



Alternate Approach Slab Reinforcement

Final Report

Prepared by the New Hampshire Department of Transportation, in cooperation with the U.S. Department of Transportation, Federal Highway Administration

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16. Abstract

The upper mat of reinforcing steel, in exposed concrete bridge approach slabs, is prone to corrosion damage. Chlorides applied to the highways for winter maintenance can penetrate this concrete layer. Eventually chlorides reach the steel and begin the corrosion process.

The objective of this research project was to investigate the performance of approach slabs constructed with structural fibers to replace the top mat of reinforcing steel. The research studied whether the performance of approach slabs reinforced with structural fibers would be equivalent to traditionally reinforced approach slabs.

NHDOT Materials & Research Bureau technicians performed standard quality acceptance tests on the fresh concrete at the time of placement. Technicians also fabricated three freeze/thaw prisms for each mix. The specimens survived freeze/thaw testing with only minor physical deterioration, consisting of slight scaling and pitting. The Civil Engineering Department of the University of New Hampshire (UNH) was contracted to perform laboratory testing. The beam samples were tested for First Crack Strength and Average Residual Strength in accordance with ASTM C 1018 and C 1399, respectively. An independent testing laboratory extracted two cores from each approach slab to evaluate the air matrix within the concrete. Comparisons of the laboratory test results show that compressive and flexural strengths are similar for both mixes. The plots resulting from the residual strength testing show that the fiber-mix had greater strength after cracking than the normal mix. Periodic visual observations of the approach slabs were made to evaluate field performance by comparing crack size, frequency and scaling. After more than three and half years in service, the two approach slabs have performed similarly and well. The expected advantages of a thicker concrete cover over steel reinforcement will not be seen for many years. The epoxy-coated steel in the conventional slab construction should also delay damage from corrosion.

Based on the performance observations to date, fiber-reinforced concrete is recommended for use in this and other applications where delaying the effects of steel corrosion is of interest. The NHDOT has implemented the use of fiber-reinforced concrete for all approach slabs as a result of this study.

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ALTERNATIVE APPROACH SLAB REINFORCEMENT STATEWIDE SPR 13733H



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June 21, 2010

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BACKGROUND

The upper mat of reinforcing steel in exposed concrete bridge approach slabs is prone to corrosion damage. The design concrete cover over the mat is typically 2.5 inches. Chlorides applied to the highways for winter maintenance can penetrate this concrete layer. Eventually chlorides reach the steel and begin the corrosion process which will crack the concrete. The cracks accelerate the deterioration process by providing direct access for contaminants to attack the reinforcing steel.

RESEARCH OBJECTIVE

The objective of this research project was to investigate the performance of approach slabs constructed with structural fibers to replace the top mat of reinforcing steel, which performs essentially as temperature steel for crack resistance. The proposed design concept effectively increases the concrete cover over the remaining bottom reinforcing mat and should delay chloride contact with the reinforcing steel and the effects of corrosion. The research studied whether the performance of approach slabs reinforced with structural fibers would be equivalent to traditionally reinforced approach slabs.

PROJECT SITE

The Pembroke-Allenstown bridge replacement Project 12978 over the Suncook River was selected as the test site for the study. It was designed to include construction of unpaved approach slabs at grade using a Class AA, Q/C-Q/A concrete mix containing 50% slag.

The 16.75-inch thick approach slab at Abutment A (south end of the bridge) was constructed with fiber reinforced concrete mix and a conventional bottom mat of #16 (mm) epoxy-coated reinforcing steel. Grace STRUX 90/40 synthetic fibers were specified in Special Provision Item 544 of the contract documents. They were added to the mix as a substitute for installing the upper reinforcing mat of NHDOT's typical approach slab design. The fiber reinforcement was added at the rate of seven LBS/CY, per the manufacturer's recommendation, to achieve the design requirements. Persons Concrete of Bow, NH supplied the mix. The approach slab at Abutment B (north end of the bridge) was traditionally reinforced with an upper and lower epoxy-coated reinforcing steel mat of #16 (mm) bars.

The contractor completed each approach slab by applying a broom finish. The slabs were covered with wet burlap and poly sheeting immediately after finishing and wet cured for seven days, per NHDOT specification. The bridge was opened to traffic on December 8, 2005.

TESTING

NHDOT Materials & Research Bureau technicians performed standard quality acceptance tests on the fresh concrete at the time of placement, October 20, 2005. Slump, air content, temperature, permeability and compressive strength tests documented the quality of the delivered fiber-reinforced and standard mixes. Each mix met the requirements of the NHDOT Standard Specifications. Laboratory test reports are included in Appendix A.

NHDOT technicians also fabricated three freeze/thaw prisms for each mix. The prisms were transported to the Vermont Agency of Transportation (VTrans) concrete laboratory where they

were tested and evaluated for freeze/thaw durability in accordance with ASTM C 666 and C 215, respectively in October 2005. The specimens survived freeze/thaw testing with only minor physical deterioration, consisting of slight scaling and pitting. The computed Durability Factors were not consistent with the physical conditions of the specimens. While the fiber-mix prisms had a range of durability factors from 106, 120 and 139, the normal concrete prisms had factors of 40, 44 and 104. Freeze/Thaw test reports are included in Appendix B.

The Civil Engineering Department of the University of New Hampshire (UNH) was contracted to perform laboratory testing. See Appendix C for the test data for this test series. A test panel was cast for each of the fiber reinforced and control concrete mixes at the time of the approach slab placements. After 28 days, the UNH staff saw-cut four 4" x 4" x 14" beam samples from each test slab.





Figure 2: Preparation of test beam slabs on 10/17/2005



The beam samples were tested in August 2006 for First Crack Strength and Average Residual Strength in accordance with ASTM C 1018 and C 1399, respectively. Testing compared mix performance and verified whether the fiber reinforced mix design strength had been achieved based on the manufacturer-recommended fiber addition rate. The maximum flexural load

placed on the beam samples showed the fiber mix to be equivalent to the conventional mix. Maximum loads for three of the fiber-mix beams ranged from 3.0 to 4.5 kips; one failed at 1.6 kips. The four normal concrete beams sustained loads ranging from 3.0 to 3.7 kips. The initial beam cracking did not appear until loading had exceeded the parameters for average residual strength computations, voiding those test procedures.

