Alaska Department of Transportation & Public Facilities
Research & Technology Transfer

Use of Steel Fiber-Reinforced Rubberized Concrete in Cold Regions

Prepared for

Alaska Department of Transportation & Public Facilities
Statewide Research Office
3132 Channel Drive
Juneau, AK 99801-7898

Prepared by

Prof. Osama Abaza, PhD., C. Eng.
Mahear Abou Eid, P.E.
University of Alaska Anchorage
College of Engineering
2900 Spirit Drive, EIB 301 L
Anchorage, Alaska 99508
907.786.6117

FHWA-AK-RD-76319, HFHWY00001

December 2017

REPORT DOCUMENTATION PAGE			Form approved OMB No.
Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503			
1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE December 2017	3. REPORT TYPE AND DATES COVERED	
4. TITLE AND SUBTITLE Use of Steel Fiber-Reinforced Rubberized Concrete in Cold Regions			5. FUNDING NUMBERS
6. AUTHOR(S) Prof. Osama Abaza, PhD., C. Eng. Mahear Abou Eid, P.E.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Alaska Anchorage College of Engineering 2900 Spirit Drive Anchorage, AK 99508			8. PERFORMING ORGANIZATION REPORT NUMBER N/A
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) State of Alaska, Alaska Dept. of Transportation and Public Facilities Research and Technology Transfer 3132 Channel Drive Juneau, AK 99801-7898			10. SPONSORING/MONITORING AGENCY REPORT NUMBER FHWA-AK-RD-76319, HFHWY00001
11. SUPPLEMENTARY NOTES Performed in cooperation with Department of Civil Engineering at the College of Engineering, University of Alaska Anchorage, under a contract with the Alaska Department of Transportation and Public Facilities (DOT&PF). Osama Abaza, Professor of Civil Engineering, University of Alaska Anchorage, was the Principal Investigator, Mahear Abou Eid, P.E., was the Research Assistant.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT No restrictions			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) This report documents and presents the use of steel fiber-reinforced rubberized concrete (SFRRC) in cold regions. Further investigation of SFRRC use was conducted with the wheel tracker rut and freeze-thaw laboratory testing procedures at the University of Alaska Anchorage. Wheel tracker results showed significant rutting improvement in SFRRC compared with asphalt, and freeze-thaw testing showed low significant resistance to cracking and compressive strength loss in SFRRC compared with standard Portland cement concrete. An experimental cast-in-place panel was installed at the University of Alaska Anchorage and subjected to traffic with little signs of wear. Following this, pre-cast panels were designed and placed in a high-traffic urban arterial to determine rutting, freeze-thaw resistance, construction methods, and life cycle cost. Design, construction, and installation of the panels were completed on the Abbott Road construction project in the summer of 2017. The panels will be monitored and analyzed to determine the viability of SFRRC in roadway systems.			
14- KEYWORDS: Concrete, steel fiber, crumb rubber, rutting, cold regions, freeze thaw, wheel tracker, pre-cast panels, roadway			15. NUMBER OF PAGES 114 (including introductory pages and Appendices)
			16. PRICE CODE N/A
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT N/A

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4		mm
ft	feet	0.3048		m
yd	yards	0.914		m
mi	Miles (statute)	1.61		km
		AREA		
in^2	square inches	645.2	millimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
		MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g
lb	Pounds (avdp)	0.454	kilograms	kg
T	Short tons (2000 lb)	0.907	megagrams	mg
		VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL
gal	Gallons (liq)	3.785	liters	liters
ft^3	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

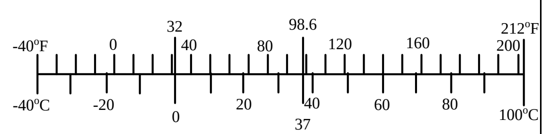
Note: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
^oF	Fahrenheit temperature	5/9 (^oF-32)	Celsius temperature	^oC
		ILLUMINATION		
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
		FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	Miles (statute)	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.471	acres	ac
		MASS (weight)		
g	grams	0.0353	Ounces (avdp)	oz
kg	kilograms	2.205	Pounds (avdp)	lb
mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces (US)	fl oz
liters	liters	0.264	Gallons (liq)	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
^oC	Celsius temperature	9/5 ^oC+32	Fahrenheit temperature	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi



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Acknowledgments

The research reported herein was performed by the School of Engineering at the University of Alaska Anchorage in collaboration with the Alaska Department of Transportation & Public Facilities (DOT&PF).

Osama A. Abaza, Professor of Civil Engineering, University of Alaska Anchorage, was the principal investigator. The other author of this report is Mahear A. Abou Eid, Research Assistant at the University of Alaska Anchorage. The work was done under the general supervision of Professor Abaza.

The research team is grateful to the Federal Highway Administration (FHWA) and the Alaska DOT&PF for their sponsorship of this research. The information, findings, and opinions of the research reflected in this report do not represent the views of the sponsoring agencies.

We would like to acknowledge the contributions of the following individuals:

- Anna Bosin, P.E., Research Engineer and Tribal Relations Liaison DOT&PF;
- James Amundsen, P.E., Chief of Highway Design DOT&PF;
- Sean Baski, P.E., Design Project Manager DOT&PF;
- Kristen Keifer, P.E. Design Project Manager DOT&PF;
- Carolyn Morehouse, P.E., Chief of Research DOT&PF;
- Jason Baxley, P.E., Construction Project Engineer DOT&PF;
- Chris Turletes, UAA Associate Vice Chancellor, Facilities, Planning & Construction;
- Kimberly Riggs, Facilities Manager, UAA College of Engineering.
- Xavier Schlee, Concrete Sales Manager, Alaska Sand and Gravel

Abstract

This report documents and presents the use of steel fiber-reinforced rubberized concrete (SFRRC) in cold regions. Investigation of SFRRC was conducted using wheel tracker rut and freeze-thaw laboratory testing procedures at the University of Alaska Anchorage (UAA). Wheel tracker results showed a significant improvement in SFRRC rutting compared with asphalt rutting, and the freeze-thaw test results showed low significant resistance to cracking and compressive strength loss in SFRRC compared with standard Portland cement concrete. An experimental cast-in-place panel was then installed at UAA in summer 2015 and showed little signs of wear after 1 year. Next, pre-cast panels were designed and placed in a high-traffic urban arterial to determine rutting, freeze-thaw resistance, construction methods, and life cycle cost. Design, construction, and installation of the panels were completed at the Abbott Road construction project in summer 2017. The panels will be monitored and analyzed to determine the viability of SFRRC in roadway systems.

Summary of Findings

The research team successfully implemented several testing procedures to determine the use of steel fiber-reinforced rubberized concrete (SFRRC). An experimental test slab was installed at UAA to verify mixing, placing, and use of the material prior to larger scale placement of pre-cast panels installed on Abbott Road for full experimental testing. Each phase of the research provided important insight to future use of SFRRC in roadway construction.

The SFRRC was tested for loss of compressive strength and material deterioration due to freeze-thaw action. The results showed the following:

- 15% increased compressive strength after the second trial completed by third party testing (Applied Testing), after freeze-thaw testing was performed.
- 15% increased compressive strength with the UAA apparatus completing ASTM C666 freeze-thaw testing consistent with the results from Applied Testing.
- No noticeable deterioration of samples from Applied Testing trial two. UAA testing showed deterioration, crumbling of corners and aggregate loss, of two samples mixed in the lab while other two samples mixed in the field showed no noticeable deterioration.
- Greater than 25% increased resistance to freeze-thaw action compared with standard Portland cement concrete (PCC) based on previous relative dynamic modulus of elasticity (RDME) results from Shang and Yi (2013).

The AASHTO T324 wheel tracker testing procedures were completed for the standard steel wheel and the modified rubber tire with studs. The results showed the following:

- much lower deformation with the steel wheel procedure on SFRRC (0.076 cm) than on HMA (0.165 cm) and a 0.64 cm deep rut with the modified rubber tire procedure across the traveled wheel path of the SFRRC sample.
- mitigation of material loss due to randomly distributed steel fibers bridging the rutted area and minimized spalling from the micro fractures.

The SFRRC UAA trial slab was created to verify mixing, placing, and use of the material prior to larger scale placement of pre-cast panels in a roadway. The results showed the following:

- transport and placement of SFRRC for the UAA trial slab were similar to a typical PCC installation.
- finishing of the material was more difficult than finishing standard PCC because the steel fibers create an intertwined bond throughout the material.
- composition showed increased resistance to micro cracking, as multiple steel fibers bridge the cracks.
- no thermal cracking, spalling, or rutting of the UAA trial slab were observed when the trial slab was inspected throughout two winter seasons.
- slight delamination of steel fibers and crumb rubber not fully embedded in the surface of the UAA trial slab were apparent.

An experimental test section was designed and then constructed at Abbott Road as part of a rehabilitation project. The test section showed the following:

- design, mixing, and pouring of SFRRC pre-cast panels can be achieved with current practices and equipment in Alaska.
- preparation of the leveling course under the test section for pre-cast panels is a crucial component to ride quality and ease of installation.
- transport and placement of the panels must be completed carefully, but did not require specialized equipment.
- once all panels are placed, fine adjustments are required for leveling the section prior to placing grout.
- use of a cast-in-place method simplifies the design and placement process, as it does not require special design for a joint system, preparation for leveling course, follow-up adjustments, or grouting.

Post-construction monitoring will be conducted on the test section for 3 years to inspect the following items:

- Falling weight deflectometer testing to determine joint transfer efficiency and load bearing capacity.
- Strain gage data monitoring for freeze-thaw stresses.
- Visual inspection for any cracking or heaving due to freeze-thaw stresses.
- Rut measurements to determine abrasion resistance to studded tires.
- IRI measurements to determine effects of frost heave to ride quality.

CHAPTER 1 – INTRODUCTION AND RESEARCH APPROACH

Background

The construction of roadway pavements has undergone change repeatedly to accommodate new transportation technologies. Larger vehicles, increased load repetitions, higher stopping forces, and improved studding traction are some of the issues that pavement technology has had to overcome. Although great improvements in pavement can be seen, an area lacking innovation is at intersections of high-volume-traffic roadways. At these intersections, transverse rutting from stud wear, displacement of asphalt due to static traffic loads, and shoving due to stopping forces occur. Because of these differing forces, especially at intersections, the use of stronger and abrasion resistant material would be beneficial.

In Alaska, the state Department of Transportation and Public Facilities (DOT&PF) designs pavement structures for a life of 20 years, but in most cases, conducts routine maintenance every 7 years. Alaska has one of the longest seasons in the U.S. for permitted stud tire use; in Anchorage, the season starts as early as the middle of September and ends the beginning of May. With the increased abrasion caused by studded tires, deterioration of pavement roadways in Alaska is extensive.

Studies have been completed that identify and alleviate these issues by methods such as modifying asphalt mix designs, routine maintenance plans, and replacement of asphalt with Portland cement concrete (PCC). These solutions may work, but only under specific situations. For example, some modifications to the mix design may not be possible because of weather and loading limitations. Routine maintenance solves issues in the short term, but can create long-term issues once materials have reached the serviceable threshold. Furthermore, maintenance work impacts the traveling public by causing construction delays, especially in summer during Alaska’s short construction season. Portland cement is a viable option for construction of an intersection if modified to withstand the freeze-thaw cycle in cold regions.

The compressive strength of concrete is much higher than that of asphalt, and concrete tolerates stud abrasion longer. A study conducted in Washington shows that concrete pavements 28 years old have an average rut depth of 0.25 inches, while asphalt pavement 3 years old in a similar area show rut depths of 1.5 inches (WSDOT – State Materials Laboratory, 2008). Resistance to abrasion would be a significant benefit if concrete were installed in a high traffic intersection. The increase in design life would lower maintenance costs caused by wear and lower the impact on the traveling public.

There are many benefits to using PCC rather than asphalt pavement, but several limitations arise when using it in cold region conditions. The freeze-thaw cycle of cold regions must be accounted for when designing roadway structures. Because of its nonflexible properties, PCC cracks when introduced to stress from frost heaving and settlement.

Recent studies have been conducted to help mitigate the freeze-thaw effect on PCC. In order to induce flexibility, small pieces of crumbed rubber are incorporated in the concrete aggregate mix design, the result of which is termed *rubberized concrete* (RC). The added flexibility allows concrete to relieve the stress from frost heave and settlement. The inclusion of rubber in place of aggregate, however, lowers the compressive strength of concrete and leads to issues with achieving load capacity for vehicular traffic. To increase the strength of concrete, research has been conducted with mixtures of concrete and rubber with the inclusion of steel fibers; this product is termed *steel fiber reinforced rubberized concrete* (SFRRC).

With research showing that SFRRC can be considered a flexible high-strength concrete, the use of the material in highway intersections must be analyzed with regard to cost, constructability, freeze-thaw resistance, and design life. The final step in the process will be to determine the safety benefits that can be attributed to elimination or minimizing of ruts in roadway intersections and ensuring adequate surface friction for stopping and starting at an intersection.

Research Objective

Many challenges accompany the use of PCC in cold regions, but with the inclusion of new technologies such as steel fibers and crumb rubber, efficient construction may be possible. The objective of this investigation is to determine if SFRRC can reduce rutting in intersections cost-effectively compared with asphalt pavement, and if SFRRC can withstand frost heave cycles and increase the roadway service life of intersections. A long-term goal (not an objective of this study) is to determine if the reduction of rutting in intersections in turn reduces the frequency of accidents—a topic for a future proposal.

Research Approach

The research of SFRRC began by conducting a thorough literature review (see Appendix B), followed by creating SFRRC samples based on optimum mix designs, as describe in Abaza and Hussein (2016). The main laboratory procedures involved wheel tracker with studs, freeze-thaw, compressive strength, and shrinkage testing. With the wheel tracker, a simulation of rutting by vehicular traffic on test samples was conducted. To simulate the studded tire wear seen in Alaska, a rubber tire was equipped with studs and placed on the wheel tracker system. A side-by-side comparison of standard asphaltic mixtures designed by DOT&PF for general highway construction was conducted. Next, several samples were replicated and placed under artificially accelerated freeze-thaw cycles to determine whether cold region conditions could be withstood.

Data were compiled, analyzed, and discussed with DOT&PF representatives to coordinate full-scale experimentation on a roadway resurfacing project. To determine if the data were significant, statistical analysis was conducted. The differences in mean rutting depths and freeze-thaw results were compared to determine if significant results were achieved.

Criteria were set to choose an optimum location for installation of SFRRC. The location required uniform traffic with minimal approaches or driveways, sufficient crash data for future comparisons, standard geometry to minimize construction issues, and availability of traffic detouring in case issues arose with SFRRC implementation.

The capital project, Abbott Road Rehabilitation-Phase I, was selected as an optimal location for implementation of a test section. The location consisted of one lane in each direction along with a shared turn lane that could be utilized during construction and monitoring. One section of the roadway was constructed of SFRRC directly followed by DOT&PF standard hot mix asphalt (HMA) for comparison purposes.

The test section was constructed with sensor equipment to calculate temperature changes, displacement (lateral and longitudinal), annual average daily traffic (AADT) volumes, and rutting depths. Criteria were set prior to construction to determine when the lane had reached its service life.

A three-year monitoring plan of the SFRRC test section will be completed to report an accurate final assessment of the product. The extended monitoring plan will include visual inspections for edge and joint deflections, cracking of the slab, grout failure, joint adhesive failure, and rutting due to studded tire wear. In addition, strain gauge data will be monitored continuously along with periodic deflection testing using a falling weight deflectometer. Pavement Management System data collected annually will be compared with adjacent pavement to track rutting, cracking and IRI. Surface friction values using a British Pendulum Unit will also be taken annually.

CHAPTER 2 – METHODOLOGY

Material Mix Design and Assurance Testing

The proposed research began by creating SFRRC samples based on an optimum mix design as describe by Abaza and Hussein (2016). During creation of the mix design, 16 separate batches were created with differing crumb rubber and steel fiber proportions. Batch number 10 was selected as the optimum mix design; it includes 15% crumb rubber replacing the fine aggregate volume and steel fibers by a volume fraction of 1.28% of total mix. The crumb rubber was obtained locally and graded to a maximum nominal size of 0.635 cm. The steel fibers used previously were Novocon FE1050, but they have been superseded by Novocon FE0730 fibers, which are produced by Propex Concrete systems. FE0730 fibers are cold drawn, have flat ends, are 3.0 cm in length, and have tensile strengths up to 1,399,636 kPa (kilopascal).

Samples of the optimized design were mixed, cast, and cured with procedures comparable to that completed by Abaza and Hussein (2016) to confirm previously established results such as compressive strength, slump, air content, unit weight, and flexural strength.

Freeze-Thaw

Once the mix was verified, further investigation was conducted to determine the freeze-thaw characteristics of the material. At the UAA materials laboratory, a system was established that simulates accelerated freeze-thaw cycles in conformance with ASTM C666 (Abaza and Bergeron, 2014). The system utilized a commercial freezing unit along with a heating element and thermal probes, as shown in Figure 1. The system is controlled by a software program that completes a freeze-thaw cycle by activating the freezer until core temperatures drop to 0°F; then the heating element brings the core temperature above freezing so that the process can be repeated. To effectively test the freeze-thaw resistance of the material, it is recommended that 300 cycles be performed.

Figure 1: UAA freeze-thaw testing system.

Several samples of SFRRC material were inserted into cylindrical test containers and placed into the freezing unit to complete the ASTM 666 procedure. The program was administered with the goal of completing 300 cycles. Once the process was complete, compressive strength testing, sample length measurements, and visual inspection were conducted.

The UAA test apparatus is a prototype and required modifications to the heating element and computer software along with refinement of the freeze-thaw cycle and procedures. Because of this, a third-party testing facility, Applied Testing and Geosciences, was employed to accelerate and verify results obtained by the UAA test apparatus.

Wheel Tracker

The wheel tracker apparatus located at the UAA materials laboratory was used for determining the abrasion resistance of the SFRRC material. The apparatus was a Controls Double Wheel Tracker (DWT), Pavetrack 77-PV33E05, state-of-the-art loaded wheel system (Figure 2).

Figure 2: The Controls Group double wheel tracker system.

The AASHTO T324 procedure uses stainless steel wheels for testing, while the EN 12697-22 uses rubber tire wheels, but no procedure has been standardized for use of studs on a rubber tire with the wheel tracker apparatus. In order to conduct experimental studded tire testing, theoretical values must be obtained and translated to accurately represent real-world situations. Using the studded rubber tire was a deviation from the AASHTO T324 specification.

Based on research completed by Kupiainen and Pirjola (2011), stud usage restrictions range depending on location. Finnish legislation restricts stud use to 50 studs per 1 m of rolling tire circumference. The weight of conventional studs in Alaska is typically 1.9 g per stud, and approximately 60% of winter vehicles are equipped with studs. For this research, a tire size of 235/60/R16 was used, which translates to a tire width of 235 mm, 60% tread height of tire, or 141 mm and a rim diameter of 406.4 mm. The mass applied to the measurement tire was 980 kg.

With these values and using Equation 3.1, we determined that a value of 7 studs for the Pavetrack tire would result in the same number of studs making contact with the pavement surface per distance traversed in real-world situations.

$$S_M = L \times S_N \left(\frac{A_T}{A_M}\right) S_M = L \text{ x } S_n \, (A_T/A_M) \qquad [3.1]$$

where

- S_M: studs required for model tire
- L: wheel circumference length (m)
- S_N: studs per meter of rolling length
- A_T: surface area of theoretical tire
- A_M: surface area of model tire

UAA Trial Slab

In addition to laboratory testing, an experimental slab was cast in place for evaluation under real-world conditions. Through coordination with the DOT&PF, local contractors, and UAA, a location was selected (see Figure 3) near the UAA Consortium Library parking garage where bus traffic is constant. Although not as great as on a highway, the traffic volume would be sufficient to test the material. A benefit of this location was the low speed limit for vehicles traversing the slab, so if any issues with the material occurred, safety risks would be minimized. After choosing the location for installation, we determined the slab thickness.

Figure 3: The SFRRC trial slab location near the UAA Consortium Library.

Several methods can be used to determine concrete slab thickness, but for this determination, the Portland Cement Association (PCA) method was used. The design criteria for PCA include general pavement design, performance, research experience, and relationship to performance of pavements in the AASHO Road Test and to studies of pavement faulting (Huang, 2004). To determine the slab thickness, we calculated many design factors and input the calculations in a design chart. Each design factor was calculated followed by a thickness determination of 17.78 cm using the AASHTO design chart.

With a thickness of 17.78 cm determined, it was necessary to create a typical slab section. For the experimental slab at UAA, the dimensions were 2.44 m long by 9.14 m wide. Calculations were completed using material properties, traffic data, and a maximum slab length of approximately 4.57 m based on AASHTO recommendations (Huang, 2004). The slab was divided into two halves by placing an expansion joint at mid span. The approximate length and orientation of the slab are shown in Figure 4.

Figure 4: SFRRC trial slab location with planned dimensions and orientation.

The trial slab installation was completed in early September 2015. The process included preparing the slab location, mixing the SFRRC material at the Alaska Sand and Gravel batch plant, transport of material to the site, and placement and finishing of the slab by the Finishing Edge concrete crew.

Abbott Road Test Section

The UAA cast-in-place (CIP) slab was completed and observed over a winter. The SFRRC material did not exhibit any immediate weakness or issues that would cause failure. The next step was to install a test section where a higher volume traffic load could be tested.

The location of the trial section was determined based on project availability, traffic volumes, and the geometry of the roadway section as shown in Figure 6. The AMATS: Abbott Road Rehabilitation project was selected, as it was scheduled for the upcoming construction season. In addition, the traffic volume was substantial, with an Annual Average Daily Traffic of approximately 15,000 and would provide rutting data within several years. This is apparent based on the existing asphalt conditions and recorded traffic counts.

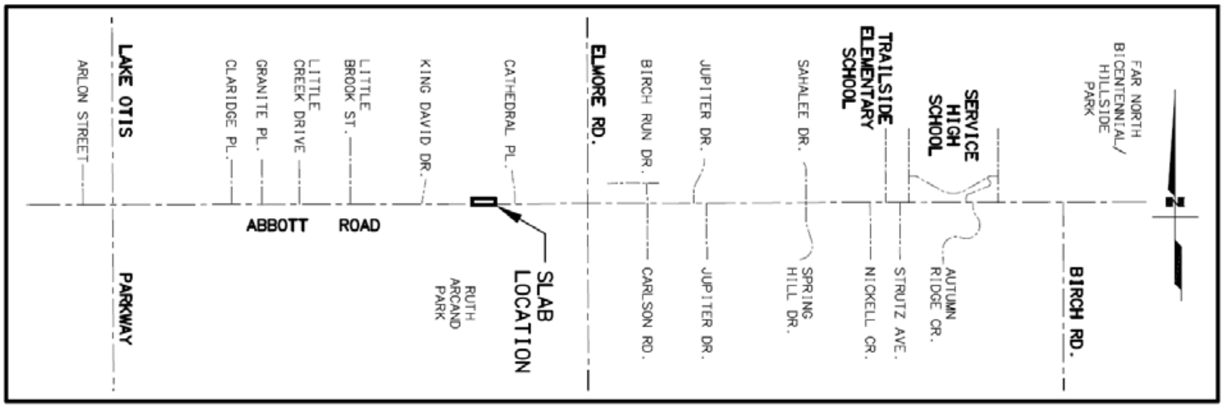

Figure 5: Selected location of SFRRC trail section on Abbott Road.

The intended use of SFRRC is at high-volume intersections, but to avoid geometric challenges and traffic-control issues and to eliminate unknown variables, a linear portion of the roadway was chosen as the test section. The location has limited turning traffic, acceleration or deceleration, and a shared left-turn lane, simplifying traffic control during construction. The detailed layout and design can be seen on the plan sheets in Appendix C.

In coordination with the DOT&PF Highway Data unit, an automated traffic recording station was added to the project for installation immediately succeeding the test section. This recording station would provide both below roadway and pavement surface ambient temperature, as well as traffic volume, and vehicle classification data.

The initial plan for placement of the material was to pour in place. In further discussions about construction sequencing for installation of the material at intersections, we concluded that it would be impractical to pour in place because the concrete would require a minimum of 7 days to cure before traffic could be allowed, an amount of time that would be difficult at a high-volume intersection. We determined that precast panels would be required for the test section.

Research was conducted into installation of precast panels, specifically a report by Minnesota DOT (2005) that used the Super-Slab system. The design and specifications shown in the report provided a template for the design of precast panels to use on Abbott Road. These panels featured slotted and doweled ends, tapered edges, lifting mechanisms, and grouting ports, details that would ensure proper load transfer, ease of placement, and filling of any voids under the panels.

Along with the data provided by the automated traffic recording station, a strain gauge system was designed for embedment in the pre-cast panels. The gauges would provide information on the freeze-thaw cycles and any sustained stresses that occur throughout the life span of the panels.

CHAPTER 3 – INTERPRETATION, APPRAISAL, AND APPLICATIONS

Assurance Testing Results

With the exception of one element, the mix design was strictly followed based on previous testing. The type of steel fibers used for the original testing procedures was Novocon FE1050, which was discontinued, superseded by Novocon FE0730. The FE0730 fibers are of similar material and design for flat ends, but are slightly shorter and have higher tensile strength than FE1050 fibers. Through assurance testing, the change in fibers was determined to produce minor changes in the test results, but still provide acceptable values.

Part of the assurance testing included air entrainment. Based on the test results, we determined that the mix design did not require any admixtures for air entrainment. Further investigation theorized that because crumb rubber particles are jagged due to the manufacturing process, natural air pockets are created within the microstructure of the material (see Figure 6). In addition, the natural microstructure of rubber is porous, allowing for microscopic air voids within the particles themselves. Air entrainment testing of the SFRRC material resulted in an air content of approximately 6%, which is determined to be near optimum based on Alaska roadway construction standards.

