BURNS COOLEY DENNIS, INC.

GEOTECHNICAL AND MATERIALS ENGINEERING CONSULTANTS

INFLUENCE OF FLY ASH, SLAG CEMENT AND SPECIMEN CURING ON SHRINKAGE OF BRIDGE DECK CONCRETE

State Study 247

Project No. 106266 167000

Prepared for
Mississippi Department of Transportation

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16. Abstract:
Cracks occur in bridge decks due to restrained shrinkage of concrete materials. Concrete materials shrink as cementitious materials hydrate and as water that is not chemically bonded to cementitious materials migrates from the high humid environment of the concrete to an environment with lower humidity. Reinforcing steel and structural supporting members provide restraint to this shrinkage which causes tensile stress in the concrete. When these tensile stresses exceed the tensile strength of the concrete, cracks occur and provide relief for these stresses. MDOT engineers wanted to determine the usefulness of supplementary cementitious to reduce shrinkage of concrete materials and subsequent cracking. This research project investigates length change of concrete as influenced by supplementary cementitious materials including Class C fly ash, Class F fly ash, and slag cement. The use of liquid membrane and 7-day, 14-day, and 28-day moist curing periods were also investigated to determine the influence of curing on length change of standard prism specimens.

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Abstract

Shrinkage induced cracks often occur in bridge decks and are generally held tight together by reinforcing steel. However, these cracks can compromise the structural integrity and durability of bridge decks by providing easy access channels for water to carry chloride ions to the reinforcing steel and cause corrosion. In an effort to minimize these shrinkage cracks, the Mississippi Department of Transportation (MDOT) commissioned this study to evaluate the usefulness of supplementary cementitious in reducing shrinkage of concrete materials and reducing subsequent cracking. This research project investigates length change of concrete as influenced by supplementary cementitious materials including Class C fly ash, Class F fly ash, and slag cement. Moist curing period and liquid membrane were also investigated to determine the influence of curing on length change of standard prism specimens.

The purpose of this research was to determine the influence of supplementary cementitious material source and replacement rate on shrinkage of bridge deck concrete. Two sources of Class C fly ash, two sources of Class F fly ash, and one source of slag cement were used and combined in various replacement rates with portland cement to develop the sixteen mixtures for this study. Replacement rates for both Class C and Class F fly ash of 15 percent, 20 percent, and 25 percent were used to develop twelve of the mixtures. Slag cement replacement rates of 40 percent, 45 percent, and 50 percent were used to produce three additional mixtures. One mixture was made with 100 percent portland cement and this mixture was used as the control mixture.

Twelve length change specimens were molded for each mixture, representing four variations in initial curing. The variations in curing include either the use of liquid membrane or initial moist curing periods of 7, 14, and 28 days.

All mixtures were batched with oven dry aggregates to reduce the influence of varying aggregate moisture contents on results of this study. In addition, aggregates were sieved into individual size fractions to limit the influence of aggregate grading on length change.

Data generated in this study can be used by engineers to determine criticality of replacement rates of supplementary cementitious materials and curing practices on shrinkage of bridge deck concrete.

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CHAPTER 1 - INTRODUCTION

BACKGROUND

The durability of concrete or its ability to resist deterioration within its environment depends on a variety of properties and circumstances. These properties and circumstances may include the design, materials, workmanship, maintenance, as well as the environment in which the concrete is exposed. Differences in concrete durability have been observed in different parts of a single structure calling into question the role of surface area exposure, the individual mixture properties, the methods of handling, finishing, placing and curing, as well as, the weather conditions and timely placement of each portion of the structure. However, designers and specifiers ultimately want their concrete structures to have a long service life with minimal maintenance.

The Mississippi Department of Transportation endeavors to increase longevity and serviceability of its reinforced concrete structures including highway bridges. The Department's efforts to increase longevity and serviceability include examinations into the quality of the concrete and the role of aggregates, cementitious materials, and admixtures in guarding against the mechanical, chemical, and environmental factors that work together in the deterioration of these structures.

Reducing shrinkage cracks in bridge decks can result in increasing service life and reducing maintenance costs. Low shrinkage of concrete materials is a desirable characteristic for producing durable concrete bridge decks. Cracks can compromise the structural integrity and durability by providing easy access channels for water to carry chloride ions to reinforcing steel and cause corrosion. Cracks occur when concrete experiences the volume changes in both its plastic and hardened state. These volume changes are small compared to the entire volume of concrete and primarily occur in the cementitious paste portion of the mixture as a result of shrinkage. A combination of shrinkage within the paste of the concrete and restraint to this shrinkage that is provided by the reinforcing steel or supporting structural elements creates the occasion for shrinkage cracks. Reducing shrinkage can minimize cracking, minimize maintenance costs, and contribute to the longevity and service life of concrete bridge decks.

Concrete is made up of aggregates, cementitious materials, water, air, and admixtures. Concrete can be divided into two major components including aggregates and cementitious

paste. The aggregate portion is comprised of various aggregate sizes through blending fine and coarse aggregates. Aggregates make up 60 to 75 percent of the total volume of concrete (1). The remaining 25 to 40 percent of the volume of concrete is void space in aggregates developed by the irregular shape of individual particles. This void space must be filled with cementitious paste.