An independent testing laboratory extracted two cores from each approach slab for UNH to evaluate the air matrix within the concrete. Measurements had been made to locate the reinforcing steel prior to the placement so that the cores could be retrieved without damaging the steel. Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete -- ASTM C 457 was followed. The data showed that the air content of the non-fiber samples and fiber samples had average air contents of 7.9 and 7.0 percent, respectively, with an average spacing factor of 0.001 for both the non-fiber and fiber concretes. The paste, fine aggregate and coarse aggregate percentages were also similar for both concretes. Based on these data, the concretes would be expected to resist cycles of freezing and thawing. Polished sections of the near surface of the fiber-reinforced and traditionally reinforced concretes were prepared for petrographic analysis. Both sections showed good distribution of aggregates and a surface that was well compacted, but not over finished. The sections also showed a uniform distribution of the fibers. Even though an attempt was made to avoid hitting reinforcement during coring, an epoxy coated reinforcement bar did appear in one of the samples.

MONITORING

Periodic visual observations of the approach slabs were made to evaluate field performance by comparing crack size, frequency and scaling. No cracks were observed in either approach slab after two years in service. A longitudinal crack was observed in the fiber-reinforced slab during a July 9, 2009 inspection. The narrow crack was located approximately two feet off centerline and extended the entire length of the approach slab. The arrows in the Figure 3 photo locate the ends of the crack.



Figure 4: Exposed aggregate in fiber mix



After four winters of snow plow abrasion, the fiber-reinforced slab shows greater signs of surface wear. Shallow scaling has exposed the aggregate in high contact areas such as the centerline crown, as shown in the Figure 4 photo. The broom finish has been lost in traffic areas. Although worn, the streaks of the broom finish are still visible in the normal slab.

Several areas in the fiber-reinforced slab have been monitored with interest. What appeared to be shallow pop-outs or potential scaling were observed along the easterly shoulder and at the centerline. These areas are now considered to be finishing defects, since they have not deteriorated or expanded since first observed during the April 2006 initial inspection after placement.







EVALUATION

Comparisons of the laboratory test results show that compressive and flexural strengths are similar for both mixes. The plots resulting from the residual strength testing show that the fiber-mix had greater strength after cracking than the normal mix. This is a known trait of fiber mixes, since their reinforcing is distributed throughout the slab.

After more than three and half years in service, the two approach slabs have performed similarly and well. Visually, they can only be identified by a slight difference in surface texture and noticeable fibers in the shoulder area where snow plowing and traffic has not worn them to the surface. Except for the longitudinal crack observed in the fiber mix following the initial monitoring period, neither slab has significantly cracked or shown excessive wear. The expected advantages of a thicker concrete cover over steel reinforcement will not be seen for many years. The epoxy-coated steel in the conventional slab construction should also delay damage from corrosion.

CONCLUSIONS AND RECOMMENDATIONS

Based on the performance observations to date, fiber-reinforced concrete is recommended for use in this and other applications where delaying the effects of steel corrosion is of interest. The NHDOT has implemented the use of fiber-reinforced concrete for all approach slabs as a result of this study.

APPENDIX A - FRESH CONCRETE TESTS

Project: PEMBROKE-ALLENSTOWN Federal#: BRO-X-361(001)

State#: Report to: Charles Flanders

12978

ş

Concrete Independent Assurance AA22033

+ +							
Cylinder#: 2	203/088	Sub	mitte	ed by:		1	0/21/2005
Source: F	Persons (Concrete	e				
Material:	AA 50% S	SLAG		Quar	ntity 40	cy.	
Purpose: A	Abut b ap	proach	slab	S			
Date Cast:	10/17/200)5					
% Air	Slump(i	n):	Mix	Temp	(F):	Air Ten	<i>цр (F):</i> сюг
Analysis		Result	Ì	Min	Max	Violation	Method
QA Testing by	с.	Flanders	i, T				
QC Testing by	Br	uce Turm	nell		·		
IA Testing by:		S. Drouin	n				
Sub Lot #		3					
Load #		2					
% Air (IA)		5.5					
% Air (QA)		5.9					
Within Toleran	ice?	Yes					
% Air (QC)		7.5					
Unit Wgt (IA)		N/A					
Unit Wgt (QA)		N/A					
Within Toleran	ice?	N/A					
Concrete Tem	p (IA)	61.0					
Concrete Tem	p (QA)	61.0					
Air Temp		58.0					
Slump (IA)		N/A					T119
Slump (QA))		N/A					T119
Within Toleran	ice?	N/A					
W/C Ratio (IA)	i	0.441					
W/C Ratio (QA	4)	0.446					
Remarks:							
Th	ree beam :	specimer	ns fab	ricated	for Deni	s Boisvert, A	ssistant

Comments: Research Engineer- Freeze/Thaw Test Method.

Date: 10/24/2005 Analysis Validated by: JA

Wednesday, February 01, 2006

Date: 10/28/2005 Sample Vaildated by: ADP

Project: PEMBROKE-ALLENSTOWN Federal#: BRO-X-361(001) State#: 12978 Report to: Charles Flanders

Compressive Strength-4000 PSI AA22064

Cylinder#: Source:	IA PA-QCQ (Person's Bow	Submitted i	by: S.DR	ROUIN 1	0/24/2005
Material:	Class AA Q/0	C-Q/A Q	uantity 4	0 cy.	
Purpose:	520.0102 QC	/QA Approa	ach Slab E	3	
Date Cast:	10/17/2005				
% Air	Slump(in):	Mix Te	mp (F): \	Air Ten	np (F):
Analysis	Resi	ult Min	ı Max	Violation	Method
Tested By:	D	F			
Date Broken	11/1	4/05			T22
Age (days)	2	8			T22
Diameter (in)		4			T22
Area (sq in)	12	.57			T22
Load Reading	9 76	300			T22
Density (Ibs/f	13) 14	5.4			T22
Density (kg/m	13) 232	9.3			T22
Strength (psi)	61	12 400	00		T22
Strength (Mp	a) 42	.14 .30.	.0		T22
Remarks:					
Comments:					

Date: 11/15/2005

Date: 11/21/2005

Quantity 40 cy.