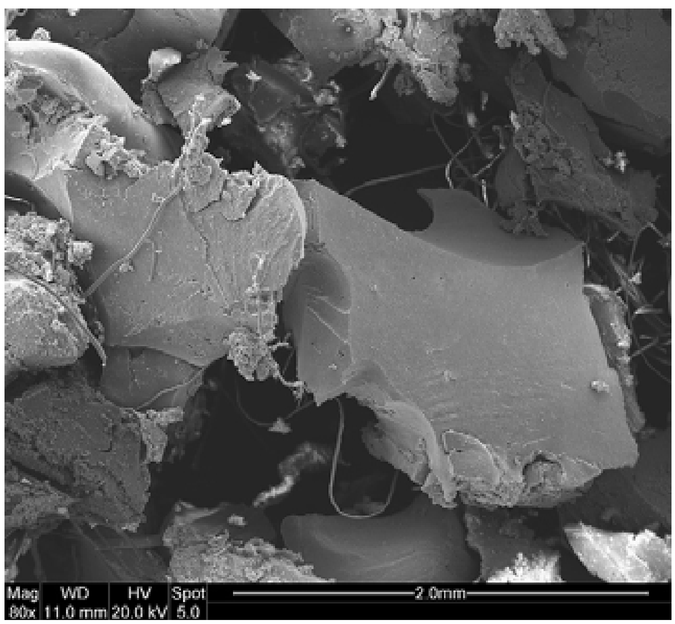

Figure 6: Crumb rubber particles at 80x magnification (Richardson, Coventry, and Ward, 2012).

Crumb rubber used as the main source for air entrainment also added to the toughness and durability of the material in resisting freeze-thaw cycles. Crumb rubber is ductile and rebounds after it has been compressed. As SFRRC freezes, the rubber allows it to compress, but unlike admixtures, when SFRRC begins to thaw, the rubber allows the material to rebound as well. With admixtures, when air voids are compressed they do not have a tendency to rebound.

Another part of the assurance testing was determining the compressive strength of SFRRC with the differing steel fibers. Several tests were conducted using FE0730 fibers, and results showed an average of 5,353 psi, with significance between all the results. The test results using FE1050 showed a compressive strength of 6,710 psi. A significant difference in compressive strength was determined between the two types of steel fibers. Since the only variable altered in the two mix designs was the steel fibers, we assume that the reduction in compressive strength is related to this element. With FE0730 being a smaller fiber, a possible reduction in adhesion between the surface area of the fibers and the concrete could occur. In addition, the smaller FE0730 fibers were more susceptible to clumping when added to the mix during batching.

The reduction in compressive strength may relate to the increase in flexural strength that was observed. The AASHTO T23 flexural strength test results show an average modulus of rupture of 1,182 psi with significance between all results. The tests performed using FE1050 fibers resulted in a modulus of rupture of 1,010 psi. This result shows an increase of 17% in flexural strength, where a decrease of 25% was noticed in compressive strength.

Although there is a greater percent decrease in compressive strength, the increase in flexural strength has greater significance. Flexural strength is greater related to freeze-thaw resistance than compressive strength. Most cracking of standard PCC can be attributed to the flexural bending and movement of material caused by freezing, heaving, thawing, and settling. An increase in compressive strength does little to mitigate these actions, but an increase in flexural strength will directly enhance resistance to cracking. In addition, compressive strength decreased with the use of FE0730 steel fibers, but based on standard concrete practices in Alaska, still provided much greater compressive strength than minimum requirements.

Similar to the decrease in compressive strength, an increase in flexural strength may be related to the geometrical differences between FE0730 steel fibers and FE1050 steel fibers. The smaller FE0730 fibers require a larger number of individual fibers. For flexural strength, this is beneficial, as a larger random distribution across SFRRC would mitigate the initial first cracking that ultimately causes flexural strength failure. In addition, with greater fiber distribution throughout the mix, micro fracturing can be minimized in more locations, increasing the overall flexural strength of the material. Test results and analysis calculations can be found in Appendix D.

Freeze-Thaw Results

With the initial methodology, we had planned to use the freeze-thaw apparatus located at UAA to conduct the ASTM C666 testing procedures. Several issues occurred with the apparatus that resulted in delays and required modifications. These issues included differing heating elements, changes in the software program, and modified containers for the sample. To avoid the risk of inaccurate or incomplete results and to expedite the testing procedure, we arranged for a third-party accredited agency to perform the ASTM C666 testing process.

The agency—Applied Testing—was able to complete the process in 5 to 6 weeks. The UAA apparatus would have required 5 to 8 months in the current configuration. Applied Testing completed the ASTM C666 procedure, and results showed a modulus of elasticity (RDME) value of 96% and a compressive strength value of 2,640 psi. A control specimen was also tested for compressive strength and resulted in a value of 2,852 psi. These values were much lower than the previous compressive strength average value of 5,353 psi.

Possible reduction in compressive strength could be attributed to several factors. The geometry of the samples for conducting the ASTM C666 procedure differs from compressive strength testing. The freeze-thaw samples tested for compressive strength were 3 in. square prisms that were saw cut into 3 in. cubes, whereas the standard compressive strength tests were conducted with 4 in. and 6 in. diameter cylinders. The length of the FE0730 fibers is 1.18 in. With the samples only 3 in. in size, proper distribution of the fibers could be hindered. In addition, with aggregate size up to 0.75 in., proper coating of the cement material could be prohibited.

We discussed proper mixing procedures with Applied Testing. The addition of material at correct intervals assured that no clumping occurred and equal distribution was achieved. Applied Testing stated that a possible deviation with the mixing procedures may have occurred.

Applied Testing performed a second trial testing procedure starting with batching the mix, molding, conducting the ASTM C666, and comparing the compressive strengths. The second trial resulted in a similar RDME value of 97%. The compressive strength results were much higher than the initial trial, but still lower than the compressive strength of 5,353 psi. Similar to the first trial, we assumed that the geometry of the sample contributed to lower compressive strength. Unlike the first trial, however, the compressive strength of 4,635 psi for the freeze-thaw sample was higher than the control sample of 4,040 psi. Both samples were created from an identical mix at the same time, which leads us to conclude that molding of the samples in the smaller cubic dimensions may introduce significant variability in the compressive strength characteristics of the samples.

Due to the requirements of Applied Testing's equipment, the 3 in. prisms were all that could be used. If future testing is performed, an additional set of 4 in. or 6 in. cylinders should be molded concurrently with the 3 in. prisms from the same mixed batch. This would provide accurate data that could be directly compared with previous compressive strength testing without variability in geometry involved. In addition, this would provide a correlation of strength between the 3 in. cubic geometry and the standard compressive strength cylinders.

After the UAA freeze-thaw apparatus was modified and the ASTM C666 procedure was completed, the samples were tested for compressive strength. The decrease in overall compressive strength from the Applied Testing results was initially determined to be caused by the molds, but interestingly, the results from the UAA freeze-thaw testing were almost identical to the second trial from Applied Testing. The freeze-thaw and control compressive strengths were within 1% between the UAA and Applied Testing procedures, and a 15% increase occurred in compressive strength after freeze-thaw testing. The UAA samples were approximately 4 in. diameter cylinders, which is similar to the standard used for compressive strength testing. The overall drop in compressive strength was not expected nor was a cause easily determined, but the close correlation between the two freeze-thaw tests suggests that the results were accurate and repeatable.

Even though the overall compressive strength was less than previous results, the increase of 15% after freeze-thaw procedures compared with the controls correlated with both tests. One possible theory is that freeze-thaw testing could contribute to hardening of the crumb rubber during the expansion and contraction process. As the material was compressed and released, the ductility of the crumb rubber may have decreased, becoming more brittle and increasing the compressive strength. In addition, the steel fibers could have benefited from the freeze-thaw cycles in a similar manner. The flexural strength testing, Applied Testing reports, and analysis can be found in Appendix E.

Wheel Tracker Results

The SFRRC material was batched, and molds were made for the DWT Pavetrack 77-PV32E05. As shown in Figure 7, the samples were molded into 36.20 cm long by 29.85 cm wide by 8.89 cm deep slabs, as required for the apparatus. The material was hand-tamped into the molds and vibrated to ensure consolidation throughout.

Figure 7: Molding of the wheel tracker SFRRC samples.

The DWT was calibrated and equipped with steel wheels to perform the AASHTO T324 procedures. Two samples of SFRRC were placed into the testing apparatus under each wheel, and the 20,000-cycle process was administered. The samples were run under wet conditions, as prescribed by the testing procedures. Inspection of the samples showed minor surface wear of less than 0.076 cm (see Figure 8).

Figure 8: SFRRC sample after 20,000 repetitions with the steel wheel.

To compare SFRRC with typical Alaska Highway HMA, samples were tested using the AASHTO T324 procedure. The material was obtained from samples taken during construction on local road and airport parking areas. The material was heated in the UAA laboratory and compacted using a Controls asphalt slab roller compactor. The samples included HMA Type II mix with local aggregate and a HMA Type VH mix with imported aggregate that had a higher durability rating designed to mitigate stud wear. However, the local aggregate resulted in lower deformation, 0.15 cm, than the imported aggregate, 0.18 cm. This result may seem contrary to the expectations of a higher durability aggregate, but the focus of AASHTO T324 is more on plastic deformation than on particle wear. The composition of the two HMA designs differs in many respects, such as the aggregate gradation, asphalt cement supplier, rock fracture requirements, and rutting requirements. The asphalt cement oil may bind better with the local aggregate, creating a microstructure more resistance to plastic deformation than the hard aggregate HMA. In addition, the difference in the results is close so that it can be used to compare HMA as a whole to the results of SFRRC.

The test results from the AASHTO T324 procedure show that SFRRC resulted in less deformation than HMA, both Type II and Type VH. There were no signs of deformation on the SFRRC sample and only minor surface wear from the procedure. Inspection of both HMA mixes showed that plastic deformation occurred as the material was consolidated under the wheel path or shoved to the edge of the sample.

The resistance to plastic deformation is a crucial aspect of SFRRC for use in intersections because of vehicular braking and acceleration. Inspection of asphalt intersections shows significant rutting and shoving as vehicles approach and decelerate, causing greater downward force. In addition, vehicles resting at an intersection during a red-light condition create static loading on the pavement. During summer months, with higher temperatures, static loading can cause permanent deformation of asphalt pavement, as it is in a higher plastic state. Based on AASHTO T324 test results, we determined that SFRRC reduces pavement deformation at intersections.

A separate issue affecting roadways during the winter season is stud wear. This wear is especially apparent at intersections where deceleration includes skidding, with studs producing greater shoving and wear on the roadway surface. As vehicles accelerate from a stopped position in winter, rutting occurs, as icing conditions allow for a slip plane that causes increased tire rotation and stud impact.

To determine SFRRC stud resistance in these conditions, we performed a modified AASHTO T324 test. A rubber wheel was embedded with standard studs, as shown in Figure 9. The studded rubber wheel was placed on the wheel tracker apparatus, and the AASHTO T324 test procedure was performed. After 20,000 cycles were completed, we inspected the sample for stud wear.

Figure 9: The DWT Pavetrack rubber tires with the studs installed.

Based on analysis of the sample, we determined that the AASHTO T324 procedure would not provide realistic results of studded tire wear because of the wheel path the apparatus traverses. In actual conditions, studs on tires make contact with the roadway in random locations. With the wheel tracker apparatus, the wheel follows the same path for all 20,000 cycles. This lack of variation results in each stud contacting one location throughout the test cycles.

To create a more representative sample, the AASHTO T324 procedure was modified. Random distribution was increased by rotating the studded wheel slightly after running it for only 100 cycles. Rotation was repeated 200 times resulting in 20,000 cycles, with much greater random distribution of stud contact on the SFRRC surface.

As shown in Figure 10, the sample received stud impacts throughout the traveled path. The slab was inspected and a rutting depth of approximately 0.64 cm was determined. The rutted surface shows particles of crumb rubber and steel fibers distributed throughout the area. No spalling of the concrete surface was noticed outside of the wheel path. The steel fibers bridge the material when micro fracturing occurs and minimize spalling, which is evident in the sample. Surface rust on the steel fibers from the water-immersed testing procedure is apparent on the sample. The steel fibers exposed at the surface act as a wear course, and as they rust, they are slowly worn away. Control wheel tracker reports, HMA mix designs, and rut depth calculations can be found in Appendix F.

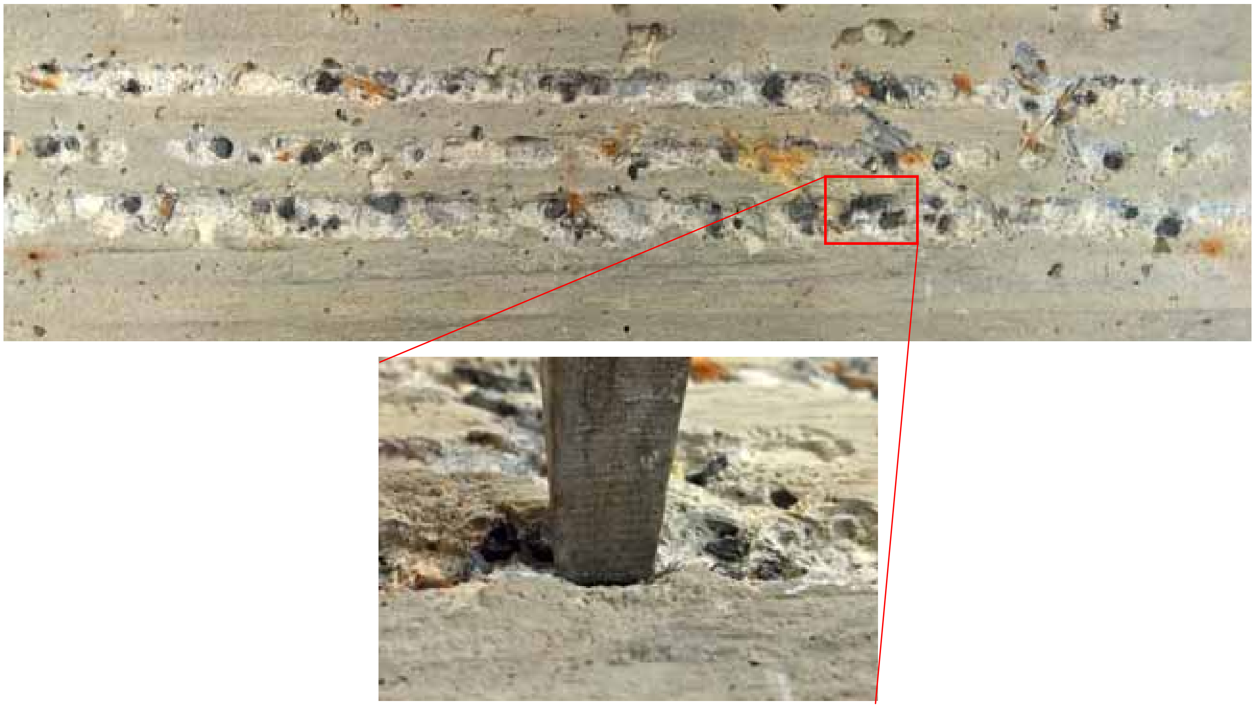

Figure 10: SFRRC after the studded wheel performed 20,000 cycles.

UAA Trial Slab Construction and Outcomes

After designing and coordinating with local agencies, we completed construction of the SFRRC slab near the UAA Consortium Library as shown in Figure 3 earlier. The location on the UAA campus at Alumni Drive chosen for the trial slab had many benefits and some minor negatives. The location has high traffic volume due to cyclical UAA shuttle services and parking garage usage, but traffic is not as significant here as at a four-way signalized intersection. A large signalized intersection would be beyond the scope of this research in testing the trial slab and could create a safety risk if unforeseen issues were to occur with the SFRRC.

Stop-and-go traffic occurs at the chosen location on campus, which assists with data collection of studded tire rutting and impacts. The traffic exiting the library and parking garage comes to a complete halt in the location of the slab prior to acceleration onto Alumni Drive. This traffic pattern provides similar stud wear as seen at signalized intersections.

Once the pour date was established, the designated location of the slab was excavated and prepared for SFRRC placement. The east and west sides were poured against an existing concrete curb and gutter, and the north and south edges were tied in with the existing asphalt. Material was removed from below the asphalt at the north and south tie-in locations to allow SFRRC to flow below the asphalt when poured, as shown in Figure 11. This created a keyed joint and allowed for more efficient load transfer from the asphalt to the SFRRC slab. In addition, the keyed joint would minimize frost heave or settlement by prohibiting water intrusion compared with a vertical joint.

Figure 11: Pavement adjacent to the slab undermined to allow keying of SFRRC with samples of crumb rubber and steel fiber used.

The local concrete manufacturer, AS&G, assisted with batching of the material. To recreate similar results as in the laboratory on a larger scale, the mixing procedures were thoroughly reviewed. The addition of steel fiber and crumb rubber was what differed from the standard concrete mixing process.

After review of the AS&G manufacturing plant and process, we determined that adding the steel fibers would be done manually as material was flowing from the mixing barrel into the concrete truck. This method would allow the fibers to disperse evenly in the concrete and minimize clumping. The steel fibers were pre-weighed based on the volume of material poured into each truck. The steel fibers were dispersed by several workers throughout the pouring process. Visual investigation of the material as it exited the transport vehicle showed a well-distributed mix, with steel fibers and crumb rubber spread throughout. No clumping of steel fibers was noticed.

The AS&G SFRRC mix was transported to the UAA slab location and poured. The procedure followed standard practice for construction placement per DOT&PF specifications. The local contractor, Finishing Edge, placed the material and provided a broom-finished surface. As the material was poured, DOT&PF staff were on-site to complete standard acceptance testing procedures.

One aspect that differed from lab procedures was the consolidation of the material. Abaza and Hussein (2016) referenced use of only external vibration to consolidate the material, but because of the nature of pouring in place, this was not possible. Consolidation of the material was completed using internal vibratory devices. To minimize settlement and segregation of the steel fibers due to higher specific gravity, only short durations of vibrating were allowed. If excess vibration was conducted, the steel fibers would settle to the lower portion of the slab and the crumb rubber would rise to the upper layer. The material was closely inspected, and steel fiber remained distributed well throughout the layer of the poured slab.

The slab was finished to proper elevations using a manual screed to match the existing asphalt pavement (see Figure 12). After the initial finish was complete, the slab was allowed to cure before a broom finish was applied. The Finishing Edge crew had more difficulty completing this task. Because of the interconnected microstructure of the steel fibers, as the broom finish was being applied the surface of the slab would shift and tear. The surface was wetted to allow the material to be more malleable and the broom finish was completed. In future use of the material, broom finishing should occur prior to allowing the long cure duration. The intertwined structure of the steel fibers is a benefit to the SFRRC slab, however, as it mitigates migration of micro cracks when the slab shifts due to freeze-thaw actions. A detailed report and images of the slab construction can be found in Appendix G.

Figure 12: Initial finish of the UAA slab and mid-slab contraction joint.

The initial observations showed smooth transitions from the existing asphalt pavement onto and off the slab. As shown in Figure 13, the surface of the concrete was fairly smooth with a broom-textured finish; no major deformations caused ponding.

Figure 13: The UAA SFRRC trial slab shortly after construction.

The SFRRC slab was observed throughout the winter at regular intervals to determine if any changes had occurred. The slab was exposed to studded tire traffic, ice and snow buildup, and snow removal equipment passing across it. No rutting or deformation of the surface was determined or thermal cracking from freeze-thaw action.

There were signs of minor delamination of crumb rubber and steel fibers that were exposed at the surface. When the slab was constructed, a trowel and broom were repeatedly passed over the surface to create a smooth finish. As this smoothing process was conducted, the cement material covering particles of crumb rubber and steel fibers was troweled away, exposing them to traffic wear. The crumb rubber and steel fibers near the surface were more susceptible to delamination from studded tires, plowing equipment, and acceleration at the approach. We noticed that these exposed particles delaminated, but succeeding particles remained intact, which shows that the uppermost layer of crumb rubber and steel fibers may be vulnerable to delamination due to a lower surface area of adhesion, but the succeeding layers are fully adhered and resist delamination.

The edge of the slab was designed to include SFRRC material extending under the adjacent material to resist any uneven heaving that would cause a lip at the joint. Inspection of the slab revealed a minor height difference at the joint between the concrete and the adjacent asphalt pavement of approximately 1.27 cm. Inspection of the concrete gutter running on both sides showed that the slab was still level with the gutter elevation. We determined that the adjacent pavement may have compacted or settled slightly as the SFRRC slab remained in place. Further investigation next winter will determine if any changes in the slab have occurred.

Figure 14: The north joint of the UAA trial slab showing an elevation difference of 1.27 cm.

Abbott Road Test Section Construction and Outcome

Once the design process was complete, the Abbott Road capital project was advertised and awarded to Quality Asphalt Paving (QAP) for construction. QAP subcontracted a local concrete company, D&S Concrete Inc., to construct the pre-cast panels at their facility. D&S created forms to meet the required 12-foot-wide by 8-foot-long by 7-inch-thick design, including grout ports and channels, dowel slots and inserts, locations for the strain gauge sensors, lifting eyes, rebar enforcement, and tapered edge designs, as shown in Figure 15. D&S created two forms to work with, so the casting process required approximately 20 days to complete the required 15 panels. After pouring 2 panels, a minimum cure period of 3 days was allowed prior to removing cured panels and pouring the next set. Pouring began on August 25, 2016 and complete September 14, 2016. Testing for compressive and flexural strength was completed on each panel. Details about the layout of the slabs as well as the site location are shown in Figure 17 Appendix C. In addition, Detailed reports on the daily pouring process and strength testing can be found in Appendix H.

Figure 15: Pre-cast SFRRC panels for Abbott Road test section.

The Abbott Road project had an anticipated completion date of October 31, 2016, but because of construction delays, QAP was unable to place the final layer of asphalt during the 2016 construction season. With this change in schedule, the panel installation was postponed until the following summer construction season.

The panels were stored at the D&S facility until May 2017, when construction on the project began. The panel location was prepared by removing the temporary hot mix asphalt (HMA) and placing a fine-grade sand layer. The panels were transported to the site on a flatbed semi-truck and trailer in May 2017. The first load brought out four panels. An excavator with a lifting harness was used to place the panels (see Figure 16). There was slight difficulty lifting the third and fourth panels high enough due to the limited reach of the excavator arm. Two loads of four panels were transported on-site, and subsequent loads only contained three panels or less per trip.

Figure 16: Placement of the first SFRRC panel using an excavator and harness.

Placement of the slabs required many detailed adjustments to the sand layer, orientation of the panels, and careful lowering with the excavator. The panels were placed from west to east. The second panel was placed, but required adjustment in order to create a level transition from one joint to the next. In addition, the orientation of the panels required precise adjustment so that the expansion joint would be even and sealed across the width of the panel. Prior to placement of each panel, the sand layer was readjusted to ensure a smooth transition and full contact when the panel was placed. Once all 15 panels were placed, further adjustments were conducted to confirm that the joint transitions were smooth. The straight edge was placed across the joints; the excavator lifted the necessary panel corner and shims were placed under it. This process was completed across all slabs.

Once the panels were placed and leveled properly, the grouting process was conducted. This process included installation of the dowel and bedding grout. The specifications required differing strength grouts, but to simplify the process, the grout supplier used one grout meeting the higher strength requirement. The dowel ports were filled first using a gravity flow method from higher to lower locations, followed by the grout ports. Some panels required more grout than others based on the number of voids present. The process was completed in a day’s shift.

Figure 17: Pouring of the dowel and bedding grout for the SFRRC test section.

The next step was to pour sealer into the expansion joints. The process required heating the sealing material and slowly pouring it until each joint was filled to the required height. This step was the final portion of work required prior to placing asphalt adjacent to the test section.

The strain gauges installed within three panels required connection to a power source, communications, and calibration. A technical representative with the strain gauge manufacturer arrived on-site to complete all connections, from the panels to the termination point at a controller cabinet installed outside of the roadway. The strain gauges were calibrated during the pouring and casting process. Once all electrical elements were finalized for the automated traffic recording system, the strain gauges were connected in the controller along with power. After detailed coordination with the DOT&PF Highway Data unit, the automated traffic recording equipment was able to share the same power source and communications system. This arrangement greatly reduces costs and simplifies the required connections.

With all aspects of the test section complete, traffic was allowed to traverse the panels. The ride quality over the panels is smooth, and a slight increase in noise when traversing the joints is noticeable. This noise was anticipated with a jointed concrete system, and is much less than expected due to the joint sealing process. In addition, data from the strain gauge system were received showing daily strain fluctuation as the temperatures rise during the day and cool at night. The strain data will be most pertinent when large temperatures shifts occur, such as the changing of the seasons. Detailed daily construction reports along with strain gauge data can be found in Appendix I.

CHAPTER 4 – CONCLUSIONS AND RECOMMENDATIONS

Introduction

The SFRRC experimental testing and trial slab showed results that suggest an increase in performance of concrete pavements in cold region roadway applications. The experimental testing and SFRRC trial slab included modifications during the process. The freeze-thaw testing procedure was altered to increase testing reliability. The wheel tracker studded tire procedure was modified to improve testing representation of typical stud wear and impact seen on roadways. The mixing of SFRRC material was altered during large-scale operations due to manufacturing limitations and to increase production efficiency. During construction of the SFRRC slab, many observations and alterations to procedures improved the finished product and increased the quality of the SFRRC. Each of these improvements, alterations, and results provided information for construction of the test section on Abbott Road.

Freeze-Thaw Discussion

Freeze-thaw testing provided a challenge because of equipment, testing requirements, and minimal testing facilities that administer the ASTM C666 procedure. The initial methodology included use of the UAA freeze-thaw apparatus to complete the procedure. As testing began, it was apparent that the time frame for completion of the 300 cycles required would be outside the scope of our work. To continue the ASTM C666 while modifying the UAA apparatus, samples were sent to Applied Testing to complete the procedure.

Results from the second trial completed by Applied Testing differed from the expected results because compressive strength increased after the freeze-thaw testing was performed. The increase in compressive strength was seen on two separate trials completed by Applied Testing. To confirm the results, the UAA apparatus completed the ASTM C666, and specimens were tested for compressive strength. Again, results showed an increase in compressive strength after administering the freeze-thaw procedure. Furthermore, the compressive strength values were nearly identical to those achieved by Applied Testing.