Concrete experiences volume changes in both its plastic state and hardened state. These volumetric changes are relatively small compared to the entire volume of concrete and primarily occur in the cementitious paste portion of the mixture as shrinkage. This shrinkage occurs as a result of chemical shrinkage, autogenous shrinkage, settlement, and plastic shrinkage.

Chemical shrinkage is a reduction in absolute volume of solids and liquids in cement paste that result from cementitious materials reacting with water. Portland cement and water occupy more volume in their individual state than when they are chemically combined (1). Consequently, as concrete sets and gains strength during hydration its volume shrinks. The volume of concrete will continue to decrease due to chemical shrinkage as long as hydration occurs.

Autogenous shrinkage occurs as water in the pores of fresh and hardened cementitious paste is consumed by hydration. This phenomenon is also known as self-desiccation (2). This shrinkage is much less than the absolute volume changes of chemical shrinkage because of the rigidity of the harden paste structure (1). Autogenous shrinkage is related to chemical shrinkage because it is influenced by hydration and is considered part of the overall volume reduction of chemical shrinkage. It is more prominent in concrete with high cementitious contents and low water contents having a water cement ratio (w/c) less than 0.42 (2). This additional consumption of water by hydration causes less volume and shrinkage in the cementitious paste. The w/c ratio used in this study ranged from 0.450 to 0.484. Therefore, autogenous shrinkage was minimized in this study because of the w/c ratio was greater than 0.42.

Settlement also contributes to volume shrinkage. Settlement occurs as heavier solids in concrete mixtures settle and water rises. This water either evaporates or is otherwise removed from the concrete mixture causing a reduction in the volume of concrete. This reduction of water causes shrinkage in the overall volume of concrete. Settlement was not measured in this study because all length change testing began after the concrete specimens had hardened.

Plastic shrinkage is a combination of chemical shrinkage, autogenous shrinkage, and rapid evaporation while the concrete is still in a plastic state. Plastic shrinkage is often attributed to surface cracking that can occur during final finishing operations. Plastic shrinkage was not considered in this study because rapid evaporation was prevented by using either moist curing or liquid membrane.

In addition to volume changes associated with chemical and autogenous shrinkage, hardened concrete also experiences volume changes with changes in moisture and temperature. Volume changes may be in the form of expansion or shrinkage. When external water is available to replace water that is consumed by chemical and autogenous shrinkage, expansion occurs. In addition, concrete can expand by absorbing small amounts of water. As hardened concrete dries due to the relative humidity of air being lower than the relative humidity of the concrete, drying shrinkage occurs. Drying shrinkage is the primary volume change documented in this study.

The effort to reduce shrinkage of bridge deck concrete has prompted two previous studies by the Department including;

1) State Study 216, "Shrinkage and Durability Study of Bridge Deck Concrete" – This study generated shrinkage and permeability data for thirty various bridge deck concrete mixtures developed with readily available materials in Mississippi. This study showed that the use of Class C fly ash, Class F fly ash, and slag increased durability of concrete because mixtures proportioned with these supplementary cementitious materials (SCM's) produced less permeability when tested in accordance with AASHTO T 277 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration." Replacing portland cement with either 50 percent slag cement or 25 percent Class F fly ash produced mixtures that performed the best with respect to permeability, followed by mixtures proportioned with 25 percent Class C fly ash. The mixtures that had the highest permeability and were the worst performing mixtures for permeability were mixtures proportioned without SCMs. The study also concluded that SCMs were useful in reducing length change (shrinkage). Mixtures that used 50 percent slag cement to replace portland cement performed the best with respect to shrinkage. Mixtures that used 25 percent Class F fly ash to replace portland cement was the next best performers. The performance of mixtures that utilized 25 percent Class C fly ash and mixtures that did not use SCMs was similar and these mixtures produced the most

shrinkage and did not perform as well as mixtures that used either 50 percent slag cement or 25 percent Class F fly ash with respect to shrinkage.

2) State Study 231, "Optimizing Mississippi Aggregates for Concrete Bridge Decks" – This study explored a wide variety of aggregate gradations to determine criticality of aggregate particle size distribution in producing durable bridge deck concrete with Mississippi gravel aggregates. This study showed that combined aggregate gradations that produce coarseness factors (CF) and adjusted workability factors (AWF) that plot in Zone I, Zone V, and the trend bar of the Modified Coarseness Factor Chat can reduce water demand compared to CF and AWF that plot within Zone II. Combined aggregate gradations that produce CF and AWF factors that plot within Zone IV should be avoided because of the increased water demand due to the amount of fines associated with Zone IV. Recommendations were provided in this study for an "optimal" zone of the Modified Coarseness Factor Chart for 1 in. nominal maximum size Mississippi gravel. Recommendations were also provided for upper and lower limits for combined percent retained on individual sieves.

OBJECTIVE

The objective of this research was to investigate the influence of supplementary cementitious source, type, and replacement rate on shrinkage of concrete. This research also documents the influence of initial curing methods on concrete shrinkage including the use of liquid membrane, and soaking in water for 7, 14, or 28 days.