AA22065

10/24/2005

Compres	sive Strengt	th-4000	PSI	AA220	66	
Cylinder#: Source: Material: Purpose: Date Cast:	PA-QCQA- <i>Stull</i> Person's Bow Class AA Q/C-Q 520.0102 QC/Q 10/17/2005	b <i>mitted by:</i> //A <i>Quar</i> A Approach	C. FLA n <i>tity</i> 40 Slab B	NDERS 1	0/24/2005	, •
% Air	Slump(in):	Mix Temp	(F):	Air Ten	w (F):	
Analysis	Result	Min	Max	Violation	Method	
Tested By: Date Broken Age (days) Diameter (in) Area (sq in) Load Readin Density (lbs/f Density (kg/m Strength (psi Strength (Mp Remarks:	DF 11/14/0 28 4 12.57 9 68400 13) 142.0 13) 2274.3) 5443 a) 37.53	5 4000 30.0			T22 T22 T22 T22 T22 T22 T22 T22 T22 T22	
Comments:						
Analysis Vali Sample Vaild	idated by: JA lated by: ADP	Date: 11/ Date: 11/	15/2005 21/2005			
Compres	sive Strengt	h-4000 l	PSI	AA220	67	
Cylinder#: Source: Material: Purpose: Date Cast: % Air	PA-QCQA- Sub Person's Bow Class AA Q/C-Q 520.0102 QC/Q/ 10/17/2005 Slump(in):	mitted by: /A Quar A Approach Mix Temp	C. FLA <i>utity</i> 40 Slab B (<i>F</i>):	NDERS 1 cy. Air Ten	0/24/2005 pp (F):	

Result

DF

11/14/05

28

4

12.57

67000

142.7

2285.3

5332

36.76

Min

Max Violation Method

T22

T22

T22

T22

T22

T22

T22

T22

T22

520.0102 QC/QA Approach Slab B Purpose: Date Cast: 10/17/2005 % Air Slump(in): Mix Temp (F): Air Temp (F): Min Max Violation Method Analysis Result DF Tested By: 11/14/05 Date Broken T22 28 T22 Age (days) T22 Diameter (in) 4 T22 Area (sq in) 12.57 74000 T22 Load Reading 145.1 T22 Density (lbs/ft3) Density (kg/m3) 2323.8 T22 5889 4000 T22 Strength (psi) Strength (Mpa) 40.60 30.0 T22 Remarks: Comments:

Analysis Validated by: JA Date: 11/15/2005 Sample Validated by: ADP Date: 11/21/2005

Comments:

Analysis

Tested By:

Date Broken

Age (days)

Diameter (in)

Area (sq in)

Load Reading

Density (lbs/ft3)

Density (kg/m3)

Strength (psi)

Strength (Mpa)

Remarks:

Analysis Validated by:	_JA	Date:	11/15/2005				
Sample Vaildated by:	ADP	Date:	11/21/2005				

4000

30.0

Wednesday, February 01, 2006

Analysis Validated by: JA

Source:

Material:

Sample Vaildated by: ADP

Compressive Strength-4000 PSI

Class AA Q/C-Q/A

Person's Bow

Cylinder#: IA PA-QCQ Submitted by: S. DROUIN

Project: PEMBROKE-ALLENSTOWN Federal#: BRO-X-361(001) State#: 12978 Report to: Charles Flanders

Concrete Independent Assurance AA22101

	-	- 	•.			1	0/25/2005
Cylinder#:	D	Sub	1	0/25/2005			
Source:	Person	S BOW	10				
Material:	QC/QA	AA WITI	۹r 	Qua	ntity +-	40Cy	
Purpose:	Abut a a	approach	sla	bs			
Date Cast:	10/20/2	005					-
% Air	Slump	(in):	Mi	x Temp	(F):	Air Ten	<i>ip (F):</i> clou
Analysis		Result	• '	Min	Max	Violation	Method
QA Testing b	by:	C.Flande	rs				
QC Testing I	oy:	B.Flande	rs				
IA Testing by	<i>r</i> :	D.John					(
Sub Lot #		4					
Load #		3					
% Air (IA)		6.0					
% Air (QA)		5.7					
Within Tolera	ance?	Yes					
% Air (QC)		n/a					
Unit Wgt (IA))	n/a					
Unit Wgt (Q/	4)	n/a					
Within Tolera	ance?	n/a					
Concrete Te	mp (IA)	61					
Concrete Te	mp (QA)	61					
Air Temp		50					
Slump (IA)		4.5					T119
Slump (QA))		4.5					T119
Within Tolera	ance?	Yes					
W/C Ratio (I	A)	.487					
W/C Ratio (0	QA)	.456					
Remarks:							

Comments:

Analysis Validated by:	JA	Date:	10/26/2005	
Sample Vaildated by:	ADP	Date:	10/28/2005	

