SELF CURING ADMIXTURE PERFORMANCE REPORT

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9. Performing Organization Name and Address Anderson Engineering & Surveying, Inc. 17681 Hwy 395 / PO Box 28 Lakeview, OR 97630 DiBrito Material Testing PO Box 14 Klamath Falls, OR 97601		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
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16. Abstract

The Oregon Department of Transportation (ODOT) has experienced early age cracking of newly placed high performance concrete (HPC) bridge decks. The silica fume contained in the HPC requires immediate and proper curing application after placement to avoid early age cracks. Many construction contractors do not consistently apply adequate curing procedures, and project sites may not have easy access to water. This problem led ODOT to investigate a self-curing admixture (SCA) for bridge deck concrete mixes. The SCA reduces wet curing requirements by counteracting to some degree water loss due to evaporation. An admixture in place of wet curing that allows HPC bridge deck concrete to cure properly without early age cracking and without decreasing other performance requirements would provide another option for contractors. The study showed that concrete with the SCA after a 3-day wet cure can produce similar results to standard HPC concrete with a 14-day wet cure. However, the concrete additives in the concrete must be compatible with the SCA

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	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.			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

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	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

DISCLAIMER

SELF CURING ADMIXTURE PERFORMANCE REPORT
CONTRACT # 29325

AGENCY

Oregon Department of Transportation
ODOT TECHNICAL SERVICES BRANCH/BRIDGE SECTION
404 FAIRVIEW INDUSTRIAL DRIVE SE, MS#4
530.986.3344
Bruce.V.Johnson@odot.state.or.us

PROJECT TEAM

ENGINEER
Darryl Anderson
Anderson Engineering & Surveying, Inc.
17681 Hwy 395 / PO Box 28
Lakeview, OR 97630
541-947-4407
darryla@andersonengineering.com

MATERIALS TESTING CONSULTANT
Bill DiBrito
DiBrito Material Testing
PO Box 14
Klamath Falls, OR 97601
541-892-6576
bdibrito@gmail.com

SCA DEVELOPER
Dr. Wen-Chen Jau
National Chiao Tung University
jau@mail.nctu.edu.tw

ODOT TECHNICAL ADVISORY COMMITTEE
Bruce Johnson
Randy Kessler **Steve Soltesz**
Craig Shike **Bill Bennett**
Terry Thames **Scott Nelson**

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REGISTERED PROFESSIONAL ENGINEER
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ABBREVIATIONS

CCT	**Certified Concrete Technician**
Ec	**Modulus of Elasticity**
HCC	**Hooker Creek Companies**
HPC	**High Performance Concrete**
IGA	**Inter-Government Agreement**
KRM	**Knife River Materials**
ODOT	**Oregon Department of Transportation**
PSI	**Pounds per Square Inch**
SCA	**Self Curing Admixture**
fc'	**Compressive Strength of Concrete**

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Project Overview

The Oregon Department of Transportation (ODOT) has experienced early age cracking of newly placed High Performance Concrete (HPC) bridge decks. The silica fume contained in the HPC requires immediate and proper curing application after placement to avoid early age cracks. Recent improvements in ODOT curing requirements and changes to ODOT deck concrete specifications have significantly reduced the extent of cracking on new decks. However, cracking still occurs on some projects because many construction contractors do not consistently apply adequate curing procedures. Also the project sites may not have easy access to water. This problem has led ODOT to look at possible self-curing additives to add to bridge deck concrete mix designs.

Dr. Wen-Chen Jau of the National Chiao-Tung University has developed a self-curing admixture (SCA) that shows promise in laboratory tests as an alternative to wet curing. ODOT entered into an Inter-Government Agreement (IGA) with the National Chiao-Tung University for Dr. Wen-Chen Jau's services for this SCA testing project. Dr. Jau states the SCA is able to draw moisture from the ambient air into the concrete; thereby counteracting to some degree, water loss due to evaporation. An admixture in place of wet curing that allows ODOT HPC bridge deck concrete to cure properly without early age cracking and without decreasing other performance requirements would provide another option for contractors. This mixture could also reduce construction time and costs. However, the ability of the SCA to perform as well as wet curing must be demonstrated before use on a bridge deck. The SCA may also be applicable to other concrete pours on a typical bridge. Using SCA in pile caps, rail structures, and other bridge components may speed up the construction process by eliminated the longer wet cure times. The accelerated curing process may allow for smoother project coordination and quicker construction scheduling.

In addition, the admixture must meet the requirements of ODOT Standard Specification 02040.10 "Chloride content of any admixture used in Portland cement concrete in contact with embedded metals shall not exceed 0.5% by weight of the admixture when tested according to ODOT TM 505."

Anderson Engineering and Surveying Inc. was retained by ODOT to test and evaluate the SCA admixture. This report covers the results of concrete test batches using the SCA with ODOT bridge deck concrete mix.

Project Objectives

A. Determine the performance of a typical ODOT bridge deck mix in a dry environmental condition typical of eastern Oregon using the SCA.

B. Measure changes in key properties for fresh and hardened concrete due to SCA additions.

C. Determine whether the SCA can produce a crack-free test slab in a typical ODOT bridge deck in the Eastern Oregon area.

Self-Curing Admixture

The self-curing admixture was provided by inventor, Dr. Wen-Chen Jau, for the test batches and slabs covered in this report. This SCA is covered by Patent No: US 8,016,939 B2. The Patent Publication attached in the Appendix for reference. This report does not evaluate the contents of the SCA admixture, only the performance when used in high performance concrete. Dr. Wen-Chen Jau was consulted through-out this project on the dose rates and use of the SCA product. Dose rates and mix times were based on Dr. Jau's recommendations. The SCA admixture is not a substitute or replacement for water in the overall mix, unlike some other admixtures.

Project Background

Some earlier tests were conducted by ODOT with the SCA admixture in the ODOT materials laboratory. High air contents and low strength resulted with the tests. Further work with Dr. Wen-Chen Jau revised SCA ingredients, mixing times, and dose rates. The revised procedures derived from the early tests were incorporated into the batch trials covered in this report.

ODOT high performance concrete used in bridge decks utilizes several ingredients other than the traditional ones of sand, gravel, water and cement. In addition to air entrainment, water reducers, and set extenders, fly ash and silica fume are added to the HPC.

Fly ash is a byproduct of coal or biomass burning power plants. Environmental laws in the 1970's brought about the re-use of materials that were dumped in landfills, and fly ash began to be used more often in concrete. Two common types of fly ash are used, Type F and Type C.

The burning of harder, older anthracite and bituminous coal typically produces Type F fly ash. This fly ash acts like a pozzolan in nature, and contains less than 20% lime. Type F fly ash possesses pozzolanic properties, but the glassy silica and alumina of Type F fly ash requires an additional activator, such as Portland cement, with the presence of water in order to react and produce a cement type compound.

Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has self-cementing properties. In the presence of water, Type

C fly ash will harden and gain strength over time. Type C fly ash generally contains more than 20% lime. Unlike Type F, self-cementing Type C fly ash does not require an activator. Alkali and sulfate contents are generally higher in Type C fly ashes.

As with fly ash, implementation of environmental laws during the mid-1970’s required silicon smelters to begin to capture and collect the silica fume, instead of placing in landfills. Since it had shown that Portland cement based concretes containing silica fumes had very high strengths and low porosities the use became a valuable admixture for concrete.

Project Phases

This project was broken into three phases:

1. *Laboratory batch trial of August 4, 2011*
2. *Truck batch trial using a minimum of one yard of HPC on August 25, 2011*
3. *Test slab trial using two 20’4” X 10’ test slabs representing a bridge deck on September 20, 2011*

All batches were to be sampled for air content, slump, and temperature. Strength samples were taken for compressive strength at 1, 2, 4, 7, 14, 28, and 56 day breaks. Shrinkage molds were also cast to monitor shrinkage.
Curing regimes were

- Air cure - no cure other than normal air temperature (at 85° F and 35% Humidity)
- Wet cure for 14 days using ODOT method of moist burlap
- Wet cure for 3 days using ODOT method of moist burlap
- Standard cure of water tank immersion for 28 days with water temperature of 68 degrees

Phase 1 – Laboratory Batch Trail

A batch trial was conducted in the laboratory of Dibrito Material Testing of Klamath Falls, Oregon. Aggregate, sand, cement, fly ash, and admixture samples were obtained from Hooker Creek Companies (HCC) of Bend, Oregon. Preliminary trial batches were conducted using HCC approved ODOT mix design the first week of July 2011. Several one cubic foot batches were conducted using the materials from HCC.

Hooker Creek Company mix design is outlined below.

Cement Type 1	416	lbs. /cubic yard
Fly Ash Type C – Boral	189	lbs. /cubic yard
Silica Fume BASF/Rheomac SF-100	25	lbs. /cubic yard
¾ to #4 Aggregate	1800	lbs. /cubic yard
#4 to 0 Aggregate	1170	lbs. /cubic yard
Water	237	lbs. /cubic yard
Water / Cement Ratio	0.38	
Air Content	6.0%	
Density	142.4 lbs. /cubic foot	
Air Entrainment Agent	BASF/AE-90	
Water Reducer	BASF/Pozzolith-200N	
High Range Water Reducer	BASF/Polyheed-997	
Water Reducer/Set Extender	BASF/Delvo	

Some problems developed in the preliminary HCC trial batches. The ¾ to #4 aggregate was larger than required in the ODOT specification making the mix unworkable after just a few minutes of mixing. All final samples were required to be taken after 45 minutes of mixing to simulate normal job conditions from batch time to placement. The un-workability was an issue and continued on each preliminary batch. Dibrito Material Testing investigated possible causes of the un-workability and found that when samples of the fly ash were mixed with only water and placed in a small cup they became very hot to the touch and hardened in only a few minutes (less than 20 minutes). HCC suggested obtaining a sample of fly ash from a different hopper at their site. This different material helped, but workability was still an issue.

The official trial batch using the Hooker Creek materials and second fly ash sample (Type C) was done on August 4, 2011. Dr. Jau and Bruce Johnson, ODOT Agency Project Manager, were on site. A concrete sample was batched and let mix for 40 minutes before sampling. The mixer drum was kept cool with water sprinkling and a damp cloth was kept over the mixer opening. Samples were taken and placed in the cylinders and molds. Dr. Jau and Mr. Johnson were a big help in filling all cylinders. The large aggregate and unworkability of the concrete made filling shrinkage molds and cylinders difficult.

Curing Regimes for test cylinders

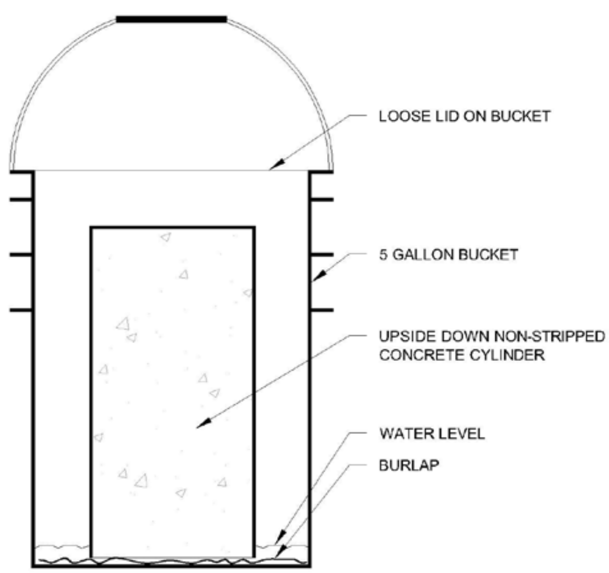
Cylinder ID Numbers 1 through 75 were cast with this test batch under the following cures.

Cylinder Set	Cylinder #	Type	Batch	Curing
1	1 thru 8	HPC/Type C Ash	Lab	Air - Lids off no strip 85 Degrees 35% Humidity
1	9 thru 11	HPC/Type C Ash	Lab	Standard tank 73 Degree water
2	12 thru 19	HPC/Type C Ash	Lab	Wet cure / burlap 14 Day Air afterward
3	20 thru 27	SCA/Type C Ash	Lab	Air - Lids off no strip 85 Degrees 35% Humidity
3	28 thru 30	SCA/Type C Ash	Lab	Standard tank 73 Degree water
4	30 Thru 38	SCA/Type C Ash	Lab	Wet cure / burlap 3 days only Air afterward
5	39 thru 46	SCA/Type C Ash	Lab	Wet cure / burlap 6 days only Air afterward
6	47 Thru 54	SCA/Type C Ash	Lab	Wet cure / burlap 7 days only Air afterward

ODOT Sets Shipped to Salem after Cure

1	55 Thru 57	SCA/Type C Ash	Lab	Air - Lids off no strip 85 Degrees 35% Humidity
2	58 Thru 60	SCA/Type C Ash	Lab	Wet cure / burlap 14 Day Air afterward
3	61 Thru 63	SCA/Type C Ash	Lab	Air - Lids off no strip 85 Degrees 35% Humidity
4	64 Thru 66	SCA/Type C Ash	Lab	Wet cure / burlap 3 Day Air afterward
5	67 Thru 69	SCA/Type C Ash	Lab	Wet cure / burlap 6 Day Air afterward
6	70 Thru 72	SCA/Type C Ash	Lab	Wet cure / burlap 7 Day Air afterward
7	73 thru 75	SCA/Type C Ash	Lab	Wet cure / burlap 14 Day Air afterward

All cures were processed under 85 degrees and 35% humidity. Wet cures were processed simulating a burlap cure on a bridge deck. These cylinders were placed in a five gallon bucket upside down (lid off) on saturated burlap as shown below.



WET CURE METHOD

HCC Concrete Sampling at Laboratory Site

Covered Concrete Mixer

The results of the laboratory testing was as follows:

Fresh concrete parameters on 4 cubic foot batch

Air Temperature	78 degrees
Slump	4 - 7/8"
Air Content	7.5%
Unit Weight	143.7 Lbs. /cubic foot

After 30 minute mix time

Air Temperature	78 degrees
Slump	3.0"
Air Content	4.8%
Concrete Temperature	75 degrees

Batch with SCA additive

Air Temperature	86.7 degrees
Slump	3.5"
Air Content	6.0%
Concrete Temperature	74 degrees

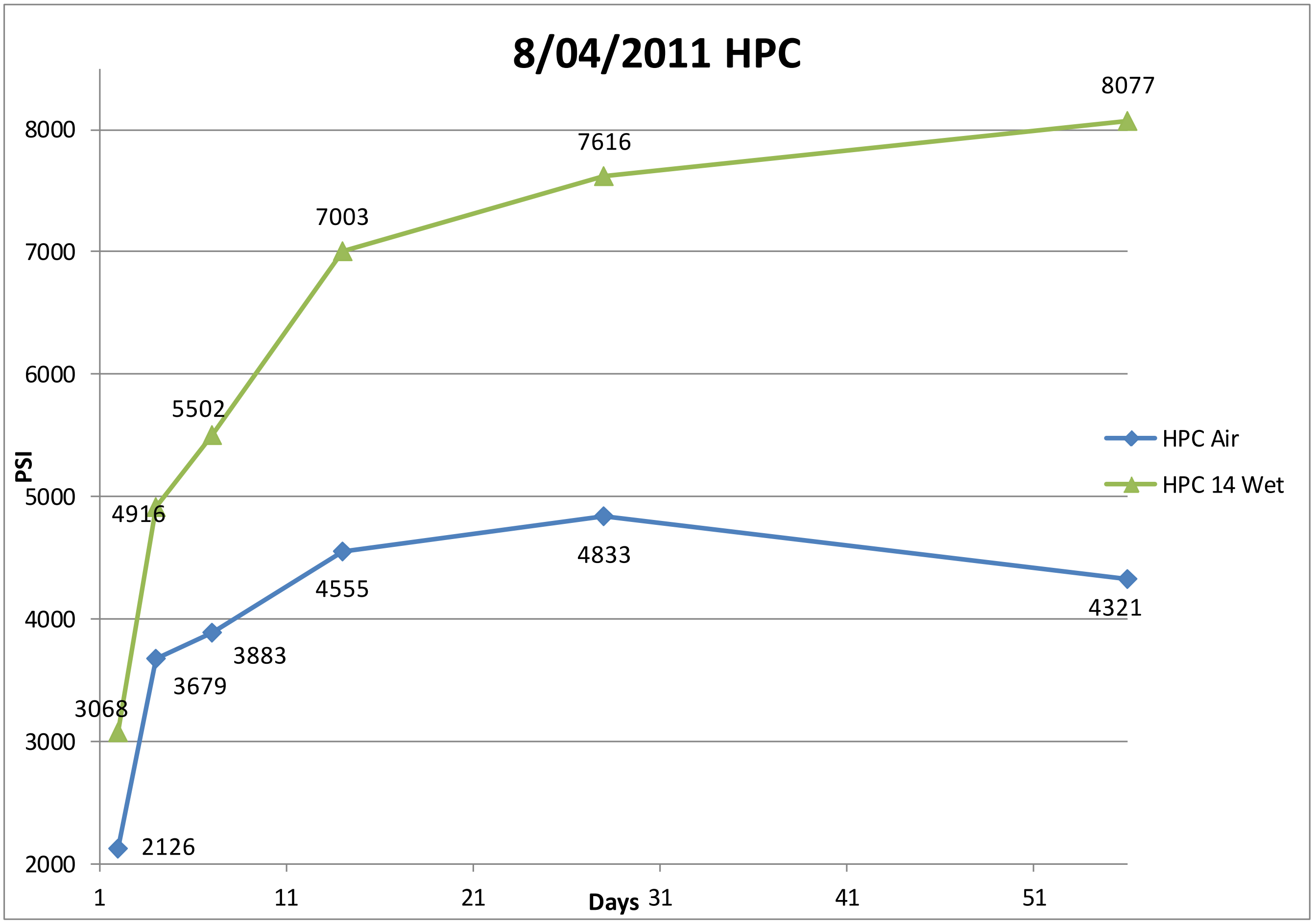
Ice was used in the mix to keep temperatures down due to the workability issue. The SCA additive was introduced after 5 minutes of mix time. SCA dose rate was 2.0% by weight of cementatious material (Cement, Fly Ash, Silica Fume). Samples were taken after an additional 5 minutes of mixing, again due to the difficult workability of the mix. Even with this mix, filling the cylinders and shrinkage molds was difficult.