APPROACH

Testing was performed on hardened concrete to determine the influence of fly ash and slag cement on compressive strength and length change. The test method used to determine compressive strength was AASHTO T 22 / ASTM C 39 "Standard Test method for Compressive Strength of Cylindrical Concrete Specimens." The test method used to measure length change was AASHTO T 160 / ASTM C 157 "Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete." These tests were conducted on each of the mixtures.

Length change according to AASHTO T 160 / ASTM C 157 uses a comparator accurate to the nearest 0.0001 in. to measure the length change of 4 in. by 4 in. by 11 ¼ in. long concrete prism specimens compared to a standard reference steel bar. Length change measurements

extended over a period of 449 to 476 days depending on the curing method and curing period followed by 448 days of drying. Expansion occurred while the specimens remained in a water bath and shrinkage occurred after the specimens were exposed to drying conditions. Specimens were then placed in a temperature and humidity controlled room after the initial curing period where length change in the form of shrinkage began. Specimens remained in this room until testing was completed. Length change resulting from drying shrinkage was calculated for each mixture. Chapter 4 "Laboratory Testing" provides a detailed description of test procedures and length change calculations.

A total of sixteen mixtures were tested to provide data for this study. Table 1 provides a general description of the experimental mixtures. Each mixture contributed four sets of length change specimens. These specimens were exposed to four curing practices to investigate the influence of type and replacement rates of supplementary cementitious materials and curing practices on shrinkage of bridge deck concrete. Two sources of Class C fly ash, two sources of Class F fly ash, and one source of slag cement were selected and combined in various replacement rates with a single portland cement source. Fly ash was introduced in replacement rates of 15, 20, and 25 percent. Slag cement replacement rates of 40, 45 and 50 percent were utilized. A single mixture of 100 percent portland cement was used as the control mixture.

Table 1: Experimental Mixtures[1]

Mix Number	Supplementary Cementitious Source	% Cement	% Class C Fly Ash	% Class F Fly Ash	% Slag Cement
1	CS-1	100	0	0	0
2	C-1	85	15	0	0
3		80	20	0	0
4		75	25	0	0
5	C-2	85	15	0	0
6		80	20	0	0
7		75	25	0	0
8	F-1	85	0	15	0
9		80	0	20	0
10		75	0	25	0
11	F-2	85	0	15	0
12		80	0	20	0
13		75	0	25	0
14	S-1	60	0	0	40
15		55	0	0	45
16		50	0	0	50

Note 1: Four variations in initial curing were evaluated for each experimental mixture including the use of liquid membrane, 7-day soak, 14-day soak, and 28-day soak.

CHAPTER 2 - MATERIALS

PORTLAND CEMENT

Portland cement is hydraulic cement and acts as a primary cementing material in portland cement concrete. Type I portland cement meeting requirements of ASTM C 150 / AASHTO M 85, "Standard Specification for Portland Cement", is hydraulic cement made to conform to specific chemical and physical property limits according to these specifications. These specifications provide for eight types of portland cement meeting various set time and exposure criteria. Type I LA (low alkali) portland cement was used in this study as the primary cementing material for the mixtures and is referred to herein as Type I. Only one source of Type I portland cement was used in this study.

Hydraulic cements react with water and produce calcium silicate hydrate and other cementing compounds that cause concrete to set and gain strength. A byproduct of this reaction is calcium hydroxide which remains suspended in the concrete matrix and may be available to react with pozzolans such as Class C or Class F fly ash and slag cement to create more cementing compounds.

Chemical and physical properties of the Type I portland cement used in this study were provided by the supplier and are presented in Table 2. The cement is from a source that is approved for use on MDOT projects.

SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMs)

Supplementary Cementitious Materials (SCMs) are included in concrete mixtures as part of the overall cementitious system. Most concrete produced in Mississippi incorporates SCMs in the mixture, particularly Class C and Class F fly ash. SCMs are often added to concrete in order to improve plastic and hardened properties of the concrete. SCMs included in this research are Class C fly ash, Class F fly ash, and slag cement. SCMs have both hydraulic and pozzolanic value in concrete. Pozzolans are materials that have little cementing value by themselves, but will react with calcium hydroxide to provide more cementing compounds.

Fly Ash

Fly ash is finely divided residue of burned ground coal, captured from the flue gases of a coal combustion device, usually at a coal-burning electric power plant. The combustion byproduct is usually harvested with electrostatic precipitators, conveyed to storage and shipping, and is commonly used as a cementitious component of concrete without further processing. Class C and Class F fly ash conform to the provisions of AASHTO M 295 / ASTM C 618 "Standard Specification for Coal Fly Ash and Calcined Natural Pozzolan for Use in Concrete." The distinction between the two classes is usually related to the type of coal burned in production of the ash. Class C fly ash can contain a total calcium content (expressed as CaO) higher than 10 percent, but MDOT projects require a CaO content of Class C fly ash greater than or equal to 8 percent. MDOT projects require a CaO content of less than 8 percent for Class F fly ash. Both classes of fly ash are predominately pozzolanic. Functionally, a Class F fly ash is typically more nearly pure pozzolan than a Class C fly ash. A Class C fly ash may have slight hydraulic cementitious reactivity and other reactive chemical components. It is possible for a fly ash source to conform to both Class C and Class F fly ash designations; however, MDOT requires that fly ash be classified as either Class C or Class F but not both. MDOT concrete specifications allow Class C and Class F fly ash to be used to replace up to 25 percent of the portland cement. This study uses two sources for the Class C and Class F fly ash. All four fly ash sources are approved for use on MDOT projects. Chemical and physical properties of the Class C and Class F fly ash in this study were provided by the supplier and are presented in Tables 3 through 6.