Wednesday, February 01, 2006

A4

Federal#: BRO-X-361(001)	Report to: Charles Flanders
Compressive Strength-4000 PSI AA22071	Compressive Strength-4000 PSI AA22073
Cvlinder#: IA PA-QCQ Submitted by: D. JOHN 10/24/2	005 Cylinder#: PA-QCQA- Submitted by: C. FLANDERS 10/24/2005
Source: Person's Bow	Source: Person's Bow
Material: Class AA Q/C-Q/A Quantity 40 cy.	Material: Class AA Q/C-Q/A Quantity 40 cy.
Purpose: 520.0102 QC/QA Approach Slab A	Purpose: 520.0102 QC/QA Approach Slab A
Date Cast: 10/20/2005	Date Cast: 10/20/2005
% Air Slump(in): Mix Temp (F): Air Temp (F):	% Air Slump(in): Mix Temp (F): Air Temp (F):
Analysis Result Min Max Violation Meth	od Analysis Result Min Max Violation Method
Tested By: DF	Tested By: DF
Date Broken 11/17/05 T22	Date Broken 11/17/05 T22
Age (days) 28 . T22	Age (days) 28 T22
Diameter (in) 4 T22	Diameter (in) 4 T22
Area (sq in) 12.57 T22	Area (sq in) 12.57 T22
Load Reading 66000 T22	Load Reading 63600 T22
Density (lbs/ft3) 140.6 T22	Density (lbs/ft3) 140.9 T22
Density (kg/m3) 2252.3 T22	Density (kg/m3) 2257.8 T22
Strength (psi) 5252 4000 T22	Strength (psi) 5061 4000 T22
Strength (Mpa) 36.21 30.0 T22	Strength (Mpa) 34.90 30.0 T22
Remarks:	Remarks:
Comments:	Comments:
Compressive Strength-4000 PSI AA22072	Compressive Strength-4000 PSI AA22074
Cylinder#: IA PA-QCQ Submitted by: D. JOHN 10/24/2	005 Cylinder#: PA-QCQA- Submitted by: C. FLANDERS 10/24/2005 Source: Person's Bow
Source: Feison's Dow	Material: Class AA Q/C-Q/A Quantity 40 cy.
Burnage 520 0102 OC/OA Approach Slab A	Purpose: 520.0102 QC/QA Approach Slab A
Data Cast: 10/20/2005	Date Cast: 10/20/2005
% Air Slumn(in) Mix Temn (F): Air Temn (F):	% Air Slump(in): Mix Temp (F): Air Temp (F):
Analysis Result Min Max Violation Meth	d Analysis Result Min Max Violation Method
Tostod But DE	Tested By: DF
Date Broken 11/17/05 T22	Date Broken 11/17/05 T22
Ang (days) 28 T22	Age (days) 28 T22
Diameter (in) 4 T22	Diameter (in) 4 T22
Area (sg in) 12.57 T22	Area (sq in) 12.57 T22
Load Reading 70000 T22	Load Reading 65200 T22
Density (lbs/ft3) 142.0 T22	Density (lbs/ft3) 141.3 T22
Density (kg/m3) 2274.3 T22	Density (kg/m3) 2263.3 T22
Strength (psi) 5570 4000 T22	Strength (psi) 5188 4000 T22
Strength (Mpa) 38.41 30.0 T22	Strength (Mpa) 35.77 30.0 T22
Remarks:	Remarks:
Comments:	Comments:
11/17/2005	Analysis Validated by: JA Date: 11/17/2005
Analysis Vallaatea by: 5A Date: 111112005	