Cylinders from Laboratory Batch Trial

Laboratory Trial Shrinkage Prisms

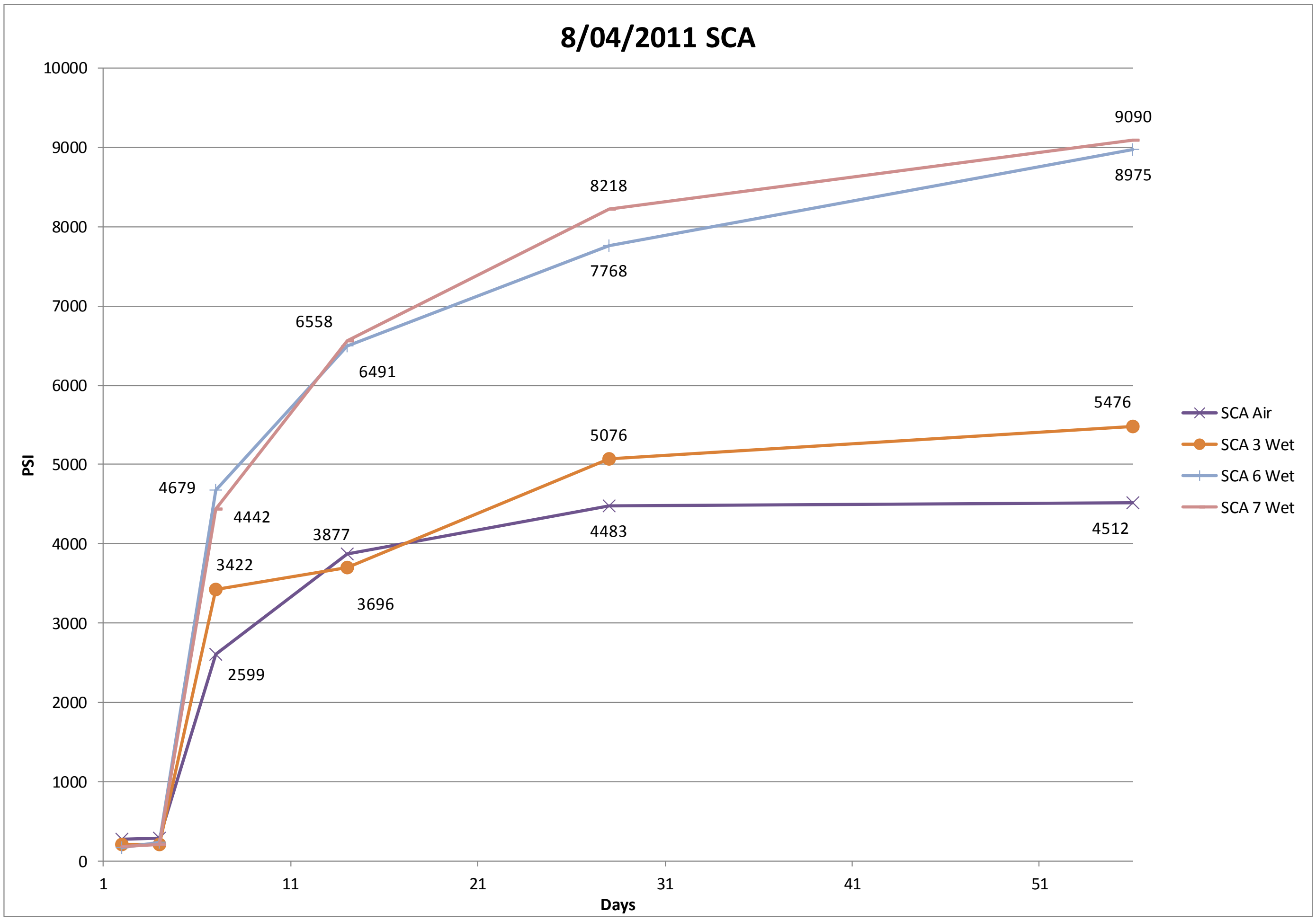
Break results of the trial batch HPC are noted below:

HPC Trial Batch Break Results



The break graph depicts a typical break curve for this type of concrete. Wet cures result in higher strengths, which is no surprise. The results provide a good baseline to compare the SCA mix.

SCA Trial Batch Break Results

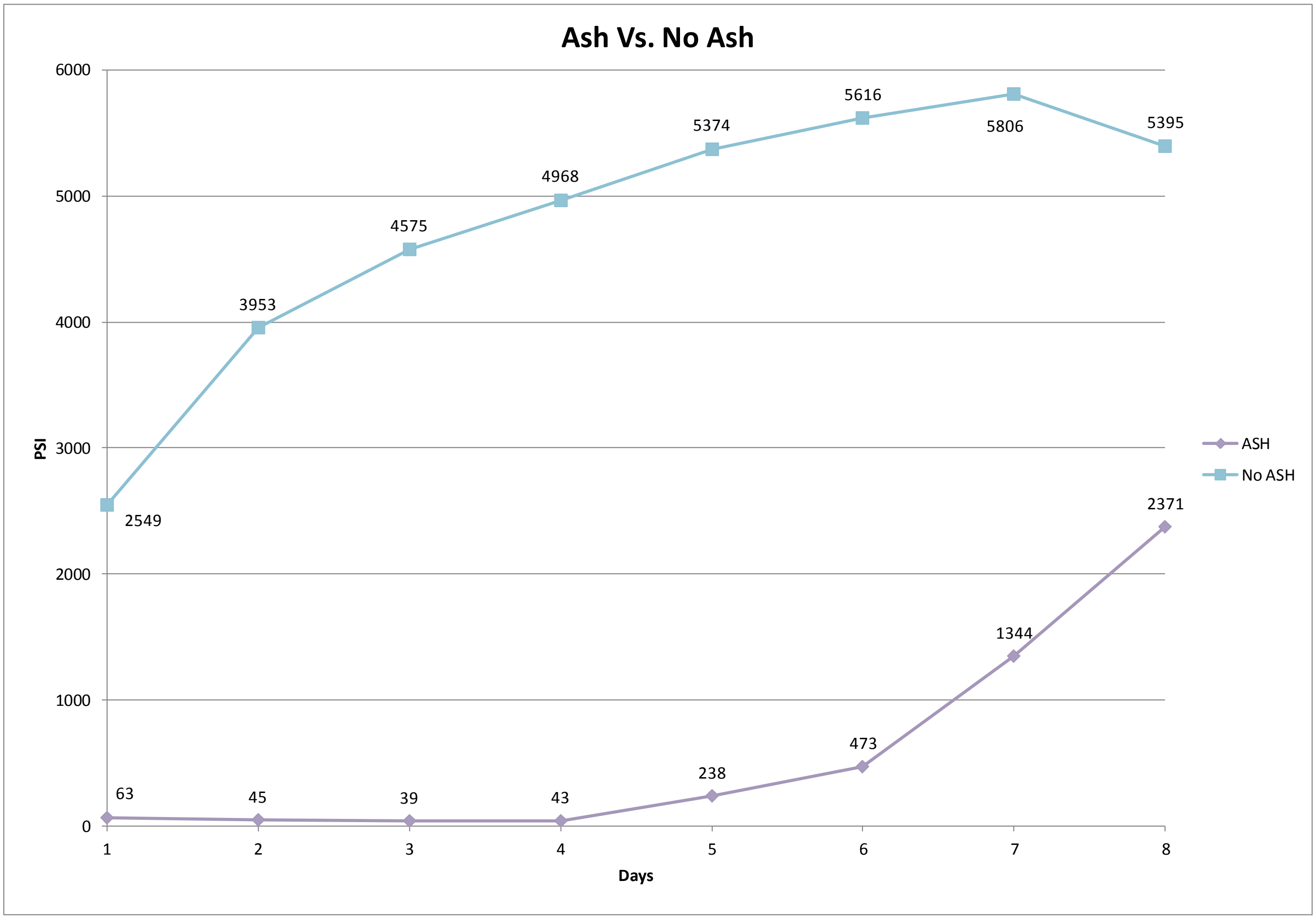


The results of concrete with the SCA additive are nearly identical to the HPC, with the exception of low early strength of the mixture. These low early strengths would be unacceptable for bridge decks required to meet construction schedules; and in many cases, reintroducing traffic as quickly as possible. The Type C fly ash was suspected of causing the retarding of early strength in combination with the SCA additive.

On August 10th an additional two batches were prepared to confirm that the Type C fly ash and the SCA caused the low early strength. One batch was processed identical to the previous test batch and the other batch with the removal of the Type C fly ash. This batch with SCA used additional cement substituted for the fly ash content, to keep the mix properties the same. Cylinders cast are noted below:

Cylinder Set	Cylinder #	Type	Batch	Curing
8	76 Thru 83	SCA/Type C Ash	Lab	Wet cure / burlap 14 Day Air afterward
9	84 Thru 91	SCA/No Ash	Lab	Wet cure / burlap 14 Day Air afterward

Ash vs. No Ash Break Results



This test proved the SCA and the Type C fly ash were not compatible for high early strengths. Although strengths are eventually gained; it is seven days before the mixture begins to work. Two points were noted in the first test batch;

- SCA does increase air content slightly
- SCA is not compatible with Type C fly ash

Phase 2 – Truck Batch Trials

Due to the un-workability issue, it was then determined to try another cement company with an approved ODOT cement mix design. We moved our testing site to Knife River Materials (KRM) in Klamath Falls, Oregon. The KRM plant was selected as the Class F fly ash was readily available and was used by KRM routinely on ODOT projects.

On August 25th we tested a larger quantity in a truck batch test of mixed concrete at the KRM Batch plant.

KRM Mix Design – ODOT Approved

Cement Type 1	488 lbs. /cubic yard
Fly Ash Type F (Jim Bridger)	189 lbs. /cubic yard
Silica Fume	30 lbs. /cubic yard
¾ to #4 Aggregate	792 lbs. /cubic yard
#4 to 0 Aggregate	90 lbs. /cubic yard
Water	280 lbs. /cubic yard
Water / Cement Ratio	0.38
Air Content	6.0%
Density	140.9 lbs. /cubic foot
Air Entrainment Agent	MB/AE-90
High Range Water Reducer	MB PS-1466
Water Reducer/Retardant	MB/Delvo

A one yard sample was batched and truck mixed for 40 minutes. The original truck batch had 10 gallons less water than the mix design. After 40 minutes of mixing 3 gallons of water was added before taking samples.

Batch Time 12:34 PM

Air Temperature	80 Degrees
Slump	6.0”
Air Content	6.5%
Unit Weight	142.44 Lbs. /Cubic Foot

After 30 minute Mix Time

Air Temperature	81 Degrees
Slump	6.0”
Air Content	5.2%
Concrete Temperature	83.2 Degrees
Unit Weight	142.60 Lbs. /Cubic Foot

Sample taken for HPC

Additional 10 minutes and SCA added

Batch with SCA additive

Air Temperature	82.0 Degrees
Slump	5.5”
Air Content	5.6%
Concrete Temperature	84.5 Degrees
Unit Weight	141.92 Lbs. /Cubic Foot

Samples and Curing Methods

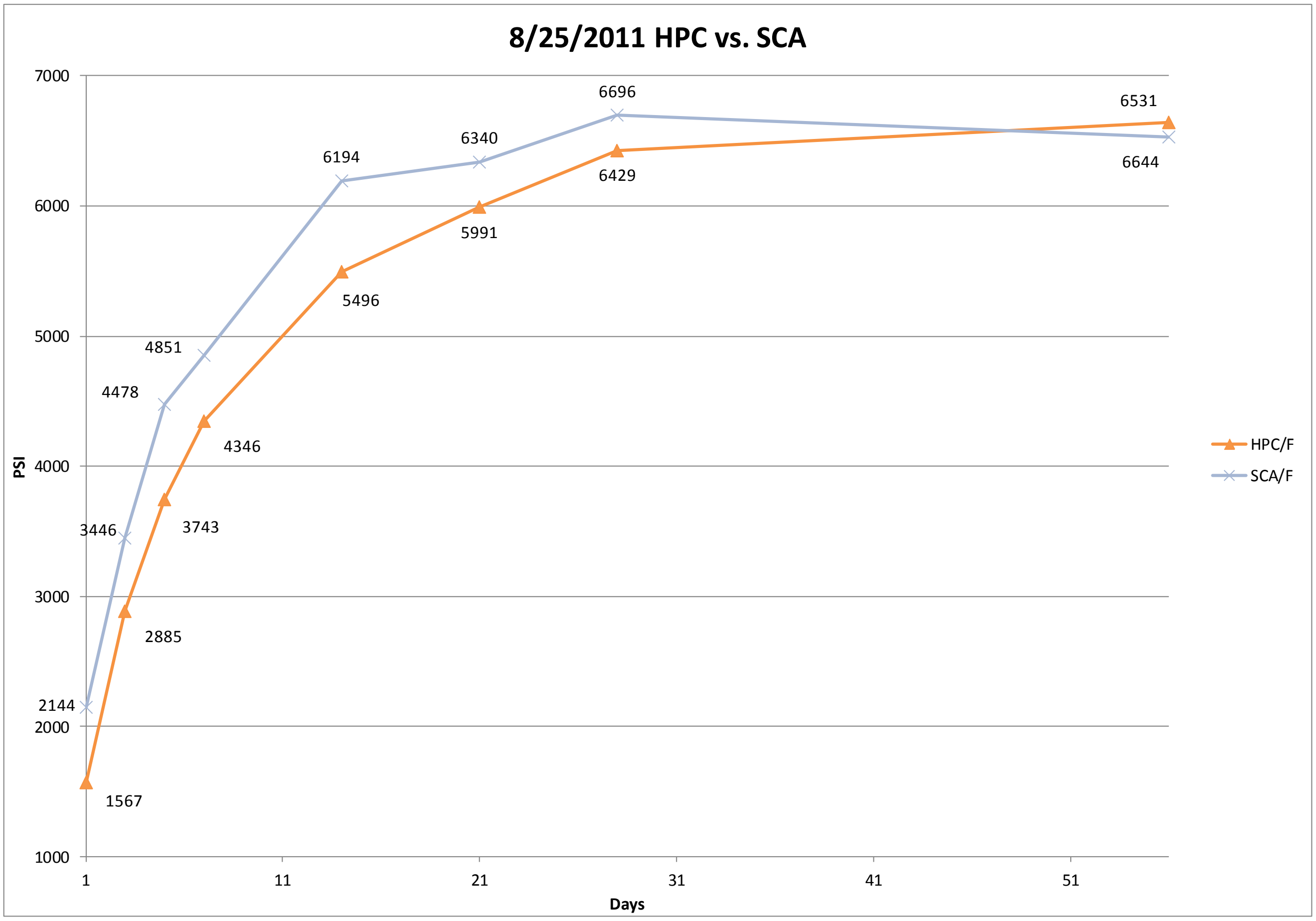
Cylinder Set	Cylinder #	Type	Batch	Curing
10	92 Thru 101	HPC /Type F Ash	Truck	Lids On 85 Degrees and 35% Humidity
11	102 Thru 111	SCA/Type F Ash	Truck	Lids On 85 Degrees and 35% Humidity

Truck Batch Samples & Shrinkage Prisms

Break results are nearly identical for the HPC and SCA type concrete using the Type F fly ash. The SCA has slightly higher break results by a rough average of 10%. However, the strength vs. time curves are nearly parallel. **The SCA additive is compatible with Type F fly ash and produces acceptable strength concrete for normal bridge deck design.**

Based on the satisfactory results of the truck batch trial, it was decided to move ahead with the test slabs. The slabs will provide a larger, real world test of the SCA and allow observation of placement, workability, and finishing.