The increase in compressive strength differed from our expectations, but provides positive reinforcement for use of SFRRC in cold regions. Applied Testing showed low deterioration of the samples, while the UAA freeze-thaw procedure showed greater deterioration for two of the four samples. This deterioration may be related to mixing procedures, as the samples batched at the AS&G facility showed less significant wear than the UAA lab samples.

We recommend that future testing of the ASTM C666 procedure include flexural strength tests to determine if there is a difference compared with control specimens. From these results, we determined that SFRRC increased the resistance to freeze-thaw action compared with standard PCC based on previous RDME results from Shang and Yi (2013). The increase in compressive strength also enforces the use of SFRRC in cold regions.

Wheel Tracker Discussion

The AASHTO T324 wheel tracker testing procedures were completed for both the standard steel wheel and the modified rubber tire with studs. The results from the steel wheel procedure indicated that SFRRC shows much lower deformation than HMA material. This result is expected, as the steel wheel primarily shows plastic deformation. Even though SFRRC has higher flexural strength than standard PCC, the concrete properties still result in greater resistance to plastic deformation than HMA.

The modified rubber tire with studs was administered to represent studded tire use as seen in cold regions. The type of studs along with their distribution was chosen based on typical studded tires used in Alaska. The AASHTO T324 was modified to provide a more accurate representation of random stud impact by rotating the rubber studded tire throughout the 20,000 cycles. This procedure allowed for stud impact to occur across the entire sample. The results showed a 0.25 in. deep rut across the wheel path of the sample. Steel fibers and crumb rubber could be seen distributed across the rutted area. The randomly distributed steel fibers assisted in mitigating material loss by bridging the rutted area and minimized spalling from the micro fractures.

The modified studded rubber tire procedure, which provided information that represented winter conditions in cold regions, would benefit from further improvements. A method that did not require manual rotation of the wheel or resetting of the software would increase performance efficiency and reliability. Allowing the rubber tire to lift off the sample and impact as it returned would more accurately represent studded tires on roadways. We recommend that a comparison between the wheel tracker and the UAA trial slab be administered to determine studded wear in actual conditions. A correlation could then be created to more accurately predict studded tire wear based on the wheel tracker procedure.

UAA Trial Slab Discussion

The UAA trial slab was a collaboration between the UAA Facilities and UAA Engineering departments along with assistance from AS&G (concrete supplier) and the Alaska DOT&PF. The accelerated placement of the slab was made possible by concurrent construction occurring in the area. Mixing the SFRRC material in a large-scale batch plant required modifications to the mixing procedure. This modification included the addition of steel fibers and crumb rubber at differing steps, compared with procedures established by Abaza and Hussein (2016). The resulting SFRRC product did not exhibit any change in strength, slump, or air content and therefore was deemed acceptable. Future large-scale production of the material may justify use of a separate bin and conveyor system to add the steel fibers and crumb rubber more efficiently.

The transport and placement of SFRRC for the UAA trial slab was similar to typical PCC installation. A step transition at the SFRRC-to-HMA interface was added to improve load transfer and reduce differential settlement. The finishing of the material was more difficult than standard PCC due to the steel fibers creating an intertwined bond throughout the material. Although the intertwined steel fibers created difficulty for surface finishing, the composition shows increased resistance to micro cracking, as multiple steel fibers bridge the cracks.

The UAA trial slab was inspected throughout the winter, and no thermal cracking, spalling, or rutting was noticed. Even with the addition of the step transition, settlement at the HMA-to-SFRRC interface was noticed. Looking at the concrete curb and gutter, the UAA trial slab was at the same elevation. Settlement of the HMA at the joint as it compacted further seems to be what occurred. Future slab installation may include a larger step joint interface to avoid the edge settlement. The surface of the UAA trial slab showed delamination of steel fibers and crumb rubber that were not embedded in the slab. This delamination would only be a cosmetic concern, as the steel fibers and crumb rubber fully embedded in the SFRRC material do not delaminate. Evidence of this can be seen, as further traffic on the slab has not caused greater steel fiber and crumb rubber loss. Future recommendations include a shorter surface-finishing process so that steel fibers and crumb rubber are not cleared off the cementitious material while troweling.

Abbott Road Test Section Discussion

Based on testing results and observations of the UAA trial slab, we recommended that SFRRC be placed in a large-scale area to determine the effects of high-speed studded tire traffic with greater AADT. Placement of the test section assisted with determining production costs and allowed for more accurate comparison of studded tire wear with the Controls Pavetrack apparatus.

An optimum location was chosen for the test section that included uniform traffic on more than one lane, sufficient crash data for future comparisons, standard geometry to minimize construction issues, and traffic detouring possibilities in case issues arose with the SFRRC test section installation. A detailed construction plan was created to avoid any variability in placing the material. For comparison purposes, the chosen roadway has one lane constructed of SFRRC and a similar lane constructed of DOT&PF standard HMA.

The pre-casting and pouring process was completed successfully, but involved minor refinements to the mix design to obtain proper workability with the SFRRC material. Due to the relatively small amount of material that was mixed per day for casting two panels, it was difficult for AS&G to calibrate the batch plant prior to finishing the process. The mix design was adjusted using a water-reducing admixture, and the workability significantly improved after the first day of casting. Both compressive and flexural strength testing was completed on all batches with results well above minimum requirements.

Placement of the test section required detailed construction of the bedding layer in order to place level panels and avoid any roughness in ride quality. Each panel required fine adjustments when placed to create even joints and for leveling prior to placement of the grout material.

The process for placement of the pre-cast panels required approximately 4–5 days of work and was considerably more expensive than pouring in place due to designing of slabs, creating formwork, pre-casting, transporting, and placing. In addition, pouring in place would have provided a much smoother final product and required less equipment. Based on testing results, traffic crossed the CIP SFRRC within 1 week, which is a similar amount of time for traffic on pre-cast panels. Based on the total duration required to prepare the bedding layer, place the pre-cast panels, grout, and place joint sealant, we recommend that pouring in place be considered as a viable option for future work.

Recommended Test Section Monitoring Plan

A thorough monitoring plan of the tensile stresses that occur in the design life of concrete panels will be vital to determining failure causes or areas where improvements to the design can be made. The test section was constructed with sensor equipment to calculate temperature changes and displacement (lateral and longitudinal). Additional equipment is available to determine AADT volumes and rutting depths at the test section.

The American Concrete Institute discusses several failure methods of concrete pavements due to tensile stresses. Tensile stresses can cause cracking due to vehicle loading of an unsupported section of the slab. Several factors can cause unsupported sections of the slab, such as moisture expansion and contraction in the subgrade and base layers resulting in volumetric changes. Temperature differentials between the top and bottom of the slab cause the upper portion to expand while the lower portion contracts so that the slab curls downward at the edges, losing contact with the supporting material. In addition, if the joints between the slabs do not function properly, restrained expansion of the joint can cause curling or cracking of the slab.

To avoid failure of the test section due to these stresses, we recommend that embedded strain gauges be continuously monitored. The strain gauges are placed in several slabs to effectively collect data and compare results. The strain data will be continuously collected, logged, and available via a wireless connection. The PCA method recommends that stresses at the mid-slab shoulder edge be considered the most critical location for fatigue analysis, and that stresses at the slab jointed corner be considered the most critical location for erosion analysis (Huang, 2004).

Post-construction testing of the SFRRC material is crucial for monitoring material strength and integrity. One method that provides non-destructive testing is the falling weight deflectometer (FWD). The FWD apparatus produces an impulse load on the material layers and collects a load-deflection response. This information is used to back-calculate the characteristics of the pavement structure and subgrade material (Federal Highway Administration, 2002). The Long-Term Pavement Performance (LTPP) program incorporated research and field trials that were used to set standards for the FWD testing procedure.

Visual inspection of joints, slab edges, and rutting depths will also be crucial to determine wear of the test section over the design life. Any joints with failing sealant or corner spalls should be documented and repaired as soon as practicable. Rutting depths can be recorded and compared with current HMA rutting rates.

Final Recommendation

The SFRRC material showed improvements in freeze-thaw resistance in comparison with standard PCC. The placement of the UAA test slab provided insight with respect to mixing, construction, and performance of SFRRC in real-world conditions. Based on test results, a test section was recommended and constructed. This test section will provide information with respect to cost analysis and integration of the material into the DOT&PF construction program. The test section will be crucial for long-term use of SFRRC. Based on current test results and observations of the UAA trial slab, SFRRC material shows viability in cold regions for resisting freeze-thaw actions. In addition, successful construction of the Abbott Road test section shows that SFRRC placement, including pre-cast panels, can be completed on Alaska roadways with non-specialized equipment. Future monitoring of the test section will be conducted to determine real-world freeze-thaw and rutting resistance of the SFRRC material. In addition, the durability of a pre-cast slab system will be accessed. The monitoring plan will include strain data, load bearing data, visual inspections and annual IRI monitoring for correlation over a three year period.

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APPENDIXES

Appendix A – List of Abbreviations

Alaska Sand and Gravel	AS&G
American Association of State Highway and Transportation Officials	AASHTO
American Society for Testing and Materials	ASTM
Annual Average Daily Traffic	AADT
Cast in Place	CIP
Department of Transportation and Public Facilities	DOT&PF
Double Wheel Tracker	DWT
European Standard	EN
Federal Highway Administration	FHWA
Flat End	FE
Hot Mix Asphalt	HMA
Portland Cement Association	PCA
Portland cement concrete	PCC
Pounds per square inch	psi
Pounds per cubic inch	pci
Precast Concrete Pavement	PCP
Precast Prestressed Concrete Pavement	PPCP
Relative Dynamic Modulus of Elasticity	RDME
Steel Fiber-Reinforced Rubberized Concrete	SFRRC
University of Alaska Anchorage	UAA

Appendix B – Literature Review

Introduction

The use of new materials to increase the service life of concrete pavements has become more prevalent as maintenance and construction costs have increased. Additives for high strength concretes have been well documented and recent studies have been conducted to determine viability of materials such as crumb rubber and steel fibers in concrete mixtures. These studies have shown there are many potential benefits to the use of these additive materials. More than one additive such as crumb rubber and steel fibers have now been combined in concrete mixtures to eliminate the negative consequences from each of these materials.

These mixtures have been laboratory tested for general attributes such as compressive strength, toughness, first crack strength and modulus of elasticity. These tests have given general values for future use of these materials, but have not addressed specific situations such as cold regions freeze-thaw cycles, rutting wear and constructability. Additionally, the service life of these materials under real world simulations has not been thoroughly investigated.

Purpose

To better define the precise needs of this study a thorough literature review was conducted on several topics in regards to concrete material compositions and additives, design life, constructability, costs and safety. As more in-depth testing is completed with the SFRRC material further literature review may be deemed necessary.

Freeze-Thaw Durability of Rubberized Portland Cement Concrete

The use of crumb rubber in asphaltic materials has been widely investigated and accepted as a suitable substitute for fine aggregate particles. Few studies have tested the freeze-thaw characteristics of crumb rubber in Portland cement concrete. For this reason, Gadkar (2013) conducted an in-depth study to better understand the freeze-thaw characteristics of PCC with crumb rubber.

The main objective was to investigate the freeze-thaw durability and air void system of rubberized concrete. Other objectives included analyzing the effects associated with freeze-thaw durability and air entrainment due to factors such as alkali content of cement, impact of supplementary cementing materials (SCMs), super-plasticizers and vibration time and frequency. Another variable that was tested for freeze-thaw characteristics was the use of latex emulsion to further modify rubberized Portland cement concrete. Since the focus of the review was to research the freeze-thaw characteristics of typical rubberized Portland cement concrete the main objective of the study will only be discussed.

At the start of the analysis, parameters were set in regards to material attributes. Two different types of crumb rubber at three different size gradations were investigated which were ambient and cryogenic at 2.36 mm, 0.60 mm and 0.30 mm. In addition, three differing levels of crumb rubber would be tested by replacing the sand within the mix design at 8%, 16% and 24%.

With mix design and material characteristics determined test samples were created. Compressive strength cylinders were prepared at differing crumb rubber types, levels of sand replacement and size gradations and tested at typical 3, 7 and 28-day time frames. Freeze-thaw prisms that were 75 mm x 75 mm x 285 mm were cured for 14 days and run through 300 cycles of the freeze-thaw procedure. Rapid freezing thawing in water was adopted where the temperature was dropped from 11.5°C to -18°C in not less than two hours or more than five hours. Readings were taken every 30 cycles and included length change, weight change and dynamic modulus of elasticity. A cryogenic dilatometer test was conducted to monitor differential linear expansion during freeze-thaw cycles. Mortar samples of sand and cement were created using eight mm diameter drinking straws as molds for the material. A vibrated table was used to compact the molds and cured in Calcium Hydroxide for 28 days after which they were cut into 25 mm lengths. Once the samples were properly cured and prepared for the cryogenic dilatometer they were tested for length change with linear sensitivity of 1.25 nanometers. The freeze-thaw temperature cycles consisted of starting at 15°C, cooling to -20°C and heating to 15°C.

After completion of the specimen testing a statistical analysis of the data was conducted. The compressive strength tests showed a proportional decrease in compressive strength with the increase in crumb rubber percentage. This is a typical trend that has been confirmed in other research reports. It was also concluded that the cryogenic rubber had higher strength due to the lower air content compared to the ambient rubber.

The freeze-thaw testing showed interesting results in regards to length change, weight change and dynamic modulus. The ambient crumb rubber generally showed low length change percentage compared to regular PCC while the cryogenic crumb rubber had extreme length change and even earlier failure for most specimens. The weight change results again showed the ambient crumb rubber had generally small changes compared to the control while the cryogenic rubber had greater changes on a majority of gradation sizes and percentages. The dynamic modulus results showed that the ambient crumb rubber performed as well or better than the control in all configurations while the cryogenic samples failed at very early stages. It is worth noting that the air entrained concrete specimens performed well in length change and dynamic modulus with results similar to the ambient crumb rubber except that significant weight change occurred during the freeze-thaw cycles.

Summarizing the findings, the author concluded crumb rubber of both ambient and cryogenic types at the finer sizes with higher percentages have the potential to improve the freeze-thaw durability of concrete. The author recommends that the addition of crumb rubber can be used for areas where potentially low strength, but high durability is needed such as precast panels for side-walks, highway noise barriers and external partition walls. Further work is necessary to detail different configurations of crumb rubber additives. In the study, only one water/cement ratio was used and this may have a significant effect on the results of the research. In addition, further research into the bond between crumb rubber and the cement paste could provide crucial insight towards improving strength and durability.

Steel Fiber-Reinforced Rubberized Concrete

A study was conducted by Abaza & Hussein (2016) on the inclusion of both steel fibers and crumb rubber in concrete to determine strengths and flexibility. In the study, Hussein investigated the use of Flat-End (FE) steel fibers and concluded that the FE provides an optimum anchorage within the concrete matrix. The steel fibers were tested at 0.64, 0.89 and 1.28% volume fractions. Rubber content was tested at 15%, 30% and 50% replacement of fine aggregate volumes. The crumb rubber was graded to a maximum nominal size of 0.25 in.

The aggregate particle distribution was determined using the Federal Highway Administration (FHWA) 0.45 power curve and maximizing the density of the gradation. In addition, mixing proportions of acceptable steel fiber limits, aggregate and cement were developed in accordance with recommended values by the American Concrete Institute (ACI).

With materials properties established control and test samples were created and tested with varying proportions of steel fibers and crumb rubber. A total of 16 mix samples were created so as to test all variables. To evenly distribute the steel fibers and prevent fiber balling they were placed into the drum mixer slowly at a steady rate for the final cycle. Flexural beams were cast from all the mixes and concrete cylinders were cast for the SFRRC mixes. In order for the material matrix to be undisturbed during casting an external vibrator was used to consolidate the material.

It was determined that with the increase of rubber content there was an increase of flexibility, but a large decrease in toughness. Once the steel fibers were added to the mix design the concrete "regained the matrix toughness that was lost by the addition of crumb rubber and exceeded that of PCC" Abaza & Hussein (2016). In addition to an increase in toughness there was an overall increase in compressive strength up to 20% with the inclusion of both steel fiber and crumb rubber.

Freeze-Thaw Durability of Air-Entrained Concrete

A study conducted by Shang & Yi (2013) stated that "Concrete is considered as one of the most nonhomogeneous and demanding engineering materials used by mankind." The environmental actions increase the challenges of creating the material to resist frost action, corrosion, permeation, carbonation, stress corrosion, chemical attacks and more. Freeze-thaw cycles are one of the main potentially damaging environmental actions to concrete, specifically in cold regions. The article describes frost damage as a progressive deterioration which starts from the surface separation or scaling and ends up with a complete collapse. As the freeze-thaw cycles are repeated the material loses stiffness and strength.

Through previous research it was recommended the air-entrainment agents should be used to improve resistance to the freeze-thaw cycles in cold regions. This article studied the relative dynamic modulus of elasticity (RDME) and weight loss of air-entrained concretes after completing many hundred cycles of freeze-thaw. Five differing samples with increasingly higher doses of air-entraining agent were used with 0.85 kg/m^3 being the lowest and 1.3 kg/m^3 being the highest. The values were compared with plain concrete without any air-entrainment.

It was determined that air-entrained concrete had a much higher freeze-thaw durability than that of plain concrete. From previous research the RDME values for the plain concrete after only 100 cycles was 62% while the highest value for the air-entrained concrete was 97% after 300 cycles. Interestingly the RDME value increase as the dose of air-entrainment increase, but only to a certain amount. The highest dose of air-entrained concrete had a lower RDME value than the second highest dose.

The weight loss of concrete occurs due to movement of water through the material causing scaling and surface separation. The surface separations allowed water to fill in the deteriorated zones and continue causing further separations. The test results showed that air-entrained concrete required many more freeze-thaw cycles to fill in these deteriorated zones compared to plain concrete.

Concrete Wear Resistance vs. Asphaltic Pavements

Treleaven (2010) with EBA Engineering Consultants conducted an investigation in Alberta, Canada where conditions are similar to Alaska to replace severely rutted asphalt with PCC at several intersections. The main focus of the study was to determine if PCC would be a viable replacement in regards to costs and maintenance life cycles. The study compared the construction costs, maintenance costs and design life of the PCC intersections compared to that of standard asphalt pavement.

Three separate sections of roadway were selected to be remediated with PCC material. In addition, the base and sub base layers were reestablished as required to meet design criteria for traffic volumes. The construction was completed one lane per day as to allow continuous movement of traffic and curing of the new material. The area of concrete constructed ranged from 1850 m^2 to 3,510 m^2 due to the existing intersection configurations.

To create an accurate analysis all construction costs such as materials, labor, mobilization of equipment, joint cutting and concrete sealing were accounted for. The life of the PCC was determined to effectively last at least 30 years, with resealing of joints every 12 years and crack sealing every five years. The costs of lane closures and materials for sealing maintenance have been taken into account for the analysis.

With the costs quantified a statistical cost comparison was conducted that included interest rates, inflation, initial and salvage costs. EBA Engineering determined that even though the initial costs and delay to traffic for the PCC intersections are greater than that of Asphalt Concrete Pavement the benefits of minor rutting, greater maintenance intervals and longer life cycle show that PCC for intersections is overall a cost-effective option.

Rut Depth Safety Impacts

In Knoxville, Tennessee Chan, Huang, Yan & Richards (2008) performed a study utilizing the pavement management system in Tennessee to analyze data with respect to rut depths and crash counts. The Pavement Management System (PMS) and Accident History Database (AHB) were acquired from the Tennessee Department of Transportation for the analysis. The variables that were used from the PMS were rut depth, international roughness index (IRI), present serviceability index (PSI) and annual average daily traffic (AADT). The AHB provided accident counts during several different scenarios such as night and day settings, poor weather conditions and heavy traffic volumes.

The variables were input into the SPSS statistical analysis software to determine significance between accident data and the differing pavement variables. With regards to the rut depth it was determined that there is a significant correlation in accidents with rain and night conditions. The analysis shows that the accident rates are the highest when rain and night conditions are present simultaneously. The study hypothesized that during clear light conditions the ruts are visible and can be seen therefore easily maneuvered. In rain conditions when the precipitation has filled in the ruts it is difficult to distinguish between the differing elevations of pavement and crossing through a rut may be an unexpected event. Also with rainwater in the ruts vehicles will have a tendency to hydroplane causing loss of control. The study concluded that “areas with more precipitation, rutting should be considered as an important safety measure in the pavement management system” Chan et al. (2008).

With regards to the PSI the analysis showed that there was a significant correlation with accident data. PSI is a comprehensive model that considers many variables such as slope variance, rut depth, cracking and patching on a scale from zero to five with the highest value correlating to the most comfortable ride quality. From the analysis, it was shown under all situations the PSI was inversely correlated to the accident frequency and when PSI value fell by one unit the accident frequency increased by 1.412 times. The correlation was even higher under specific situations such as nighttime, rain conditions and high traffic volumes. The research concluded the PSI is a valuable measurement in predicting accident frequency since typically each state's PMS would have the data readily available.

Pavement Conditions vs. Crash Severity

An analysis was conducted by Yingfeng, Chunxiao & Linang (2013) on crash severity based on the pavement conditions. The Texas Department of Transportation (TxDOT) Crash Record Information System (CRIS) and Pavement Management Information System (PMIS) were both used to correlate crash information with pavement conditions. The CRIS had over 140 variables that were available, but in order to use only relevant information for the study only six variables were used. These were commercial vehicle involvement such as yes or no, surface conditions such as wet or dry, crash severity ranging from non-injured to fatal, light conditions, number of vehicles involved and the month. The PMIS system provided data on the conditions and types of pavements, skid resistance, ride quality and the IRI score.

To properly integrate the CRIS and PMIS data ArcGIS, a mapping tool, was used to overlay the two datasets. Tabulated results were created based off the location and year of the crash that corresponded to the PMIS data at the particular point. In some areas, multiple PMIS datasets occurred at the same location such as at an intersection. In these areas, the data was averaged and manually entered so as to correlate with the set parameters. Another item that was discussed and should be considered is that the PMIS data is collected annually so in some instances the pavement conditions at the date of the crash could be up to a year old. Since there is a large number of data points and the pavement conditions typically take several years to deteriorate this was determined to be within an acceptable margin of error. The resulting data was analyzed using Chi-Square methods to determine which pavement variables were statistically significant in relation to crash severity.

Three different pavement types, asphaltic concrete pavement (ACP), continuously reinforced concrete pavement (CRCP) and jointed concrete pavement (JCP) were analyzed for significance. In general, the results illustrated that vehicle accidents on JCP resulted in a significantly higher crash severity than both ACP and CRCP. These results were found significant under certain situations such as crashes on urban non-freeway arterials, poor lit conditions and roadways with relatively high speeds. The author hypothesized that this may be due to a majority of JCP failures occurring at the joints and result in a significant impact to driving conditions. Furthermore, vehicles maneuvering to avoid these failures at high speeds could lead to severe crashes.

The Chi-Square analysis was conducted on the pavement distress scores and suggested that there was a significant impact on the crash severity. The analysis was completed based on four ratings of distress ranging from very poor, poor, good to very good and showed that under poor conditions crash severity was the highest. The author theorizes that due to the pavement conditions drivers have to make unexpected maneuvers to avoid the poor distresses resulting in more severe accidents. The results also showed that the second greatest crash severity was on very good pavements, which is hypothesized to be because drivers tend to move faster on little or no distressed pavements.

The analysis for both the ride quality and the IRI ratings resulted in similar outcomes. Both suggest that for a better ride quality or IRI the severity of the crashes increase significantly. The crash severity is the lowest with both poor ride quality and IRI ratings. This is also a similar result as with the pavement distress in which the little or no distressed pavements had fairly high crash severity. Again, the cause is believed to be related to drivers moving faster under optimal pavement and ride conditions and therefore experiencing a more severe crash.

The author concluded that even though significant differences were encountered in relation to crash severity they were still relatively minor in reality. A comparison of the distress score groups showed that even though the data was significant there is only three percentage points between the highest and lowest crash severities when involving injuries or fatalities. Due to the many differing variables, the study provided a general insight to the crash severity and pavement conditions. To further analyze the data, specific situations need to be investigated in greater detail.

Precast Concrete Slabs for Highway Construction

In highway reconstruction or repairs, one of the main challenges that can be faced is dealing with the traveling public. In Virginia Shabbir & Celik (2012) used precast slabs on the reconstruction of I-66 to test the constructability and initial performance of pavement repair options. Three differing methods were chosen for the concrete repairs which were cast-in-place (CIP), precast concrete pavement (PCP) and precast prestressed concrete pavement (PPCP). The performance period for evaluation after construction was chosen to be 1.5 years. Three methods of measuring the performance during the evaluation period were visual inspection, ride quality using an inertial profiler and load transfer of joints using a falling weight deflectometer (FWD).

Each trial method required differing installation procedures. The CIP required minimal work prior to removal of the deteriorated existing material. The removal may also include unstable sub-base materials prior to placement of high-early-strength hydraulic concrete. For PCP, the removal of the defective area is similar to the CIP except that the concrete is precast and cured off-site. The inclusion of reinforcing steel is optional dependent on the design engineer and the strength requirements. Joints are fitted with dowel bars with the intention of transferring the loads. The subgrade must be carefully graded using laser control to achieve high accuracy of elevations. Once the PCP is place bedding grout is pumped underneath the slab to fill any remaining voids. The PPCP slabs are constructed prior to installation similar to PCPs, but during the construction they are prestressed in the perpendicular direction to traffic and after installation are post-tensioned parallel to traffic. This allowed for thinner slabs to be constructed and used, typical sizes are up to 37 ft. wide, 10 ft. long and seven in. or eight in. deep. Each of the test sections ranged from 100 ft. to 160 ft. long.

The mix designs for each method were determined using ASTM International standards. The PPCP included Class F fly ash while the other two methods did not. Standard testing was conducted to ensure compliance to ASTM C39, C143, C231 and C138 for compressive strength, slump, air content and density, respectively.

Prior to full scale installation, trial sections were construction for the PCP and PPCP based on special provisions written into the specification for the methods. The trial construction was performed off-site at the contractor's facility for the PCP and near the project staging area for the PPCP. Issues were noticed with aligning and placing the rigid rods for the PPCP and the method of installation was altered prior to permanent placement.