Wednesday, February 01, 2006

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Permeability of Concrete AA22068 Cytinderii: PA-QCOA-Submitted by: C.FLANDERS 1024/2005 Source:: Personi Bow Matterial: Class AA QC-QA Quantity 40 cy. Purpose: 520.0102 QC/QA Approach Slab B Date Cast: 10172005 Date of Pucarrent 101705 Date of Pucarrent 1021705 Date Tested 121306 Age (and) 70 Testes By: RD Remarks: Comments: Analysis Yalidated by: A.P. Date: 121/32005 Sumple Validated by: A.D.P. Date: 121/32005 Surve: Persons Bow Material: Class A.Q.CC/A. Quantity 40 cy. Purpose: 520.0102 QC/GA Approach Slab A Date Cast: Sumple Validated by: A.P. Date: 121/32005 Synte: Sumple Validated by: A.P. Date: 121/32005 Synte: Sumple Validated by: A.P. Date: 121/32005 Synte: Sumple Validated by: A.P. Date: 121/32005 Date cast:		Project: Federal#:	PEMBROKE BRO-X-361(00	ALLENSTOW	N	State#: Report to	12978 Charles Flanders		· · ·
Ovinderfi PA-CCA- Submitted by: C. FLANDERS 10/24/2005 Source: Person's Bow Material: Class AA 20:-O/A Quantity 40 cy. Purposes 520.0102 CO/CA Approach Siab B Date Carls: 10/17/2005 Date Carls: 10/17/2005 Date Tested 12/13005 Age (sign) 57 Rema-Coulombs 1000 100 4000 Tested By: RD Remarks: Comments: Permeability of Concrete AA22075 Cylinderfi PA-CCA- Submitted by: C. FLANDERS 10/24/2005 Source: Person's Bow Material: Class AA OIC-O/A Quantity 40 cy. Purposes 520.0102 CO/CA Approach Siab A Date Carls: 10/202005 Material: Stangt by: A DP Date: 12/15/2005 Source: Person's Bow Material: Class AA OIC-O/A Quantity 40 cy. Purposes 520.0102 CO/CA Approach Siab A Date Carls: 10/202005 Date Tested 12/15/00 App (sign) 56 Source: Person's Bow Material: Class AA OIC-O/A Quantity 40 cy. Purposes 520.0102 CO/CA Approach Siab A Date Carls: 10/202005 Date Tested 12/15/00 App (sign) 56 Source: Tested 12/15/00 App (sign) 50 App (si		Permeab	oility of Conc	rete	AA22068				
Source: Person's Bow Material: Class AA C/IC-C/A Quantity 40 cy. Purpose: 520.0102 CC/QA Approach Slab B Date Carl: 10/172005 % Air Shanq(n): Mix Temp (P): Air Temp (P): Analysis Result Min Max Violation Method Date of Plasement 10/1705 Date Tested 12/1305 Age (syn) 57 Remm- Coulombs 1900 100 4000 Remarks: Comments: Analysis Validated by: AD Date: 12/15/2005 Source: Person Bow Material: Class AA C/IC-Q/A Quantity 40 cy. Purpose: 520.0102 CC/GA Approach Slab A Date Of Plasement 10/2005 Source: Jose SAA C/IC-Q/A Quantity 40 cy. Purpose: 520.0102 CC/GA Approach Slab A Date Class Max Mix Temp (P): Air Temp (P): Analysis Remark Mix Mix Xiolation Method Date Of Plasement 10/2005 Date Tested 12/1505 Age (syn) 56 Remarks: Comments: Analysis Validated by: AD Date: 12/15/2005 Source: Plasement 10/2005 Date Tested 12/1505 Age (syn) 56 Remarks: Comments:		Cylinder#:	PA-QCQA- Sub	mitted by: C. FLA	NDERS 10/24/2005				
Material: Class AA OL-GIA guantity 40 9. Purpose: S20.0102 COLA Approach Slab B: Date Cast: 10/172005 % At: Slampfoli): Mix Temp (P): Air Temp (P): Analysis Result Min Max Violation Method Date of Placement 10/1705 Date Tested 12/13/05 Age (49x) 57 (comments: Analysis Validated by: AD Date: 12/13/2005 Sample Validated by: AD Date: 12/15/2005 Source: Person's Bow Material: Class AA OL-GIA Quantity 40 Cy. Purpose: 520.0102 COCAA Pyroach Slab A Date Cast Min Max Violation Method Date Offacement 10/2005 Material: Class AA OL-GIA Quantity 40 Cy. Purpose: 520.0102 COCAA Pyroach Slab A Date Cast Min Max Violation Method Date Offacement 10/2005 Data Tested 12/1505 Age (49x) 56 Resumeth: Comments: Comm		Source:	Person's Bow	(A A A _					
Dete Cast: 10/17/2005 % Alt: Simplify: Mix Temp (P): Alt Temp (P): Analysis Result Min Max Violation Method Date of Piecement 10/17/05 Date Tested 12/13/06 Age (days) 57 Remarks: Comments: Analysis Vielidated by: AD Date: 12/15/2005 Sample Vielidated by: AD Date: 12/15/2005 Sumple Vielidated by: AD Date: 12/15/2005 Sumple Vielidated by: AD Date: 12/15/2005 Sumple Vielidated by: AT Date: 12/15/2005 Attraction State State Min Max Violation Method Date Officement 10/2005 Date Tested 12/15/05 Ap (days) 65 Permearks: Comments: Analysis Vielidated by: AD Date: 12/15/2005 Sumple Vielidated by: AD Date: 12/15/2005 Sumple Vielidated by: AD Date: 12/15/2005		Material: Purpose:	520.0102 QC/QA	A Approach Slab B	Cy.		· .		
% Air Shampfory: Mix Tamp (D): Mix Tamp (D): Analysis Result Min Max Violation Method Date of Placement 101705 Date Tested 121305 Age (disy) 57 Formation Source: Comments: Tested By: RD Rot: Analysis Visitated by: AD Date: 12130205 Sample Validated by: AD Date: 12152005 Permeability Of Concrete AA22075 Cylinder#: PA-QCQA- Cylinder#: PA-QCQA- Submitted by: A Quantity 40 cy. Purpose: 520 0102 QC(QA Approach Slab A Date: 12150205 Surrec: Person's Bow Material Min Max Violation Method Date Cast: 10202005 Date: 121505 Analysis Result Min Max Violation Method Date Tested 121505 Ape (disy) 66 Remarks: Comments: 2156205 Sample Validated by: AD Remarks: Comments: 2156205 Sample Validated by: AD Date: 12150		Date Cast:	10/17/2005						
Analysis Result mit mit mit mit mit mit mit mit mit mi		% Air	Slump(in):	Mix Temp (F):	Air Temp (F):				
Date Tested 12/1305 Age (days) 57 Resume Conformation 100 100 4000 Tested By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/13/2005 Sample Validated by: ADP Date: 12/15/2005 Optimedraft: PA-QCQA- Submitted by: C.FLANDERS 10/24/2005 Source: Ferson's Bow Material: Class AA O/C-O/A Quantity 40 oy. Purpose: 520.0102 QC/QA Approach Slab A Date Color 10/20205 % Air Stump(In): Mix Temp (P): Air Temp (P): Analysis Result Min Max Violation Method Data of Placement 10/2005 Data Tested 12/1505 Age (days) 56 Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Validated by: ADP Date: 12/15/2005		Date of Place	ement 10/17/05	min max	violation method				
Age (days) 57 Tested By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/13/2005 Sample Validated by: ADP Date: 12/15/2005 Sample Validated by: ADP Date: 12/15/2005 Source: Person's Bow Material: Class AA Q/C-Q/A Quantity 40 cy. Purpose: S20.0102 QU/CA Approach Slab A Date Cast: 10/20/2005 % Air Shung(h): Mix Temp (P): Analysis Result Min Max Violation Method Date of Placement 10/2005 Deta Tested 12/15/05 Age (days) 56 Bean eds (By) RD Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005		Date Tested	12/13/05	5 .	,				
Ferner, Coulombia 100 100 4000 Testels By: RD Remarks: Comments: Analysis Validated by: AD Date: 12/13/2005 Sample Validated by: ADP Date: 12/15/2005 Permeability of Concrete AA22075 Cylinder#: PA-CCQA-Submitted by: C. FLANDERS Nuterial: Class AA Q/C-Q/A guantity 40 cy. Purpose: 520.0102 QC/QA Approach Slab A Date Ctatt: 10/20/2005 % Air Stump(Ri): Mix Temp (P): Analysis Result Min Date Chatt: 10/20/2005 % Air Stump(Ri): Mix Temp (P): Analysis Result Min Date Of Placement 10/20/2005 Date Grassed 12/15/05 Age (tawy) 56 Remarks: Comments: Analysis Validated by: AD Date: 12/15/2005 Sample Validated by: ADP Date: 12/21/2005		Age (days)	57						
Remarks: Comments: Analysis Validated by: JA Date: 12/13/2005 Sample Vaitdated by: APP Date: 12/13/2005 Sample Vaitdated by: APP Date: 12/15/2005 Source: Person's Bow Material: Class AA Q/C-QIA Quantity 40 cy. Purpose: 520/102 Q/CAA Approach Slab A Date Crast: 10/20/2005 % Air Shumpfin): Mix Temp (F): Air Temp (F): Analysis Result Min Max Violation Method Date of Bacement 10/2005 Date Tested 12/15/05 Age (days) 56 Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Validated by: APP Date: 12/15/2005	ferm	 Coulombs Tested By: 	1600 BD	100 4000					
Comments: Analysis Yalidated by: A.P. Date: 12/15/2005 Formeability of Concret AA22075 Cylinderff: PA-QQA- Submitted by: Cylinderff: PA-QQA- Submitted by: Material: Class AA Q/C-Q/A Purpose: S200102 QC/QA Approach Slab A Date: 10/2005 % Air Slump(in): Mix Temp (F): Analysis Result Min< Max Violation Method		Remarks:							
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Analysis Validated by: JA Date: 12/15/2005 Sample Validated by: ADP Date: 12/15/2005 Permeability of Concrete AA22075 Cylinder#: PA-QCQA- Submitted by: C. FLANDERS 10/24/2005 Source: Person's Bow Material: Class AQ/C-QIA Quantity 40 cy. Purpose: 520.0102 QC/QA Approach Slab A Date Cast: 10/20/2005 % Air Stump(in): Mix Temp (F): Air Temp (F): Analysis Result Min Max Violation Method Date of Placement 10/20/2005 Date Tested 12/15/05 Age (days) 56 Permeability Of Quantity AD 4000 Testel By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Validated by: ADP Date: 12/21/2005		Comments:							
Sample Vaildated by: ADP Date: 12/15/2005 Permeability of Concrete AA22075 Cylinder#: PA-QCQA- Submitted by: C. FLANDERS 10/24/2005 Source: Person's Bow Material: Class AA Q(C-Q)A Quantity 40 cy. Purpose: 520.0102 QC/QA Approach Slab A Date Cast: 10/20/2005 % Air Slump(in): Mix Temp (7): Air Temp (7): Analysis Result Min Max Violation Method Date of Placement 10/2005 Date Tested 12/15/05 Age (days) 56 Feameeth: Different 102005 Reumerks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Analysis Val	idated by: JA	Date: 12/13/2005					
Permeability of Concrete AA22075 Cylinderft: PA-QCQA- Submitted by: C.FLANDERS 10/24/2005 Source: Person's Bow Material: Class AA Q/C-Q/A Quantity 40 cy. Purpose: 520 0102 QC/QA Approach Slab A Date Cast: 10/20/2005 % Air Stump(in): Mix Temp (F): Air Temp (F): Analysis Result Min Max Violation Method Date Tested 12/15/05 Age (days) 56 Feameedu Üburbas 1548 Tested By: RD Aralysis Validated by: AD Date: 12/15/2005 Sample Validated by: ADP		Sample Vail	dated by: ADP	Date: 12/15/2005					
Source: Person's Bow Material: Class AA Q/C-Q/A Quantity 40 cy. Purpose: 520.0102 QC/QA Approach Slab A Date Cast: 10/20/2005 % Air Slump(in): Mix Temp (F): Air Temp (F): Analysis Result Min Max Violation Method Date of Placement 10/20/05 Date Tested 12/15/05 Age (days) 56 Posmeebs/Signulombs 1546 100 4000 Tested By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Permeab	ility of Conc	rete	AA22075				•
Autors Assult Init		Source: Material: Purpose: Date Cast: % Air	Person's Bow Class AA Q/C-Q/ 520.0102 QC/QA 10/20/2005 <i>Slump(in):</i>	A <i>Quantity</i> 40 Approach Slab A <i>Mix Temp (F):</i> Min Max	cy. Air Temp (F): Violation Mathod			•	
Date Tested 12/15/05 Age (days) 56 Powereabio Doubles 1548 100 4000 Tested By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Date of Place	ement 10/20/05	in in inux	riotunion method				
Age (days) 56 Power eta bic Epulombs 1546 100 4000 Tested By: RD Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Date Tested	12/15/05	i					
Remarks: Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005	Peraneal	Age (days) Coulombs Tested By:	56 1546 RD	100 4000					•
Comments: Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Remarks:							
Analysis Validated by: JA Date: 12/15/2005 Sample Vaildated by: ADP Date: 12/21/2005		Comments:							
Analysis Validated by: ADP Date: 12/21/2005		An abasis Val	Iduand have 14	Data: 12/15/2005					
		Anaiysis Val Sample Vaili	dated by: SA	Date: 12/21/2005					
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	•		•				· ,		