HPC vs. SCA Break Results



Phase 3 - Test Slab Trial

On September 20th two concrete tests slabs were constructed at the KRM site in Klamath Falls, Oregon. These slabs were constructed to resemble a typical bridge deck section or impact panel, and each required a 6 cubic yard batch load of concrete. Slabs were formed above ground using form grade plywood for a base. Thornton Builders from Lakeview, Oregon constructed the slab forms, bases, and poured the slabs. Slab pouring was also witnessed by Dr. Jau and Bruce Johnson.

Re-Bar Placement for the Test Slab

Test Slab Base Construction

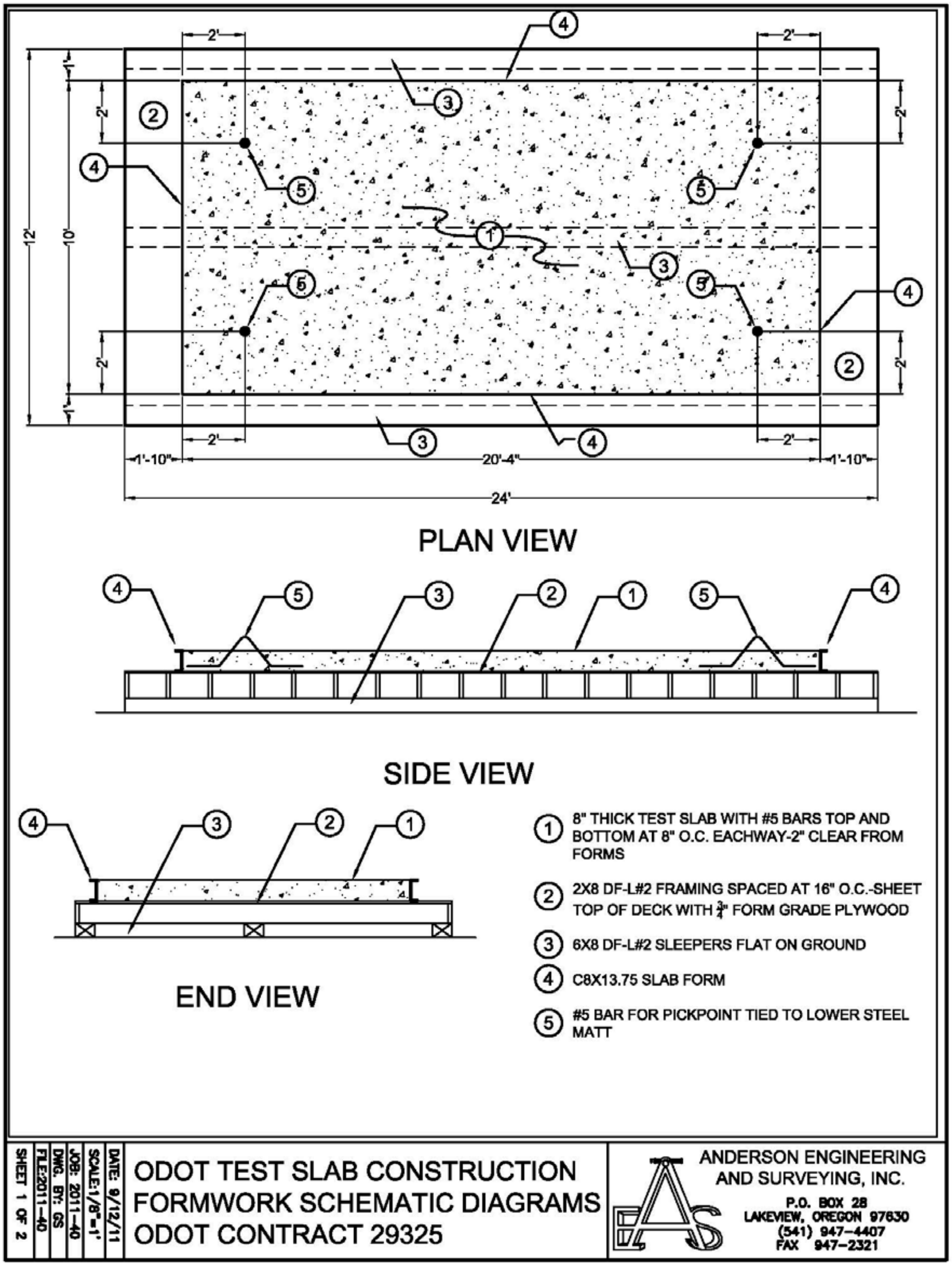
Adding Self-Curing Admixture

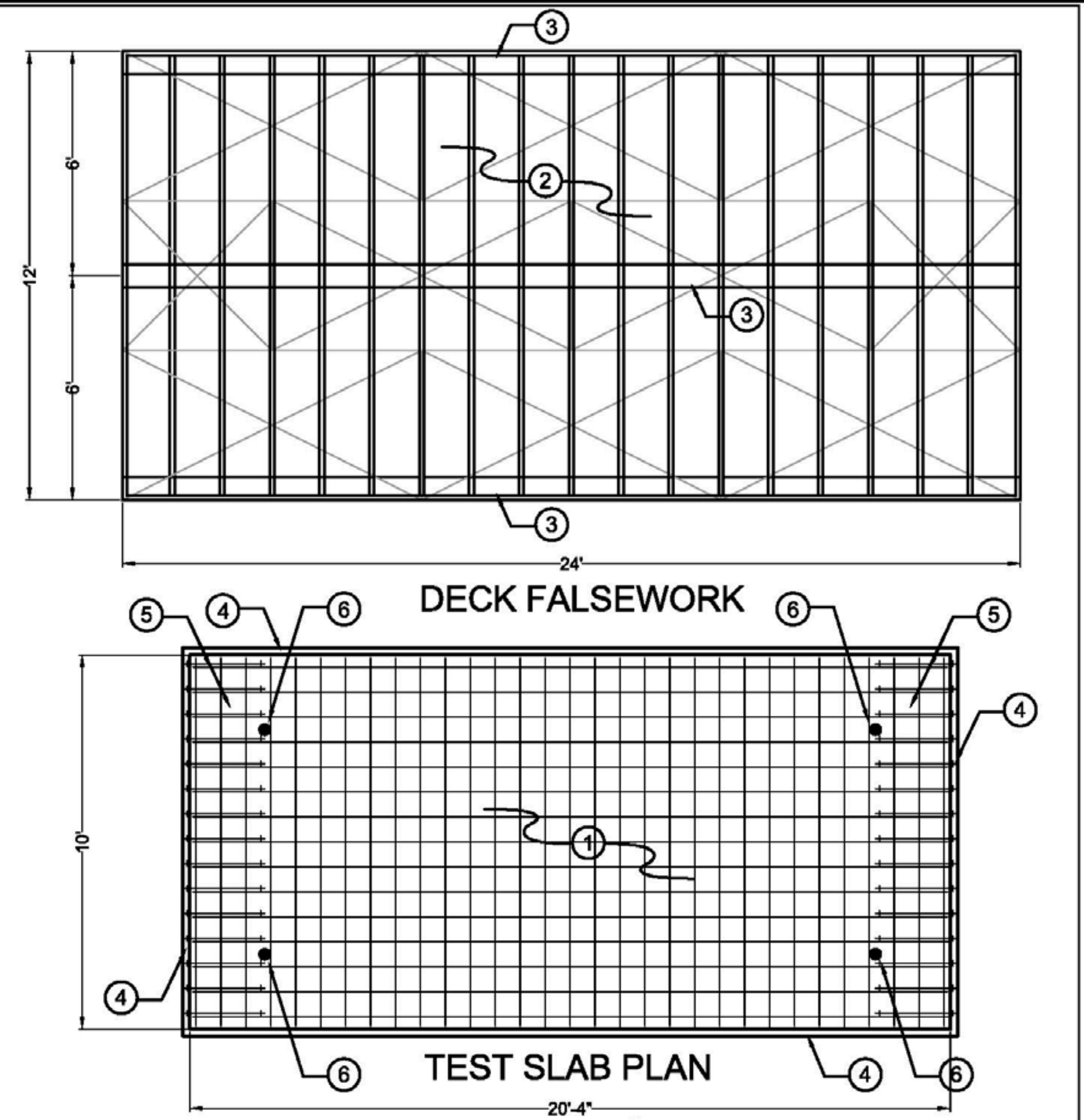
Placing Burlap over the Test Slab

Covering Test Slab with Polyethylene

SCA Batch Pour for Test Slab

Slab dimensions were 10 feet by 20’-4”. Reinforcing was two layers of #5 bars on 8” centers each way. Steel forms were used consisting of 8 X 13.75 lb. channel sections. Threaded bars were used on each end to prevent shrinkage in the long direction and force cracking. Test slab construction drawings are included below.





1. 8" THICK TEST SLAB WITH #5 BARS TOP AND BOTTOM AT 8" O.C. EACHWAY-2" CLEAR FROM FORMS
2. 2X8 DF-L#2 FRAMING SPACED AT 16" O.C.-SHEET TOP OF DECK WITH ¾" FORM GRADE PLYWOOD
3. 6X8 DF-L#2 SLEEPERS FLAT ON GROUND
4. C8X13.75 SLAB FORM
5. ¾" DIAMETER THREADED ROD BOLTED THRU SIDE OF FORMS WITH NUT AND WASHER EACH END. EMBED MIN. OF 30" INTO SLAB
6. PICK POINT BAR LOCATION

DATE: 9/12/11
SCALE:1/8"=1'
JOB: 2011-40
DWG. BY: GS
FILE:2011-40
SHEET 2 OF 2

ODOT TEST SLAB CONSTRUCTION
FORMWORK SCHEMATIC DIAGRAMS
ODOT CONTRACT 29325

ANDERSON ENGINEERING
AND SURVEYING, INC.
P.O. BOX 28
LAKEVIEW, OREGON 97630
(541) 947-4407
FAX 947-2321

The concrete was batched at the KRM plant using their approved ODOT mix design. One slab was poured with SCA and one without. All concrete was placed via pumping to simulate an actual bridge deck pour.

Fresh concrete test results:

HPC Batch with no SCA / Pour at 7:00 AM

Batch Time 7:00 AM

Air Temperature	44 Degrees
Slump	7.0”
Air Content	5.2%
Unit Weight	143.3 Lbs. /Cubic Foot
Concrete Temperature	64.3 Degrees

After 50 minute Mix Time

Air Temperature	46.1 Degrees
Slump	5.5”
Air Content	4.7%
Concrete Temperature	69.5 Degrees
Unit Weight	143.9 Lbs. /Cubic Foot

Sample taken for HPC

HPC Batch with SCA

30 minutes of mixing time and SCA added
For 6 yard pour 88.8 pounds of SCA added (2.0%)

Air Temperature	53.1 Degrees
Slump	8.0”
Air Content	8.0%
Concrete Temperature	53.1 Degrees
Unit Weight	138.5 Lbs. /Cubic Foot

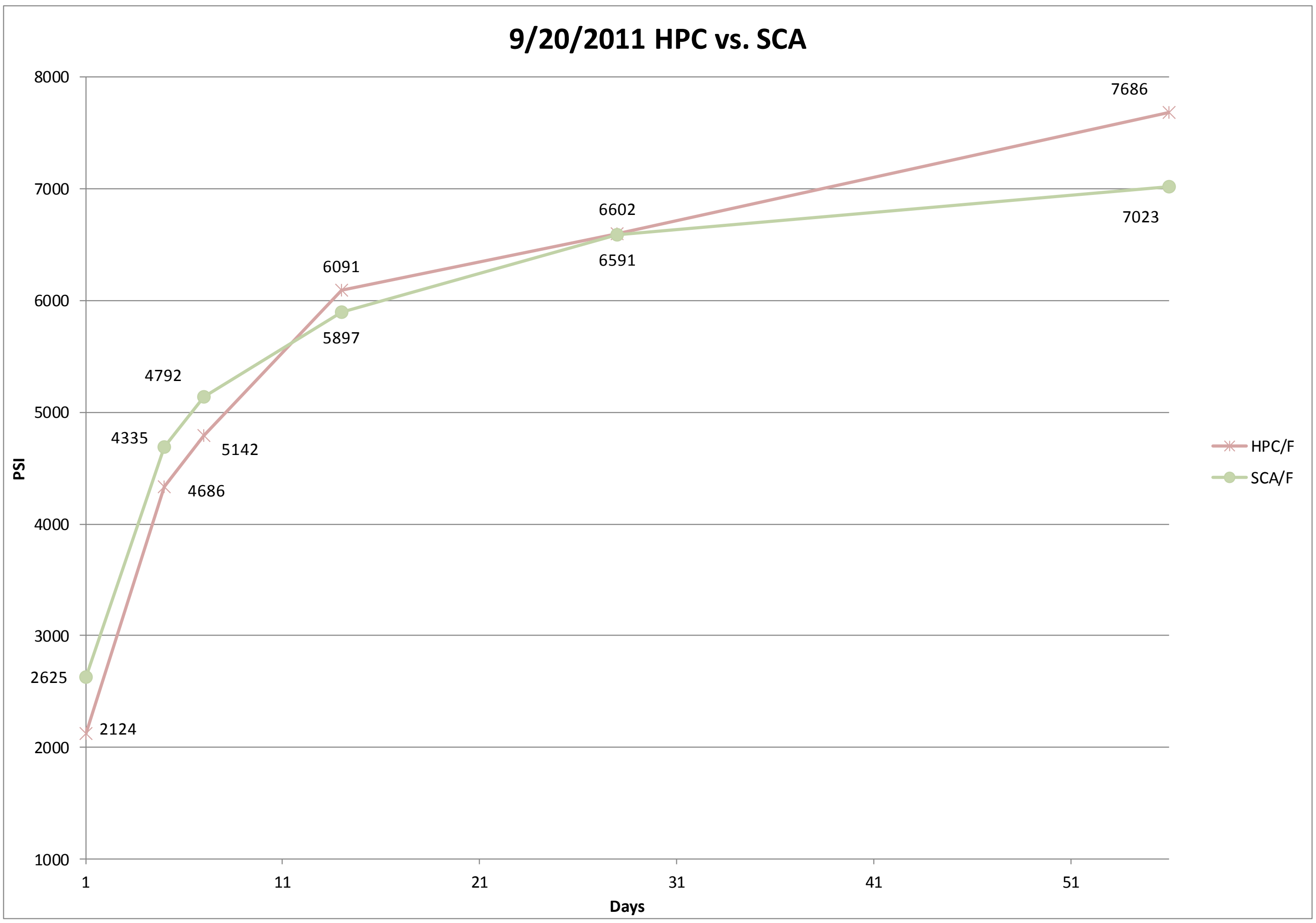
The relative humidity at 8:30 was 66. The relative humidity at 9:30 was 58.

This truck batch had high air content. The Batch Plant CCT (Certified Concrete Technician) had added more air entrainment additive to bring the air up from the previous batch. In addition, 10 gallons of water was added. Once the SCA was added we had no choice but to pour the slab (Not unlike actual bridge construction). We were only furnished the amount of SCA needed for the pour, even though more was requested, in case of spills, etc. Due to the higher air content this batch had a slightly lower unit weight.

Samples and Curing Methods

Cylinder Set	Cylinder #	Type	Batch	Curing
12	112 Thru 129	HPC /Type F Ash	Slab	Wet cure / burlap 14 Day Air afterward
12	130 Thru 132	HPC /Type F Ash	Slab	Standard tank 73 Degree water
13	133 Thru 150	SCA/Type F Ash	Slab	Wet cure / burlap 3Day Air afterward
13	151 Thru 153	SCA /Type F Ash	Slab	Standard tank 73 Degree water

HPC vs. SCA Test Slab Break Results



Slab finishes were rodded (screeded) and bull floated, no other finish work was done. Curing methods by ODOT standard construction specifications require burlap, water soaking application, and a cover of polyethylene. This is to be done as soon as possible. Curing methods for the slabs were as per Section 00540.51, a and b, as per ODOT Standard Specifications. Burlap was placed with soaker hoses at 36" centers and covered with the plastic tarp.