For full scale construction, the installation method and timeframe differed for test sections. Installation of the CIP required two shifts, one for removal of existing material and the second for installation of the concrete. For PCP and PPCP the removal and installation was conducted during one shift. The PCP was placed sequentially in slabs 12 ft. wide and 10 ft. to 16 ft. long. The dowels were preinstalling into one end of the slabs while the other ended and slots for receiving the dowels from the preceding slab. The PPCP could be constructed into wider panels and ranged in size from 12 ft. to 27 ft.; the slabs were uniform in length at 10 ft. The PPCP slabs were placed similar to the PCP, but were tensioned together to create post-tensioned sections ranging from 100 ft. to 160 ft.

Post-construction testing and observations were conducted in to determine surface distresses, ride quality and load transfer efficiencies (LTEs). The PCP showed stable mid-slab cracks that occurred immediately after construction and remained in acceptable condition after 1.5 years. The PPCP section showed signs of separation at the joints up to two in. and debris accumulation, but the concrete slab showed no signs of cracking. The ride quality was measured using a laser mounted vehicle system that drove the test sections and measured the IRI. The results showed that the IRI measurements for the existing pavements had consistent decrease in ride quality over the 1.5 years while the PPCP showed increasing ride quality over the time frame. This increase in ride quality for PPCP is theorized to be in conjunction with settlement and leveling of joints due to traffic loading and concrete wear. PCP showed negligible decrease in ride quality over the 1.5-year period. To determine the LTE of the slabs a FWD was used to measure deflection and quickly detect voids at the concrete base interface. Deflection at the mid-slab and edges of intermediate slabs was determined to be less than 10 mils, but deflections at the edges of the expansion joints were high. These results indicated there was curling or presence of voids at the expansion joints that could be the result of erosion of fines due to water penetration. The PCP slabs were similarly investigated with the FWD and the results showed minimal curling or voids immediately after construction and 1.5 years later. The distress cracks that formed in the middle of PCP slabs were tested for LTE and resulted in acceptable reading.

The study resulted in a better understanding and recommendations for future use of PCP and PPCP slabs in highway construction. The PCP and PPCP were both recommended for use when longevity and minimal traffic impact is required. Production rates show that PCP can be placed to yield the most area during the shift followed by PPCP and CIP, respectively. The research recommends that quality assurance and modified tolerance should be considered when implementing a PCP system in the future. Proper fitting slabs are crucial to the integrity of the system along with production, handling, delivery and placement to avoid mid-slab cracking. PPCP, similar to PCP require proper interlocking slabs to strengthen the joint system and avoid joint gaps and edge spalling.

Life Cycle Analysis

A life cycle cost analysis conducted by Applied Research Associates, Inc. (2011) compared the long-term costs of asphalt to Portland cement pavements in regards to traffic volume and classifications. The benefits of a Life-Cycle Cost Analysis (LCCA) would assist in the bidding process for justifications of funding PCC based on long term savings instead of the initial costs compared to asphaltic pavements. Similar design life and structurally equivalent strength was required to create a reasonable comparison.

To create equivalent designs for the ridge concrete and flexible asphalt pavements the Mechanistic-Empirical Pavement Design Guide (MEPDG) was incorporated. The failure modes experienced with flexible and ridged materials differ and must be taken into account. The main mode of failure for low volume flexible pavements was reduction in smoothness and fatigue cracking on higher volume areas. For ridged pavement, the limiting factor was primarily faulting of the joints due to reduction in joint load transfer efficiencies. Once the MEPDG was used and cross-sections created they were reviewed by a panel of design experts to confirm structural equivalence in regards to strength.

With the designs complete the elements required for a LCCA were calculated. An analysis period of 25 years was chosen for the project to include the initial service life of 25 years followed by major rehabilitation costs. Maintenance and rehabilitation plans were estimated to include time frames, required quantity and costs. For flexible pavement, these items included resealing, spot repairs, milling and resurfacing. For ridged pavements, they included joint resealing, partial and full depth repairs and texturizing. The unit costs for installation, maintenance and rehabilitation were established along with frequency of repairs to determine total cost for the life of the design. The total cost was determined using the net present worth method by discounting all maintenance and repairs throughout the life of the project to present day values.

The results of the study showed that with Annual Average Daily Truck Traffic (AADTT) ranging from 250 to 10,000 that the overall cost of ridged pavements is at least six percent less than that of flexible pavements. In addition, on a major arterial with AADTT greater than 10,000 the ridged pavements provide up to 25% savings in cost compared to flexible pavements.

Appendix C – Abbott Road Test Section Plan Sheets

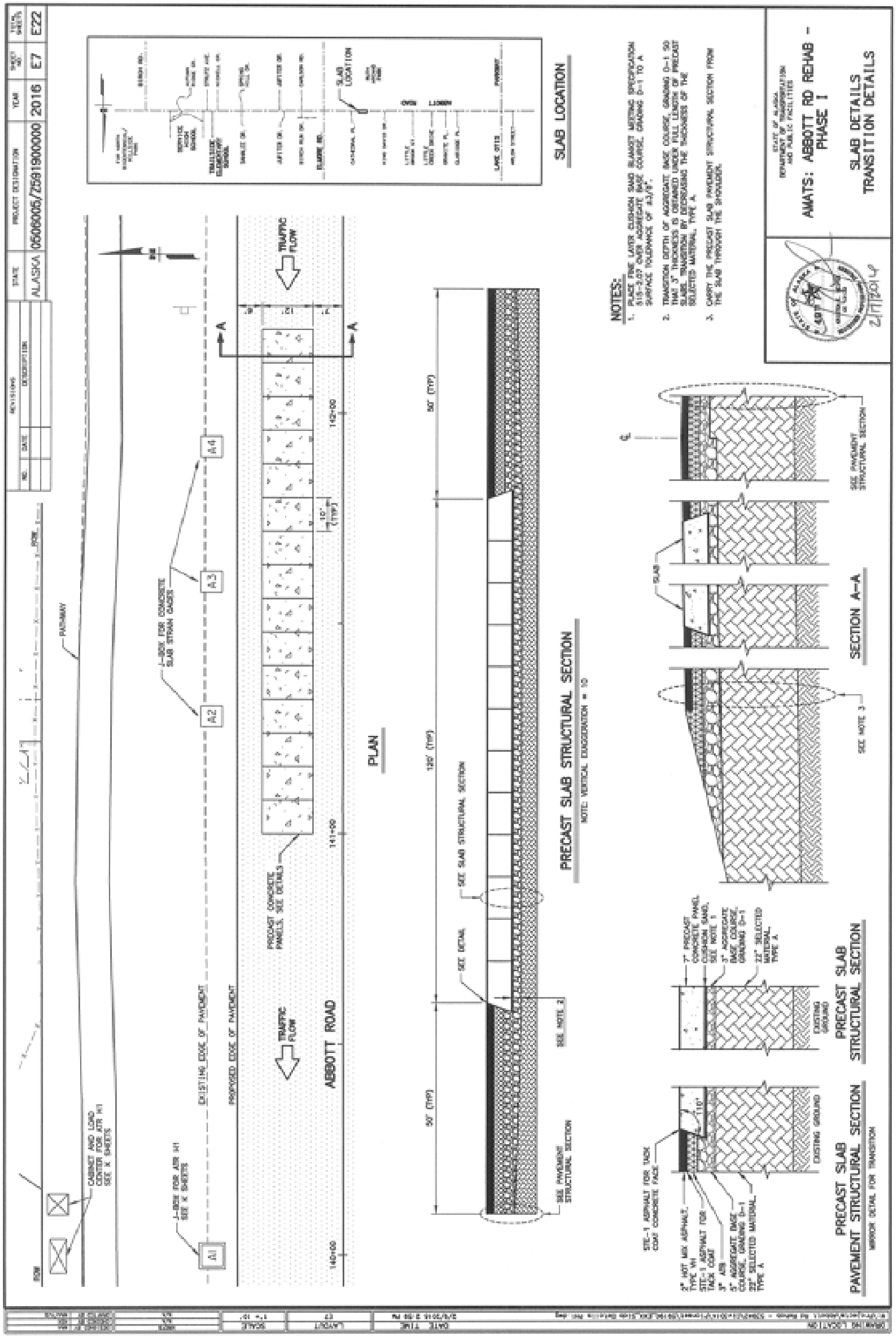
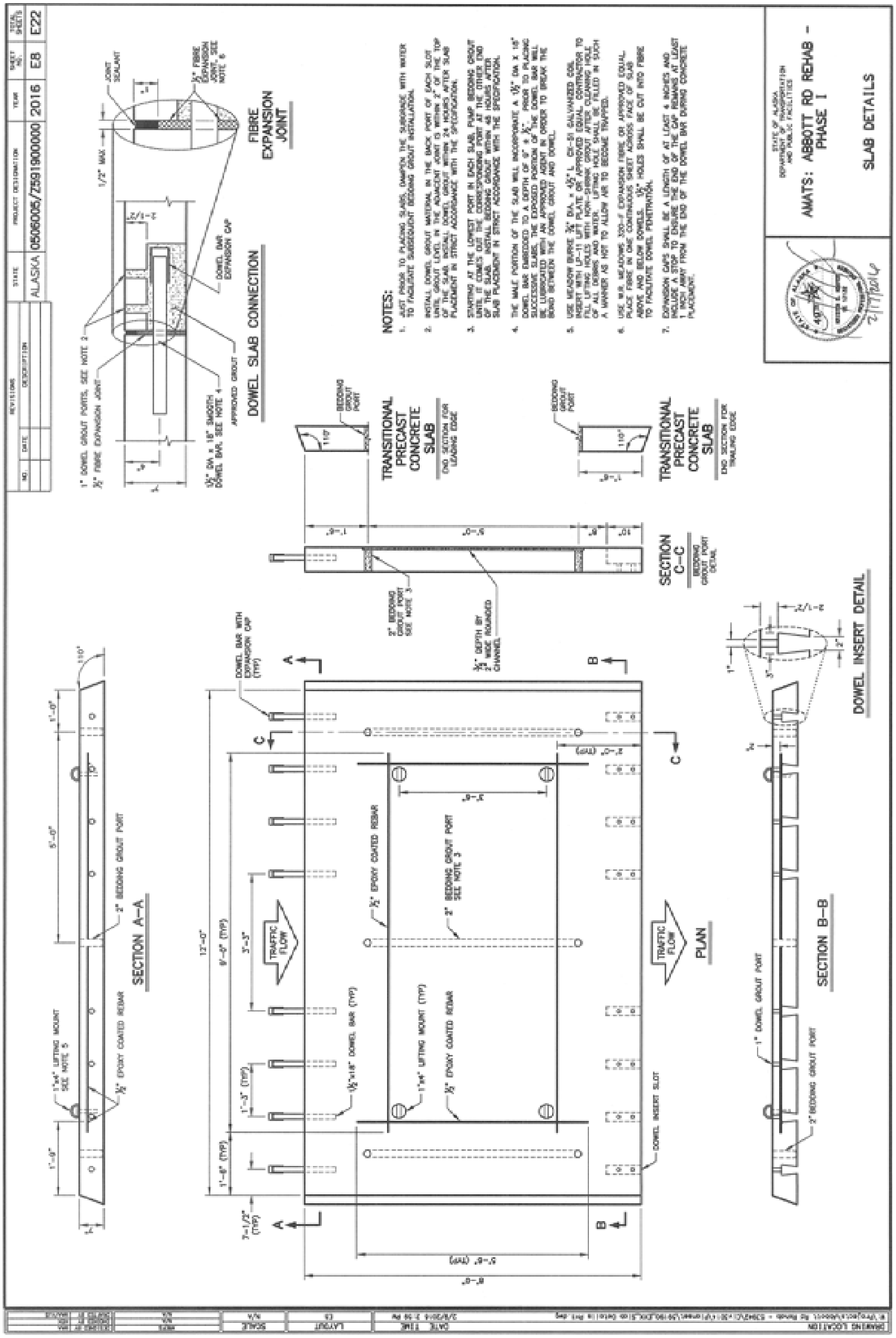
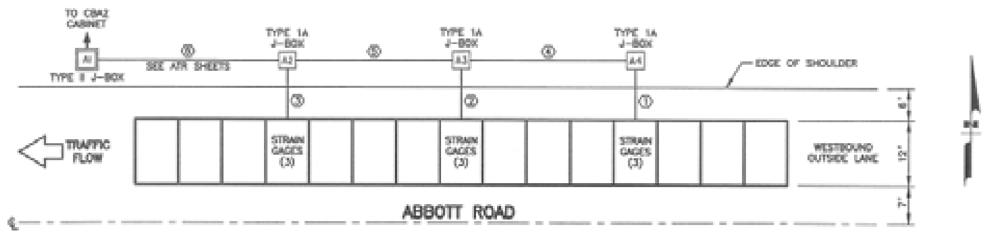


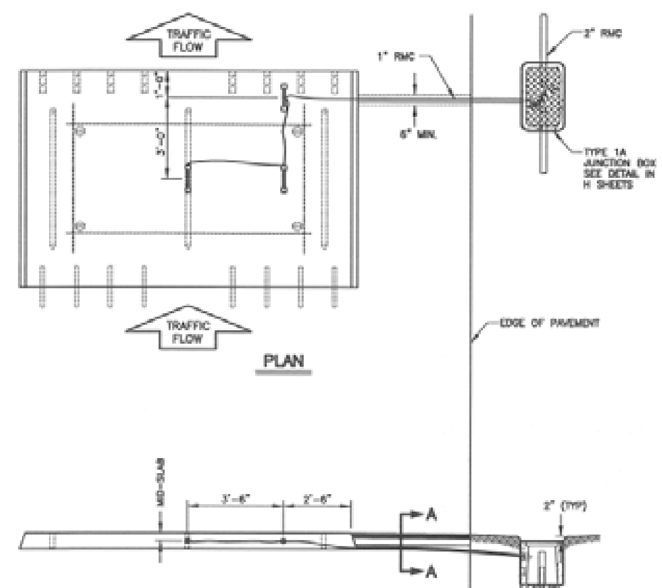
Figure 18: AMATS: Abbott Rd Rehab Test Section Plan Sheets (3 pages).


ALASKA
0506005/Z591900000
2016
E8
E22
DOWEL SLAB CONNECTION
FIBRE EXPANSION JOINT
NOTES:
TRANSITIONAL PRECAST CONCRETE SLAB
SECTION C-C
SECTION A-A
PLAN
SECTION B-B
DOWEL INSERT DETAIL
TRAFFIC FLOW
AMATS: ABBOTT RD REHAB - PHASE I
SLAB DETAILS

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0506005/Z591900000	2016	E9	E22



PLAN



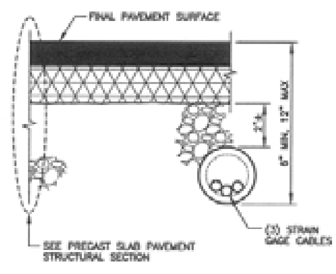
PROFILE

STRAIN GAGE SYSTEM

CONDUIT AND CONDUCTOR SCHEDULE

CONDUIT NO.	CONDUIT SIZE	FROM	TO	CABLE QTY.	CABLE TYPE	CABLE NUMBER
1	1"	SLAB	JBA4	3	STRAIN GAGE CABLE	S01, S02, S03
2	1"	SLAB	JBA3	3	STRAIN GAGE CABLE	S04, S05, S06
3	1"	SLAB	JBA2	3	STRAIN GAGE CABLE	S07, S08, S09
4	2"	JBA4	JBA3	3	STRAIN GAGE CABLE	S01, S02, S03
5	2"	JBA3	JBA2	6	STRAIN GAGE CABLE	S01 - S06
6	2"	JBA2	JBA1	9	STRAIN GAGE CABLE	S01 - S09

SEE ATR SHEETS FOR CONDUIT AND CONDUCTOR SCHEDULE BEYOND JBA1.



SECTION A–A

NOT TO SCALE

STRAIN GAGE SYSTEM NOTES:

1. STRAIN GAGES TO BE INSTALLED INTO FRESH UN-CURED CONCRETE AT MID DEPTH. EMBED CABLES AND ROUTE TO SLAB EDGE, AVOID DAMAGING WIRE DURING INSTALLATION, TRANSPORT AND PLACEMENT OF SLABS.
2. FEED STRAIN GAGE CABLE UNDER SHOULDER ASPHALT LAYER AND ABOVE THE SUBBASE IN THE CRUSHED AGGREGATE BASE TO JUNCTION BOX.

2/17/2014

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

AMATS: ABBOTT RD REHAB – PHASE I

SLAB DETAILS
STRAIN GAGE SYSTEM

Appendix D – Assurance Testing Results and Calculations

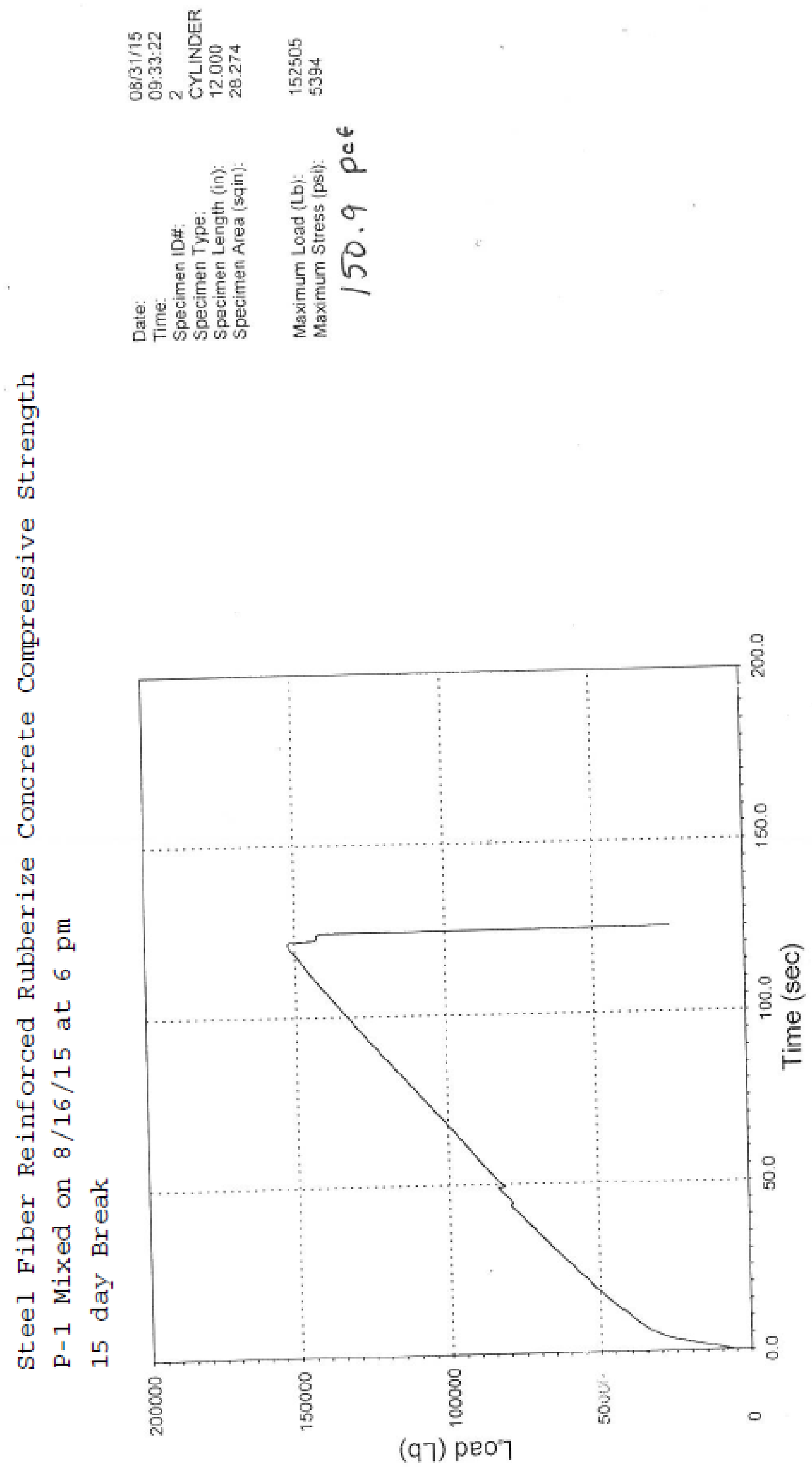


Figure 19: Compressive strength curve of UAA batched SFRRC tested on 8-31-15.

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

Laboratory Report

Information

Laboratory No.: **2015A-3574**

Name: **Steel Reinforced Rubberized Conc.in Cold Regions** Project No.: **76319 / 40000(159)**
Sample: **PCC Cylinders** Item/Spec No.: Field No.: **I-P-2**
Sampled From: **Batch**
Source **AS&G** Quantity Represented: **1 Days Pour**
Location: **Anchorage** Submitted By: **M. Aboueid**
Examined For: **Compressive Strength**

Date Sampled: **08/16/2015**
Date Received: **09/14/2015**
Date Completed: **09/14/2015**
Date Reported: **09/14/2015**

Mix Design No.:
Class of Concrete: OTHER
Compressive Strength by AASHTO T22 / ASTM 1231

Portion of Structure Represented:
Test batch

Specimen Number	Test Date	Age Days	Dia. inches	Area sq. in.	Maximum Load lbs	Type of Fracture	Specimen Defect	Strength psi	Tech
1	09/14/2015	29	6.01	28.37	147230	Side		5190	PJS
2	09/14/2015	29	6.02	28.46	157560	Side		5540	PJS

Specifications
@

29 Day
Avg psi
5370

Remarks:

D8 The Material as Submitted Conforms to Specifications
Yes [ ] No [ ] NA [X]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

Signature: Newton Bingham
Newton J. Bingham, PE
Regional Materials Engineer

Figure 20: Compressive strength curve of UAA batched SFRRC tested on 9-14-2015.

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

Acceptance

Laboratory Report

Laboratory No.: **2015A-3246**

Name: **Steel Reinforced Rubberized Conc.in Cold Regions** Project No.: **76319 / 40000(159)**
Sample: **PCC Cylinders** Item/Spec No.: Field No.: **P-1**
Sampled From: **Batch** Date Sampled: **09/04/2015**
Source **UAA** Quantity Represented: **50 cy** Date Received: **09/08/2015**
Location: **Anchorage** Submitted By: **T. Burlingham** Date Completed: **10/03/2015**
Examined For: **Compressive Strength** Date Reported: **10/03/2015**

Mix Design No.:
Class of Concrete:
Compressive Strength by AASHTO T22 / ASTM 1231

Portion of Structure Represented:
Approach Slab

Specimen Number	Test Date	Age Days	Dia. inches	Area sq. in.	Maximum Load lbs	Type of Fracture	Specimen Defect	Strength psi	Tech
1	10/02/2015	28	6.01	28.37	149300	Side		5260	PS
2	10/02/2015	28	6.02	28.46	153170	Side		5380	PS

Specifications
@

28 Day
Avg psi
5320

Remarks:

D8 The Material as Submitted Conforms to Specifications
Yes [ ] No [ ] NA [X]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

Signature: Newton Bingham
Newton J. Bingham, PE
Regional Materials Engineer

Figure 21: Compressive strength curve of AS&G batched SFRRC tested on 10-03-2015.

Table 1: SPSS Statistical T-Test analysis for compressive strength.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
CompStngth	5	5352.8000	134.71897	60.24815

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
CompStngth	88.846	4	.000	5352.80000	5185.5243	5520.0757

Table 2: SPSS Statistical T-Test analysis for flexural strength.

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
ModofRup	3	1182.0000	157.42935	90.89188

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
ModofRup	13.004	2	.006	1182.00000	790.9238	1573.0762

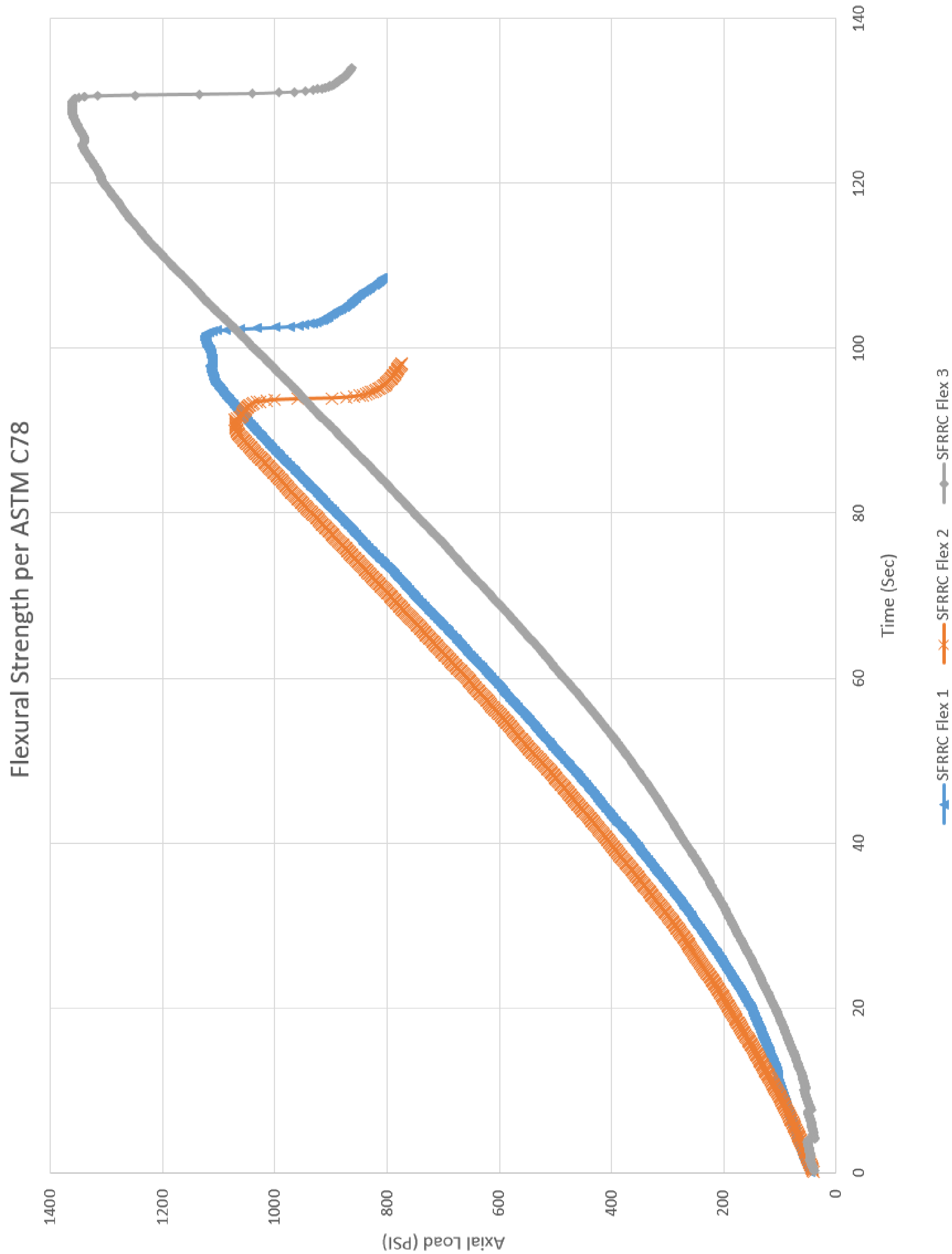


Figure 22: Flexural strength curves for SFRRC tests.