Slag Cement

Slag cement is produced from water-quenched molten slag from an iron-making blast furnace according to AASHTO M 302 / ASTM C 989 "Slag Cement for Use in Concrete and Mortars." It is hydraulic cement with additional pozzolanic properties. Slag cement is the molten mineralogical byproduct of iron ore from the blast furnace, but must be processed through "granulation" (rapid water quenching), drying, and grinding in a ball mill or roller press to produce slag cement. MDOT concrete specifications allow up to 50 percent replacement of portland cement with slag cement. Restrictive controls of the iron-making process lessen the variations in chemical composition from an individual plant, but the composition may vary

between sources. When molten slag is rapidly water-cooled, it forms a glassy, sand-like, granulated material that when dried and ground into a fine powder, has cementitious properties. Slag that is allowed to cool slowly in air will form crystalline products that have no cementitious properties. Slag cement in the presence of water and activators supplied by the presence of portland cement will hydrate and set in a manner similar to portland cement. Slag cement is graded along a three-tiered activity index based on 7-day and 28-day strength results. This study uses one source of slag cement and this source is approved for use on MDOT projects. Chemical and physical properties of the slag cement used in this study were provided by the supplier and are presented in Table 7.

Table 2: Type I Portland Cement (CS-1)

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	19.7
Aluminum Oxide (Al_2O_3), %	5.6
Ferric Oxide (Fe2O3), %	3.5
Calcium Oxide (CaO), %	64.4
Magnesium Oxide (MgO), %	0.8
Sulfur Trioxide (SO_3), %	3.1
Loss of Ignition (LOI), %	2.2
Insoluble Residue, %	0.33
Free Lime, %	1.06
Alkalies (Na_2O equivalent), %	0.52
Carbon Dioxide (CO2), %	0.9
Limestone, %	2.5
$CaCO_3$ in limestone, %	79
Tricalcium Silicate (C_3S), %	58
Dicalcium Silicate (C_2S), %	12
Tricalcium Aluminate (C_3A), %	9
Tetracalcium Aluminoferrite (C_4AF), %	11
Physical Properties	**Results**
Blaine Fineness, m2/kg	396
325 Mesh (% passing)	90.4
Time of setting (Vicat) Initial Set, minutes	85
Time of setting (Vicat) Final Set, minutes	190
Time of Setting (Gillmore) Initial Set, minutes	145
Time of Setting (Gillmore) Final Set, minutes	235
Air Content, %	7.3
False Set, %	75
Normal Consistency, %	24.5
Autoclave Expansion, %	0.04
Expansion in Water, %	0.008
Compressive Strength, 1 day (psi)	2500
Compressive Strength, 3 day (psi)	4090
Compressive Strength, 7 day (psi)	4930

Table 3: Class C Fly Ash Source (C-1)

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	38.29
Aluminum Oxide (Al_2O_3), %	20.50
Iron Oxide (Fe_2O_3), %	6.34
Sum of Constituents, %	65.13
Sulfur Trioxide (SO_3), %	1.62
Calcium Oxide (CaO), %	22.11
Moisture Content, %	0.04
Loss on Ignition, %	0.47
Available Alkalies, as Na_2O, %	1.52
Physical Properties	**Results**
Fineness, % retained on # 325	15.71
Fineness Uniformity,%	0.84
Strength Activity Index 7 day, % of control	101
Strength Activity Index 28 day, % of control	107
Water Requirement, % control	95
Autoclave Soundness	0.01
Density	2.63
Density Uniformity,%	0.51

Table 4: Class C Fly Ash Source 2 (C-2)

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	36.35
Aluminum Oxide (Al_2O_3), %	20.16
Iron Oxide (Fe_2O_3), %	5.62
Sum of SiO_2, Al_2O_3, & Fe_2O_3	62.13
Magnesium Oxide, % (MgO)	4.78
Sulfur Trioxide (SO_3), %	1.37
Moisture Content, %	0.05
Loss on Ignition, %	0.23
Available Alkalies, as Na_2O, %	1.59
Calcium Oxide, % (CaO)	25.27
Physical Properties	**Results**
Fineness, % retained on # 325 sieve	8.81
Water Requirement, % Control	94
Specific Gravity	2.59
Autoclave Expansion, %	-0.04
Strength Activity Index 7 day, % of control	110

Table 5: Class F Fly Ash Source (F-1)