The SCA slab was cured with this method for 3 days and the no-SCA slab was cured for 14 days. The temperature and humidity chart for the area is listed on the following page from the pour date until the 31st of October.

Klamath Falls Area Temperature and Humidity Chart

PDT	Max TempF	Mean TempF	Min TempF	Max Humidity	Mean Humidity	Min Humidity
9/20/2011	80	58	36	85	56	21
9/21/2011	83	61	38	100	55	13
9/22/2011	85	62	39	92	56	13
9/23/2011	90	64	38	85	51	11
9/24/2011	85	63	40	83	47	20
9/25/2011	63	50	36	96	60	40
9/26/2011	72	53	33	100	69	31
9/27/2011	76	57	37	92	67	29
9/28/2011	75	56	37	100	81	35
9/29/2011	84	62	39	92	57	16
9/30/2011	82	63	44	80	50	23
10/1/2011	66	56	46	76	58	36
10/2/2011	65	51	37	93	60	30
10/3/2011	53	47	41	92	65	38
10/4/2011	57	47	36	100	82	47
10/5/2011	43	39	35	92	86	62
10/6/2011	50	39	28	100	88	52
10/7/2011	56	44	32	100	82	55
10/8/2011	62	46	29	100	88	36
10/9/2011	65	47	28	100	82	34
10/10/2011	60	54	48	100	83	66
10/11/2011	59	46	33	100	70	43
10/12/2011	62	45	28	100	86	21
10/13/2011	69	50	31	100	71	32
10/14/2011	72	54	35	100	80	38
10/15/2011	71	55	38	100	75	37
10/16/2011	67	51	35	100	75	42
10/17/2011	70	49	28	100	66	27
10/18/2011	71	52	32	92	64	26
10/19/2011	69	52	34	92	68	26
10/20/2011	68	49	30	100	69	32
10/21/2011	66	48	30	100	74	36
10/22/2011	69	49	29	100	79	28
10/23/2011	70	49	28	100	72	28
10/24/2011	56	43	30	100	62	20
10/25/2011	53	37	20	71	44	19
10/26/2011	54	37	20	77	49	17
10/27/2011	59	39	19	84	57	19
10/28/2011	61	41	20	88	55	11
10/29/2011	62	46	29	100	68	42
10/30/2011	65	48	30	100	93	52
10/31/2011	55	43	31	100	78	22

Thermometers were placed in each end of the slabs to monitor internal temperature during the curing process. Results are listed below.

Slab Tempertures
Reading in degrees F

Date	SCA Slab		HPC Slab		
	East End	West End	West End	East End	
20-Sep	70	70	70	70	
21-Sep	86	86	80	80	
22-Sep	83	81	81	82	
23-Sep	75	75	75	75	Tarp/water/Burlap stripped off SCA slab
24-Sep	78	77	76	78	
25-Sep	64	62	75	75	
26-Sep	60	58	70	70	
27-Sep	57	55	68	69	
28-Sep	68	66	69	70	
29-Sep	72	70	71	73	
30-Sep	69	68	69	73	
1-Oct	67	66	67	74	
3-Oct	55	53	57	68	
4-Oct	52	51	55	70	Tarp/water/Burlap stripped off SCA slab
5-Oct	47	45	45	46	
7-Oct	52	50	50	51	
8-Oct	60	57	57	60	
9-Oct	60	56	56	59	Unrestrained sides on HPC slab / some separation
10-Oct	55	53	53	52	
12-Oct	44	41	41	40	
19-Oct	50	50	50	50	

The SCA slab had a quicker cooling trend since the curing material was taken off earlier. However, once the curing materials were off the HPC slab the temperatures of both slabs became very similar.

Shrinkage Results

Shrinkage molds were cast at each of the pours and cured under the same conditions as the cylinders:

- Non SCA wet cured with water and burlap for 14days
- SCA cured with water and burlap covering for 3 days

Standard molds were used and values measured with a comparator supplied by ODOT. The shrinkage log, for the 56 day amounts, is shown on the following page.

Shrinkage Log

	Type	Date Cast	1ST M	22nd M	Change	Wt 1	Wt 2	Change	Prisim Cure
I.D.			08/05/11	09/29/11	55	08/05/11	09/29/11		
1-1	HPC	08/04/11	0.1324	0.1382	-0.0058	3908.1	*3835.9*	-72.2	Air 85 Degrees 35% Humidity
1-2	HPC	08/04/11	0.0982	0.1046	-0.0064	3933.4	*3861.1*	-72.3	Air - 85 Degrees 35% Humidity
1-3	HPC	08/04/11	0.1318	0.1382	-0.0064	3907.7	*3835.7*	-72.0	Air - 85 Degrees 35% Humidity
1-4	HPC	08/04/11	0.1350	0.1346	0.0004	3987.6	4028.3	40.7	Standard tank 73 Degree water
1-5	HPC	08/04/11	0.1284	0.1280	0.0004	3950.3	3991.8	41.5	Standard tank 73 Degree water
1-6	HPC	08/04/11	0.0955	0.0948	0.0007	3958.0	3997.6	39.6	Standard tank 73 Degree water
2-1	HPC	08/04/11	0.1292	0.1364	-0.0072	*3960.3*	*3904.9*	-55.4	Wet cure / burlap 14 Day Air afterward
2-2	HPC	08/04/11	0.1140	0.1206	-0.0066	*3959.4*	*3908.6*	-50.8	Wet cure / burlap 14 Day Air afterward
2-3	HPC	08/04/11	0.1246	0.1317	-0.0071	*3937.5*	*3878.7*	-58.8	Wet cure / burlap 14 Day Air afterward
3-1	SCA	08/04/11	0.1076	0.1142	-0.0066	3935.2	*3852.4*	-82.8	Air - 85 Degrees 35% Humidity
3-2	SCA	08/04/11	0.1328	0.1392	-0.0064	3958.4	*3873.7*	-84.7	Air - 85 Degrees 35% Humidity
3-3	SCA	08/04/11	0.0961	0.1032	-0.0071	3947.5	*3853.4*	-94.1	Air - 85 Degrees 35% Humidity
3-4	SCA	08/04/11	0.1466	0.1468	-0.0002	4004.4	4039.0	34.6	Standard tank 73 Degree water
3-5	SCA	08/04/11	0.1240	0.1240	0.0000	3971.5	4004.4	32.9	Standard tank 73 Degree water
3-6	SCA	08/04/11	0.1218	0.1223	-0.0005	4048.2	4083.7	35.5	Standard tank 73 Degree water
4-1	SCA	08/04/11	0.1126	0.1203	-0.0077	*4034.9*	*3962.8*	-72.1	Wet cure / burlap 3Day Air afterward
4-2	SCA	08/04/11	0.1279	0.1364	-0.0085	*3932.2*	*3850.9*	-81.3	Wet cure / burlap 3Day Air afterward
4-3	SCA	08/04/11	0.0901	0.0966	-0.0065	*3956.6*	*3885.7*	-70.9	Wet cure / burlap 3Day Air afterward
5-1	SCA	08/04/11	0.1170	0.1236	-0.0066	*3936.8*	*3888.5*	-48.3	Wet cure / burlap 6Day Air afterward
5-2	SCA	08/04/11	0.1097	0.1169	-0.0072	*4072.3*	*4014.7*	-57.6	Wet cure / burlap 6Day Air afterward
5-3	SCA	08/04/11	0.0550	0.0616	-0.0066	*4032.3*	*3988.6*	-43.7	Wet cure / burlap 6Day Air afterward
6-1	SCA	08/04/11	0.0698	0.0774	-0.0076	*4022.5*	*3959.1*	-63.4	Wet cure / burlap 6Day Air afterward
6-2	SCA	08/04/11	0.0678	0.0749	-0.0071	*4039.5*	*3971.0*	-68.5	Wet cure / burlap 6Day Air afterward
6-3	SCA	08/04/11	0.0562	0.0633	-0.0071	*3990.3*	*3941.7*	-48.6	Wet cure / burlap 6Day Air afterward
Truck		Knife River	08/26/11	10/20/11	55	08/26/11	10/20/11	55	Air 85 Degrees 35% Humidity
10-1	HPC	08/25/11	0.1309	0.1363	-0.0054	3798.2	3650.0	-148.2	Air 85 Degrees 35% Humidity
10-2	HPC	08/25/11	0.1016	0.1074	-0.0058	3820.0	3668.2	-151.8	Air 85 Degrees 35% Humidity
10-3	HPC	08/25/11	0.1289	0.1346	-0.0057	3798.6	3651.0	-147.6	Air 85 Degrees 35% Humidity
11-1	SCA	08/25/11	0.1024	0.1090	-0.0066	3841.8	3691.7	-150.1	Air 85 Degrees 35% Humidity
11-2	SCA	08/25/11	0.0993	0.1058	-0.0065	3919.6	3769.9	-149.7	Air 85 Degrees 35% Humidity
11-3	SCA	08/25/11	0.1316	0.1382	-0.0066	3871.8	3724.1	-147.7	Air 85 Degrees 35% Humidity
Slab		Knife River	09/21/11	11/15/11	55	09/21/11	11/15/11	55	
12-1	HPC	09/20/11	0.1205	0.1248	-0.0043	3890.0	3813.6	-76.4	Wet cure / burlap 14 Day Air afterward
12-2	HPC	09/20/11	0.1266	0.1317	-0.0051	3899.5	3823.1	-76.4	Wet cure / burlap 14 Day Air afterward
12-3	HPC	09/20/11	0.1369	0.1421	-0.0052	3880.8	3804.4	-76.4	Wet cure / burlap 14 Day Air afterward
13-1	SCA	09/20/11	0.1274	0.1331	-0.0057	3764.8	3684.3	-80.5	Wet cure / burlap 3Day Air afterward
13-2	SCA	09/20/11	0.0888	0.0952	-0.0064	3771.0	3690.1	-80.9	Wet cure / burlap 3Day Air afterward
13-3	SCA	09/20/11	0.0648	0.0698	-0.0050	3738.0	3661.2	-76.8	Wet cure / burlap 3Day Air afterward

Prism dimensions are 3"x3"x 11.25 Long,

In general, the results of the shrinkage measurements show relatively comparable values for the HPC and SCA concrete mixes. The SCA values are approximately 13% greater in all the batches. Test slabs with SCA had a slightly higher average shrinkage value, 0.0057 inches as compared to 0.0049 inches. This was also true of the truck batch under the temperature and humidity conditions, 0.0065 for the SCA and 0.0056 for the HPC.

The weight loss change in the shrinkage log is in grams and represents the number of milliliters of water lost due to weight loss.

Wet cures of both non-SCA and SCA showed the least shrinkage, as expected, while other shrinkages were relatively comparable. An average comparison is noted below.

Total Shrinkage Measured on Noted Days

		6 days	28 days	56 days
Phase I - Laboratory Batch Trial				
HPC			0.0047	0.0062
SCA			0.0042	0.0067
Phase 2 - Truck Batch Trial				
HPC	Set 10	0.0040	0.0050	0.0056
SCA	Set 11	0.0047	0.0058	0.0065
Phase 3 - Test Slab Trial				
HPC			0.0003	0.0049
SCA			0.0017	0.0057

The modulus of elasticity (Ec) for high strength concrete is - (Ec = 33Wc^1.5(fc')^1/2) for design purposes. This results in 3,865,369 PSI for high strength concrete comparable to the HPC in this test. A unit weight of 140 pounds per cubic foot was used with a compressive strength of 5,000 PSI.

Actual stress strain measurements were taken using the shrinkage prisms. A prism was placed in the compression machine with a dial indicator to indicate deformation.

Compression Machine

At 4000 PSI the SCA concrete resulted in a modulus of 3,500,000 PSI, close to the design formula. This verification shows the SCA property of Ec is comparable to HPC in basic concrete properties.

Using an average shrinkage rate of 0.0005 inches per inch, (0.0057/11.25 inches from the prism length), results in a total amount of 0.1236 inches in a 20' 4" slab. Using 0.1236 inches in a 20' 4" slab with a cross sectional area of 960 square inches, and an Ec of 3,500,000 results in a tensile stress due to shrinkage of 1,770 PSI. This is above allowable design tension stresses in the concrete (530 PSI). No tension tests were performed on this project so actual tension values are unknown. However, it appears shrinkage stresses would exceed the ability of the concrete to resist them in an un-reinforced section. These values are totally based on the Ec of the concrete, higher strengths result in more inelastic concrete and brittle type performance.

No shrinkage cracks were noticed in our test slabs, at 14 or at 50 days. Concrete had not pulled away from the forms, ends, or sides of the SCA slab. In the plain HPC slab, the concrete had pulled away from the forms 0.33 inches in the long direction. Where the slabs were restrained, no cracks or movement was noted in the long direction. It appears the SCA does restrict shrinkage in shorter cure times compared to a well cured slab.

Average shrinkage amounts are roughly identical in the test prisms for both slabs. The weather conditions were approaching cooler temperatures at this time and evaporation from the slabs were probably minimal after removal of the curing material.

Chloride Resistance

Cast cylinders of the SCA product were sent to the ODOT Materials Laboratory for chloride penetration resistance. Bridge decks can be subject to environmental attack of chloride ingress or penetration of chloride ions. This leads to corrosion of the reinforcing steel and the resulting loss of strength and serviceability of the bridge. More impenetrable concrete results in better protection of the reinforcing steel from the chloride ions. Chloride resistance ratings as per ASTM C 1202 are shown below.

Chloride Resistance Ratings – ASTM C 1202

Charge passed (Coulombs)	Chloride ion Penetrability
>4000	High
2,00 to 4,000	Moderate
1,000 to 2,000	Low
100 to 1,000	Very low
<100	negligible

The results from the ODOT Materials Laboratory are shown below. Values were below 1000 coulombs which is considered very low value. The SCA concrete is acceptable for bridge deck use and provides a reasonable protection against chloride attack.

SPECIMEN NUMBER	DIAMETER (INCHES)	QX (COULOMBS)	QS (COULOMBS)	
130	4	1091	959	
131	4	1034	909	**HPC Slab**
132	4	769	676	
153	4	880	773	
151	4	723	635	**SCA Slab**
152	4	777	683	

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11.2. If the specimen diameter is other than 95 mm (3.75 in.), the value for total charge passed established in Section 11.1 must be adjusted. The adjustment is made by multiplying the value established in Section 11.1 by the ratio of the cross-sectional areas of the standard and the actual specimens. That is:

$$Q_s = Q_x(3.75/x)^2$$

where:

Q_s = charge passed (coulombs) through a 3.75-in. diameter specimen,

Q_x = charge passed (coulombs) through x in. diameter specimen, and

x = diameter (in.) of the nonstandard specimen.

Costs

Current estimated costs of the SCA additive is $13 per kilogram in small quantities. In large quantities the price may be $6.50 per Kilogram according to the supplier. In our demonstration project 88.8 pounds (40.3 Kg) was added to a 6 cubic yard batch, making the cost per yard $87.27. If larger quantities resulted in one half the costs, $43.63 per yard may be possible.

For a bridge deck pour of 100 feet X 20 feet, (50 yard pour) typical of one lane of a smaller bridge in Eastern Oregon, total cost for SCA would be around $2,181.00. Assuming the contractor provided a minimum cure time of 3 days following ODOT specifications using normal HPC concrete, curing costs would be $4,500.00. This is based on a $1,500.00 per day cost estimate for slab curing. Two different contractors were asked for approximate curing costs and the range was from $1,500.00 to $2,500.00 per day. For this analysis the lower figure was used.

If wet cures are done correctly, especially in areas without access to water, costs would include all curing materials, water truck, pump and hoses, as well as a worker to keep all covers in place, etc. In addition, set-up costs and cleanup costs are required. These costs are quite expensive. Also, it may be difficult to get compliance from the contractor.

Using a comparison of curing costs for a 50 yard pour and assuming placement and the base cost of the concrete remain the same. The following table illustrates the savings of using the SCA. As with our test slabs a three day cure is assumed to be placed on the SCA.

	Pour C.Y. Quantitiy	Base Price Yard	Cost of SCA	Curing Days	Curing cost Day	Total Cost
HPC with SCA Additive	50	$ 125.00	$ 2,181.50	3	$ 1,500.00	$ 12,931.50
Regular HPC concrete	50	$ 125.00	$ -	14	$ 1,500.00	$ 27,250.00

Using this analysis the SCA is cost effective up to a 400 cubic yard pour, at the $43.63 cost per yard.

Conclusions

- Concrete with the SCA additive after only a three day cure can produce similar results to Standard HPC concrete with a 14 day wet cure. However, the concrete additives in the concrete must be compatible to the SCA.