Flexural Strength Testing
Based on Standard Test Method for Flexural Strength of Concrete ASTM C78
Load Rating:

$$r = \frac{Sbd^2}{L} \quad (1)$$

where:
r = loading rate, N/min [lb/min],
S = rate of increase in maximum stress on the tension face, MPa/min [psi/min],
b = average width of the specimen as oriented for testing, mm [in.],
d = average depth of the specimen as oriented for testing, mm [in.], and
L = span length, mm [in.].

r=	1542.85714	lb/min
S	150	psi/min
b	6	in
d	6	in
L	21	in

Start Load: Approx 432 lbs

8. Calculation

8.1 If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = \frac{PL}{bd^2} \quad (2)$$

where:
R = modulus of rupture, MPa [psi],
P = maximum applied load indicated by the testing machine, N [lbf],
L = span length, mm [in.],
b = average width of specimen, mm [in.], at the fracture, and
d = average depth of specimen, mm [in.], at the fracture.

NOTE 3—The weight of the beam is not included in the above calculation.

Specimen	Length (in)	Width (in)	Depth (in)	Max Load (lbf)	Fracture Location	Mod of R (psi)
1	21.25	6	6	11329.527	Middle Third	1114.59467
2	21	6	6	11006.688	Middle Third	1070.094667
3	21.25	6	6	13842.74	Middle Third	1361.843634
					Average=	**1182.177657**

Figure 23: Flexural strength modulus of rupture calculations

Appendix E – Freeze-Thaw Tests and Calculations

Applied Testing & Geosciences, LLC
When Quality Counts

ATG Report No.: C059-123015-12075-3946-1
Sample ID: 3946

Test Report - Freeze Thaw of Concrete

1. Project

Project	Purpose	Summary
UAA & AK DOT (12075)	To determine the durability of concrete exposed to rapid freezing and thawing cycles.	ASTM C666 run on 3 cast bars.

Company / Client	Company Address	Reported To
University of Alaska, Anchorage	3211 Providence Dr. Anchorage, AK, 99508	Mahear Abou Eid

2. Test Standard

Source	Designation	Year	Title	Service Code
ASTM	C666A	2008	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing	C059 x 3

3. Sample Identification

Sample By	Sample Date	Sample Collection Address	ATG ID #
Client	1/5/2016 (Cast by lab)	N/A	3946

4. Shipping / Handling

Inspected By	Receipt Date	Condition	Carrier	Handling	Storage
Z. Jacobs	12/30/2015	Intact	Conway	No MSDS	Ambient Temp Ambient Humidity

5. Specimen Description

Description	Mix (per manufacturer)	Dimensions
Concrete Prisms Cast by Lab (C192 Mixing)	SFRRC Mix Design - 8/8/2015	3" x 4" x 16" (approximate)

6. Material Properties (as reported by manufacturer)

Material	Type	W/C Ratio	Temp (°F)	Air (%)	Weight (pcf)	Spread (in)
Concrete	NP	NP	NP	NP	NP	NP

7. Supplemental Information

Drawing	Attachments	Photos
N/A	Chain of Custody Mix Design Extended Data	9

8. Test Summary

Durability Factor	Specification (300 cycles)	Compliance
96% (average of 3 bars)	For Information Only	For Information Only

(Samples showed significant mass loss and visual deterioration - See Photos)

9. Signatures

Technician	Test Start Date	Test End Date	Lab Manager	Technical Manager
Mike Speroni	1/21/2016	3/11/2016	Tom Smith	Craig Joss, Ph.D, P.E.

C059-123015-12075-3946-1
C059 Rev 7/1/15
Page 1 of 8

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Figure 24: Applied Testing report of freeze-thaw testing (Report 1 of 2, 8 pages)

10. Test Setup

Test was run according to ASTM C666 Procedure A. The specimens are alternately exposed to freezing and thawing conditions. Samples are cooled to 0 deg F and are then thawed by raising the temperature to 40 deg F. Samples are immersed in water at all times. At the end of the thaw cycle the temperature is once again lowered to 0 deg F and the cycle starts over. This is repeated 300 times with weight and Relative Dynamic Modulus of Elasticity (RDME) readings taken every 30 cycles. RDME readings were taken upon completition of the thaw cycle at a temperature of 40°F ± 3°F. The test ran continuously with pauses for sample readings, sample rotation, and equipment maintenance.

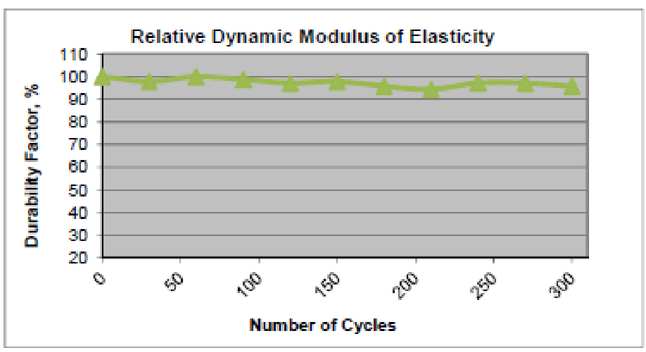
11. Test Data - Freeze Thaw Readings

Date	Cycle	Average FTF (hz), Cast	Average Weight (g)**
01/21/2016	0	1849	6930
01/27/2016	30	1829	6928
02/01/2016	60	1849	6925
02/08/2016	90	1838	6917
02/12/2016	120	1823	6902
02/16/2016	150	1829	6893
02/22/2016	180	1810	6884
02/26/2016	210	1797	6868
03/01/2016	240	1823	6869
03/07/2016	270	1823	6858
03/11/2016	300	1810	6837

**Weight changes can be attributable to material loss and/or water absorption.

12. Test Results

Date	Cycle	$RDME_{avg}$ (Cast)
01/21/2016	0	100
01/27/2016	30	98
02/01/2016	60	100
02/08/2016	90	99
02/12/2016	120	97
02/16/2016	150	98
02/22/2016	180	96
02/26/2016	210	94
03/01/2016	240	97
03/07/2016	270	97
03/11/2016	300	96



		Spec Limit
RDME Average: (Average of 3 bars)	96%	≥ 90% (cast bars)

13. Notes

1 Test Method ASTM C666A Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing, 2008

2 The client is authorized to reproduce or distribute the report only if reproduced in its entirety.

3 The results presented relate only to the items & materials tested.

4 Reference ASTMs

ASTM C215: Test Method for Fundamental Transverse Frequency of Concrete Specimens

ASTM C490: Determination of Length Change

ASTM C511: Moist Rooms

5 Samples cast by lab & soaked in lime saturated water for 14 days prior to start of testing.

6 This test was run in sequence with a control set of concrete bars not subjected to freeze-thaw cycles. One bar from each set was taken at the day of ASTM C666's completion. These bars were cut into 3" cubes and tested for compressive strength. A summary of the results are listed below.

Compressive Strength Analysis				
Type	Cast Date	Test Age	Compressive Strength (psi)	ATG Report
Control	01/06/2016	69 Days	2852	M01-010616-12075-01
Freeze-Thaw	01/05/2016	69 Days	2640	M01-010516-12075-01

Attachment 1 - Chain of Custody

Applied Testing & Geosciences, LLC
When Quality Counts

COC-123015-12075-3946
Project No.: 12075
Date Received: 123015
Lab ID: 3946
Notes: -

Lab Chain of Custody-Sample Submittal Form

1. Client

Company Name	Company Address	Project Name
UAA & AK DOT	Not Provided	12075 UAA & AK DOT
Contact Name	**Phone**	**Email Address**
Mahear Aboueid	(907) 350-6777	mahear.aboueid@alaska.gov
PO #		
-		

2. Sample Collection

Sampled by	Company	Location	Date	Time	Sample Method
Client	UAa & AK DOT	-	-	-	-

3. Shipping / Delivery

# Samples	Carrier	Ship Date	Tracking #	Delivery Date/Time	Received By	Condition
13	Con-way	12/15/2015	420-083241	12/30/2015 9:30:00 AM	Jacobs, Zachary D.	Small tear in bag of cement. Otherwise, all samples intact

4. Sample Identification

Client ID	ATG	Sample Notes	Sample Notes 2	Description	Storage Conditions	Quantity
1	3946-1	Sand	All Purpose	AS&G,	349-3333, 60 lb bag	2
2	3946-2	Coarse Aggregate	3/4" Gravel	AS&G, 349-3333, 60 lb bag	Ambient	4
3	3946-3	Portland Cement	Type I	Alaska Basic Industries, 94 lb bag	Ambient	1
4	3946-4	Intermediate Aggregate	3/8" Pea Gravel	AS&G, 349-3333, 1 60 lb bag and 1 6" x 12" cylinder	Ambient	2
5	3946-5	No flyash included in this sample	-	-	-	-
6	3946-6	No water included in this shipment.	-	-	-	-
7	3946-7	Admixtures	500mL POLY HEED, 997	Alaska Freeze/Thaw	Ambient	1
8	3946-8	Rubber Pellets	~1/3 of a 5 gallon bucket	-	Ambient	1

Attachment 2 - Mix Design (provided by manufacturer)

Mahear Abou Eid
Steel Fiber Reinforced Rubberized Concrete

SFRRC Mix Design and Quantity Calculations
8/18/2015

Mix Design per Cubic Foot		
Cement	23.1	lb/ft3
Water	9.5	lb/ft3
w/c ratio	0.4	
Coarse Aggregate	68.9	lb/ft3
Intermediate Aggregate b	6.5	lb/ft3
Fine Aggregate	31.3	lb/ft3
PolyHeed-997	102.5	ml/ft3
Crumb Rubber	2.3	lb/ft3
Steel Fiber	6.3	lbs/ft3

Mix Design per Cubic Yard		
Cement	624.6	lb/CY3
Water	255.2	lb/CY3
w/c ratio	0.4	
Coarse Aggregate	1860.4	lb/CY3
Intermediate Aggregate b	174.6	lb/CY3
Fine Aggregate	844.8	lb/CY3
PolyHeed-997	2768.5	ml/CY3
Crumb Rubber	62.1	lb/CY3
Steel Fiber	169.3	lb/CY3

Sieve Size	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Blend Gradation	% Passing for 1-in Max Aggregate Size
2"	100	100	100	100	100
1-1/2"	100	100	100	100	100
1"	100	100	100	100	94-100
3/4"	97.4	100	100	98.5	76-82
1/2"	57.4	100	100	75.3	65-76
3/8"	31.3	98.3	100	60.1	56-66
#4	3.2	16.3	99.9	39.2	45-53
#8	0.2	0.5	91.3	33.5	36-44
#16	0	0.4	71.6	26.2	29-38
#30	0	0	47.3	17.3	19-28
#50	0	0	18.7	6.8	2-8
#100	0	0	4.7	1.7	0-2
#200	0	0	0.9	0.3	0-2
Blend Ratio	58%	5.50%	36.50%	100%	100%

Attachment 3 - Photos

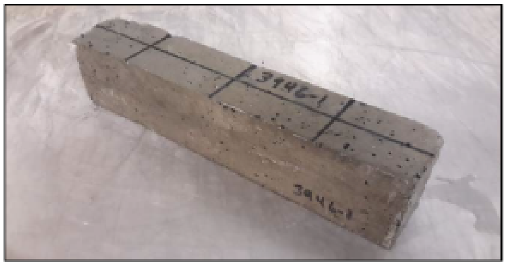


Photo #1
Date: 1/21/2016
Notes: Prisms 3946-1 pre-test

Photo #2
Date: 3/11/2016
Notes: Prisms 3946-1 post-test

Photo #3
Date: 1/21/2016
Notes: Prisms 3946-2 pre-test

Photo #4
Date: 3/11/2016
Notes: Prisms 3946-2 post-test

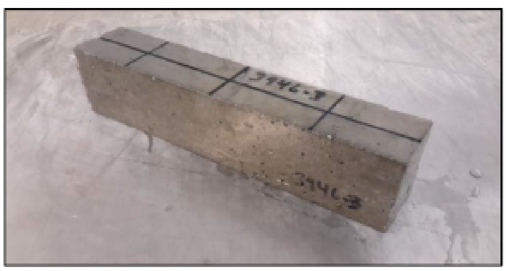


Photo #5
Date: 1/21/2016
Notes: Prisms 3946-3 pre-test

Photo #6
Date: 3/11/2016
Notes: Prisms 3946-3 post-test

Attachment 3 - Photos

Photo #7
Date: 2/12/2016
Notes: Prisms 3946-1 (120 Cycles)

Photo #8
Date: 2/12/2016
Notes: Prisms 3946-2 (120 Cycles)

Photo #9
Date: 2/12/2016
Notes: Prisms 3946-3 (120 Cycles)

Attachment 4 - Extended Data (Fundamental Transverse Frequency(Hz))

		3946-1 (Cast) Machine2			3946-2 (Cast) Machine2			3946-3 (Cast) Machine2		
Date	Cycle	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1/21/2016	0	1836	1836	1836	1836	1836	1836	1875	1875	1875
1/27/2016	30	1816	1816	1816	1816	1816	1816	1855	1855	1855
2/1/2016	60	1836	1836	1836	1836	1836	1836	1875	1875	1875
2/8/2016	90	1816	1816	1836	1816	1816	1816	1875	1875	1875
2/12/2016	120	1797	1797	1797	1816	1816	1816	1855	1855	1855
2/16/2016	150	1816	1816	1816	1797	1797	1797	1875	1875	1875
2/22/2016	180	1777	1777	1777	1797	1797	1797	1855	1855	1855
2/26/2016	210	1777	1777	1777	1758	1758	1758	1855	1855	1855
3/1/2016	240	1797	1797	1797	1797	1797	1797	1875	1875	1875
3/7/2016	270	1797	1797	1797	1816	1816	1816	1855	1855	1855
3/11/2016	300	1797	1797	1797	1797	1797	1797	1836	1836	1836
		RDME:	96	@300 Cycles	RDME:	96	@300 Cycles	RDME:	96	@300 Cycles
			Weight Gain(g):	-67.9		Weight Gain(g):	-120.4		Weight Gain(g):	-89.5

Figure 1 - 3946-1 Durability Data

End of Report

Applied Testing & Geosciences, LLC
When Quality Counts

ATG Report No.: C059-123015-12075-3946-2
Sample ID: 3946

Test Report - Freeze Thaw of Concrete

1. Project

Project	Purpose	Summary
UAA & AK DOT (12075)	To determine the durability of concrete exposed to rapid freezing and thawing cycles.	ASTM C666 run on 3 cast bars. (Cast #2)

Company / Client	Company Address	Reported To
University of Alaska, Anchorage	3211 Providence Dr. Anchorage, AK, 99508	Mahear Abou Eid

2. Test Standard

Source	Designation	Year	Title	Service Code
ASTM	C666A	2008	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing	C059 x 3

3. Sample Identification

Sample By	Sample Date	Sample Collection Address	ATG ID #
Client	2/11/2016 (Cast by lab)	N/A	3946-10

4. Shipping / Handling

Inspected By	Receipt Date	Condition	Carrier	Handling	Storage
Z. Jacobs	12/30/2015	Intact	Conway	No MSDS	Ambient Temp Ambient Humidity

5. Specimen Description

Description	Mix (per manufacturer)	Dimensions
Concrete Prisms Cast by Lab (Per Client's Mixing Instructions - See attached.)	SFRRC Mix Design - 8/8/2015	3" x 4" x 16" (approximate)

6. Material Properties (as reported by manufacturer)

Material	Type	W/C Ratio	Temp (°F)	Air (%)	Weight (pcf)	Spread (in)
Concrete	NP	NP	NP	NP	NP	NP

7. Supplemental Information

Drawing	Attachments	Photos
N/A	Chain of Custody Mix Design & Procedures Extended Data	6

8. Test Summary

Durability Factor	Specification (300 cycles)	Compliance
97% (average of 3 bars)	For Information Only	For Information Only

(Samples showed significant mass loss and visual deterioration - See Photos)

9. Signatures

Technician	Test Start Date	Test End Date	Lab Manager	Technical Manager
Jay Ragland	2/25/2016	4/15/2016	Tom Smith	Craig Joss, Ph.D., P.E.

C059-123015-12075-3946-2
C059 Rev 7/1/15
Page 1 of 8

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Figure 25: Applied Testing report of freeze-thaw testing (Report 2 of 2, 8 pages)

10. Test Setup

Test was run according to ASTM C666 Procedure A. The specimens are alternately exposed to freezing and thawing conditions. Samples are cooled to 0 deg F and are then thawed by raising the temperature to 40 deg F. Samples are immersed in water at all times. At the end of the thaw cycle the temperature is once again lowered to 0 deg F and the cycle starts over. This is repeated 300 times with weight and Relative Dynamic Modulus of Elasticity (RDME) readings taken every 30 cycles. RDME readings were taken upon completition of the thaw cycle at a temperature of 40°F ± 3°F. The test ran continuously with pauses for sample readings, sample rotation, and equipment maintenance.

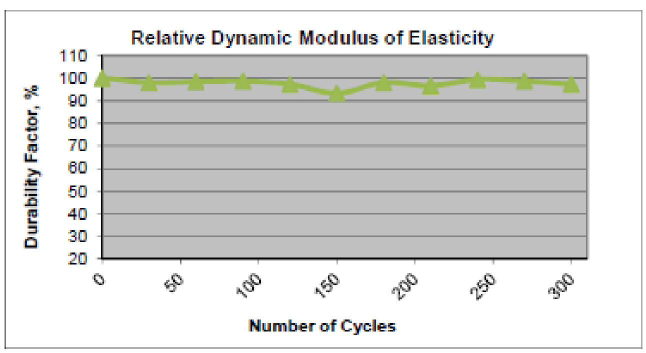
11. Test Data - Freeze Thaw Readings

Date	Cycle	Average FTF (hz), Cast	Average Weight (g)**
02/25/2016	0	1921	7263
03/01/2016	30	1901	7248
03/07/2016	60	1906	7220
03/11/2016	90	1908	7197
03/15/2016	120	1895	7183
03/22/2016	150	1855	7152
03/28/2016	180	1901	7154
04/01/2016	210	1888	7214
04/06/2016	240	1914	7123
04/11/2016	270	1908	7108
04/15/2016	300	1895	7090

**Weight changes can be attributable to material loss and/or water absorption.

12. Test Results

Date	Cycle	$RDME_{avg}$ (Cast)
02/25/2016	0	100
03/01/2016	30	98
03/07/2016	60	98
03/11/2016	90	99
03/15/2016	120	97
03/22/2016	150	93
03/28/2016	180	98
04/01/2016	210	97
04/06/2016	240	99
04/11/2016	270	99
04/15/2016	300	97



		Spec Limit
RDME Average:	97%	For Information Only
(Average of 3 bars)		

13. Notes

1 Test Method ASTM C666A Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing, 2008

2 The client is authorized to reproduce or distribute the report only if reproduced in its entirety.

3 The results presented relate only to the items & materials tested.

4 Reference ASTMs

ASTM C215: Test Method for Fundamental Transverse Frequency of Concrete Specimens

ASTM C490: Determination of Length Change

ASTM C511: Moist Rooms

5 Samples cast by lab & soaked in lime saturated water for 14 days prior to start of testing.

6 An additional bar was cast and stored in lime for the duration of the freeze thaw test. Upon completion, 1 freeze thaw bar and the additional bar were saw cut into (3) 3" cubes and tested for compressive strength. Results are summarized below.

Compressive Strength Analysis					
Type	Cast Date	Test Age	Compressive Strength (psi)	ATG Report	
3" Control Cubes	02/11/2016	69 Days	4040	M01-021116-12075-01	(average of 3)
3" Freeze-Thaw Cubes	02/10/2016	69 Days	4635	M01-021016-12075-01	(average of 3)

Attachment 1 - Chain of Custody

Applied Testing & Geosciences, LLC
When Quality Counts

COC-123015-12075-3946
Project No.: 12075
Date Received: 123015
Lab ID: 3946
Notes: -

Lab Chain of Custody-Sample Submittal Form

1. Client

Company Name	Company Address	Project Name
UAA & AK DOT	Not Provided	12075 UAA & AK DOT
Contact Name	**Phone**	**Email Address**
Mahear Aboueid	(907) 350-6777	mahear.aboueid@alaska.gov
PO #		
-		

2. Sample Collection

Sampled by	Company	Location	Date	Time	Sample Method
Client	UAa & AK DOT	-	-	-	-

3. Shipping / Delivery

# Samples	Carrier	Ship Date	Tracking #	Delivery Date/Time	Received By	Condition
13	Con-way	12/15/2015	420-083241	12/30/2015 9:30:00 AM	Jacobs, Zachary D.	Small tear in bag of cement. Otherwise, all samples intact

4. Sample Identification

Client ID	ATG	Sample Notes	Sample Notes 2	Description	Storage Conditions	Quantity
1	3946-1	Sand	All Purpose	AS&G,	349-3333, 60 lb bag	2
2	3946-2	Coarse Aggregate	3/4" Gravel	AS&G, 349-3333, 60 lb bag	Ambient	4
3	3946-3	Portland Cement	Type I	Alaska Basic Industries, 94 lb bag	Ambient	1
4	3946-4	Intermediate Aggregate	3/8" Pea Gravel	AS&G, 349-3333, 1 60 lb bag and 1 6" x 12" cylinder	Ambient	2
5	3946-5	No flyash included in this sample	-	-	-	-
6	3946-6	No water included in this shipment.	-	-	-	-
7	3946-7	Admixtures	500mL POLY HEED, 997	Alaska Freeze/Thaw	Ambient	1
8	3946-8	Rubber Pellets	~1/3 of a 5 gallon bucket	-	Ambient	1

Attachment 2 - Mix Design (provided by manufacturer)

Mahear Abou Eid
Steel Fiber Reinforced Rubberized Concrete

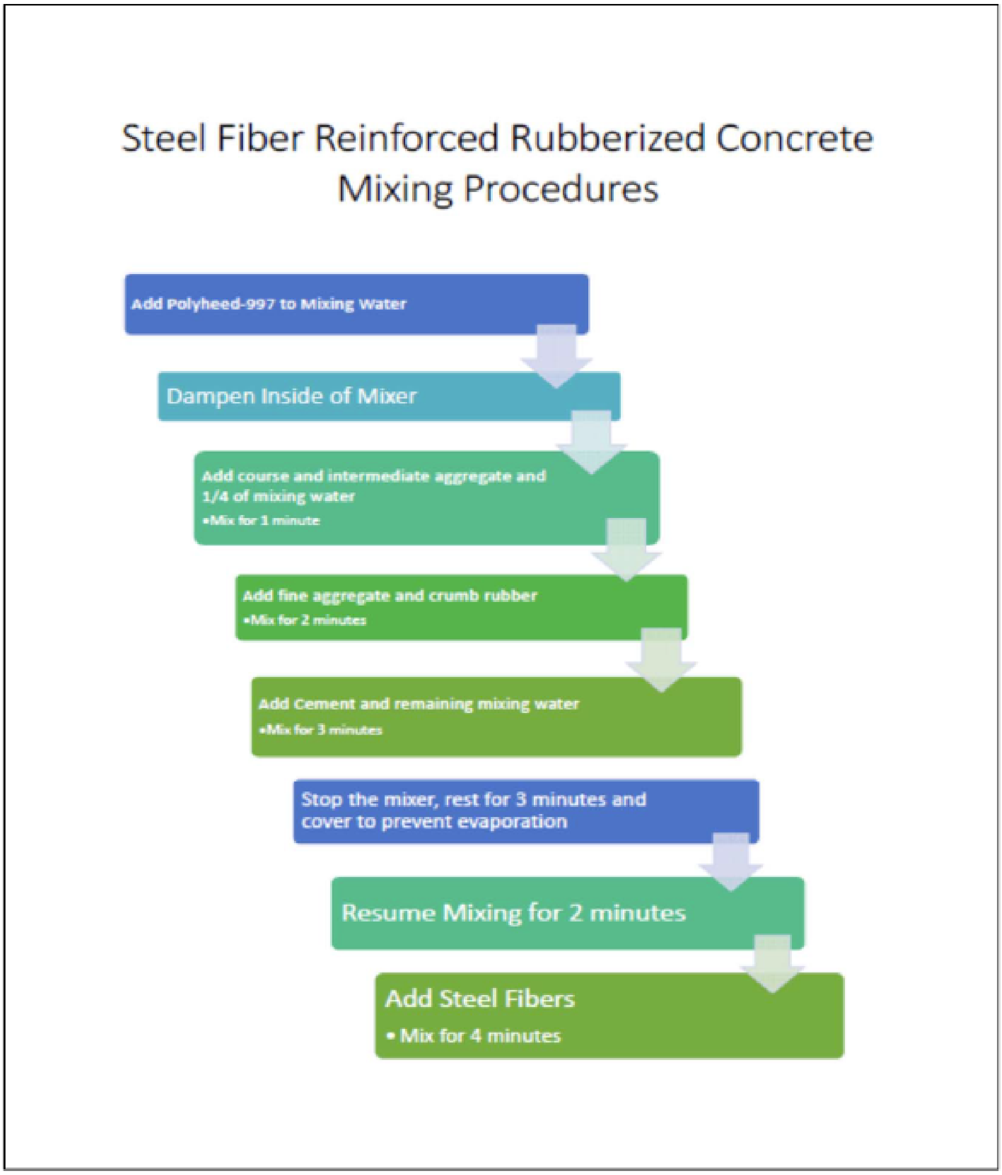
SFRRC Mix Design and Quantity Calculations
8/18/2015