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	59.31
Aluminum Oxide (Al_2O_3), %	19.37
Iron Oxide (Fe_2O_3), %	9.13
Sum of SiO_2, Al_2O_3, & Fe_2O_3	87.81
Magnesium Oxide (MgO), %	1.45
Sulfur Trioxide (SO_3), %	0.44
Moisture Content, %	0.09
Loss on Ignition, %	0.24
Available Alkalies, as Na_2O, %	0.55
Calcium Oxide (CaO), %	5.38
Physical Properties	**Results**
Fineness, % retained on # 325 sieve	26.51
Water Requirement, % control	95
Specific Gravity	2.42
Autoclave Soundness	-0.09
Strength Activity Index 7 day, % of control	82
Strength Activity Index 28 day, % of control	85

Table 6: Class F Fly Ash Source 2 (F-2)

Chemical Properties	Results
Total Silica, Aluminum, Iron, %	84.6
Silicon Dioxide (SiO_2), %	48.0
Aluminum Oxide (Al_2O_3), %	19.6
Iron Oxide (Fe_2O_3), %	17.1
Sulfur Trioxide (SO_3), %	1.6
Calcium Oxide (CaO), %	6.5
Moisture Content, %	0.0
Loss on Ignition, %	2.0
Available Alkalies, as Na_2O, %	0.6
Sodium Oxide, %	0.20
Potassium Oxide, %	0.67
Physical Properties	**Results**
Fineness, % retained on # 325 sieve	18.4
Strength Activity Index 7 day, % of control	83.9
Strength Activity Index 28 day, % of control	91.4
Water Requirement, % control	94.2
Autoclave Soundness	-0.02
Drying Shrinkage, Increase at 28 day, %	0.00
Density Mg/m^3	2.41

Table 7: Slag Cement (S-1)

Chemical Properties	Results
Sulfide S, %	1.15
Sulfate Ion (SO_3), %	0.13
Total Alkalies as Na_2O, %	0.69
C_3S	61
C_2S	13
C_3A	7
C_4AF	8.22
Physical Properties	**Results**
+45 µm (No. 325) Sieve, %	0.43
Blaine Fineness (m2/kg)	602
Air Content, %	5.45
Slag Activity 7 Day Index, %	78
Slag Activity 28 Day Index, %	116
Compressive Strength Slag-Ref, 7 day (psi)	3360
Compressive Strength Slag-Ref, 28 day (psi)	6400
Reference Cement 7 Day, %	4320
Reference Cement 28 Day, %	5550
Blaine Fineness (m2/kg)	360
Compressive Strength MPa, 7 day (psi)	4300
Compressive Strength MPa, 28 day (psi)	5390

AGGREGATES

The aggregates used in the study consist of one coarse and one fine aggregate from the same aggregate source. Multiple tests were performed on separate samples to determine sieve analysis, gravities, and absorption. Average aggregate properties are presented in Table 8. The aggregates are from a source that is approved for MDOT projects.

The fine and coarse aggregates used in this study were oven-dried for processing and reduced to individual sieve size fractions, taking care not to overload any individual sieve. Care was taken to guard against contamination of these individual size fractions through the use of dedicated containers with well-fitting lids, in a controlled moisture/temperature environment. Having the aggregates in individually sieved fractions facilitated recreating the same combined aggregate grading for each mix, based on percent retained quantities.

Table 8: Average Aggregate Properties

Sieve Size	No.57		Sand	
	Individual % Retained	**Total % Passing**	**Individual % Retained**	**Total % Passing**
1”	4.5	95.5	0.0	100.0
¾”	12.6	82.9	0.0	100.0
½”	24.1	58.9	0.0	100.0
3/8”	15.7	43.2	0.0	100.0
No. 4	40.5	2.7	1.7	98.3
No. 8	2.5	0.2	9.1	89.2
No. 16	0.1	0.1	8.2	81.0
No. 30	0.0	0.1	17.0	63.9
No. 50	0.0	0.1	51.8	12.2
No. 100	0.0	0.1	11.8	0.4
No. 200	0.0	0.0	0.3	0.1
FM	6.70		2.55	
Bulk Gravity (DRY)	2.473		2.625	
Bulk Gravity (SSD)	2.528		2.632	
Absorption, %	2.23		0.28	
DRUW (lbs/ft^3)	103.4		NA	
Void Content, %	37		NA	

CHAPTER 3 - MIXTURES

MIXTURE DEVELOPMENT

The influence of the supplementary cementitious materials (SCMs) source, type, and replacement rate on concrete's length change using a variety of curing practices is described herein. The results are based on laboratory tests and experience gained during production of sixteen concrete mixtures with each producing four different sets of length change specimens. Each of the four sets of length change specimens were initially cured using one of four different curing methods including, (liquid membrane, 7-day soak, 14-day soak, and 28-day soak).

The mixture proportions used in this research were based on initial trial batches. The purpose of these trial batches was to determine the amount of water content necessary to produce a 3 ± ¾ inch slump with a predetermined about of portland cement. The weight of cement used for these trial batches was 526.4 pounds per cubic yard (pcy), with a corresponding weight of water of 236.88 pcy, i.e., 28.4 gallons of water pcy. Settling on these parameters for the control mixture and allowing 2.5 percent for entrapped air content, absolute paste volume including entrapped air was calculated to be 7.15 cubic feet per cubic yard and this volume was held constant for all mixtures. This in turn, created a fixed absolute volume for aggregates of 19.85 cubic feet per cubic yard and this volume was also held constant for all mixtures. Therefore, our experimental mixtures have an aggregate volume of 73.52 percent of the total volume of concrete and the cement paste has a volume of 26.48 percent of the total volume of concrete.