- The SCA additive was not compatible with Type C fly ash. The reaction could have been to the Type C that was available or it may be incompatible to all of Type C fly ash. However, Type C fly ash should not be used with the SCA additive unless a trial batch is tested first, to prevent low strengths in the first few days of curing and short workability times.

- SCA is compatible with Type F fly ash or mixes with only cement.

- Our results showed only an issue with type C fly ash. However, batch tests should be performed to ensure compatibility with the type of water reducer, as well as any set extenders and super plasticizers used in the mix before adding SCA. Different manufactures of these various products may produce different results since all possible uses were not tested under this project.

- Concrete with SCA can have less shrinkage or comparable shrinkage to HPC concrete with only three days of wet curing.

- SCA additive is cost effective for most slab pours on a typical bridge in eastern Oregon. This can provide a good alternative to the problems encountered with a 14 day wet cure.

- The SCA product provides acceptable resistance to chloride penetration for use on bridge decks.

- SCA must be added only a few minutes before concrete placement. This eliminates the additive being added at the batch plant. Early tests by ODOT indicated increased air content and lower strengths resulted from longer mix times. This was also noted in these tests by the higher air content after only a few minutes of mixing. This could present some problems for quality control at the bridge site during multi truck pours. A comprehensive SCA specification is needed, as well as a thorough inspection procedure specification. In practice less air entrainment additive could be used to result in correct air amounts at the site.

- SCA appears to keep water in the concrete and reduce shrinkage and cracking. The SCA test slab was poured at a higher water cement ratio but still resulted in comparable shrinkage to the HPC slab.

Recommendations

A larger trial needs to be performed on an actual slab under July or August conditions. Testing to date has proven that the SCA concrete will produce reliability and strengths necessary for bridge slab construction. An actual slab or impact panel would provide further data on the practicality of the SCA. Shrinkage measurements could be made on a whole slab basis, as well as further observations.

The higher strength concrete is a very brittle and inelastic product. Lowering the strength resulting in a lower Ec would provide better resistance to shrinkage and a more flexible product.

Actual tensile values need be obtained from tensile testing indicating the resistance available to shrinkage cracks.

APPENDIX

EXHIBIT 1

PATENT

US008016939B2

(12) **United States Patent**
Jau

(10) **Patent No.: US 8,016,939 B2**
(45) **Date of Patent: Sep. 13, 2011**

(54) **SELF-CURING CONCRETE**

(76) Inventor: **Wen-Chen Jau**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1060 days.

(21) Appl. No.: **11/802,243**

(22) Filed: **May 21, 2007**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

May 23, 2006 (CN) 2006 1 0080647

(51) **Int. Cl.**
C04B 24/02 (2006.01)

(52) **U.S. Cl.** **106/724**; 106/823

(58) **Field of Classification Search** 106/724, 106/823
See application file for complete search history.

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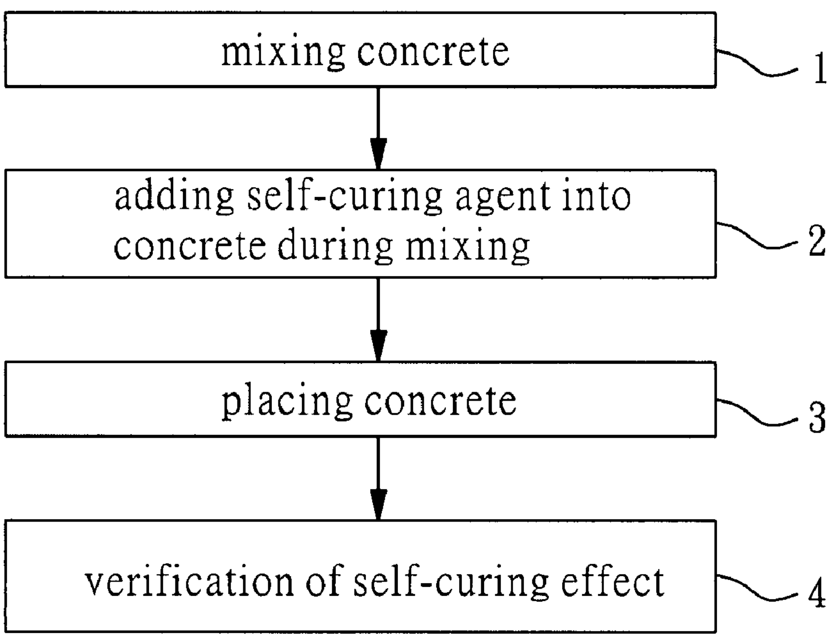
Primary Examiner — Paul Marcanton
(74) *Attorney, Agent, or Firm* — Muncy, Geissler, Olds & Lowe, PLLC

(57) **ABSTRACT**

A self-curing concrete is provided to absorb water from atmosphere from air to achieve better hydration of cement in concrete. It solves the problem that the degree of cement hydration is lowered due to no curing or improper curing, and thus unsatisfactory properties of concrete. According to the invention, high-performance self-curing agent about 0.1~5 wt % of cement weight of the concrete is added to concrete during mixing. The self-curing agent can absorb moisture from atmosphere and then release it to concrete. The self-curing concrete means that no curing is required for concrete, or even no any external supplied water is required after placing. The properties of this self-cured concrete of this invention are at least comparable to and even better than those of concrete with traditional curing.

10 Claims, 7 Drawing Sheets



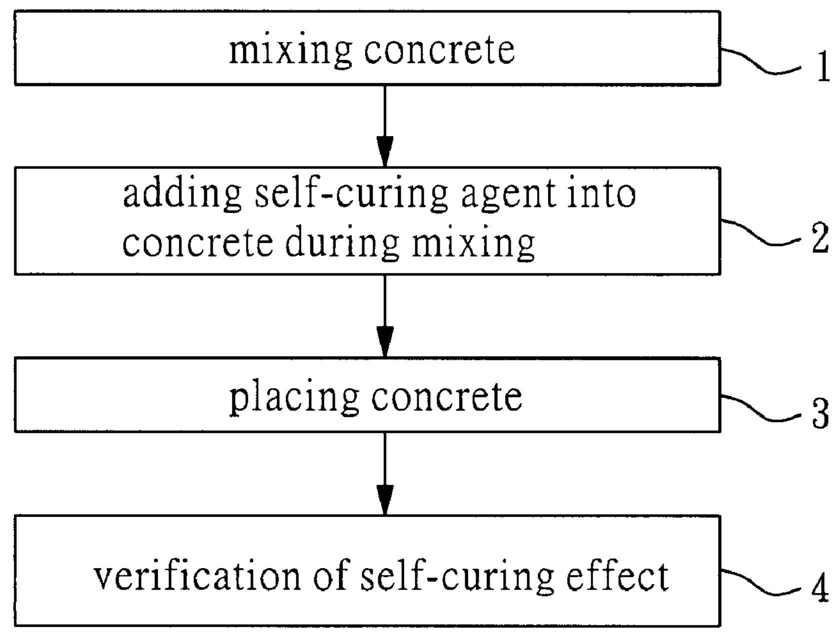

mixing concrete
1
adding self-curing agent into concrete during mixing
2
placing concrete
3
verification of self-curing effect
4

FIG. 1

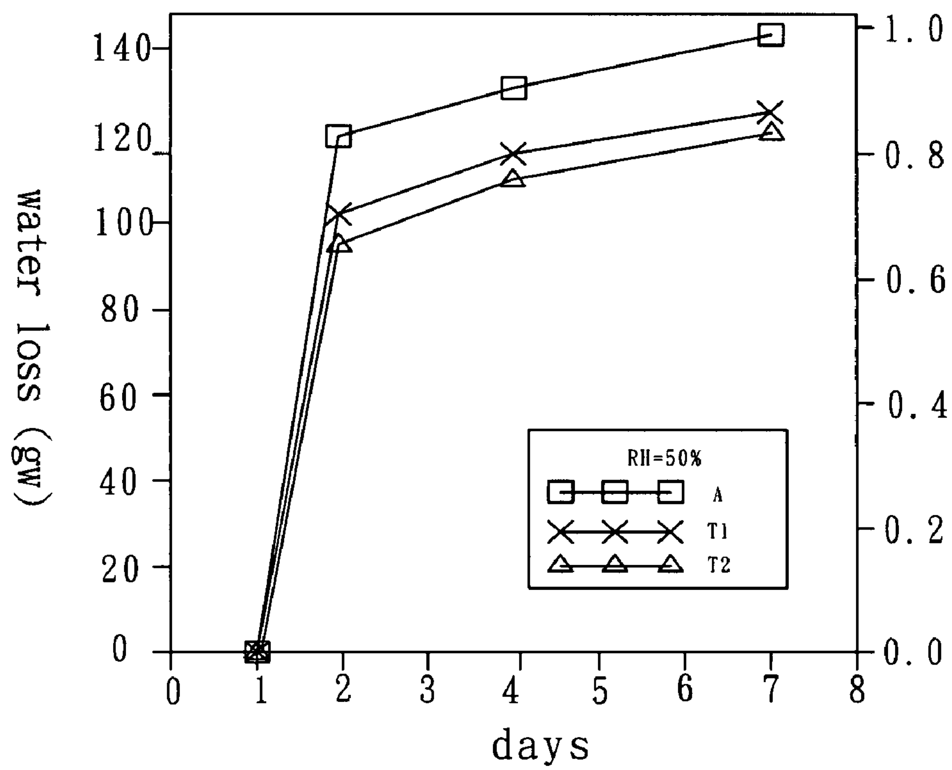

water loss (gw)
140
120
100
80
60
40
20
0
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
days
RH=50%
A
T1
T2

FIG. 2A

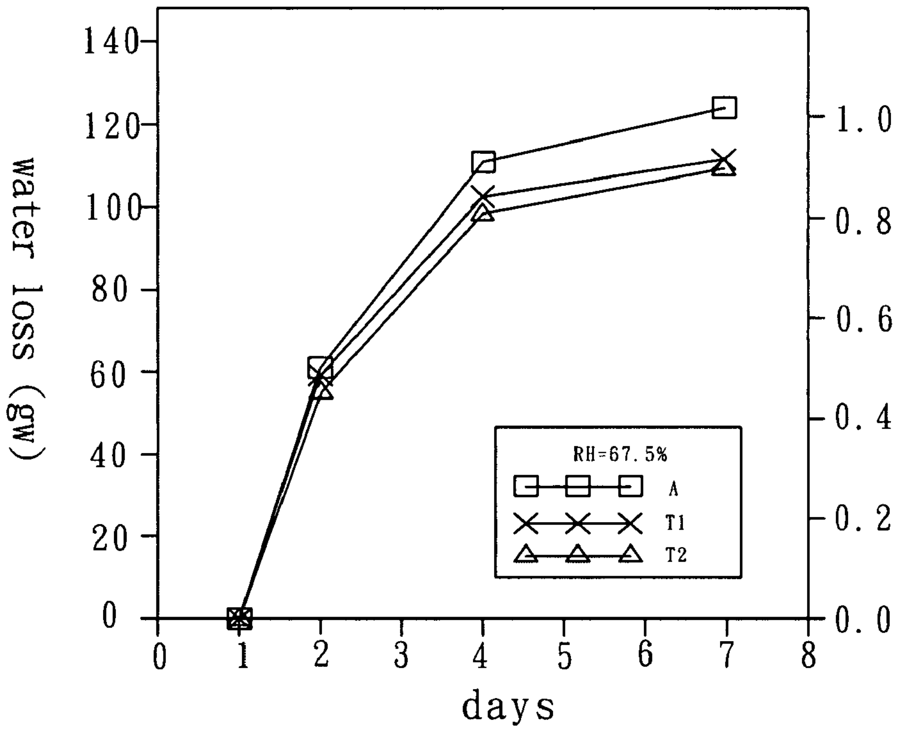

140
120
100
80
60
40
20
0
water loss (gw)
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8
days
RH=67.5%
A
T1
T2

FIG. 2B

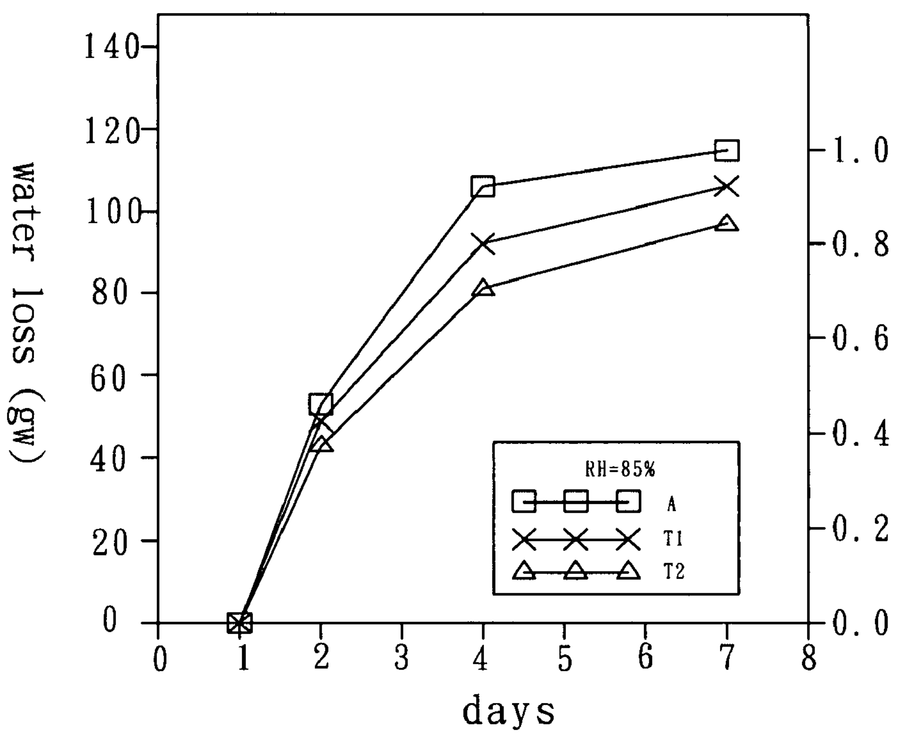

140
120
100
80
60
40
20
0
water loss (gw)
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8
days
RH=85%
A
T1
T2

FIG. 2C

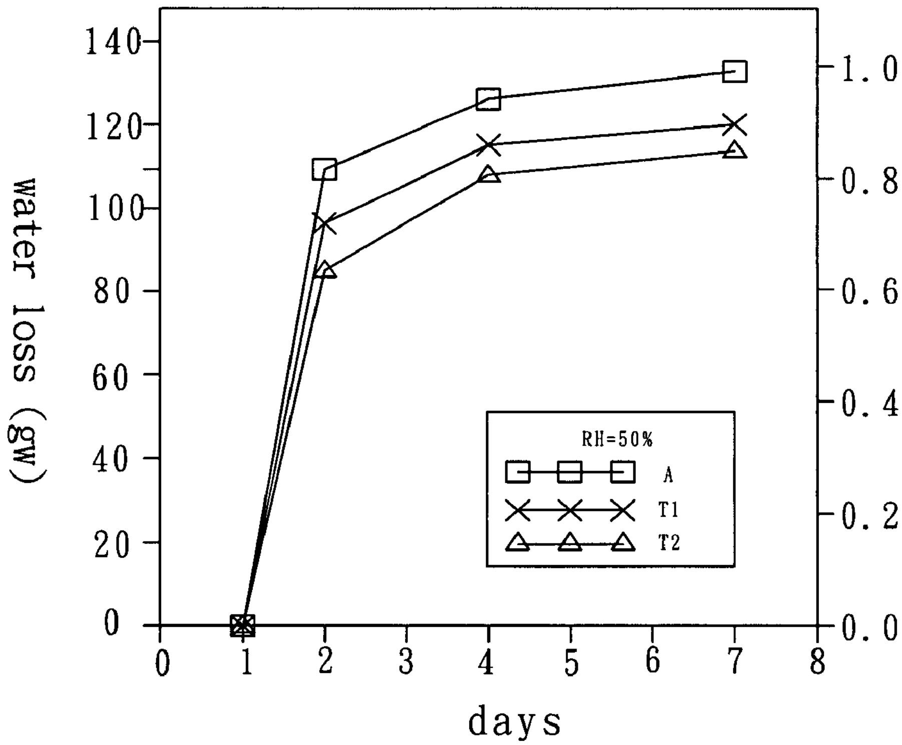

140
120
100
80
60
40
20
0
1.0
0.8
0.6
0.4
0.2
0.0
water loss (gw)
0
1
2
3
4
5
6
7
8
days
RH=50%
A
T1
T2