Mix Design per Cubic Foot		
Cement	23.1	lb/ft3
Water	9.5	lb/ft3
w/c ratio	0.4	
Coarse Aggregate	68.9	lb/ft3
Intermediate Aggregate b	6.5	lb/ft3
Fine Aggregate	31.3	lb/ft3
PolyHeed-997	102.5	ml/ft3
Crumb Rubber	2.3	lb/ft3
Steel Fiber	6.3	lbs/ft3

Mix Design per Cubic Yard		
Cement	624.6	lb/CY3
Water	255.2	lb/CY3
w/c ratio	0.4	
Coarse Aggregate	1860.4	lb/CY3
Intermediate Aggregate b	174.6	lb/CY3
Fine Aggregate	844.8	lb/CY3
PolyHeed-997	2768.5	ml/CY3
Crumb Rubber	62.1	lb/CY3
Steel Fiber	169.3	lb/CY3

Sieve Size	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Blend Gradation	% Passing for 1-in Max Aggregate Size
2"	100	100	100	100	100
1-1/2"	100	100	100	100	100
1"	100	100	100	100	94-100
3/4"	97.4	100	100	98.5	76-82
1/2"	57.4	100	100	75.3	65-76
3/8"	31.3	98.3	100	60.1	56-66
#4	3.2	16.3	99.9	39.2	45-53
#8	0.2	0.5	91.3	33.5	36-44
#16	0	0.4	71.6	26.2	29-38
#30	0	0	47.3	17.3	19-28
#50	0	0	18.7	6.8	2-8
#100	0	0	4.7	1.7	0-2
#200	0	0	0.9	0.3	0-2
Blend Ratio	58%	5.50%	36.50%	100%	100%

Attachment 3 - Mixing Procedures (provided by manufacturer)



Attachment 4 - Photos

Photo #1
Date: 2/25/2016
Notes: Prisms 3946-10A pre-test

Photo #2
Date: 4/15/2016
Notes: Prisms 3946-10A post-test

Photo #3
Date: 2/25/2016
Notes: Prisms 3946-10B pre-test

Photo #4
Date: 4/15/2016
Notes: Prisms 3946-10B post-test

Photo #5
Date: 2/25/2016
Notes: Prisms 3946-10C pre-test

Photo #6
Date: 4/15/2016
Notes: Prisms 3946-10C post-test

Attachment 5 - Extended Data (Fundamental Transverse Frequency(Hz))

		3946-10-A (Cast) Machine3			3946-10-B (Cast) Machine3			3946-10-C (Cast) Machine3		
Date	Cycle	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
2/25/2016	0	1914	1914	1914	1934	1934	1934	1914	1914	1914
3/1/2016	30	1895	1895	1895	1914	1914	1914	1895	1895	1895
3/7/2016	60	1895	1895	1895	1934	1934	1914	1895	1895	1895
3/11/2016	90	1914	1914	1914	1914	1914	1914	1895	1895	1895
3/15/2016	120	1895	1895	1895	1914	1914	1914	1875	1875	1875
3/22/2016	150	1836	1836	1836	1875	1875	1875	1855	1855	1855
3/28/2016	180	1895	1895	1895	1914	1914	1914	1895	1895	1895
4/1/2016	210	1875	1875	1875	1914	1914	1914	1875	1875	1875
4/6/2016	240	1914	1914	1914	1934	1934	1934	1895	1895	1895
4/11/2016	270	1914	1914	1914	1934	1934	1934	1875	1875	1875
4/15/2016	300	1895	1895	1895	1934	1934	1934	1855	1855	1855
		RDME:	98	@300 Cycles	RDME:	100	@300 Cycles	RDME:	94	@300 Cycles
			Weight Gain(g):	-219.3		Weight Gain(g):	-119.3		Weight Gain(g):	-179.5

Figure 1 - 3946-10 Durability Data

End of Report

Table 3: Compressive Strength comparison for UAA vs. Applied Testing.

Freeze-Thaw Samples

Sample	Poured	Mixed At	Tested	Compressive Strength (PSI)	
1	8/16/2015	UAA Lab	11/8/2016	5030	
2	8/16/2015	UAA Lab	11/8/2016	4735	
4	9/4/2015	AS&G	11/8/2016	4348	
5	9/4/2015	AS&G	11/8/2016	4270	
Average:				**4595.8**	Difference
Third Party Applied Testing Result:				**4635**	101%

Control Samples

Sample	Poured	Mixed At	Tested	Compressive Strength (PSI)	
3	8/16/2015	UAA Lab	11/8/2016	4170	
7	9/4/2015	AS&G	11/8/2016	3833	
Average:				**4001.5**	Difference
Third Party Applied Testing Result:				**4040**	101%

UAA Test vs Control Samples:	115%
Applied Testing Test vs Control Samples:	115%

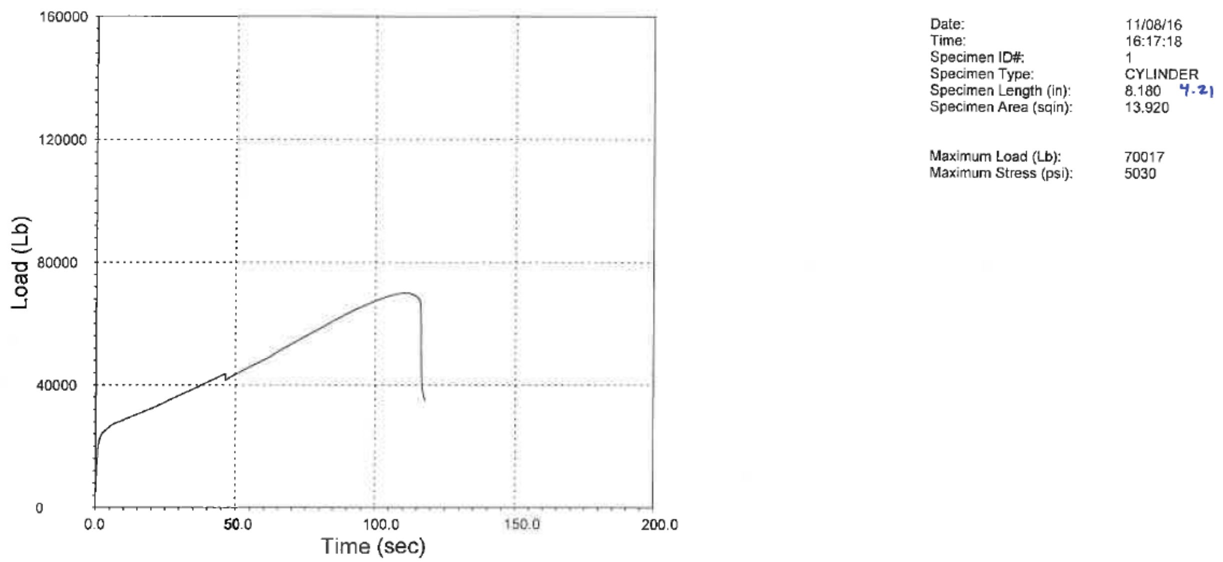


Figure 26: Compressive strength curve for experimental freeze-thaw UAA batched sample.

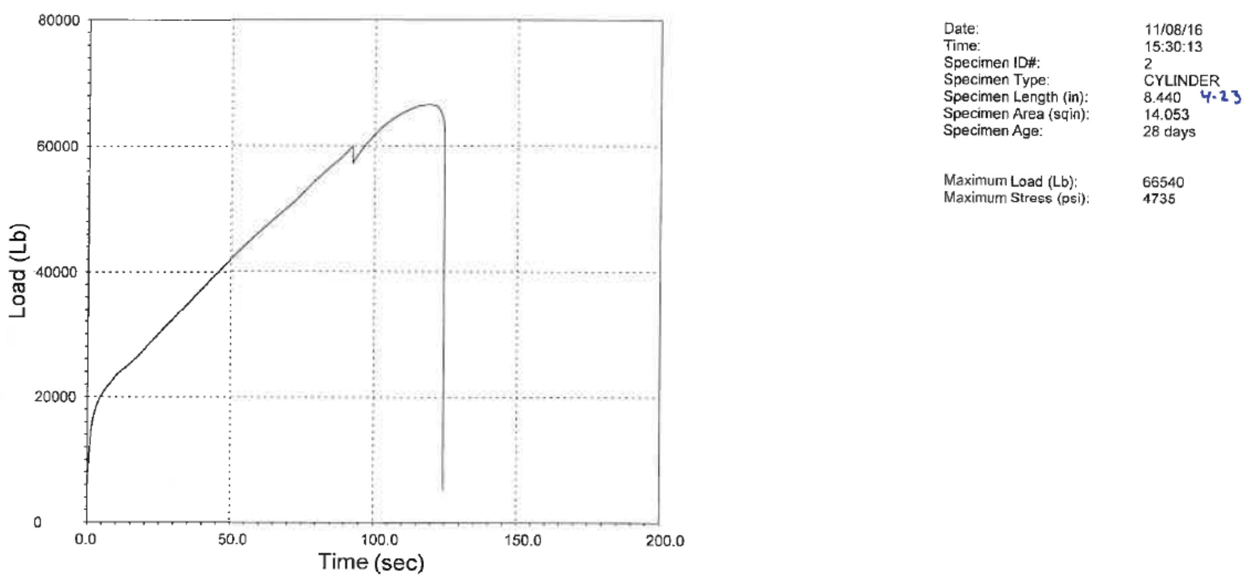


Figure 27: Compressive strength curve for control freeze-thaw UAA batched sample.

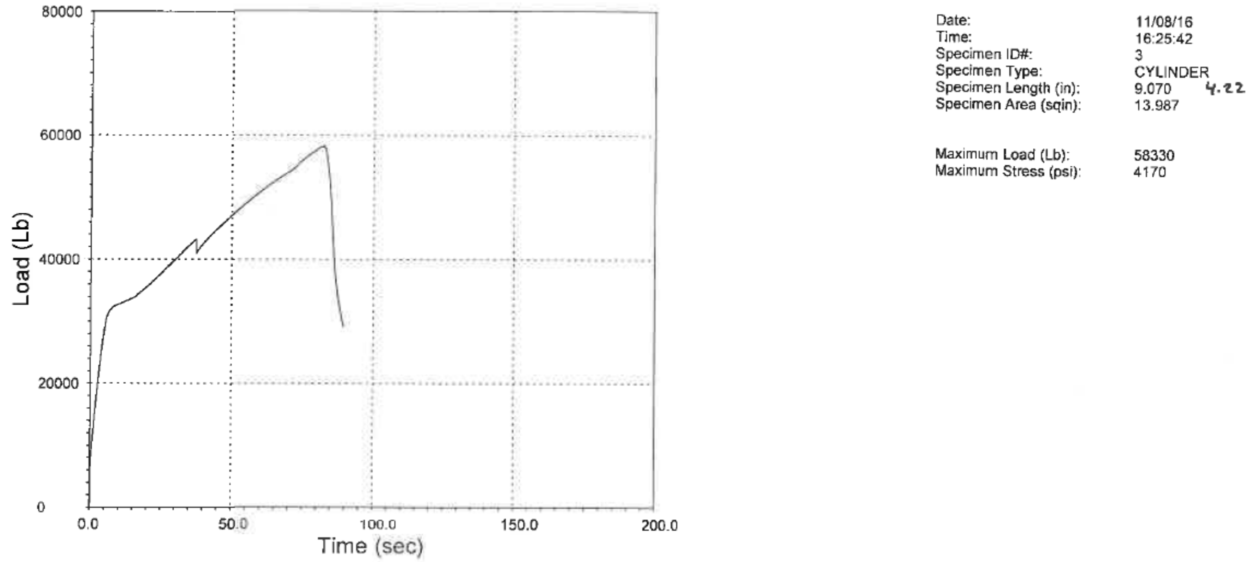


Figure 28: Compressive strength curve for control freeze-thaw UAA batched sample.

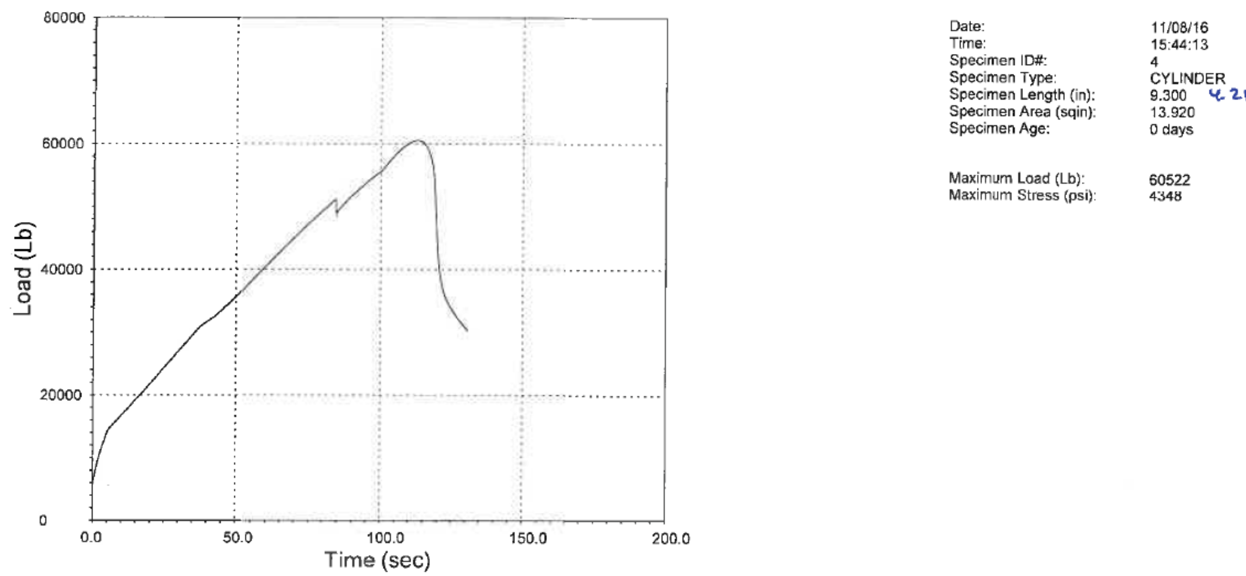
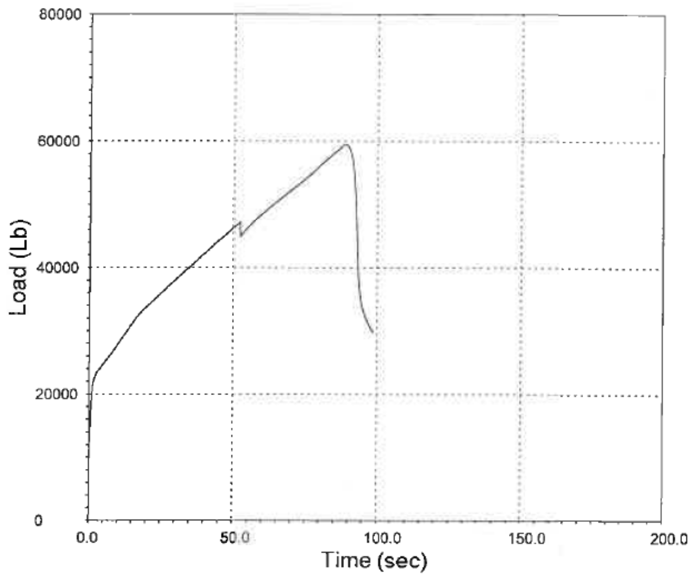
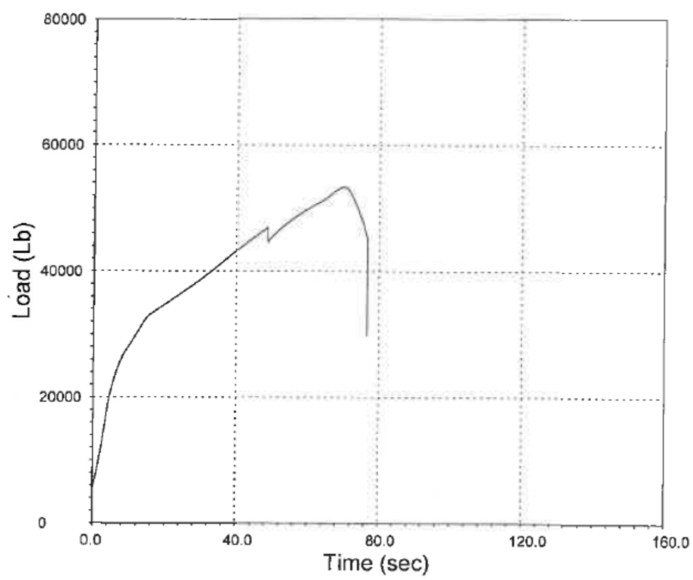


Figure 29: Compressive strength curve for experimental freeze-thaw AS&G batched sample.



Date:	11/08/16
Time:	16:04:22
Specimen ID#:	5
Specimen Type:	CYLINDER
Specimen Length (in):	9.070 4.21
Specimen Area (sqin):	13.920
Maximum Load (Lb):	59443
Maximum Stress (psi):	4270

Figure 30: Compressive strength curve for experimental freeze-thaw AS&G batched sample.



Date:	11/08/16
Time:	15:56:08
Specimen ID#:	7
Specimen Type:	CYLINDER
Specimen Length (in):	9.290 4.21
Specimen Area (sqin):	13.920
Maximum Load (Lb):	53363
Maximum Stress (psi):	3833

Figure 31: Compressive strength curve for control freeze-thaw AS&G batched sample.

Appendix F – Wheel Tracker Tests and Calculations

Report singol test

General Data

Final rut depth	-0,03 mm		
Failure test	NO	End	Cycle number
Density	1571 Kg/m^3	Void Percentage	
Type of thermal medium	Water	Feedback used	In tank
Max Temp	27,6 °C	in Cycles	19871
Min Temp	23,0 °C	in Cycles	38
Customer	<Generic>		

Mixture

Mixture	NoMisture		
	Type	Weight (%)	Spec. weight (kg/m3)
Aggregate	-	0,00	0
Filler	-	0,00	0
Bitumen	-	0,00	0
Calculated Max Density	0 Kg/m^3	Production Type	-
Production Date	28/02/2016		
Compaction Type	-	Time conditioning	-

Start data test

Sample on test	1	Sample Number	4
ID Sample	2	Sample Name	full test1
Date	26/02/2016 11.33.20	Sample Type	Plate
Lenght	360,00 mm	Width	298,00 mm
Diameter		Thikness	89,00 mm
Weight	15,000 Kg	Age	28 dd
Max Rut depth	25,00	Max Number cycles	20000
Test Temp	21,0 °C	Wheels speed	25,0 cycle/min
Time to start	1 min	Operator	MF
Cond. cycles	20 Cycles	Temp Limit.	25,0 °C

Test processing

Processing type	No Procedure

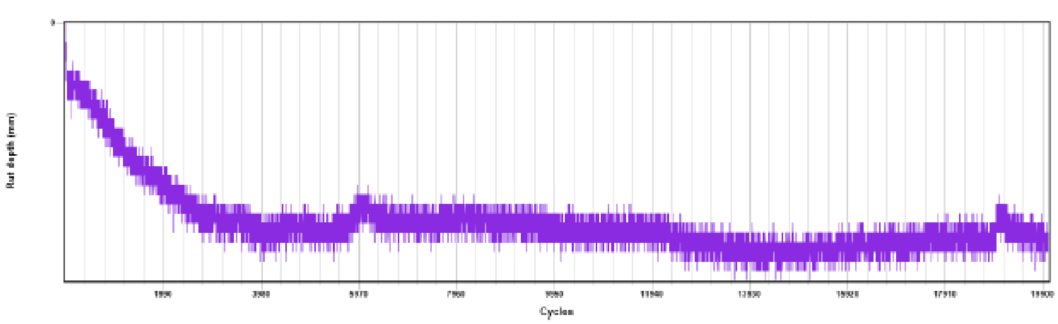


Figure 32: Pavelab wheel tracker output for steel wheel test (Report 1 of 2).

CONTROLS PAVELAB SYSTEMS

EXCELLENCE IN PAVEMENT TESTING SOLUTIONS

Report singol test

General Data

Final rut depth	-0,01 mm		
Failure test	NO	End	Cycle number
Density	1571 Kg/m^3	Void Percentage	
Type of thermal medium	Water	Feedback used	In tank
Max Temp	27,1 °C	in Cycles	18973
Min Temp	22,5 °C	in Cycles	45
Customer	<Generic>		

Mixture

Mixture	NoMisture		
	Type	Weight (%)	Spec. weight (kg/m3)
Aggregate	-	0,00	
Filler	-	0,00	0
Bitumen	-	0,00	0
Calculated Max Density	0 Kg/m^3	Production Type	-
Production Date	28/02/2016		
Compaction Type	-	Time conditioning	-

Start data test

Sample on test	2	Sample Number	5
ID Sample	3	Sample Name	Full test2
Date	26/02/2016 11.33.21	Sample Type	Plate
Lenght	360,00 mm	Width	298,00 mm
Diameter		Thikness	89,00 mm
Weight	15,000 Kg	Age	28 dd
Max Rut depth	25,00	Max Number cycles	20000
Test Temp	21,0 °C	Wheels speed	25,0 cycle/min
Time to start	1 min	Operator	MF
Cond. cycles	20 Cycles	Temp Limit.	25,0 °C

Test processing

Processing type	No Procedure

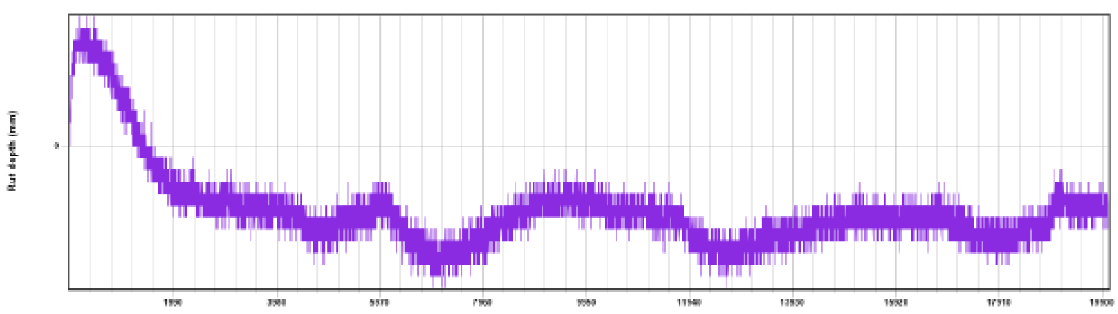


Figure 33: Pavelab wheel tracker output for steel wheel test (Report 2 of 2).

Table 4: HMA Wheel Tracker Results with Steel and Studded Rubber Wheel.