The combined aggregate grading for each mixture was assembled at the individual sieve size fraction level and held constant for all mixtures. Operating with these paste and aggregate volume constants and no subsequent requirement for slump, w/cm ratio, temperature, air content or unit weight, minimized the volumetric variables across the sixteen mixtures to only those driven by the different specific gravities and replacement rates of the five SCMs within this study.

COARSE AGGREGATE CONTENT

The total weight of coarse aggregate was calculated based on MDOT's requirements for minimum coarse aggregate content for concrete paving mixtures. Section 501 "Portland Cement Concrete Pavement" of the MDOT's Specifications for Road and Bridge Construction requires a

minimum coarse aggregate content of 72 percent of the volume of a cubic yard of concrete. The minimum dry weight of coarse aggregate per cubic yard (pcy) of concrete is then calculated using Equation 1.

$$W_{CA} = 0.72 \; x 27 \; x \; DRUW \qquad (1)$$

Where:

W_{CA} = Weight of Coarse Aggregate

DRUW = Dry Rodded Unit Weight

The average dry rodded unit weight (DRUW) of the No. 57 gravel used in this study was 103.4 pounds per cubic foot (pcf). Using this weight in Equation 1 gives a dry coarse aggregate weight of 2010 pounds. This coarse aggregate weight was used for all sixteen mixtures. The absolute volume of cement, water, coarse aggregate and entrapped air was then calculated and subtracted from a total of 27 cubic feet to determine the volume and weight of sand needed for proper yield.

COMBINED AGGREGATE GRADING

The gravel and sand portions of the combined aggregates were assembled from individually sieve size fractions. An example of individual size aggregate samples is shown in Figure 1. Aggregate sizes retained on the No. 4 sieve and larger were taken from the coarse aggregate sample using a bulk specific gravity (dry) of 2.473 to calculate absolute volume. Aggregate sizes passing the No. 4 sieve and retained on the No. 8 sieve and smaller were taken from the fine aggregate sample using a bulk specific gravity (dry) of 2.625 to calculate. While the pan-size fraction of the combined aggregate gradation was minimal, steps were taken to arrive at a blended specific gravity of 2.509 for this portion of the combined gradation. Weights of volumes of aggregate used in each mixture are presented in Table 9.

Figure 1: Individual Size Fractions of Aggregate

The combined percent retained gradation for all mixtures in this study was the same gradation used for Mix 1 of State Study 231. The combined percent retained chart is presented in Figure 2. This combined aggregate grading when evaluated in terms of coarseness factor (CF) and workability factor (WF) is a fair representation of a typical mixture used for MDOT projects with a coarseness factor of 64.5 and workability factor of 33.1. The workability factor is adjusted to accommodate fine material introduced to the mixtures by the cementitious materials and the adjusted workability factors are provided on each mixture design worksheet presented in Appendix "A".

Our original combined gradation was based on 2,010 lbs of coarse aggregate and 1,118 pounds of sand for a total aggregate weight of 3,128 lbs/yd^3. In a traditional blending of these two aggregates for mixing, some individual sieve size fractions such as 3/8 inch and below would be a blend of the two aggregates and consequently carry a blended specific gravity. The parameters of our study supplied the functionality and the logic point to know the exact contribution of each material at each sieve increment. Consequently, the total aggregate weight represented by our combined gradation is heavier (3,134 lbs/yd^3) due to the higher bulk specific gravity of the sand, but represents the same volume of 19.85 ft^3.

Table 9: Aggregate Content - Absolute Volume and Weight

Contributing Sample	Sieve Size	% Retained	Specific Gravity	Volume (ft^3)	Dry 1 yd^3 wt. (lbs.)
Gravel	1.0 in	5.20	2.473	1.0323	159.2922
	3/4 in	11.43	2.473	2.2690	350.1365
	1/2 in	17.14	2.473	3.4025	525.0515
	3/8 in	9.37	2.473	1.8600	287.0322
	No 4	18.95	2.473	3.7618	580.4974
Sand	No 8	4.77	2.625	0.9469	155.1010
	No 16	3.15	2.625	0.6253	102.4252
	No 30	7.52	2.625	1.4928	244.5199
	No 50	17.29	2.625	3.4322	562.2006
	No 100	4.65	2.625	0.9231	151.1991
	Pan	0.52	2.509	0.1032	16.1611
	Total	NA	NA	19.85	3133.6167