FIG. 3A

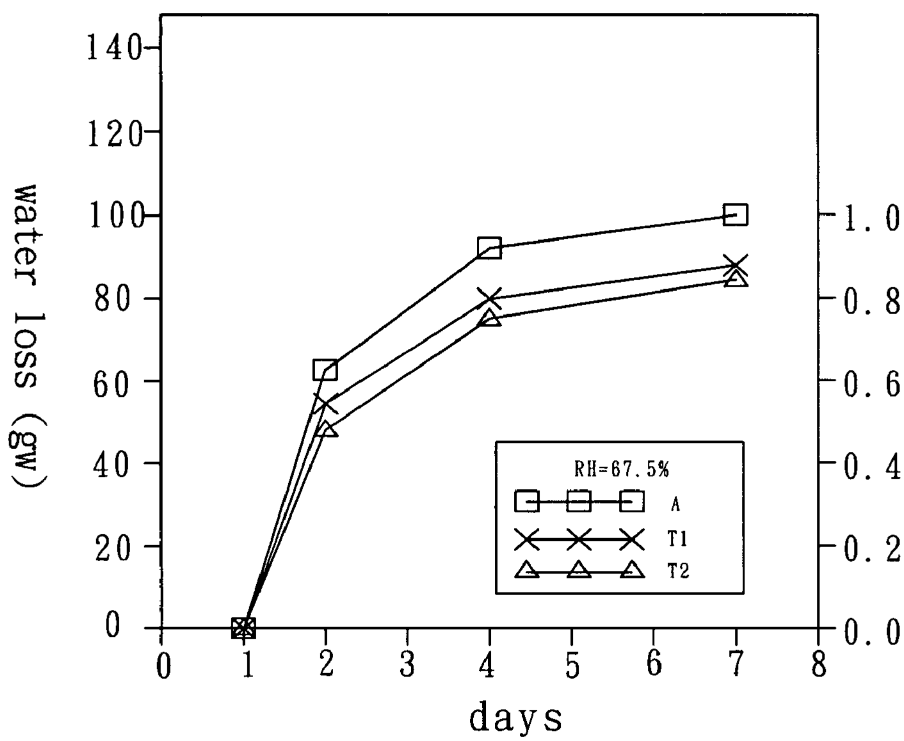

140
120
100
80
60
40
20
0
1.0
0.8
0.6
0.4
0.2
0.0
water loss (gw)
0
1
2
3
4
5
6
7
8
days
RH=67.5%
A
T1
T2

FIG. 3B

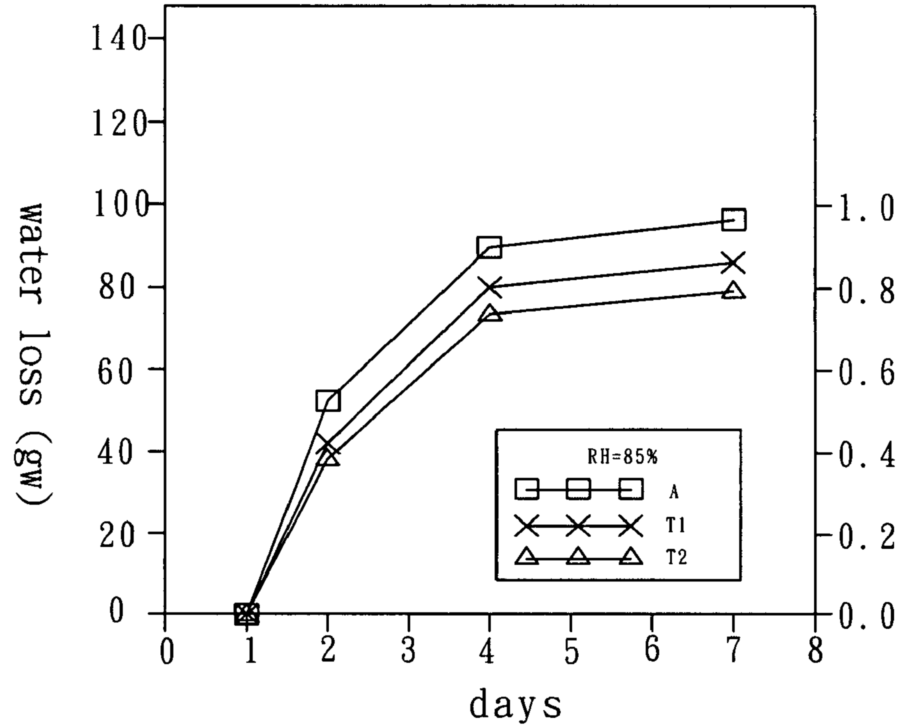

water loss (gw)
140
120
100
80
60
40
20
0
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
days
RH=85%
A
T1
T2

FIG. 3C

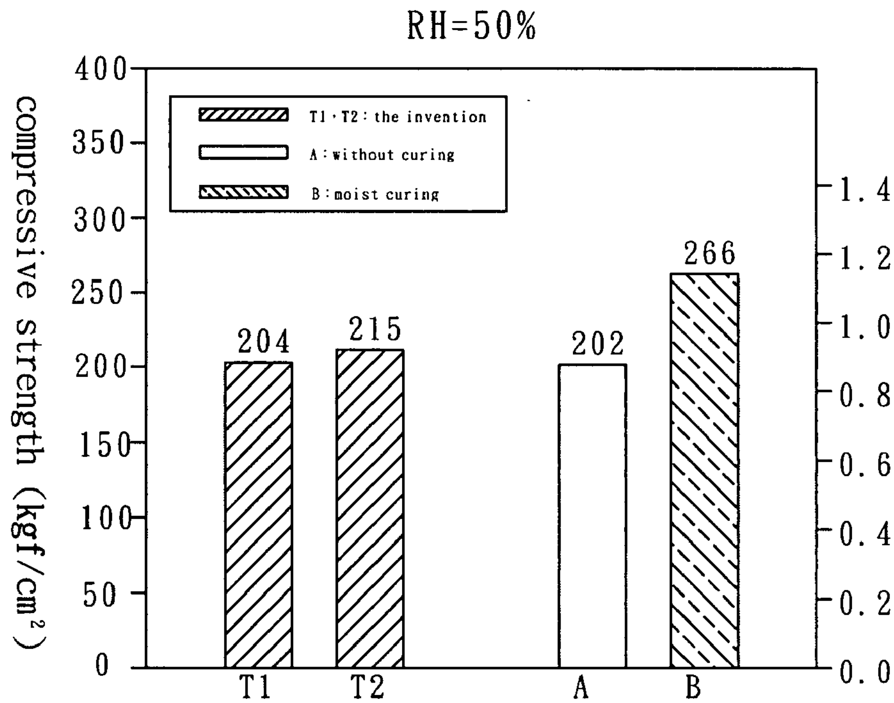

RH=50%
compressive strength (kgf/cm²)
400
350
300
250
200
150
100
50
0
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
T1・T2: the invention
A: without curing
B: moist curing
204
215
202
266
T1
T2
A
B

FIG. 4A

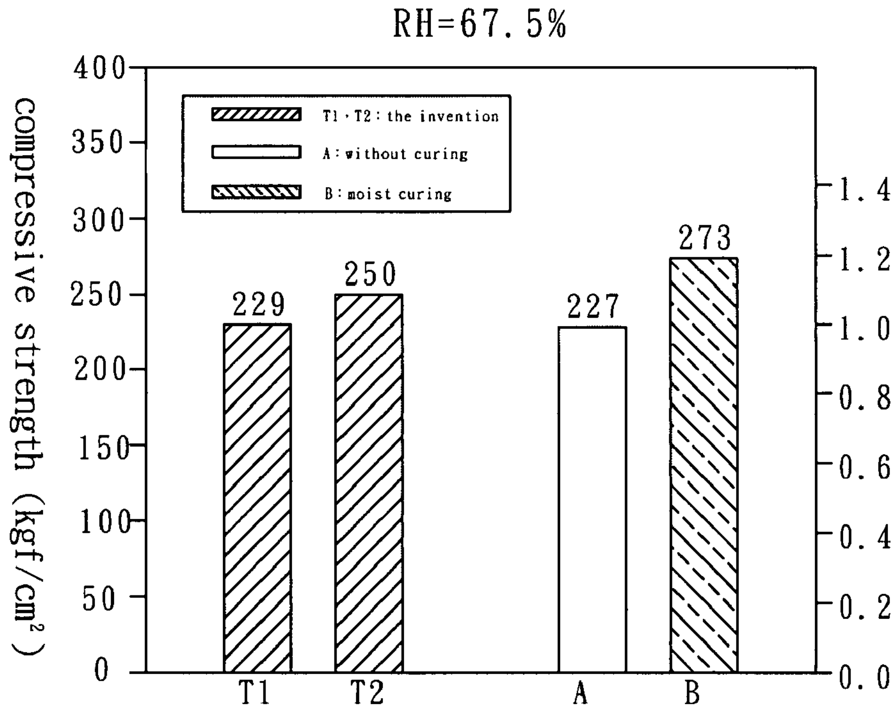

RH=67.5%
compressive strength (kgf/cm²)
T1、T2: the invention
A: without curing
B: moist curing
229
250
227
273
T1
T2
A
B
0
50
100
150
200
250
300
350
400
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

FIG. 4B

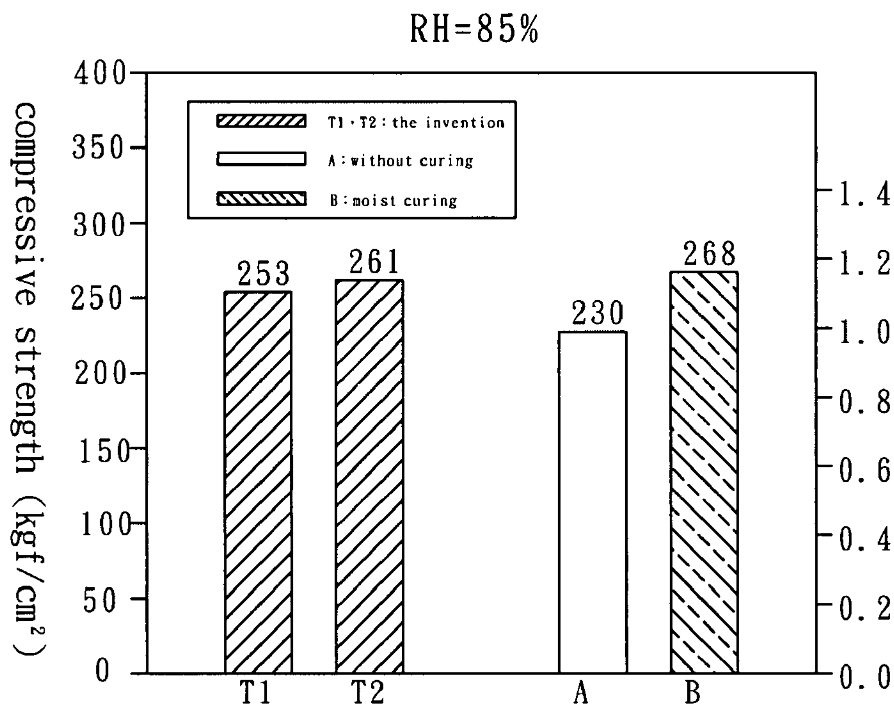

RH=85%
compressive strength (kgf/cm²)
T1、T2: the invention
A: without curing
B: moist curing
253
261
230
268
T1
T2
A
B
0
50
100
150
200
250
300
350
400
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

FIG. 4C

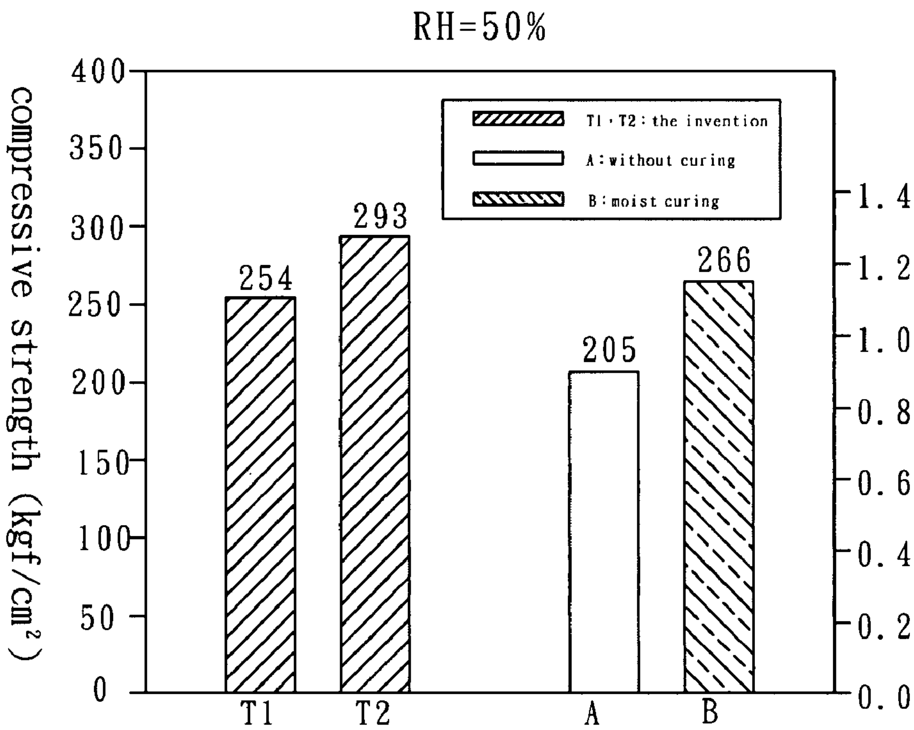

RH=50%
compressive strength (kgf/cm²)
400
350
300
250
200
150
100
50
0
T1、T2: the invention
A: without curing
B: moist curing
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
254
293
205
266
T1
T2
A
B

FIG. 5A

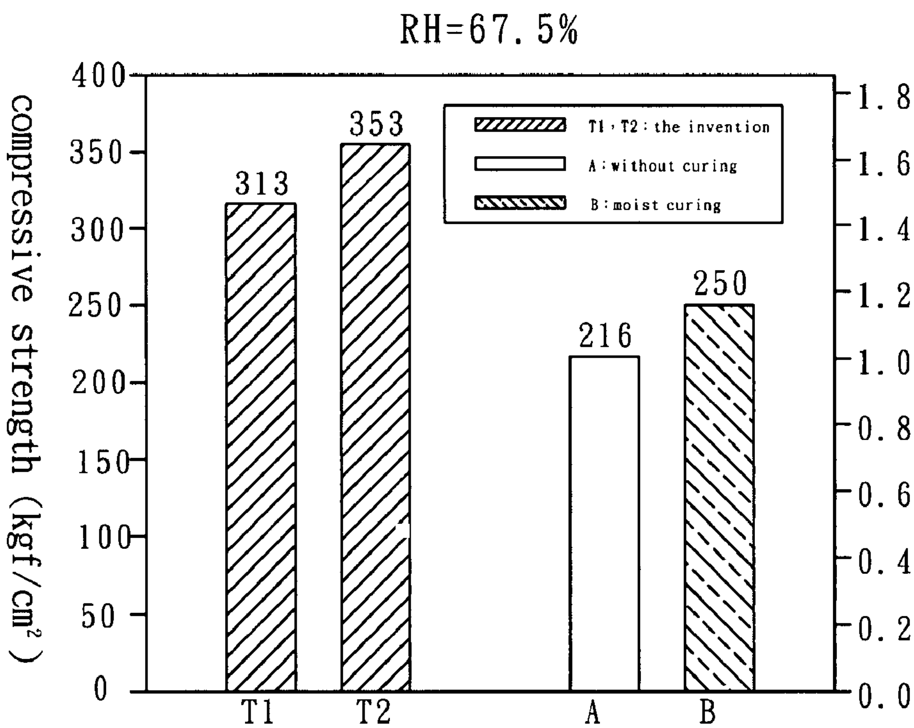

RH=67.5%
compressive strength (kgf/cm²)
400
350
300
250
200
150
100
50
0
T1、T2: the invention
A: without curing
B: moist curing
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
313
353
216
250
T1
T2
A
B

