR 3011 October 12, 2010

Project: Grafton/Campbells Mill Bridges.

Contractor: Russell Standard

Supplier: Ligonier Stone & Lime Concrete Co.

Placement Date: 10-13-10
Yards Placed: 100
Placement Start Time: 08:30 Placement Completion Time: 13:30

Weather

Start	Temp 41	Wind Speed	7mph	Rel. Humidity 89%
Finish	Temp 68	Wind Speed	8mph	Rel. Humidity 24%

Cloud Cover: Scattered clouds with sun
Other Weather Remarks:

All plant test results (Air, Slump, & Temp)

Load 1	5"	7.6%	62 degrees
Load 2	5"	6.9%	62 degrees
Load 3	5.25"	7.2%	63 degrees

All AAAP vs AAA comparison tests results

AAAP (7 day)	3489, 3493 (<u>3491</u>)	AAA (7day)	4113, 3925 (<u>4019</u>)
AAAP (14 day)	4355, 4425 (<u>4390</u>)	AAA (14day)	5018, 4920 (<u>4969</u>)
AAAP (28 day)	5229, 5242 (<u>5236</u>)	AAA (28 day)	5841, 5914 (<u>5878</u>)

Placement Observations: No one, was not able to attend placement.

Finishing Observations: N/A

Comments: N/A

Field Evaluation Data – SR 322

SR 322 October 14, 2011 (District 10)

	AAAP	AAA
Slump (inches)	5.25	5.5
Air Content (%)	6.3	5.6
Temperature (F)	63	65
Compressive Strength (psi)		
7 Day	3175	n/a
14 Day	4112*	n/a
28 Day	6331	n/a
56 Day	6994	n/a
Cementitious Content	580	635
W/C Ratio	0.43	0.41
56 Day RCP (Coulombs)	1670	n/a
Shrinkage Value (-)		
7 Day	0.021	0.014
14 Day	0.034	0.027
28 Day	0.041	0.038
56 Day	0.050	0.045

*** 12 Day**

AAAP Deck Placement and Condition Report
SR 322 October 14, 2010

Project: SR 322 Sec 551 ECMS No. 25987

Contractor: F. J. Palo, Inc.

Supplier: Glenn Redi – Mix

Placement Date: 10/14/10
Yards Placed: 17.00 cy
Placement Start Time: 7:30am Placement Completion Time: 9:00am

Weather

Start	Temp	50 deg	Wind Speed 0	Rel. Humidity 100%
Finish	Temp	50 deg	Wind Speed 0	Rel. Humidity 100%

Cloud Cover: Overcast
Other Weather Remarks: Light Rain, Drizzle

All plant test results (Air, Slump, & Temp)

AAAP	6.3%	5.25"	63 degrees
AAA	5.6%	5.50"	65 degrees

All AAAP vs AAA comparison tests results – N/A

Placement Observations: Crane & Bucket

Finishing Observations: Small Pour, negative moment, hand screed and bullfloated, tacky, gummy, hard to close.

Comments: N/A

Appendix B - Photos

SR 3011

SR 472

SR 2070

SR 2014

SR 322

Pennsylvania Aggregates and Concrete Association

3509 North Front Street, Harrisburg, PA 17110
Ph: 717-234-2603 Fax: 717-234-7030
Web: www.pacaweb.org www.specifyconcrete.org