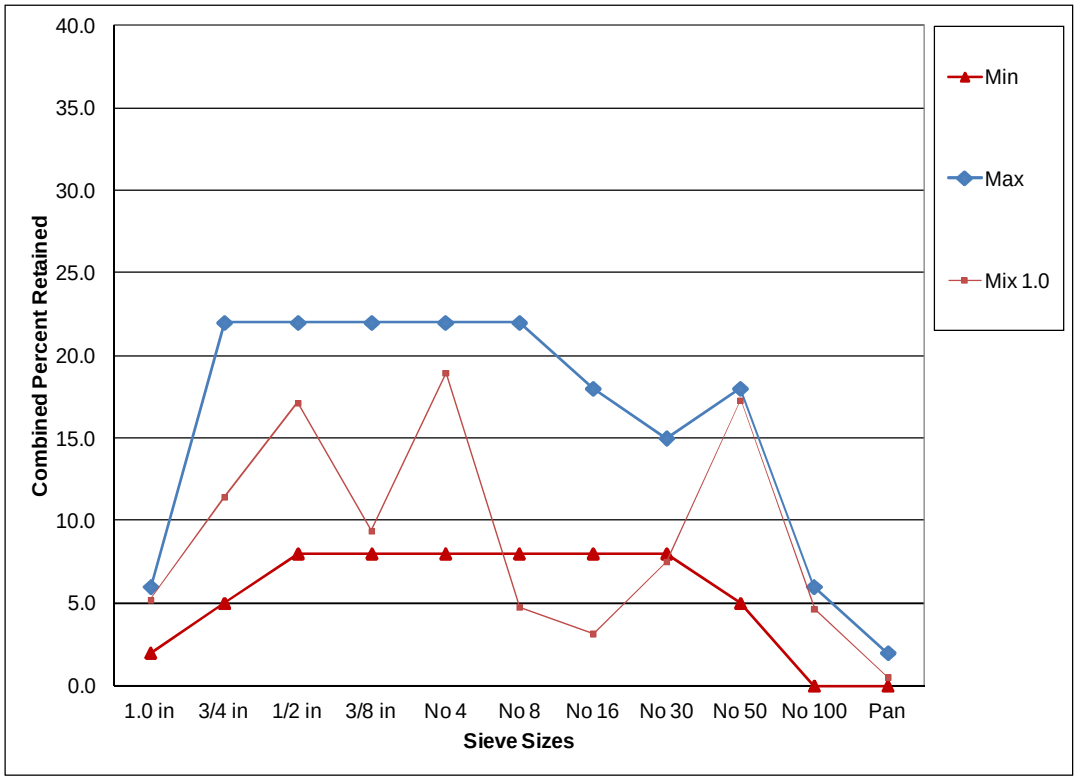


Figure 2: Combined Percent Retained Chart for All Experimental Mixtures

CONTROL MIXTURE

Utilizing the data, experience, and logic points supplied through trial batches and supporting mixture history, the study was able to take an approach to sixteen subject mixtures that would share a variety of design constants. Total water for all mixtures was 236.88 lbs/yd³, or 3.7962 ft³. Total aggregate volume for all mixtures was 19.8500 ft³. Total volume attributed to entrapped air was estimated at 2.5 percent or 0.6750 ft³. Total cementitious volume for all mixtures was also held at a constant absolute volume of 2.6781 ft³. These constants allowed other constants to be established across all sixteen mixtures. For example, all mixtures had a design cementitious paste absolute volume of 7.1500 ft³ or 26.48 percent of the volume of the mixture. The water volume of 3.7962 ft³ meant it was 53.09 percent of the volume of cementitious paste volume. Proportions for the control mixture (Mix 1) are presented in Table 10.

Table 10: Control Mixture Proportions

Material	Dry Weights (lbs/yd^3)	Absolute Volume (ft^3)
Portland Cement	526.40	2.68
Gravel	1902.01	12.33
Sand	1231.61	7.52
Water	236.88	3.80
Entrapped Air (2.5%)	0	0.68
Total	3896.90	27.00
w/cm	0.45	

MIXTURES WITH SUPPLEMENTARY CEMENTITIOUS MATERIALS

With total cementitious volume held constant across all mixtures (2.6781ft³) the process of adjusting the experimental mixtures with varying levels of SCMs becomes solving simultaneous equations. The total cementitious materials weight is determined and SCM replacement rates are then used to determine the weight of portland cement and the weight of SCM used in the experimental mixtures. Equations 1 through 3 were used to determine weights of portland cement and SCM used in mixtures 2 through 16. Replacement rates for SCMs were as follows; 15, 20, 25 percent for fly ash, and 40, 45, 50 percent for slag cement. Portland cement, fly ash, and slag cement weights are presented in Table 11.

$$\frac{(A * WCm)}{(3.15 * 62.4)} + \frac{(B * WCm)}{(SG * 62.4)} = 2.6781\ ft^3 \qquad (1)$$

$$WPC = A * WCm \qquad (2)$$

$$WSCm = B * WCm \quad (3)$$

Where:

A = percent portland cement converted to a decimal.

B = percent supplementary cementitious material converted to a decimal.

SG = specific gravity of supplementary cementitious material.

WCm = total weight of cementitious material in pounds.

WPC = weight of portland cement in pounds.

WCm = weight of supplementary cementitious materials in pounds.