UAA Pavement Lab | Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA) | AASHTO T 324

Ingra and Gambell, HMA Type VH						
Comp. Date	6/14/2016	6/16/2016	6/17/2016	6/18/2016	6/21/2016	6/21/2016
Sample	1	2	3	4	5	6
Truck	343	325	555	342	357	353
Ticket	500110	500066	49978	499927	499882	500284
Time	3:02 AM	11:38 AM	8:50 AM	2:31 AM	9:39 PM	12:44 AM
Temperature	335°F	347°F	340°F	336°F	350°F	342°F
Station	61+50	27+00	100+00	28+70	153+50	41+50
Offset	50'RT	60'RT	15'RT	50'RT	10'R	60'LT
Lift	TOP2"	TOP2"	TOP2"	TOP2"	TOP2"	TOP2"
Sampler	TC 1062	TC 1062	AA 764	TC 1062	TC 1062	TC1062
Date	9/22/15	9/22/15	9/20/15	9/21/15	9/21/15	9/23/15
Test	HMAVH-30	HMAVH 28	HMAVH 21ck	HMAVH-27	HMAVH-25	HMAVH
	Measurements taken after heating sample to proper compaction temperatures					
Out the Oven	11:30:00 AM	14:30 PM	15:30 PM	16:30 PM	11:00:00 AM	1:40:00 PM
Weight (lb)	10.8	11.4	12.3	11.9	12.2	12.2
Height (in)	4.53	5.00	5.38	5.24	5.36	5.35
Cycles	100	90	8	11	10	11
	Measurements taken after performing roller wheel compaction					
Density (pcf)	150.06	144.37	147.64	147.01	143.72	144.20
Weight (lb)	10.8	11.4	12.3	11.9	12.2	12.2
Height (in)	0.38	0.42	0.44	0.43	0.45	0.45
Volume (cf)	0.072	0.079	0.084	0.081	0.085	0.085
Wheel Rotations during Test			10	10	20	20
Rut Depth, Steel Wheel (in)			0.09	0.05	0.06	0.08
Rut Depth, Studded Rubber Wheel (in)			0.17	0.13	0.14	0.16
Percent Difference			187%	254%	239%	195%

Lake Hood A-B Parking, HMA Type II						
Comp. Date	6/23/2016	6/23/2016	6/23/2016	6/23/2016	6/23/2016	6/23/2016
Sample	7	8	9	10	11	12
Truck	A180	924	373	A798	A079	512
Ticket	2454700b	24546925	24546859	24546724	24546832	24546764
Time	4:26 PM	11:01 AM	4:47 PM	5:38 PM	2:15 PM	9:02 AM
Temperature	310°F	320°F	345°F	311°F	324°F	324°F
Station	1+10	3+81	2+50	1+00	1+82	4+84
Offset	240'LT	114'LT	185'LT	80'LT	213'LT	18'LT
Lift	TOP2"	TOP2"	TOP2"	TOP 4FT*	TOP2"	TOP2"
Sampler	VC923	VC923	VC923	VC923	VC923	AA764
Date	5/8/2015	5/8/2015	4/8/2015	3/8/2015	4/8/2015	4/8/2015
Test	HMA-6	HMA-5	HMA-4	HMA-1	HMA-3	HMA-2
	Measurements taken after heating sample to proper compaction temperatures					
Out the Oven	9:00:00 AM	10:00:00 AM	11:00:00 AM	12:00:00 AM	2:00:00 PM	3:00:00 PM
Weight (lb)	12.2	11.9	12.2	11.9	11.9	12.1
Height (in)	5.37	5.24	5.36	5.24	5.23	5.31
Cycles	37	42	57	28	25	47
	Measurements taken after performing roller wheel compaction					
Density (pcf)	143.61	143.63	143.59	143.76	143.63	143.66
Weight (lb)	12.2	11.9	12.2	11.9	11.9	12.1
Height (in)	0.45	0.44	0.45	0.44	0.44	0.44
Volume (cf)	0.085	0.083	0.085	0.083	0.083	0.084
Wheel Rotations during Test			20	20	10	10
Rut Depth, Steel Wheel (in)			0.06	0.08	0.05	0.05
Rut Depth, Studded Rubber Wheel (in)			0.14	0.16	0.13	0.13
Percent Difference			240%	200%	249%	248%

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201
Laboratory Report

REVISED
08/22/2015

Quality
Laboratory No.: **2015A-3134**

Name: **Ingra and Gambell Phase I paving, 5th to 36th** Project No.: **57858** /000 1546
Sample: **HMA type VH** Item/Spec No.: **408(1H)** Field No.: **Q-HMAVH-MD-1**
Sampled From: **Manufacturer's Stock** Date Sampled: **06/17/2015**
Source **Cantwell / MP78 (KASH) / QAP** Quantity Represented: **Source** Date Received: **06/20/2015**
Location: **Anchorage** Submitted By: **QAP** Date Completed: **08/20/2015**
Examined For: **Bituminous Mix Design** Date Reported: **08/20/2015**

AGGREGATE

Blend Ratio 14:22; :32:32: ;
CA:IA:NF:CF:BS:MF:RP

Blend Specific Gravity Bulk **2.754** Effective **2.815**

Sieve	% Pass		Specs
1"			
3/4"	100		100
1/2"	90		84-96
3/8"	80		74-86
#4	55		49-61
#8	40		34-46
#16	29		24-34
#30	21		17-25
#50	13		9-17
#100	8		5-11
#200	5.6		3.6-7.6
FA FM		2.98	
FA Angularity		48.0	45 min
CA Absorption		0.6	2.0 max
% Fracture Double Face		99	98 min
% Flat / Elongated @ 1:3		19	
@ 1:5		2	8 max
Plastic Index		NP	NP

ASPHALT

Brand & Typ	EP 58-34
Specific Gravity	1.006
Mixing Temp. Range	325-335°F
Comp. Temp. Range	305-315°F

ANTI-STRIP ADDITIVE

Brand & Type	Morelife 5000
Minimum Required	0.25%

AASHTO R35
75 Gyrations

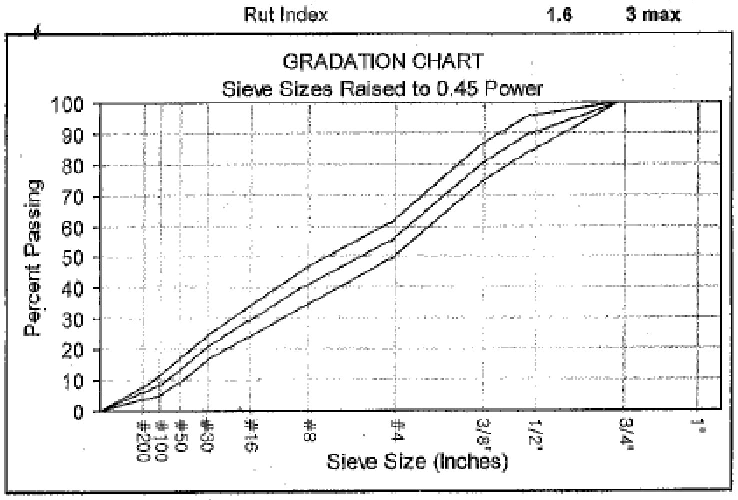
Related Tests
2015A-1869
2015A-0614

Oven 3, 5D

ASPHALT CONTENT, %

@ 4.0% Voids Total Mix	5.1
Approved Optimum	5.3
Specifications	4.9-5.7

PROPERTIES @ OPTIMUM		Specs
Max. SpG (AASHTO T209)	2.570	
Max. SpG Unit Wt., pcf	160.0	
Voids		
Filled	78	65-78
Total Mix	3.0	4.0
In Mineral Aggregate	14.4	13.0+
In Coarse Aggregate		
Stability, lbs		
Flow, 0.01 inches		
Unit Weight, pcf	155.0	
Dust/Asphalt Ratio	1.2	0.6-1.2
Rut Index	1.6	3 max



Remarks:

```
Transferred from lab No. 2015A-1868 on 08/20/2015.
Sample originally completed on 07/07/2015.
Gyrations    %Gmm    Specs.
Nini   7     87.5    <90.5
Ndes  75     96.0     96.0
Nmax 115     97.2    <98.0
```

From NL

Signature: DRAFT
Newton J. Bingham, PE
Regional Materials Engineer

D1X The Material as Submitted Conforms to Specifications
Yes [ ] No [ ] NA [ ]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

Figure 34: DOT&PF HMA mix design for Type V asphalt with hard aggregate.

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

Laboratory Report

Quality

Laboratory No.: **2015A-1242**

Name: **Lake Hood A&B Parking Rehabilitation** | Project No.: **54465 / 3-02-0013-XXX-2014**
Sample: **HMA Type IIA** | Item/Spec No.: **P-401a** | Field No.: **Q-HMAIIA-MD-1**
Sampled From: **Manufacturer's Stock** | Date Sampled: **05/26/2015**
Source **MP 39 Glenn Highway / AS&G** | Quantity Represented: **Source** | Date Received: **05/30/2015**
Location: **Anchorage** | Submitted By: **Granite Const.** | Date Completed: **06/29/2015**
Examined For: **Bituminous Mix Design** | Date Reported: **06/29/2015**

AGGREGATE

Blend Ratio **24:26: :50: : :**
CA:IA:NF:CF:BS:MF:RP

Blend Specific Gravity: Bulk **2.709**, Effective **2.761**

Sieve	% Pass		Specs
1"			
3/4"	**100**		**100**
1/2"	**85**		**79-91**
3/8"	**71**		**65-77**
#4	**49**		**43-55**
#8	**34**		**28-40**
#16	**22**		**17-27**
#30	**15**		**11-19**
#50	**10**		**6-14**
#100	**7**		**4-10**
#200	**5.0**		**3.0-7.0**
FA FM		**3.20**	
FA Angularity			
CA Absorption		**0.7**	2.0 max
% Fracture Double Face		**99**	**90 min**
% Flat / Elongated @ 1:3		**16**	
@ 1:5		**2**	**8 max**
Plastic Index		**NP**	**6 max**

ASPHALT

Brand & Typ **Denali PG 58-34**
Specific Gravity **1.007**
Mixing Temp. Range **325-335°F**
Comp. Temp. Range **305-315°F**

ANTI-STRIP ADDITIVE

Brand & Type **Morelife 5000**
Minimum Required **0.25%**

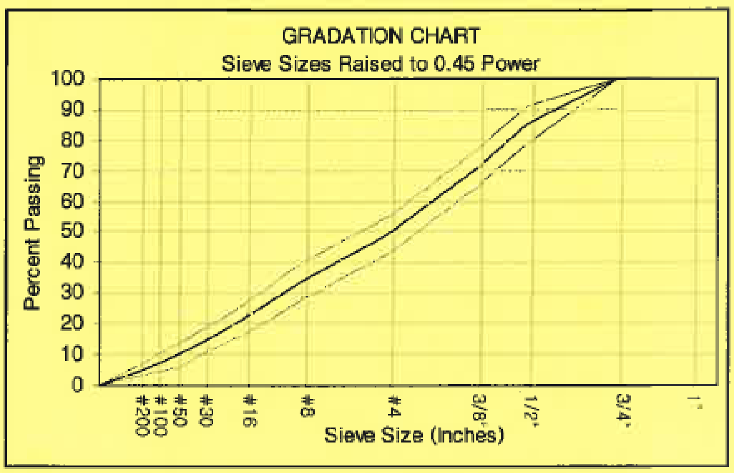
ATM 417
75 Blow

Related Tests
2015A-1243
2015A-1195

ASPHALT CONTENT, %

@ 4.0% Voids Total Mix	**5.2**	
Approved Optimum	**5.3**	
Specifications	**4.9-5.7**	

PROPERTIES @ OPTIMUM		Specs
Max. SpG (AASHTO T209)	**2.528**	
Max. SpG Unit Wt., pcf	**157.4**	
Voids		
Filled	**75**	
Total Mix	**3.8**	**2.8-4.2**
In Mineral Aggregate	**15.0**	**13.0+**
In Coarse Aggregate		
Stability, lbs	**3210**	**2150+**
Flow, 0.01 inches	**12**	**10-14**
Unit Weight, pcf	**151.4**	
Dust/Asphalt Ratio	**1.1**	
Rut Index		



Remarks:

D9 The Material as Submitted Conforms to Specifications
Yes [X] No [ ] NA [ ]

Signature: Newton Bingham
Newton J. Bingham, PE
Regional Materials Engineer

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

Figure 35: DOT&PF HMA mix design for Type II standard asphalt.

Appendix G – Trial Slab Calculations and Photos

Table 5: SFRRC Testing and UAA Trial Slab quantity calculations (3 pages)

Mahear Abou Eid
Steel Fiber Reinforced Rubberized Concrete

SFRRC Mix Design and Quantity Calculations
8/18/2015

Mix Design per Cubic Foot			Blend Ratio
Cement	23.1	lb/ft3	
Water	9.5	lb/ft3	
w/c ratio	0.4		
Coarse Aggregate	68.9	lb/ft3	65%
Intermediate Aggregate b	6.5	lb/ft3	6%
Fine Aggregate	31.3	lb/ft3	29%
PolyHeed-997	102.5	ml/ft3	
Crumb Rubber	2.3	lb/ft3	
Steel Fiber	6.3	lbs/ft3	

Mix Design per Cubic Yard		
Cement	624.6	lb/CY3
Water	255.2	lb/CY3
w/c ratio	0.4	
Coarse Aggregate	1860.4	lb/CY3
Intermediate Aggregate b	174.6	lb/CY3
Fine Aggregate	844.8	lb/CY3
PolyHeed-997	2768.5	ml/CY3
Crumb Rubber	62.1	lb/CY3
Steel Fiber	169.3	lb/CY3

Sieve Size	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Blend Gradation	% Passing for 1-in Max Aggregate Size
2"	100	100	100	100	100
1-1/2"	100	100	100	100	100
1"	100	100	100	100	94-100
3/4"	97.4	100	100	98.5	76-82
1/2"	57.4	100	100	75.3	65-76
3/8"	31.3	98.3	100	60.1	56-66
#4	3.2	16.3	99.9	39.2	45-53
#8	0.2	0.5	91.3	33.5	36-44
#16	0	0.4	71.6	26.2	29-38
#30	0	0	47.3	17.3	19-28
#50	0	0	18.7	6.8	2-8
#100	0	0	4.7	1.7	0-2
#200	0	0	0.9	0.3	0-2
Blend Ratio	58%	5.50%	36.50%	100%	100%

Preliminary Testing Quantites

Description	Wheel Tracker	Freeze-Thaw	Compressive Strength	Prall Test
Area (ft2)	1.16	0.20	0.20	0.08
Thickness (in)	4	8	12	1.18
Number of Samples	4	8	3	6
Volume (ft3)	1.55	1.05	0.59	0.05
Total Volume (ft3)	3.24			

Total Quantities Required				Remarks
Cement	23.1	74.9	lb	
Water	9.5	30.6	lb	
w/c ratio	0.4	0.4		
Coarse Aggregate	68.9	223.0	lb	
Intermediate Aggregate	6.5	20.9	lb	
Fine Aggregate	31.3	101.3	lb	Adjusted weight based on 15% Crumb Rubber Replacement
PolyHeed-997	102.5	331.9	ml	
Crumb Rubber (%)	2.3	7.4	lbs	Based on SPG of 1.11 for Crumb Rubber and SPG of 2.715 for fine aggregate
Steel Fiber	6.3	20.3	lbs	

Converting Crumb Rubber Percentage to Weight Replacement of Fines

Fine Aggregate		
Weight	101.3 lb	
SPG	2.715	Specific Gravity
Volume (ft3)	0.60 ft3	Wt /(SPG x 62.4)
Crumb Rubber		
SPG	1.11	Specific Gravity
Volume (ft3)	0.09 ft3	15% x Fine Volume
Weight	6.21 lb	Rubber Volume x SPG x 62.4

Rubber Content By Total Weight of Mix 0.9%

UAA Trial Slab

Description	UAA Slab			
Area (ft2)	300.00			
Thickness (in)	7			
Number of Samples	1			
Volume (ft3)	175.00			
Total Volume (ft3)		**175.00**		

Total Quantities Required				Remarks
Cement	23.1	4048.5	lb	
Water	9.5	1654.2	lb	
w/c ratio	0.4	71.5		
Coarse Aggregate	68.9	12058.5	lb	
Intermediate Aggregate	6.5	1131.8	lb	
Fine Aggregate	31.3	4654.4	lb	Adjusted weight based on 15% Crumb Rubber Replacement
PolyHeed-997	102.5	17944.0	ml	
Crumb Rubber (%)	2.3	335.8	lbs	Based on SPG of 1.11 for Crumb Rubber and SPG of 2.715 for fine aggregate
Steel Fiber	6.3	1097.0	lbs	

Converting Crumb Rubber Percentage to Weight Replacement of Fines

Fine Aggregate			
Weight	5475.8	lb	
SPG	2.715		Specific Gravity
Volume (ft3)	32.32	ft3	Wt /(SPG x 62.4)
Crumb Rubber			
SPG	1.11		Specific Gravity
Volume (ft3)	4.85	ft3	15% x Fine Volume
Weight	335.81	lb	Rubber Volume x SPG x 62.4

Rubber Content By Total Weight of Mix 0.8%

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:		Project Name:	UAA SFRRC Slab			
Weather: 55 F Cloudy and Light Rain		Shift:	11:00 AM	to	4:00 PM	Tuesday, September 8, 2015
Contractor's Representative and Title:						

Contractor's Equipment						Contractor's Work Force	
No.	Description	Hours			Remarks	No.	Classification/Duties
		Worked	Stdby	Down			
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							Finishing Edge
2	Finishing Edge P/U Trucks					1	Manager (Chuck McHenry)
1	Finishing Edge Flatbed P/U Truck					4	Concrete Finishing Laborers

Limits of Work/Material Placement							
Item No.	Description	Sources(Limits)		Placement		Approx. Quantity	Sections/Work Completed & Accepted
		From	To	From	To		
	Portland Cement Concrete					6 CY	
	1" Steel Fibers					1100 Lbs	Novocon 0730FE
	No. 8 Crumb Rubber					395 Lbs	QAP Stockpile

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Figure 36: Inspector's daily report for SFRRC UAA slab mixing and placement (2 pages).

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were cloudy and calm with light showers, temperatures ranging from 48 to 55 degrees.

11:30 AM: Arrived at AS&G Batch Plant to discuss proportions and mixing with Scott Brown and Pat Walter. A 6 cubic yard batch will be made in order to ensure that excess material is made if necessary for further testing. We discussed air entrainment and decided in order to keep consistent with our laboratory testing that we would not inject any air entrainment admixtures. We also discussed proportions of the steel fibers and the crumb rubber to verify batch size. The steel fibers were shipped in 45 pound boxes so it was determined for our batch size that 25 boxes would be needed. In addition, we discussed the procedures for adding the steel fibers and crumb rubber to the batch. The steel fibers will be added to the concrete truck as the concrete is slowly poured out of the mixing barrel. By doing this the steel fibers can mix thoroughly throughout the entire batch and the mixing barrel will not require a full cleaning procedure to remove any remaining steel fibers. The addition of the crumb rubber was determined to be most effectively completed after the steel fibers and other materials were mixed into the concrete truck. The truck would pull under a platform where a large sack with the required weight of crumb rubber could be lifted and dumped into the truck chute as it is mixed. The rubber would be dispersed slow enough that the material would thoroughly mix throughout the concrete truck barrel.

12:10 PM: The mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures.

12:15 PM: The mixed material was slowly poured out of the mixing barrel as 4 laborers, 2 on each side of the chute leading down to the concrete truck, sprinkled the steel fiber material into the chute. The 45 pound boxes were easily transportable and served to proportion the adding of the steel fibers so that no clumping could occur.

12:20 PM: The addition of the steel fibers was complete without any issues. The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.

12:25 PM: Addition of the crumb rubber material was complete and it was agreed that the method was efficient and effective. The truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product.

12:30 PM: The mixed material was poured into a wheel barrel for testing purposes and visually determined to be evenly distributed with steel fibers and rubbers. Slump and air entrainment tests were complete and resulted in 3.5" and 4.5%, respectively. In addition, 3 compressive strength cylinders and 3 flexural strength beams were formed.

12:35 PM: The truck left the AS&G batch plant and transported the SFRRC material to the UAA Slab location at the west entrance to the UAA parking garage near the Consortium Library.

12:42 PM: The concrete truck arrived to the prepared site where Finishing Edge was ready to begin the placement and finishing of the material. Finishing Edge had a crew of 4 people and already had prepared the surface by spreading plastic material near the transverse joints and placed expansion fiber at the edge joints against the existing concrete curb and gutters.

1:00 PM: Alaska DOT Materials Tech, Tim Burlingham was onsite and tested the material for slump and air entrainment with results of 4.5" and 6%, respectively. Tim's values were higher than that of AS&G and is believed to be from the further mixing of the material as it was transported.

1:30 PM: The pouring of the SFRRC material was complete and excess material was taken from the concrete truck for testing specimens to be formed.

1:50 PM: The concrete truck completed removal and cleaning of remaining material and left the site. Finishing Edge continued to spread and finish the concrete surface. A contraction joint was formed into the concrete at the center of the slab.

2:30 PM: The excess material was formed into 3 compressive strength cylinders, 3 flexural strength beams, 6 wheel tracker slabs, 3 Prall test cylinders and 4 Freeze-Thaw cylinders. Finishing Edge remained onsite to allow concrete to harden prior to establishing a broom finish in the slab.

3:30 PM: The material cured enough that a broom finish could be placed on the surface. All crews left the site and work was concluded on the slab at this point. The traffic control will remain in place until Tuesday morning so that the slab concrete could cure for over 3 days prior to allowing traffic on it.

Date: 9/4/2015	Inspector's Signature:	Page No. 2 of 2

Figure 37: Novocon 1050 FE Steel fibers being prepared for pouring

Figure 38: Pouring in steel fibers to mixing chute leading to transport vehicle

Figure 39: Adding pre-weighed crumb rubber from large sack to transport vehicle chute.

Figure 40: Performing slump test at AS&G facility.

Figure 41: Preparing test molds at UAA trial slab location for SFRRC pour.

Figure 42: UAA trial slab SFRRC placement with Finishing Edge on-site to place material.

Figure 43: Finishing Edge spreading and troweling SFRRC material.

Figure 44: Finishing of UAA trial slab surface.

Figure 45: UAA trial slab during first winter season of use.

Figure 46: Close view of SFRRC during first season of use.

Appendix H – Abbott Rd. Casting Panel Reports, Testing and Photos

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	AMATS: Abbott Rd Rehab-Phase I		
Weather:	55 F	Cloudy and Light Rain	Shift:	10:00 AM	to	2:30 PM	Thursday, August 25, 2016
Contractor's Representative and Title:						

Contractor's Equipment						Contractor's Work Force	
No.	Description	Hours			Remarks	No.	Classification/Duties
		Worked	Stdby	Down			
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement							
Item No.	Description	Sources(Limits)		Placement		Approx. Quantity	Sections/Work Completed & Accepted
		From	To	From	To		
Portland Cement Concrete						2.5	
1" Steel Fibers						425 Lbs	Novocon 0730FE
No. 8 Crumb Rubber						155 Lbs	QAP Stockpile
515(1) Precast Concrete Slab System						1 of 15 Panels	Forming and pouring
							Page No. 1 of 2

Figure 47: Pre-casting Inspection Reports (7 reports)

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were cloudy and calm with light showers, temperatures ranging from 55 to 60 degrees.
10:15 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures.
10:30 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.
10:35 PM: The addition of the steel fibers was complete without any issues. Some clumping of the fibers was noticed and may be due to the large garbage pale pour instead of dispersing each box slowly and individually. The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.
10:40 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product.
10:50 AM: The mixed material was poured into a wheel barrel for testing purposes and visually determined to be more dry and course than previous batches. Slump and air entrainment tests were complete and resulted in 0.5" and 3.5%, respectively. In addition, compressive strength cylinders and flexural strength beams were formed. The dryness and courseness of the mix was discussed and may be due to the smaller batch volume. Fine particles during any batching operation will adhere to the inside of a concrete truck barrel, but since this is such a small batch the proportion of fines in the mix that is required to coat the inside of the barrel is greater than typical with a 6-8 cu yard pour. Possible mitigation to the situation will be only batching a minimum of 4-5 cu yds.
11:18 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled form began. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers.
11:25 AM: Alaska DOT Materials Technicians, Tim Burlingham and Abbey Castle were onsite and tested the material for slump and air entrainment with results of 2" and 2.5%, respectively. The drop in air content was a different result then the last batch trial, where the air content rose after mixing and transport. Again batch size may be related to the differences in the material characteristics. It is assumed that the crumb rubber contributes to air entrainment and if a large percentage of these particles adhere to the truck barrel a drop in air content could result.
12:25 PM: The pouring of the SFRRC material was complete and a final sample was taken by UAA for washing and determination of material proportions. The concrete truck completed cleaning of remaining material and left the site. D&S completed the first finishing of the SFRRC surface. Josh stated that placing was a little more difficult than typical concrete, but finishing it was fairly easy.
2:15 PM: The material cured enough that a broom finish could be placed on the surface. Josh stated that the second finish was more difficult than the initial and required working the material more than usual to get the correct finish.

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STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	AMATS: Abbott Rd Rehab-Phase I		
Weather:	55 F	Cloudy and Light Rain	Shift:	12:30 PM	to	4:00 PM	Monday, August 29, 2016
Contractor's Representative and Title:						

Contractor's Equipment						Contractor's Work Force	
No.	Description	Hours			Remarks	No.	Classification/Duties
		Worked	Stdby	Down			
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No.	Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
	Portland Cement Concrete					5.25	
	1" Steel Fibers					889	Novocon 0730FE
	No. 8 Crumb Rubber					326	QAP Stockpile
	515(1) Precast Concrete Slab System					Panels 2 & 3 of 15	Forming and pouring

Page No. 1 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were clear and sunny, temperatures ranging from 60 to 70 degrees.

12:20 PM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.

12:35 PM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute. Discussed with the laborers that it was important to slowly pour the fibers so that clumping could be avoided and allow time for them to spread away from one and another.

12:40 PM: The addition of the steel fibers was complete without any issues. Less clumping of the fibers was noticed than the previous pour, but was still present.

12:45 PM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.

12:50 PM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product.

12:55 PM: The mixed material was poured into a wheel barrel for testing purposes and visually determined to be more workable and consistent than the previous batch on 8/25/16. Slump and air entrainment tests were complete and resulted in 6.5" and 5%, respectively. In addition, compressive strength cylinders were formed.

1:12 PM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. The two forms were equipped with the three strain gages and inspected by Subterra who was onsite. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers.

1:20 PM: Alaska DOT Materials Technicians, William Nelson and Abbey Castle were onsite along with Anna Ferntheil, the Materials Rover and tested the material for slump and air entrainment with results of 5" and 9.5%, respectively. The drop in slump was consistent with standard concrete on a warm day, but the rise in air by almost double was unusual. This could be due to the additional high range admixture coupled with the concrete truck driver agitating the mix aggressively once onsite as directed by the AS&G Quality Control Manager. Possibly less agitation would solve the increase in air issue.

1:53 PM: As the material was being finished it was noticeably easier to work with per Josh Harmon, but there was an issue with the surface layer having linear voids opening up as they screeded the material. This was determined to be due to the lower fines content and the high ambient temperatures drying out the surface. Josh requested to mist the surface to allow for increase in workability and to try finishing the voids. Discussed this with the UAA material rep and approved the request.

2:05 PM: The added misting to the surface allowed the slab to be sealed smoothly and finish well. All equipment and crews completed work until the material cured adequately to begin the broom finishing process.

3:20 PM: With the sun shining bright and ambient temperatures so high the material cured quicker than previous pours and broom finishing was started.

3:40 PM: The crew completed work for the day.