FIG. 5B

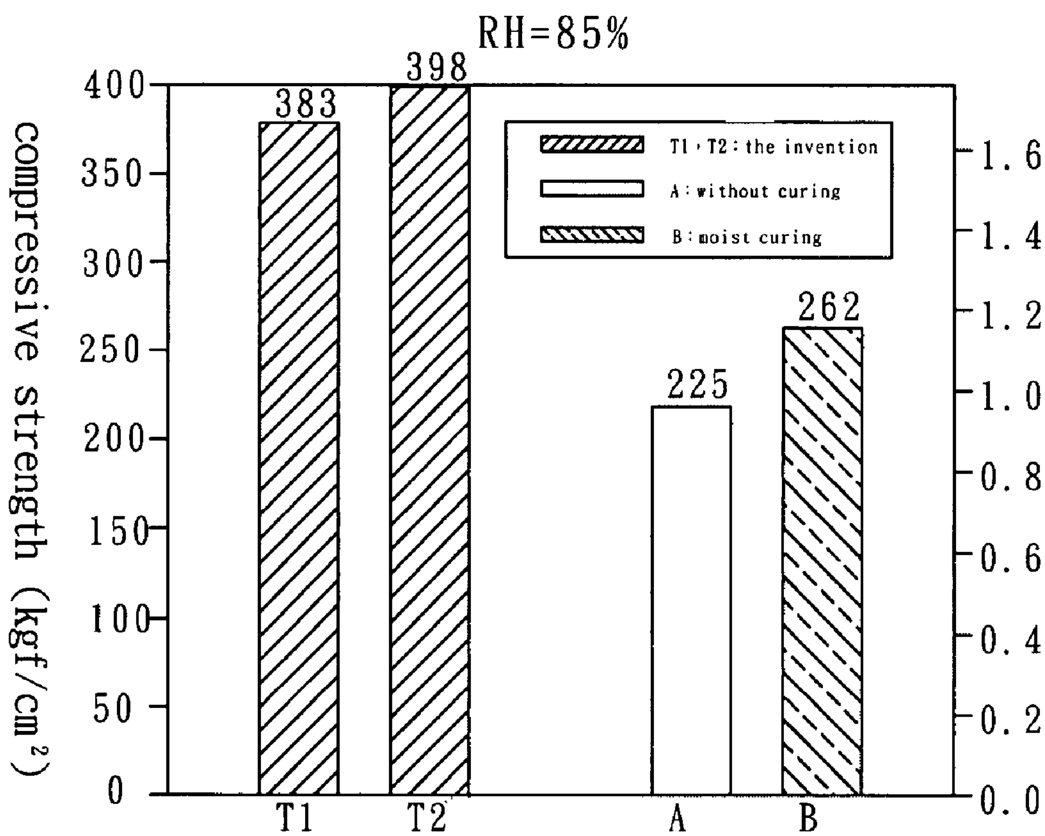

RH=85%
compressive strength (kgf/cm²)
400
350
300
250
200
150
100
50
0
383
398
225
262
T1 · T2 : the invention
A : without curing
B : moist curing
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
T1
T2
A
B

FIG. 5C

SELF-CURING CONCRETE

FIELD OF THE INVENTION

The present invention relates generally to a concrete, and more particularly to a self-curing concrete which features water absorbability and humectation.

BACKGROUND OF THE INVENTION

If no any curing measure is taken for concrete against natural setting or hardening, substantial water losses will occur due to fast water evaporation, thus prevents cement from hydration and leads to dusting or drying crack on concrete surface. In such case, the strength and durability of concrete will be reduced. After placing of concrete, curing shall be duly required to avoid water loss and drying crack. External curing is generally required for concrete after placing. In other words, water spraying or covering by plastic membrane or burlaps is applied to concrete surface to maintain enough moisture, namely, so-called “moist curing” is performed to ensure full cement hydration for a higher compressive strength. However, “moist curing” method needs regular maintenance such as manual watering, sprinkling or spraying, while repetitive wetting and drying will result in cracks against structural integrity.

In addition, available common methods for curing concrete include membrane curing and water-proof covering. According to membrane curing method, when liquid membrane-forming compounds for curing concrete (also referred to as membrane protective agent) is sprayed onto fresh concrete surface, the curing agent will rapidly form a water-proof film on the concrete surface, which prevents water evaporation and provides hydration conditions for cement. The curing agents, which are generally made of silica gel or latex film, can easily aggregate at depressed concrete surface, thus reducing the surface friction coefficient. Water-proof covering method applies only to large-sized simple structure. Despite of domestic and foreign regulations on “proper curing”, the relevant research shows that, even the most fundamental curing requirements are not met, or totally ignored in practical engineering.

SUMMARY OF THE INVENTION

The major object of the present invention is to provide a self-curing concrete. Self-curing agent can absorb moisture from atmosphere and then release the moisture into concrete. It’s added into concrete during mixing, such that concrete can be self-cured after placing without the need of any external curing. Thus, water evaporation after removal of formworks can be reduced, and the degree of cement hydration improved without extra standard curing. Furthermore, compressive strength will be enhanced with the reduced shrinkage arising from water evaporation, making it ideal for concrete placing without any external curing.

In the present invention, the self-curing agent, which can absorb moisture from atmosphere and then release the moisture to concrete, is added to self-curing concrete during mixing, such that concrete can be self-cured after placing without the need of any external curing. When a specific amount of self-curing agent is provided, the compressive strength of self-curing concrete may be increased at least 10% as compared to that of concrete without any curing. The added self-curing agent accounts about 0.1~5 wt % of cement weight of the concrete. In the preferred embodiment, the added amount of self-curing agent accounts 2 wt % of cement weight of the

concrete. This allows simple and cost-effective curing of concrete to meet the requirement of quality control and construction design inspections.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows the flow chart of self-curing concrete of the present invention.

FIGS. **2**A to **2**C show the comparison diagram of water loss and duration of OPC under different curing conditions at RH=50%, RH=67.5% and RH=85%.

FIGS. **3**A to **3**C show the comparison diagram of water loss and duration of SCC under different curing conditions at RH=50%, RH=67.5% and RH=85%.

FIGS. **4**A to **4**C show the comparison diagram of compressive strength of OPC under different curing conditions at RH=50%, RH=67.5% and RH=85%.

FIGS. **5**A to **5**C show the comparison diagram of compressive strength of SCC under different curing conditions at RH=50%, RH=67.5% and RH=85%.

DETAIL DESCRIPTION OF THE INVENTION

The features and the advantages of the present invention will be more readily understood upon a thoughtful deliberation of the following detailed description of a preferred embodiment of the present invention with reference to the accompanying drawings.

To ensure a simple and efficient curing of concrete, the high-performance self-curing agent of the present invention, which features higher humectation and water absorbability, shall be added to the mixed concrete for self-curing purpose. “Self-curing concrete” means that no labor work is required to provide water for concrete, or even no any external curing is required after placing which the properties of this concrete are at least comparable to and even better than those of concrete with traditional curing.

Referring to FIG. **1**, a work flow of self-curing method comprises: step **1**: “mixing concrete”; step **2**: “adding self-curing agent into concrete during mixing”; step **3**: “placing concrete”; step **4**: “verification the effect of self-curing”.

Firstly, an optional concrete mixture proportion is selected for step **1**, which contains coarse aggregates, fine aggregates, cement, pozzolans (optional), superplasticizer (optional) and mixing water, such as ordinary Portland concrete (OPC), self-consolidating concrete (SCC), high-performance concrete (HPC), lightweight concrete or mass concrete. In step **2**, the self-curing agent included polyvalent alcohol, selected from the group consisting of polyethylene glycol (PEG), propylene glycol (PG), dipropylene glycol (DPG), butylene glycol, neopently glycol (NPG), xylitol, sorbitol and glycerine; or phytosterols, hyaluronic acid, polyxyethylene (POE), sodium pyrrolidone carboxylate (PCA-Na), stearyl alcohol, cetyl alcohol or poly-acrylic acid, are added to concrete during mixing. The added self-curing agent accounts about 0.1 to 5 wt % of cement weight of the concrete. In the preferred embodiment, the added amount of self-curing agent accounts 2 wt % of cement weight of the concrete. In other words, the added amount of self-curing agent is proportional to cement weight of the concrete. For example, the self-curing material made of poly-acrylic acid is characterized by its strong capability of absorbing moisture from atmosphere and providing water required for curing concrete.

In the preferred embodiment of the present invention, ordinary Portland concrete (OPC) and self-consolidating concrete (SCC) were tested and compared to verify the function of water loss reduction. The test results for OPC are shown in

Table 1 and 2, and those for SCC shown in Table 3 and 4. Yet, the following tests provide only typical results for the efficacy of the present invention.

TABLE 1

Water Loss for OPC (RH = 67.50%)					
w/c = 0.6 (w/b = 0.37)	water weight loss (unit: g)				weight loss
admixture	1 day	2 days	4 days	7 days	ratio
plain concrete	0	60.5	110.5	121.9	1
1% self-curing agent	0	58.5	102.4	112.7	0.924
2% self-curing agent	0	54.1	98.85	110.5	0.906

TABLE 2

Water Loss for OPC (RH = 85%)					
w/c = 0.6 (w/b = 0.37)	water weight loss (unit: g)				weight loss
admixture	1 day	2 days	4 days	7 days	ratio
plain concrete	0	52.8	104.9	114	1
1% self-curing agent	0	48.5	90.9	104.5	0.917
2% self-curing agent	0	43.1	81.1	97.6	0.856

Of which, RH represents relative humidity. As listed in Table 1 and 2, self-curing concrete of the present invention can reduce water loss for desirable self-curing effect based on OPC, whether 1% or 2% self-curing agent is added thereto. Referring also to FIGS. **2**A, **2**B, **2**C, self-curing concrete of the present invention can be evidenced by reduction of water loss OPC, either in RH 50%, 67.5% or 85%.

TABLE 3

Water Loss for SCC (RH = 67.50%)					
w/c = 0.6 (w/b = 0.37)	water loss (unit: gw)				weight loss
admixture	1 day	2 days	4 days	7 days	ratio
plain concrete	0	61.6	91.1	101.2	1
adding 1% self-curing agent	0	53.4	80.7	90.2	0.891
adding 2% self-curing agent	0	49.2	75	86.6	0.855

TABLE 4

Water Loss for SCC (RH = 85%)					
w/c = 0.6 (w/b = 0.37)	water loss (unit: gw)				weight loss
admixture	1 day	2 days	4 days	7 days	ratio
plain concrete	0	51.3	90.5	95.9	1
adding 1% self-curing agent	0	42.8	80.1	85.2	0.888
adding 2% self-curing agent	0	38.3	74.4	79.6	0.830

As listed in Table 3 and 4, self-curing concrete of the present invention can reduce water loss for desirable self-curing-based on SCC, whether 1% or 2% self-curing agent is added thereto. Referring also to FIGS. **3**A, **3**B, **3**C, self-curing concrete of the present invention can be self-cured evidenced by reduction of water loss of SCC, under RH 50%, 67.5% or 85%.

In addition, FIGS. **4**A, **4**B and **4**C show the comparative compressive strengths of OPC (ordinary Portland concrete) with self-curing agent but no extra water curing, without any curing under RH=50%, RH=67.5% and RH=85%, and with moist curing. A represents OPC without curing, B represents OPC with standard moist curing, of which the basic OPC concrete compositions of T1, T2, A and B are almost the same except for the self-curing agent. The added amount of the self-curing agent in T1 is about 1 wt % of cement weight of OPC, in T2 about 2 wt % of cement weight. For all the cases of RH 50%, 67.5% and 85%, self-curing concrete T1 and T2 of the present invention have a higher compressive strength than normal concrete A without curing and close to concrete B with standard moist curing. The compressive strengths are (204 and 215) versus 202, (229 and 250) versus 227, (253 and 261) versus 268 (unit: kgf/cm^2; 1 MPa=10.1972 kgf/cm^2) respectively. It's thus concluded that, self-curing agent can easily absorb moisture from atmosphere and then release it into concrete. Self-curing concrete of the present invention features a better compressive strength of OPC.

Besides, self-curing concrete of the present invention provides a better compressive strength when applied to SCC (self-consolidating concrete). This is because the self-curing agent added to concrete can absorb moisture from atmosphere and then release to concrete. Referring to FIGS. **5**A, **5**B, **5**C, self-curing concrete T1 and T2 of the present invention, for the cases of RH 50%, 67.5% or 85%, SCC have a higher compressive strength than SCC concrete A without any curing and SCC concrete B with moist curing, of which the basic SCC concrete compositions of T1, T2, A and B are almost the same except for the self-curing agent. It's calculated that, the compressive strength of self-curing concrete T1 and T2 is 10% higher than that of SCC A without curing in same RH conditions, i.e, (254 and 293) versus 205, (313 and 353) versus 216, (383 and 398) versus 225 (unit: kgf/cm^2; 1 MPa=10.1972 kgf/cm^2) respectively. With the higher RH, compressive strength of self-curing concrete T1 and T2 of the present invention is improved significantly, or even higher than the compressive strength of SCC B with standard moist curing. This indicates that self-curing concrete of the present invention needs no long-lasting moist curing, which saves cost and guarantees a higher compressive strength and better quality.

Although the invention has been explained in relation to its preferred embodiment, it is to be understood that many other possible modifications and variations can be made without departing from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A self-curing concrete primarily comprising coarse aggregates, fine aggregates, cement, and mixing water, and further comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releases it into the concrete, thereby achieving self-curing without external curing method after placing, wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing is achieved, wherein the added solid amount of the self-curing agent is about 1-2 wt % of cement weight of the concrete, wherein the added self-curing agent comprises polyvalent alcohol selected from the group consisting of xylitol, sorbitol, phytosterols and butylene glycol.

2. The self-curing concrete as claimed in claim **1**, wherein the said concrete is a self-consolidating concrete.

3. The self-curing concrete as claimed in claim **1**, wherein the said concrete is a Portland cement concrete.

4. The self-curing concrete as claimed in claim **1**, wherein the said concrete is a high performance concrete.

5. A self-curing concrete primarily comprising coarse aggregates, fine aggregates, cement, and mixing water, and further comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releases it into the concrete, thereby achieving self-curing without external curing method after placing, wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing is achieved, wherein the added solid amount of the self-curing agent is about 0.1 to 5 wt % of cement weight of the concrete, wherein the added self-curing agent is sodium pyrrolidone carboxylate.

6. A self-curing concrete primarily comprising coarse aggregates, fine aggregates, cement, and mixing water, and further comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releases it into the concrete, thereby achieving self-curing without external curing method after placing, wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing is achieved, wherein the added solid amount of the self-curing agent is about 0.1 to 5 wt % of cement weight of the concrete, wherein the material of the added self-curing agent is selected from the group consisting of stearyl alcohol and cetyl alcohol.

7. A self-curing concrete primarily comprising coarse aggregates, fine aggregates, cement, and mixing water, and further comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releases it into the concrete, thereby achieving self-curing without external curing method after placing, wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing is achieved, wherein the added solid amount of the self-curing agent is about 0.1-5 wt % of cement weight of the concrete, wherein the added self-curing agent is selected from the group consisting of sodium pyrrolidone carboxylate, hyaluronic acid and polyxyethylene.