Wednesday, February 01, 2006

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APPENDIX B - FREEZE-THAW TESTS

STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NU	MBER:	NH no fi	ber Ref.	DATE	CAST:	10/17/2005	
SPECIMEN I.	D.:	NH REF.	1	SPECIMEN	SIZE:	3 x 3 x 16	
TRAY NUMBER	2:	#1					
	MAT	TAT. SOI	IRCE AND C	ENERAL COMME	NTS		
3/4	11171	EKTAD DOG	JICE HID C	DEMERCIAL COMME			
Sand				air admix:			
Cement				water reducer a	admix:		
pozz admix				H.R.W.R:			
pozz admix							
pozz admix					н	I.R.W.R - high range water	reducer
		FRESH	CONCRETE	DATA			
unit weight	(lb/cf)			concrete tem	p (F)		
% air				air temp (F)			
slump (in.)							
water/cemen	it ratio					•	
דעענ	CVCLE	WETCHT	\$ NOT 1099	FRECIENCY *		COMMENTS	
DAIL	CICHE	WEIGHT	% NGT. DODD	PREQUENCE			
11/04/05		3860.00		2002			
11/10/05	51	3860.20	0.0	1758		good	
11/18/05	105	2050 40	0 0	2052		good	
11/17/05	TOP	3859.40	0.0	2052		good	
11/23/05	154	3857.3	0.1	2046		good	
12/01/05	220	3857.3	0.1	2004		good	
					Verv s	light scaling	around
12/09/05	287	3859.9	0.0	1477	,51, 53	bottom	
					Very s	Light scaling	around
12/13/05	322	3861.2	0.0	1275	. 1	bottom	
				i i			1

Note: Not sure why frequency dropped, bars showed no signs of deteriation.

Durability factor (DF) = (end frequency ^2/start frequency ^2) *100% = 40.56

* FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION T 161-86

Freeze-Thaw tests.xls

STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NU SPECIMEN I. TRAY NUMBER	MBER: D.:	NH no fi NH REF. #2	ber Ref. 1	DATE SPECIMEN	CAST: 10/17/2005 I SIZE: 3 x 3 x 16			
3/4	MAT	'ERIAL SOU	JRCE AND G	ENERAL COMME	INTS			
Sand			,	air admix:				
Cement	1	water reducer admix:						
pozz admix				H.R.W.R:				
pozz admix								
pozz admix					H.R.W.R - high range water reducer			
unit weight % air	(lb/cf)	FRESH	CONCRETE	concrete tem air temp (F)	ър (F)			
slump (in.) water/cemen	t ratio				1997 - 1997 -			
DATE	CYCLE	WEIGHT	% WGT. LOSS	FREQUENCY *	COMMENTS			
11/04/05		3856.10		1975				
11/10/05	51	3855.30	0.0	1751	Good			
11/17/05	105	3852.50	0.1	2147	Good			
11/23/05	154	3850.7	0.1	2150	Good			
12/01/05	220	3851.6	0.1	1824	Good			
12/09/05	287	3853.5	0.1	1401	Good			
12/13/05	322	3854.7	0.0	1320	Good			
Note: Not sure why frequency dropped, bars showed no signs of deteriation.								

* FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION

T 161-86

Freeze-Thaw tests.xls

Slight scaling

Slight scaling

104.05

STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NU SPECIMEN I TRAY NUMBER	MBER: D.: 2:	NH no fi NH REF. #3	ber Ref. 1	DATE SPECIMEN	CAST: SIZE:	10/17/2005 3 x 3 x 16		
	MAT	ERIAL SOU	JRCE AND G	ENERAL COMME	NTS			
3/4								
Sand				air admix:				
Cement				water reducer a	admix:			
pozz admix				H.R.W.R:				
pozz admix						N .		
pozz admix						H.R.W.R - high range water reducer		
		FRESH	CONCRETE	DATA	()			
unit weight	(lb/cf)		concrete temp (F)					
% air				air temp (F)				
slump (in.)								
water/cemer	it ratio							
DATE	CYCLE	WEIGHT	% WGT. LOSS	FREQUENCY *		COMMENTS		
11/04/05		3896.60		1845				
11/10/05	E 1	2004 00	0 1	1796	Very	slight weight loss &		
11/10/05 51 3894.00 0.1 1/96 scalin						scaling		
11/17/05	105	2002 20	0 1	1741	Very	slight weight loss &		
11/1//05	105	3092.20	0.1	1/41		scaling		
11/23/05	154	2001 E	0.1	1727	Very	slight weight loss &		
	104 104		0.2			scaling		
12/01/05	220	3892	0.1	1775	Very	slight weight loss &		
1 12,01,00	220	5072		1,10		scaling		

Freeze-Thaw tests.xls

12/09/05

12/13/05

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287

322

3895.2

3893.5

0:0

0.1

Durability factor (DF) = (end frequency ^2/start frequency ^2) *100% =

* FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION

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STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NU	MBER:	NH Fiber DATE CAST: 10/17/2005					
SPECIMEN I.	D.:	NH Fiber #1 SPECIMEN SIZE: 3 x 3 x 16					
TRAY NUMBER	:	#4					
	мал	TERTAL SOL	IRCE AND G	ENERAL COMME	INTS		
3/4		DRIMI DOC					
Sand .				air admix:			
Cement		admix:					
pozz admix	admix H.R.W.R:						
pozz admix		<u>`</u>					
pozz admix			·		H.R.W.R - high range water reducer		
		FRESH	CONCRETE	DATA	•		
unit weight	(lb/cf)			concrete ten	np (F)		
% air				air temp (F)			
slump (in.)							
water/cemen	t ratio						
DATE	CYCLE	WEIGHT	% WGT. LOSS	FREQUENCY *	COMMENTS		
11/04/05		3912.60		1650			
11/10/05′	51	3910.80	0.0	1638	Very slight weight loss & scaling		
11/17/05	105	3911.10	0.0	1429	Very slight weight loss & scaling		
11/23/05	154	3909.1	0.1	1394	Very slight weight loss & scaling 10 to 15 fibers balled up in bottom		
12/01/05	220	3910	0.1	1447	Very slight scaling		
12/09/05	287	3910.6	0.1	1631	Very slight scaling		
12/13/05	322	-3-911.1-	0.0	1-7-0-6	Very_slight_scaling		
Durabili	ty factor	(DF) = (end	frequency	^2/start fremu	$encv^2$ *100% = 106 Q0		

* FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION T 161-86

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Freeze-Thaw tests.xls

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STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NU SPECIMEN I TRAY NUMBER	MBER: .D.: R:	NH Fiber NH Fiber #5	#1	DATE SPECIMEN	CAST: 10/17/2005 SIZE: 3 x 3 x 16			
	MAT	ERIAL SOU	JRCE AND G	ENERAL COMME	INTS			
3/4								
Sand				air admix:				
Cement	Cement			water reducer admix:				
pozz admix				H.R.W.R:				
pozz admix								
pozz admix					H.R.W.R - high range water redu			
	(1) (FRESH	CONCRETE	DATA				
unit weight	(ID/CI)			concrete tem	ip (F)			
₹ alr				air cemp (r)				
siump (in.)	nt ratio							
water/celler	ic ideio							
DATE	CYCLE	WEIGHT	% WGT. LOSS	FREQUENCY *	COMMENTS			
11/04/05		3867.20		1241				
11/10/05	51	3868.50	0.0	1351	Good			
11/17/05	. 105	3866.60	0.0	1628	Good			
11/23/05	154	3866	0.0	1601	Good			
12/01/05	220	3867.7	0.1	1870	Good			
12/09/05	287	3870.3	0.1	1728	Very slight scaling			
12/13/05	322	3869.1	0.0	İ362	Very slight scaling			
· · · · · · · · · · · · · · · · · · ·								
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Durability factor (DF) = (end frequency ^2/start frequency ^2) *100% = 120.45 * FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION

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Freeze-Thaw tests.xls

STATE OF VERMONT AGENCY OF TRANSPORTATION MATERIALS AND RESEARCH DIVISION STRUCTURAL CONCRETE SUBDIVISION

FREEZE-THAW DATA WORKSHEET

WORKPLAN NUMBER:		NH Fiber		DATE	E CAST: 10/17/2005				
SPECIMEN I.D.:		NH Fiber #1		SPECIMEN	I SIZE: 3 x 3 x 16				
TRAY NUMBER	2:	#6		×					
	MAT	ERIAL SOU	JRCE AND G	SENERAL COMME	INTS				
3/4									
Sand				air admix:					
Cement	admix:								
pozz admix				H.R.W.R:					
pozz admix									
pozz admix					H.R.W.R - high range water reducer				
		FRESH	CONCRETE	DATA					
unit weight	(lb/cf)			concrete ten	np (F)				
% air				air temp (F)					
slump (in.)									
water/cemer	it ratio								
DATE	CYCLE	WEIGHT	% WGT. LOSS	FREQUENCY *	COMMENTS				
11/04/05		3921.80		/ 1205					
11/10/05	51	3921.00	0.0	1696	Slight pitting				
11/17/05	105	3920.00	0.0	1280	Slight pitting				
11/23/05	154	3920.6	0.0	1350	Slight pitting				
12/01/05	. 220	3919.2	0.1	1327	Slight pitting				
12/09/05	287	3923	0.0	1387	Slight pitting				
12/13/05	322	3920.6	0.0	1422	Slight pitting				
				· · · ·					

Durability factor (DF) = (end frequency ^2/start frequency ^2) *100% = 139.26

* FUNDAMENTAL TRANSVERSE FREQUENCY; REFER TO AASHTO DESIGNATION T 161-86

Freeze-Thaw tests.xls

APPENDIX C - BEAM TESTING AND PETROGRAPHICS

Alternate Approach Slab Reinforcement SPR Project 13733-H

Final Report

July 24, 2008

Submitted to New Hampshire Department of Transportation

By

David Gress Department of Civil Engineering University of New Hampshire

Background

The Pembroke Bridge construction project was selected by the NHDOT to evaluate an alternate approach slab reinforcement technique. One approach slab was conventionally placed as per traditional practice (reinforcement top and bottom both directions. The alternate slab consisted of fiber reinforced concrete with only bottom reinforcement (both directions). This work consisted of the laboratory evaluation of the two concretes.