Date: 8/25/2016	Inspector's Signature:	Page No. 2 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	**AMATS: Abbott Rd Rehab-Phase I**		
Weather:	65 F	Clear	Shift:	10:00 AM	to	2:00 PM	Wednesday, August 31, 2016
Contractor's Representative and Title:	Martin Meenaghan, QAP Project Engineer					

Contractor's Equipment						**Contractor's Work Force**	
No.	Description	Hours			Remarks	No.	Classification/Duties
		Worked	Stdby	Down			
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No.	Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
	Portland Cement Concrete					5.25	
	1" Steel Fibers					889	Novocon 0730FE
	No. 8 Crumb Rubber					326	QAP Stockpile
	515(1) Precast Concrete Slab System					Panels 4 & 5 of 15	Forming and pouring

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STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were clear and sunny, temperatures ranging from 60 to 70 degrees.
10:20 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.
10:25 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.
10:35 AM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.
10:53 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product. The mixed material was poured into a wheel barrel for testing purposes and visually determined to more dry and stiff than the previous mix on 8/29/16. An additional 20 oz of BASF PS 1466 was added to the mixing barrel and agitated. Slump and air entrainment tests were complete and resulted in 2" and 5.2%, respectively. The low slump was unusual based on previous results and the addition of the high range admixture. Some variability could be due to the truck barrels, either being used for earlier work during the day or not. The previously used trucks would already have moisture and possibly fines still in them which would allow the mix to not lose any properties compared to the trucks just starting with the dry barrels.
11:15 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. One of the two forms was equipped with the three strain gages and inspected by Subterra who was onsite. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers.
11:30 AM: Alaska DOT Materials Technicians were onsite and tested the material for slump and air entrainment with results of 3" and 7%, respectively. The increase in both slump and air could be related to the late addition of the high range admixture. As the truck transported the SFRRC to the site the additional mixing allowed the high range to react properly.
12:00 PM: Pouring of both slabs was completed and the truck left the site. The crew continued to finish the surface of the concrete.
1:00 PM: With the sun shining bright and ambient temperatures so high the material cured quicker than previous pours and broom finishing was started
1:40 PM: The crew completed work for the day.

Newt Bingham was onsite to inspect the material and provide suggestions on the mixing, finishing and consistency issues that have been encountered.

Date: 8/31/2016	Inspector's Signature:	Page No. 2 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:		**AMATS: Abbott Rd Rehab-Phase I**		
Weather:	65 F	Clear	Shift:	10:00 AM	to	2:00 PM	Friday, September 2, 2016
Contractor's Representative and Title:		Martin Meenaghan, QAP Project Engineer					

Contractor's Equipment						**Contractor's Work Force**	
No.	Description	Hours Worked	Hours Stdby	Hours Down	Remarks	No.	Classification/Duties
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No.	Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
	Portland Cement Concrete					5.25	
	1" Steel Fibers					889	Novocon 0730FE
	No. 8 Crumb Rubber					326	QAP Stockpile
	515(1) Precast Concrete Slab System					Panels 6 & 7 of 15	Forming and pouring

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STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were clear and sunny, temperatures ranging from 60 to 70 degrees.

10:20 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.

10:25 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.

10:35 AM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.

10:40 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product. The mixed material was poured into a wheel barrel for testing purposes and visually it was very wet and liquid than previous mix on 9/2/16. Slump and air entrainment tests were complete and resulted in 7.25" and 7%, respectively Variability could be due to the truck barrels, either being used for earlier work during the day or not. The previously used trucks would already have moisture and possibly fines still in them which would allow the mix to not lose any properties compared to the trucks just starting with the dry barrels. Earlier concrete work had occurred during the day for other projects and it is likely that the interior of the truck barrel was already moist prior to being used to haul the SFRRC mix.

11:00 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers. The material flowed very easily and the D&S crew would prefer the mix in this manner, but compressive and flexural strength testing will need to be conducted to determine if performance is effected by the high W/C ratio.

11:10 AM: Alaska DOT Materials Technicians were onsite and tested the material for slump and air entrainment with results of 8.5" and 12%, respectively. The increase in both slump and air could be because as the truck transported the SFRRC to the site the additional mixing allowed the high range to react further. With no air entrainment admixtures the large increase in air is still concerning.

11:25 AM: Due to the high flowability of the mix pouring of both slabs was completed quickly and the truck left the site. The crew continued to finish the surface of the concrete.

12:30 PM: With the sun shining bright and ambient temperatures so high the material cured quicker than previous pours and broom finishing was started

1:00 PM: The crew completed work for the day.

Date: 9/2/2016	Inspector's Signature:	Page No. 2 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	**AMATS: Abbott Rd Rehab-Phase I**		
Weather:	55 F	Partially Cloudy	Shift:	10:00 AM	to	2:00 PM	Thursday, September 8, 2016
Contractor's Representative and Title:	Martin Meenaghan, QAP Project Engineer					

Contractor's Equipment						**Contractor's Work Force**	
No.	Description	Hours Worked	Hours Stdby	Hours Down	Remarks	No.	Classification/Duties
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No.	Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
	Portland Cement Concrete					5.25	
	1" Steel Fibers					889	Novocon 0730FE
	No. 8 Crumb Rubber					326	QAP Stockpile
	515(1) Precast Concrete Slab System					Panels 10 &11 of 15	Forming and pouring

Page No. 1 of 2

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were overcast, temperatures ranging from 50 to 60 degrees.

10:20 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.

10:20 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.

10:30 AM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.

10:35 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product. The mixed material was poured into a wheel barrel for testing purposes and visually it flowed well. Slump and air entrainment tests were complete and resulted in 8.25" and 6.5%, respectively Variability could be due to the truck barrels, either being used for earlier work during the day or not. The previously used trucks would already have moisture and possibly fines still in them which would allow the mix to not lose any properties compared to the trucks just starting with the dry barrels. Earlier concrete work had occurred during the day for other projects and it is likely that the interior of the truck barrel was already moist prior to being used to haul the SFRRC mix.

10:55 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers. The material flowed very easily and the D&S crew would prefer the mix in this manner, but compressive and flexural strength testing will need to be conducted to determine if performance is effected by the high W/C ratio.

11:10 AM: Alaska DOT Materials Technicians were onsite and tested the material for slump and air entrainment with results of 7" and 8%, respectively. The decrease in slump and increase in air could be because as the truck transported the SFRRC to the site the additional mixing allowed the high range to react further. With no air entrainment admixtures the increase in air is still concerning.

11:25 AM: Due to the high flowability of the mix pouring of both slabs was completed quickly and the truck left the site. The crew continued to finish the surface of the concrete.

12:30 PM: The material cured quickly and broom finishing was started.

1:00 PM: The crew completed work for the day.

Date:	9/8/2016	Inspector's Signature:	[signature]	Page No.	2 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	**AMATS: Abbott Rd Rehab-Phase I**		
Weather:	55 F	Partially Cloudy	Shift:	10:00 AM to 2:00 PM		Monday, September 12, 2016
Contractor's Representative and Title:	Martin Meenaghan, QAP Project Engineer					

Contractor's Equipment						Contractor's Work Force	
No.	Description	Hours Worked	Hours Stdby	Hours Down	Remarks	No.	Classification/Duties
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No. / Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
Portland Cement Concrete					5.25	
1" Steel Fibers					889	Novocon 0730FE
No. 8 Crumb Rubber					326	QAP Stockpile
515(1) Precast Concrete Slab System					Panels 12 & 13 of 15	Forming and pouring

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STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were overcast, temperatures ranging from 50 to 60 degrees.

10:25 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.

10:30 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.

10:35 AM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.

10:40 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product. The mixed material was poured into a wheel barrel for testing purposes and visually it flowed well. Slump and air entrainment tests were complete and resulted in 5.5" and 3.5%, respectively.

10:55 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers. The material flow was optimum without having too high of flowability or stiffness. One of the precast molds has been modified to be the trailing end of the slab system with the male dowels on one side and an angled transition on the other. The next pour will have the other end section with dowel ports and the angled transition.

11:10 AM: Alaska DOT Materials Technicians were onsite and tested the material for slump and air entrainment with results of 4" and 6%, respectively. The decrease in slump and increase in air could be because as the truck transported the SFRRC to the site the additional mixing allowed the high range to react further. With no air entrainment admixtures the increase in air is still concerning.

11:30 AM: Due to the high flowability of the mix pouring of both slabs was completed quickly and the truck left the site. The crew continued to finish the surface of the concrete.

1:00 PM: The material was cured sufficiently and broom finishing was started.

1:30 PM: The crew completed work for the day.

Date: 9/12/2016	Inspector's Signature:	Page No. 2 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

Project No:	0506005/Z591900000		Project Name:	AMATS: Abbott Rd Rehab-Phase I		
Weather:	55 F	Partially Cloudy	Shift:	10:00 AM	to	2:00 PM	Wednesday, September 14, 2016
Contractor's Representative and Title:	Martin Meenaghan, QAP Project Engineer					

Contractor's Equipment						Contractor's Work Force	
No.	Description	Hours Worked	Hours Stdby	Hours Down	Remarks	No.	Classification/Duties
1	AS&G Batch Plant						**AS&G**
1	AS&G Concrete Truck					1	Superintendent (Scott Brown)
1	AS&G Forklift					1	Material Tech (Patrick Walter)
						4	Laborers
						1	Concrete Truck Driver
							D&S Concrete
1	Viberating Concrete Probe					1	Foreman (Josh Harmon)
1	Concrete Finishing Roller					3	Concrete Finishing Laborers

Limits of Work/Material Placement

Item No.	Description	Sources(Limits) From	Sources(Limits) To	Placement From	Placement To	Approx. Quantity	Sections/Work Completed & Accepted
	Portland Cement Concrete					5.25	
	1" Steel Fibers					889	Novocon 0730FE
	No. 8 Crumb Rubber					326	QAP Stockpile
	515(1) Precast Concrete Slab System					Panels 14 & 15 of 15	Forming and pouring

Page No. 1 of 2

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

MAHEAR ABOUEID

INSPECTOR'S DAILY REPORT

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractors, ect.)

Weather Conditions for the day were overcast, temperatures ranging from 50 to 60 degrees.
10:20 AM: Arrived at AS&G Batch Plant and the mixing procedure was started with the required fine aggregate, intermediate aggregate, course aggregate, concrete cement, water and polyheed water reducer. This process was completed using the standard automated batch plant procedures. Per our discussions regarding the workability of the mix an additional 12 oz/cu yd of BASF PS 1466 High Range admixture was combined with the material.
10:30 AM: The mixed material was slowly poured out of the mixing barrel as 2 laborers on each side of the chute leading down to the concrete truck, added the steel fiber material into the chute. The 45 pound boxes containing the steel fibers were emptied into large garbage pales and the material was dumped into the chute.
10:35 AM: The concrete truck pulled out of the batch plant and under the platform so that crumb rubber from the weighed super sack could be added. A forklift raised the sack above the chute at the rear of the concrete truck and an orifice at the bottom of the sack was opened to allow the rubber to pour out slowly and evenly.
10:40 AM: Addition of the crumb rubber material was complete and the truck was now allowed to mix the material for 5 minutes prior to testing and visual observation of the final product. The mixed material was poured into a wheel barrel for testing purposes and visually it flowed well. Slump and air entrainment tests were complete and resulted in 5" and 5.5%, respectively.
11:00 AM: The truck left the AS&G batch plant and transported the SFRRC material to the D&S Concrete manufacturing location and pouring of material into the preassembled forms began. The D&S concrete crew consisted of a foreman, Josh Harmon and 3 laborers. The material flow was optimum without having too high of flowability or stiffness. One of the precast molds has been modified to be the trailing end of the slab system with the male dowels on one side and an angled transition on the other.
11:15 AM: Alaska DOT Materials Technicians were onsite and tested the material for slump and air entrainment with results of 6" and 6.8%, respectively. The increase in slump and air could be because as the truck transported the SFRRC to the site the additional mixing allowed the high range to react further. With no air entrainment admixtures the increase in air is still concerning.
11:30 AM: Due to the high flowability of the mix pouring of both slabs was completed quickly and the truck left the site. The crew continued to finish the surface of the concrete.
1:00 PM: The material was cured sufficiently and broom finishing was started.
1:30 PM: The crew completed work for the day. This concluded pouring of all the required slabs.

Date: 9/14/2016	Inspector's Signature: [signature]	Page No.	2 of 2

Table 6: SFRRC pre-cast pour test results.

AMATS: Abbott Rd Rehab-Phase I

0506005/Z591900000

515(1) Precast Concete Slab System

Steel Fiber Reinforced Rubberized Concrete Slab Pour Field Test Results

Date	Pour	Slabs	Slump AS&G (in.)	Slump DOT (in.)	AIR AS&G	AIR DOT	Remarks
8/25/2016	1	1	0.5	2	3.5%	2.5%	
8/29/2016	2	2,3	6.5	5	5.0%	9.5%	12 OZ/CY of BASF PS 1466 ADDED
8/31/2016	3	4,5	2	3	5.2%	7.0%	12 OZ/CY of BASF PS 1466 ADDED
9/2/2016	4	6,7	7.25	8.5	7.0%	12.0%	12 OZ/CY of BASF PS 1466 ADDED
9/6/2016	5	8,9		2.5		2.0%	Was not present to inspect pour
9/8/2016	6	10,11	8.25	7	6.5%	8.0%	12 OZ/CY of BASF PS 1466 ADDED
9/12/2016	7	12,13	5.5	4	3.5%	6.0%	12 OZ/CY of BASF PS 1466 ADDED
9/14/2016	8	14,15	5.5	6	5.0%	6.8%	12 OZ/CY of BASF PS 1466 ADDED
		Average:	**5.1**	**4.8**	**5%**	**7%**	

SFRRC Precasting Acceptance Tests (28 day breaks)

Date	Pour	Slabs	Compressive Strength (PSI)	Flexural Strength	AIR DOT
8/25/2016	1	1	5670	690	2.5%
8/29/2016	2	2,3	4630	675	9.5%
8/31/2016	3	4,5	5390	840	7.0%
9/2/2016	4	6,7	4660	767	12.0%
9/6/2016	5	8,9	7450	873	2.0%
9/8/2016	6	10,11	5310	843	8.0%
9/12/2016	7	12,13	6310	823	6.0%
9/14/2016	8	14,15	6930	923	6.8%
		Average:	**5793.8**	**804.3**	

Figure 48: Formwork for pre-cast SFRRC panel with strain gauges installed.

Figure 49: Placing SFRRC material in forms, with strain gauges installed.

Appendix I – Test Section Construction Reports, Photos and Strain Gauge Data

Figure 50: Transporting, lifting and placing of test section panels.

Figure 51: Placing de-bonding agent on dowels and the installed joint expansion board.

Figure 52: Placing of the test section panels with proper alignment and leveling.

AMATS: ABBOTT RD REHAB - PHASE I

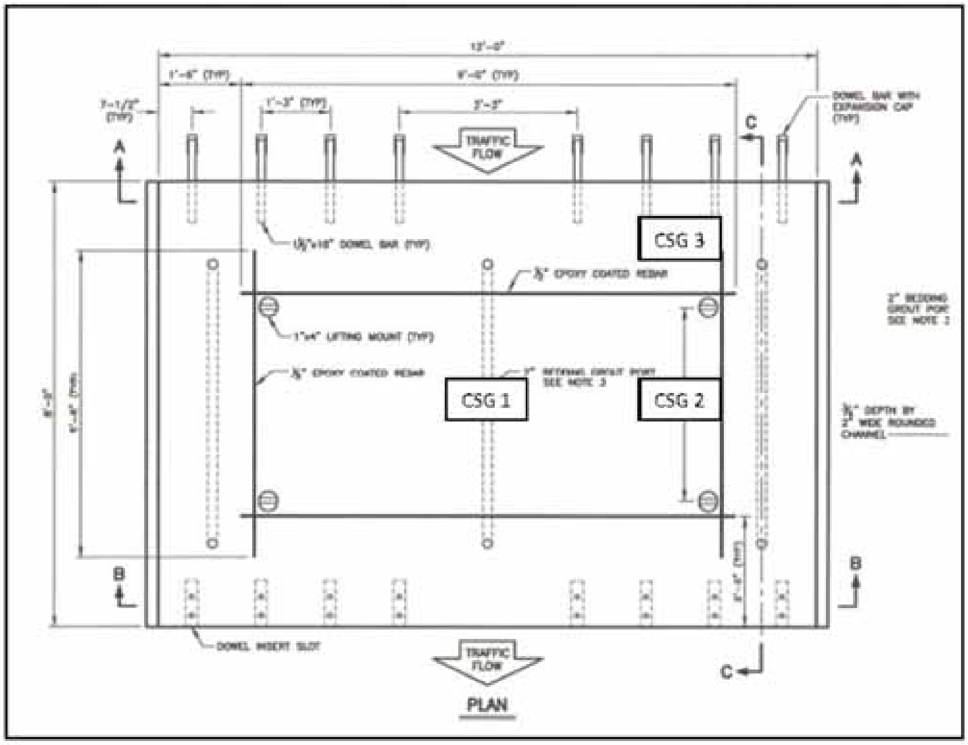
PRE-CAST PANEL STRAIN GAGE INSTRUMENTATION DATA

Prepared for Quality Asphalt Paving

SubTerra Inc.®

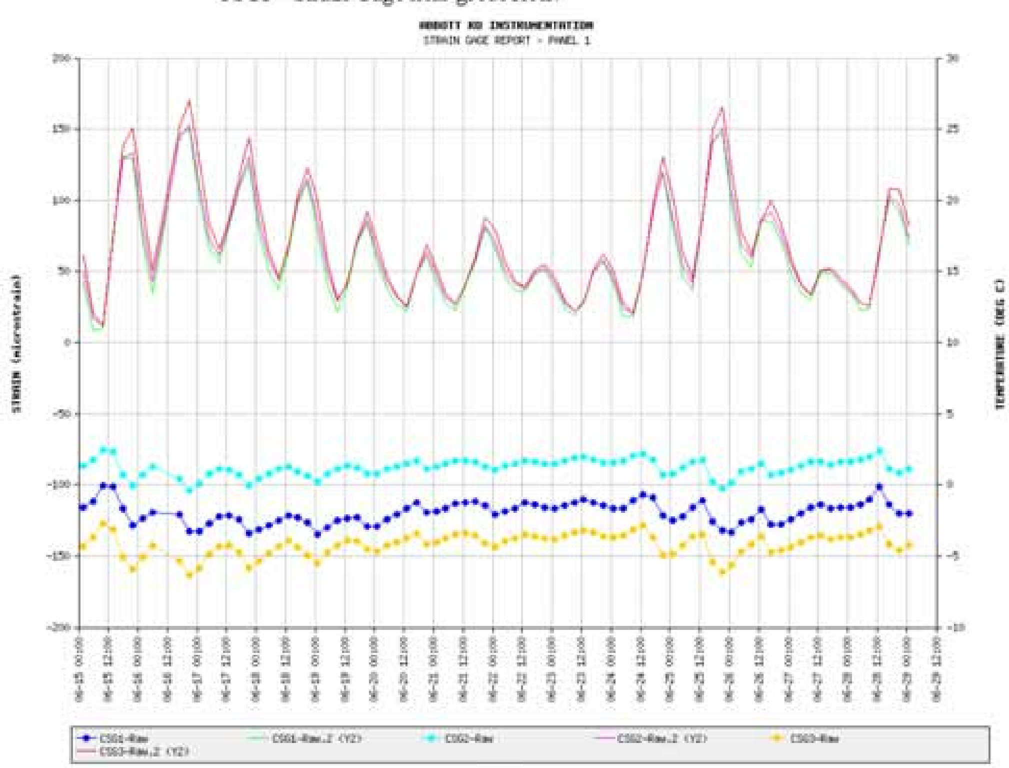
06-29-2017

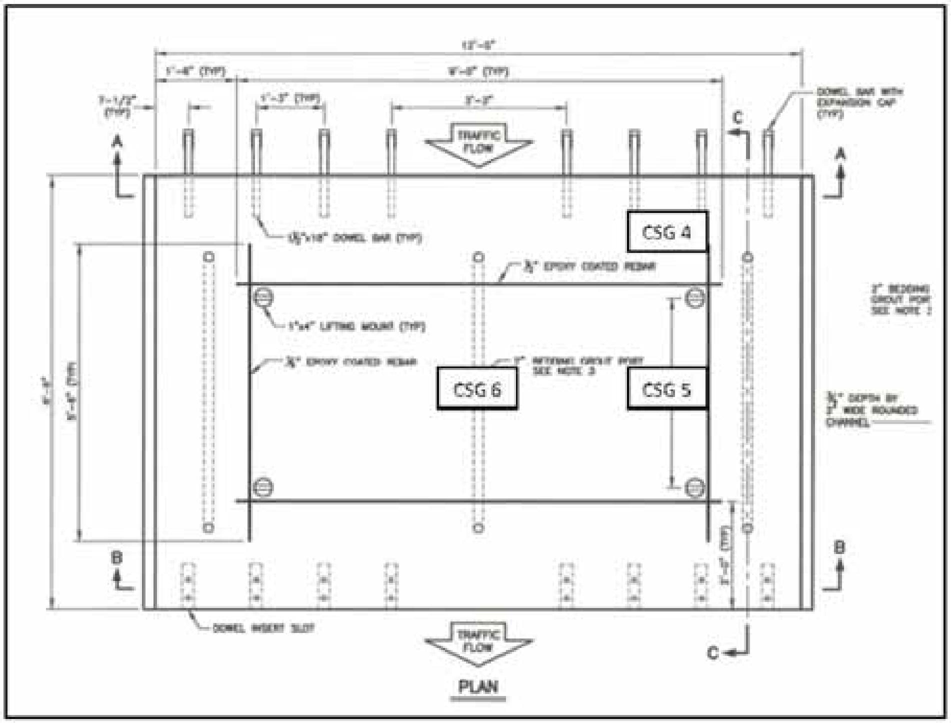
Figure 53: Strain gauge data report from SubTerra Inc. (4 pages).



Instrumented Precast Concrete Slab: Panel 1

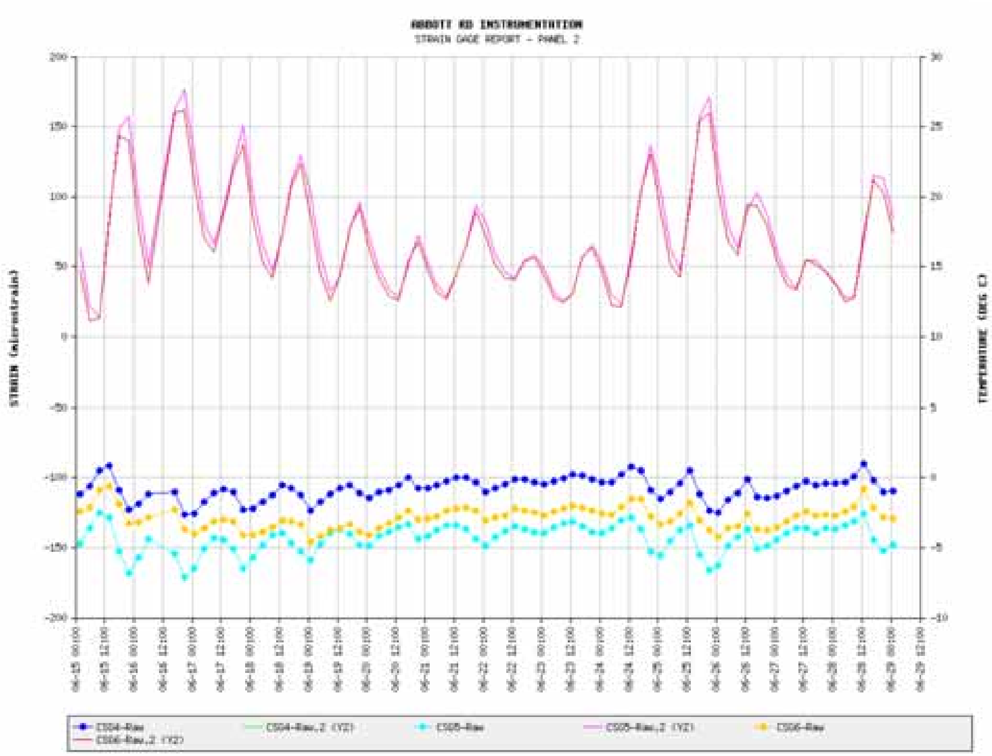
CSG1 - Strain Gage near the middle grout port.
CSG2 - Strain Gage between the lifting mounts.
CSG3 - Strain Gage near grout slots.

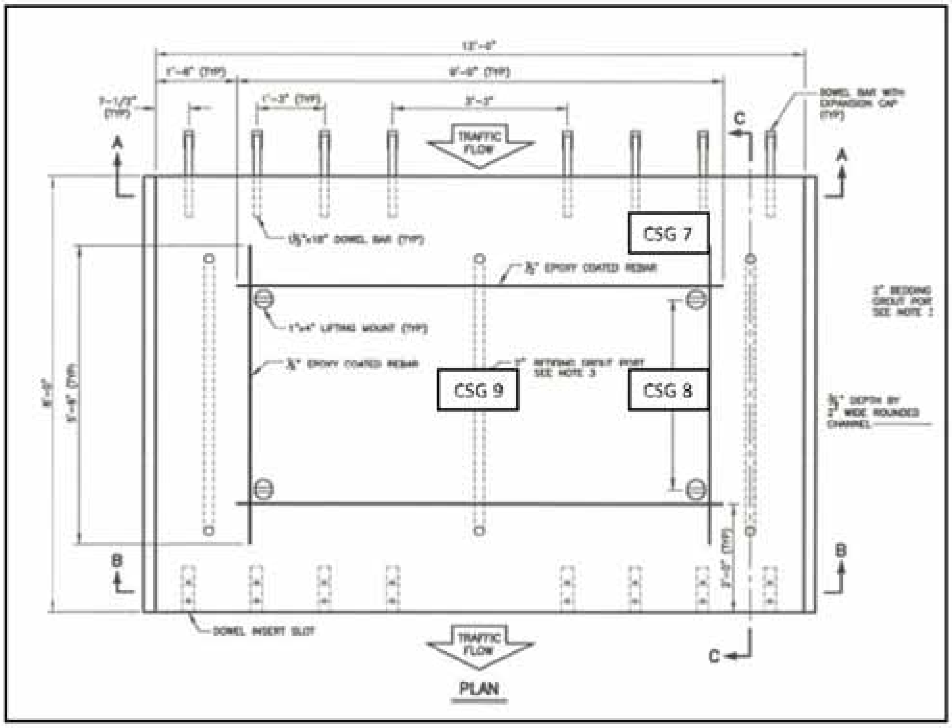




Instrumented Precast Concrete Slab: Panel 2

CSG4 - Strain Gage near grout slots.
CSG5 - Strain Gage between the lifting mounts.
CSG6 - Strain Gage near the middle grout port.





Instrumented Precast Concrete Slab : Panel 3

CSG7 - Strain Gage near grout slots.
CSG8 - Strain Gage between the lifting mounts.
CSG9 - Strain Gage near the middle grout port.