8. The self-curing concrete as claimed in claim **7**, wherein the said concrete is a self-consolidating concrete.

9. The self-curing concrete as claimed in claim **7**, wherein the said concrete is a Portland cement concrete.

10. The self-curing concrete as claimed in claim **7**, wherein the said concrete is a high performance concrete.

* * * * *

EXHIBIT 2

CYLINDER LOG

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
1	08/04/11	2	08/06/11	4.00	26710	2126	70	3935.3	149.12	HPC	1	Cone	Air
2	08/04/11	4	08/08/11	4.00	46235	3679	60	3982.6	150.92	HPC	1	Cone	Air
3	08/04/11	7	08/11/11	4.00	48800	3883	60	3979.1	150.78	HPC	1	Shear	Air
4	08/04/11	14	08/18/11	4.00	57240	4555	60	3927.5	148.83	HPC	1	Shear	Air
5	08/04/11	28	09/01/11	4.00	60735	4833	70	3958.9	150.02	HPC	1	Shear	Air
6	08/04/11	28	09/01/11	4.00	60760	4835	70	3925.7	148.76	HPC	1	Shear	Air
7	08/04/11	56	09/29/11	4.00	60625	4824	70	3947.0	149.57	HPC	1	Type 6	Air
8	08/04/11	56	09/29/11	4.00	54295	4321	70	3917.3	148.44	HPC	1	Type 6	Air
9	08/04/11	28	09/01/11	4.00	92985	7400	70	4029.1	152.68	HPC	1	Shear	STD Wet
10	08/04/11	28	09/01/11	4.00	118900	9462	70	4053.2	153.59	HPC	1	Shear	STD Wet
11	08/04/11	28	09/01/11	4.00	115695	9207	70	4038.9	153.05	HPC	1	Shear	STD Wet
12	08/04/11	2	08/06/11	4.00	38550	3068	50	4005.0	151.77	HPC	2	Columnar	14 Wet
13	08/04/11	4	08/08/11	4.00	61775	4916	60	4028.0	152.64	HPC	2	Shear	14 Wet
14	08/04/11	7	08/11/11	4.00	69140	5502	60	3983.4	150.95	HPC	2	Shear	14 Wet
15	08/04/11	14	08/18/11	4.00	88000	7003	60	4012.0	152.03	HPC	2	Columnar	14 Wet
16	08/04/11	28	09/01/11	4.00	100015	7959	70	3990.8	151.23	HPC	2	Cone	14 Wet
17	08/04/11	28	09/01/11	4.00	95705	7616	70	3982.1	150.90	HPC	2	Shear	14 Wet
18	08/04/11	56	09/29/11	4.00	101500	8077	70	4011.3	152.00	HPC	2	Cone	14 Wet
19	08/04/11	56	09/29/11	4.00	105365	8385	70	4016.4	152.20	HPC	2	Type 6	14 Wet
20	08/04/11	2	08/06/11	4.00	3370	268	50	3928.4	148.86	SCA	3	Crumble	56 Air
21	08/04/11	4	08/08/11	4.00	3650	290	50	3904.8	147.97	SCA	3	Cone	56 Air
22	08/04/11	7	08/11/11	4.00	32660	2599	50	3927.4	148.83	SCA	3	Columnar	56 Air
23	08/04/11	14	08/18/11	4.00	48715	3877	60	3949.2	149.65	SCA	3	Columnar	56 Air
24	08/04/11	28	09/01/11	4.00	56680	4510	70	3931.3	148.97	SCA	3	Shear	56 Air
25	08/04/11	28	09/01/11	4.00	56340	4483	70	3927.9	148.84	SCA	3	Shear	56 Air

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
26	08/04/11	56	09/29/11	4.00	59880	4765	70	3952.8	149.79	SCA	3	Cone	56 Air
27	08/04/11	56	09/29/11	4.00	56705	4512	70	3929.3	148.90	SCA	3	s	56 Air
28	08/04/11	28	09/01/11	4.00	87560	6968	70	3965.3	150.26	SCA	3	Shear	STD Wet
29	08/04/11	28	09/01/11	4.00	88250	7023	70	4013.4	152.08	SCA	3	Shear	STD Wet
30	08/04/11	28	09/01/11	4.00	90385	7193	70	3993.9	151.34	SCA	3	Shear	STD Wet
31	08/04/11	2	08/06/11	4.00	2550	203	50	3984.8	151.00	SCA	4	Cone	3 Wet
32	08/04/11	4	08/08/11	4.00	2590	206	50	4004.6	151.75	SCA	4	Cone	3 Wet
33	08/04/11	7	08/11/11	4.00	43000	3422	60	3944.2	149.46	SCA	4	Cone	3 Wet
34	08/04/11	14	08/18/11	4.00	46440	3696	60	3948.7	149.63	SCA	4	Shear	3 Wet
35	08/04/11	28	09/01/11	4.00	63790	5076	70	3959.2	150.03	SCA	4	Shear	3 Wet
36	08/04/11	28	09/01/11	4.00	67495	5371	70	3959.6	150.05	SCA	4	Shear	3 Wet
37	08/04/11	56	09/29/11	4.00	76180	6062	70	3941.9	149.37	SCA	4	Shear	3 Wet
38	08/04/11	56	09/29/11	4.00	68815	5476	70	3941.1	149.34	SCA	4	Shear	3 Wet
39	08/04/11	2	08/06/11	4.00	2110	168	50	3999.9	151.57	SCA	5	Cone	6 wet
40	08/04/11	4	08/08/11	4.00	2880	229	50	3985.6	151.03	SCA	5	Cone	6 wet
41	08/04/11	7	08/11/11	4.00	58795	4679	60	3995.1	151.39	SCA	5	Columnar	6 wet
42	08/04/11	14	08/18/11	4.00	81570	6491	60	3960.0	150.06	SCA	5	Shear	6 wet
43	08/04/11	28	09/01/11	4.00	108230	8613	70	3960.2	150.07	SCA	5	Shear	6 wet
44	08/04/11	28	09/01/11	4.00	97610	7768	70	3963.7	150.20	SCA	5	Shear	6 wet
45	08/04/11	56	09/29/11	4.00	117960	9387	70	4004.5	151.75	SCA	5	Cone	6 wet
46	08/04/11	56	09/29/11	4.00	112785	8975	70	3971.5	150.50	SCA	5	Cone	6 wet
47	08/04/11	2	08/06/11	4.00	2320	185	50	3980.4	150.83	SCA	6	Cone	7 Wet
48	08/04/11	4	08/08/11	4.00	2580	205	50	3958.4	150.00	SCA	6	Cone	7 Wet
49	08/04/11	7	08/11/11	4.00	55815	4442	60	3981.4	150.87	SCA	6	Columnar	7 Wet
50	08/04/11	14	08/18/11	4.00	82415	6558	60	4021.7	152.40	SCA	6	Shear	7 Wet

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
51	08/04/11	28	09/01/11	4.00	106320	8461	70	3973.7	150.58	SCA	6	Cone	7 Wet
52	08/04/11	28	09/01/11	4.00	103275	8218	70	3983.4	150.95	SCA	6	Cone	7 Wet
53	08/04/11	56	09/29/11	4.00	114225	9090	70	3978.9	150.78	SCA	6	Shear	7 Wet
54	08/04/11	56	09/29/11	4.00	120320	9575	70	3971.2	150.48	SCA	6	Shear	7 Wet
55	08/04/11			6.00					0.00	SCA	1	Visual	Air
56	08/04/11			6.00					0.00	SCA	1	Visual	Air
57	08/04/11			6.00					0.00	SCA	1	Visual	Air
58	08/04/11			6.00					0.00	SCA	2	Visual	14 Wet
59	08/04/11			6.00					0.00	SCA	2	Visual	14 Wet
60	08/04/11			6.00					0.00	SCA	2	Visual	14 Wet
61	08/04/11			6.00					0.00	SCA	3	Visual	Air
62	08/04/11			6.00					0.00	SCA	3	Visual	Air
63	08/04/11			6.00					0.00	SCA	3	Visual	Air
64	08/04/11			6.00					0.00	SCA	4	Visual	3 Wet
65	08/04/11			6.00					0.00	SCA	4	Visual	3 Wet
66	08/04/11			6.00					0.00	SCA	4	Visual	3 Wet
67	08/04/11			6.00					0.00	SCA	5	Visual	6 Wet
68	08/04/11			6.00					0.00	SCA	5	Visual	6 Wet
69	08/04/11			6.00					0.00	SCA	5	Visual	6 Wet
70	08/04/11			6.00					0.00	SCA	6	Visual	7 Wet
71	08/04/11			6.00					0.00	SCA	6	Visual	7 Wet
72	08/04/11			6.00					0.00	SCA	6	Visual	7 Wet
73	08/04/11			6.00					0.00	SCA	7	Visual	14 Wet
74	08/04/11			6.00					0.00	SCA	7	Visual	14 Wet
75	08/04/11	2	08/06/11	6.00	4000	141	60		0.00	SCA	7	Cone	14 Wet

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
76	08/10/11	1	08/11/11	4.00	790	63	50		0.00	ASH	8	Cone	Wet
77	08/10/11	2	08/12/11	4.00	565	45	50		0.00	ASH	8	Crumble	Wet
78	08/10/11	3	08/13/11	4.00	495	39	50		0.00	ASH	8	Cone	Wet
79	08/10/11	4	08/14/11	4.00	540	43	50		0.00	ASH	8	Cone	Wet
80	08/10/11	5	08/15/11	4.00	2990	238	50		0.00	ASH	8	Crumble	Wet
81	08/10/11	6	08/16/11	4.00	5940	473	50		0.00	ASH	8	Crumble	Wet
82	08/10/11	7	08/17/11	4.00	16895	1344	50		0.00	ASH	8	Shear	Wet
83	08/10/11	8	08/18/11	4.00	29800	2371	50		0.00	ASH	8	Crumble	Wet
84	08/10/11	1	08/11/11	4.00	32030	2549	50		0.00	No ASH	9	Shear	Wet
85	08/10/11	2	08/12/11	4.00	49675	3953	60		0.00	No ASH	9	Cone	Wet
86	08/10/11	3	08/13/11	4.00	57490	4575	60		0.00	No ASH	9	Shear	Wet
87	08/10/11	4	08/14/11	4.00	62430	4968	60		0.00	No ASH	9	Cone	Wet
88	08/10/11	5	08/15/11	4.00	67530	5374	60		0.00	No ASH	9	Cone	Wet
89	08/10/11	6	08/16/11	4.00	70570	5616	60		0.00	No ASH	9	Shear	Wet
90	08/10/11	7	08/17/11	4.00	72965	5806	70		0.00	No ASH	9	Shear	Wet
91	08/10/11	8	08/18/11	4.00	67795	5395	70		0.00	No ASH	9	Shear	Wet
92	08/25/11	1	08/26/11	4.00	19695	1567	60		0.00	HPC/F	10	Cone	KR HPC
93	08/25/11	3	08/28/11	4.00	36260	2885	60		0.00	HPC/F	10	Split	KR HPC
94	08/25/11	5	08/30/11	4.00	47040	3743	60		0.00	HPC/F	10	Columnar	KR HPC
95	08/25/11	7	09/01/11	4.00	54615	4346	70	3836.4	145.38	HPC/F	10	Columnar	KR HPC
96	08/25/11	14	09/08/11	4.00	69060	5496	70		0.00	HPC/F	10	Shear	KR HPC
97	08/25/11	21	09/15/11	4.00	75280	5991	70	3824.6	144.93	HPC/F	10	Shear	KR HPC
98	08/25/11	28	09/22/11	4.00	80785	6429	70	3799.9	143.99	HPC/F	10	Cone	KR HPC
99	08/25/11	28	09/22/11	4.00	82655	6577	70	3831.6	145.19	HPC/F	10	Cone	KR HPC
100	08/25/11	56	10/20/11	4.00	83495	6644	70	3830.0	145.13	HPC/F	10	Cone	KR HPC

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
101	08/25/11	56	10/20/11	4.00	84805	6749	70	3809.2	144.35	HPC/F	10	Cone	KR HPC
102	08/25/11	1	08/26/11	4.00	26945	2144	60		0.00	SCA/F	11	Cone	KR SCA
103	08/25/11	3	08/28/11	4.00	43305	3446	60		0.00	SCA/F	11	Cone	KR SCA
104	08/25/11	5	08/30/11	4.00	56275	4478	60		0.00	SCA/F	11	Split	KR SCA
105	08/25/11	7	09/01/11	4.00	60965	4851	70	3860.4	146.29	SCA/F	11	Shear	KR SCA
106	08/25/11	14	09/08/11	4.00	77830	6194	70		0.00	SCA/F	11	Cone	KR SCA
107	08/25/11	21	09/15/11	4.00	79670	6340	70	3819.0	144.72	SCA/F	11	Cone	KR SCA
108	08/25/11	28	09/22/11	4.00	84600	6732	70	3827.5	145.04	SCA/F	11	Shear	KR SCA
109	08/25/11	28	09/22/11	4.00	84150	6696	70	3808.6	144.32	SCA/F	11	Shear	KR SCA
110	08/25/11	56	10/20/11	4.00	87685	6978	70	3807.5	144.28	SCA/F	11	Cone	KR SCA
111	08/25/11	56	10/20/11	4.00	82070	6531	70	3838.8	145.47	SCA/F	11	Cone	KR SCA
112	09/20/11	1	09/21/11	4.00	27145	2160	50	3881.8	147.10	HPC/F	12	Cone	KR HPC
113	09/20/11	1	09/21/11	4.00	26695	2124	50	3892.3	147.49	HPC/F	12	Cone	KR HPC
114	09/20/11	1	09/21/11	4.00	28415	2261	50	3892.0	147.48	HPC/F	12	Cone	KR HPC
115	09/20/11	5	09/25/11	4.00	54480	4335	50	3895.5	147.62	HPC/F	12	Shear	KR HPC
116	09/20/11	5	09/25/11	4.00	56285	4479	50	3896.6	147.66	HPC/F	12	Shear	KR HPC
117	09/20/11	5	09/25/11	4.00	54710	4354	50	3894.2	147.57	HPC/F	12	Shear	KR HPC
118	09/20/11	7	09/27/11	4.00	60215	4792	70	3877.1	146.92	HPC/F	12	Shear	KR HPC
119	09/20/11	7	09/27/11	4.00	60555	4819	70	3916.5	148.41	HPC/F	12	Shear	KR HPC
120	09/20/11	7	09/27/11	4.00	63080	5020	70	3843.7	145.65	HPC/F	12	Shear	KR HPC
121	09/20/11	14	10/04/11	4.00	79390	6318	70	3874.2	146.81	HPC/F	12	Cone	KR HPC
122	09/20/11	14	10/04/11	4.00	76545	6091	70	3891.8	147.48	HPC/F	12	Cone	KR HPC
123	09/20/11	14	10/04/11	4.00	77730	6186	70	3889.9	147.40	HPC/F	12	Shear	KR HPC
124	09/20/11	28	10/18/11	4.00	88290	7026	70	3885.8	147.25	HPC/F	12	Shear	KR HPC
125	09/20/11	28	10/18/11	4.00	82960	6602	70	3894.5	147.58	HPC/F	12	Cone	KR HPC

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
126	09/20/11	28	10/18/11	4.00	88170	7016	70	3865.5	146.48	HPC/F	12	Shear	KR HPC
127	09/20/11	56	11/15/11	4.00	99315	7903	70	3827.0	145.02	HPC/F	12	Shear	KR HPC
128	09/20/11	56	11/15/11	4.00	97585	7766	70	3831.5	145.19	HPC/F	12	Cone	KR HPC
129	09/20/11	56	11/15/11	4.00	96590	7686	70	3817.9	144.68	HPC/F	12	Shear	KR HPC
130	09/20/11			4.00					0.00	HPC/F	12	RCPT	KR HPC
131	09/20/11			4.00					0.00	HPC/F	12	RCPT	KR HPC
132	09/20/11			4.00					0.00	HPC/F	12	RCPT	KR HPC
133	09/20/11	1	09/21/11	4.00	37635	2995	50	3816.3	144.62	SCA/F	13	Cone	KR SCA
134	09/20/11	1	09/21/11	4.00	32985	2625	50	3735.7	141.56	SCA/F	13	Cone	KR SCA
135	09/20/11	1	09/21/11	4.00	34355	2734	50	3807.4	144.28	SCA/F	13	Cone	KR SCA
136	09/20/11	5	09/25/11	4.00	58885	4686	50	3733.2	141.47	SCA/F	13	Shear	KR SCA
137	09/20/11	5	09/25/11	4.00	61625	4904	50	3827.5	145.04	SCA/F	13	Shear	KR SCA
138	09/20/11	5	09/25/11	4.00	62205	4950	50	3773.3	142.99	SCA/F	13	Shear	KR SCA
139	09/20/11	7	09/27/11	4.00	64615	5142	70	3729.0	141.31	SCA/F	13	Shear	KR SCA
140	09/20/11	7	09/27/11	4.00	69150	5503	70	3797.3	143.90	SCA/F	13	Shear	KR SCA
141	09/20/11	7	09/27/11	4.00	66280	5274	70	3722.9	141.08	SCA/F	13	Shear	KR SCA
142	09/20/11	14	10/04/11	4.00	75280	5991	70	3767.8	142.78	SCA/F	13	Shear	KR SCA
143	09/20/11	14	10/04/11	4.00	79505	6327	70	3746.2	141.96	SCA/F	13	Shear	KR SCA
144	09/20/11	14	10/04/11	4.00	74100	5897	70	3748.9	142.06	SCA/F	13	Shear	KR SCA
145	09/20/11	28	10/18/11	4.00	82830	6591	70	3749.8	142.10	SCA/F	13	Shear	KR SCA
146	09/20/11	28	10/18/11	4.00	84770	6746	70	3817.3	144.65	SCA/F	13	Cone	KR SCA
147	09/20/11	28	10/18/11	4.00	83515	6646	70	3761.2	142.53	SCA/F	13	Cone	KR SCA
148	09/20/11	56	11/15/11	4.00	88250	7023	70	3807.6	144.29	SCA/F	13	* Shell	KR SCA
149	09/20/11	56	11/15/11	4.00	89730	7140	70	3745.4	141.93	SCA/F	13	*Shell	KR SCA
150	09/20/11	56	11/15/11	4.00	91140	7253	70	3800.0	144.00	SCA/F	13	Shear	KR SCA

ID	Cast	Age	Test	Size	Pounds	PSI	Pad	Weight	PCF+/-	Design	Set	Failure	Cure
151	09/20/11			4.00					0.00	SCA/F	13	RCPT	KR SCA
152	09/20/11			4.00					0.00	SCA/F	13	RCPT	KR SCA
153	09/20/11			4.00					0.00	SCA/F	13	RCPT	KR SCA