Procedure

The procedure to obtain viable laboratory samples was to cast 4" slabs large enough to prevent segregation and alignment of fibers during casting but small enough to transport back to UNH and cut 4" x 4" x 14" beams for flexural testing. Two field cores were obtained from each approach slab for determining air void parameters using petrographic analysis.

Beam testing was based on procedures outlined in ASTM C 1018 and C 1399. The intent of these two ASTM testing procedures was to compare the benefits of fiber reinforced concrete to conventional concrete. Emphasis was placed on First crack Toughness, toughness after the first crack, total toughness, Average Residual Strength and conventional flexural strength. Third point loading was used with a span of 12". An Instron closed loop testing machine was used with digital dial gauges monitoring the deformations.

Cores obtained by Turner Testing and Engineering were cut and polished for air void analysis as per ASTM C457 modified point count procedure.

Data

Data from the beam laboratory testing is presented in Table 1. Four beams from each approach slab were tested. The traditional concrete was identified as samples NF1 through NF4 and the fiber reinforced concrete as F1 through F4.

The average flexural strengths of the traditional and fiber reinforced concretes were 730 psi and 660 psi respectively. The quality of the two concretes is apparent with the high flexural strengths. As would be expected with a plastic fiber the flexural strength of the fiber reinforced concrete was reduced by 70 psi, approximately 10 percent.

First Crack Toughness as defined by the maximum load as is used in determining the standard flexural strength was an average of 178.4 psi for the traditional concrete and 53.8 psi for the fiber reinforced concrete. This is basically the energy required per unit volume of concrete to cause the first crack to occur. The benefit of the fiber is not obvious due the difference between the two by approximately a factor of three. The presence of the fibers lowers the strength, as previously shown by the flexural strength, as well as the First Crack Toughness.

Boom	Flexural	First crack	After first crack	Total toughness,	ARS^{1} ,
Deam	Strength, psi	toughness, in-lb	toughness, in-lb	in-lb	psi
NF1	750	78.2	0	0	0
NF2	660	38.8	0	0	0
NF3	825	558.7	0	0	0
NF4	675	37.7	0	0	0
Avg	730	178.4	0	0	0
F1	565	31.1	223.7	254.8	160
F2	660	35.4	275.0	310.4	330
F3	845	78.3	526.9	605.2	290
F4	565	70.2	233.0	303.2	170
Avg	660	53.8	314.7	368.4	240

Table 1: Beam laboratory testing data

Note: ¹ ARS is Average Residual Strength after the first crack

The amount of unit energy required to fail the concrete after the first crack is exceptionally large for the fiber reinforced concrete and equal to 0 for the traditional concrete. Likewise the total toughness shows the real benefit of using fibers in concrete. Comparing the average of the two values shows a difference of approximately a factor of two (368.4/178.4) again showing the real benefit of the fiber is after it cracks.

The Average Residual Strength (ARS) was estimated to be an average of 240 psi. This is just another way to identify the remaining strength after the first crack, again showing the benefit of using fibers.

Petrographic

Figures 1 and 3 show the polished sections of the near surface of the fiber reinforced and traditionally reinforced concretes. Both show good distribution of aggregates and a surface well compacted but not over finished. Even though an attempt to avoid hitting reinforcement during coring was made, Figure 3 shows an epoxy coated reinforcement bar. The two areas of the figure showing little epoxy cover may be the result of pulling the coating during polishing. Figure 2 shows a close up of the section noted by an arrow in Figure 1. This shows the uniform distribution of the fibers.

Air Void Analysis

Three cores were cut and polished to analyze the air void properties of the two approach slabs as per ASTM C 457 – 98 Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete. Table 2 presents the results of the air void testing. These data show that the air content of the non fiber samples and fiber samples had average air contents of 7.9 and 7.0 percent with a average spacing factors of 0.001 for the non fiber and fiber concretes. The paste, fine aggregate and coarse aggregate percentages were also similar for both concretes. Based on these data the concretes would be expected to be resistant to cycles of freezing and thawing.

Sample	Paste	Air	Aggregate		Spacing Factor		Specific Surface
			Fine	Coarse	Inches	mm	α, in-1
NF1 top	37.9%	7.0%	18.1%	37.0%	0.0013	0.033	3657
NF1 bot	37.7%	8.8%	17.0%	36.6%	0.0012	0.030	3657
Average	37.8%	7.9%	17.5%	36.8%	0.0012	0.032	3657
F1 top	38.3%	8.7%	17.4%	35.6%	0.0012	0.030	3657
F1 bot	39.1%	6.0%	18.2%	36.7%	0.0014	0.036	3657
F2 top	39.7%	6.5%	17.6%	36.3%	0.0014	0.035	3657
F2 bot	37.4%	6.8%	17.2%	38.6%	0.0013	0.034	3657
Average	38.6%	7.0%	17.6%	36.8%	0.0013	0.034	3657

Table 2: ASTM C 457 Air void analysis data

Conclusions

The laboratory testing of the approach slab concretes showed the benefit of fiber reinforcing. Petrographic analysis showed the fibers to be very uniformly dispersed suggesting they would be expected to control cracking if and when cracking occurs in the field. Both concretes were shown to have air void systems capable of resisting freeze thaw cycles supporting the hypothesis that fibers have little if any impact on entraining air.

Recommendations

Based on the laboratory data it is recommend that future approach slabs be designed and placed without any conventional reinforcing. This is consistent with state of the art airport pavement design procedures, which typically require no reinforcing what so ever for much thicker slabs. On the other hand since the use of fibers is so inexpensive and their presence has such a significant impact on crack arrest it is highly recommended future approach slabs always specify them.