Table 11: Cementitious Material Weights

SCM	SCM Source	Portland Cement / SCM Percentage	Specific Gravity	Cement Weight (lbs/yd^3)	SCM Weight (lbs/yd^3)	Total Cementitious (lbs)	Total Cementitious Volume (ft^3)
None	CS-1	100/0	3.15	526.40	0	526.40	2.6781
Class C Ash	C-1	85/15	2.63	434.55	76.69	511.24	
		80/20		405.10	101.28	506.38	
		75/25		376.20	125.40	501.61	
Class C Ash	C-2	85/15	2.59	433.38	76.48	509.86	
		80/20		403.66	100.92	504.58	
		75/25		374.55	124.85	499.41	
Class F Ash	F-1	85/15	2.42	428.07	75.54	503.61	
		80/20		397.16	99.29	496.45	
		75/25		367.11	122.37	489.49	
Class F Ash	F-2	85/15	2.41	427.74	75.48	503.22	
		80/20		396.76	99.19	495.94	
		75/25		366.65	122.22	488.87	
Slag Cement	S-1	60/40	2.89	304.87	203.25	508.11	
		55/45		278.26	227.66	505.92	
		50/50		251.87	251.87	503.74	

CHAPTER 4 – LABORATORY TESTING

AGGREGATE TESTING

Typical aggregate testing was conducted on the aggregate samples for use in the concrete mixtures. These tests include; (1) AASHTO T 85 / ASTM C 127 "Specific Gravity and Absorption of Coarse Aggregate", (2) AASHTO T 84 / ASTM C 128 "Specific Gravity and Absorption of Fine Aggregate" (3) AASHTO T 27 / ASTM C 136 "Sieve Analysis of Fine and Coarse Aggregates", and AASHTO T 19 / ASTM C 29 "Bulk Density ("Unit Weight") and Voids in Aggregate" for the coarse aggregate.

Unit Weight and Voids in Aggregates

Dry-rodded unit weight (DRUW) and voids in aggregate were determined according to AASHTO T 19 / ASTM C 29 "Bulk Density ("Unit Weight") and Voids in Aggregate" for the coarse aggregate. This DRUW was then used in accordance with MDOT's requirement for minimum coarse aggregate for concrete paving. Section 501 "Portland Cement Concrete Pavement" of the MDOT Specifications for Road and Bridge Construction requires a minimum coarse aggregate content of 72 percent of the volume of a cubic yard of concrete. The dry-rodded unit weight of 103.4 lbs/ft^3 meant a minimum dry coarse aggregate weight of 2010 pounds for all mixtures.

MIXING

Laboratory mixing was conducted in 2.25 cubic feet batch quantities using a revolving drum mixer in accordance with ASTM C 192 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory". Chapter 3 gives a detailed description of the laboratory mixture designs.

In accordance with ASTM C 192, the inside of the revolving-drum mixer received a thin layer of fresh concrete to prevent loss of mortar from the test batch. To add consistency to our process, a masonry brush was used to spread the fresh layer of concrete uniformly around the interior of the drum. The drum was inverted for a two minute time waiting period to allow any free water to make its exit from the drum before continuing. This mixer was then charged with the combined aggregates and approximately half the free mixing water. After minimal

revolutions of the drum to blend the aggregates and water, the mixer was stopped and covered to guard against moisture loss. A two minute rest period was introduced to our procedure to accommodate some degree of absorption by the oven-dry aggregates. After this two minute rest, the cementitious materials and remaining mix water were added to the mixer. A three minute mixing, three minute rest, two minute final mixing pattern was performed taking steps to guard against moisture loss during the rest period and segregation when discharging to a wheel barrow.

PLASTIC PROPERTIES

The fresh concrete was tested for density, yield, slump, air content, and temperature. Fresh properties were recorded for each mixture. All testing was performed using ACI certified technicians according to the following standards:

- **Density and Yield** – AASHTO T 121 / ASTM C 138 "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete" (Figure 3)
- **Slump** – AASHTO T 119 / ASTM C 143 "Standard Test Method for Slump of Hydraulic-Cement Concrete" (Figure 4)
- **Air Content** – AASHTO T 196 / ASTM C 173 "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method" (Figure 5)
- **Making and Curing Cylinder and Prisms** – AASHTO R 39 / ASTM C 192 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory." (Figure 6)
- **Temperature** – ASTM C 1064 " Standard Test Method For Temperature of Freshly Mixed Hydraulic-Cement Concrete"

Figure 3: Unit Weight Testing

Figure 4: Slump Testing

Figure 5: Air Content Testing

Figure 6: Making and Curing Cylinders and Prisms

HARDENED PROPERTIES

Compressive Strength

Compressive strength specimens were cast immediately following testing of plastic properties. ACI certified technicians made the 4 in. x 8 in. specimens and used external vibration (vibrating table) as the method of consolidation. Upon completion of consolidation and strike-off finishing of the top surfaces, strength specimens were moved to a temperature controlled moisture room for curing until testing. Specimens were tested by ACI certified strength technicians in accordance with AASHTO T 22 / ASTM C 39 "Standard Test method for Compressive Strength of Cylindrical Concrete Specimens." Eleven specimens were tested for each mixture as follows: 2 at 1-day, 2 at 7-days, 2 at 14-days, 3 at 28-days, and 2 at 56-days.

Length Change of Hardened Concrete

Length change was measured for each mixture according to AASHTO T 160 / ASTM C 157 "Length Change of Hardened Hydraulic-Cement Mortar and Concrete" and AASHTO M 210 / ASTM C 490 "Standard Practice for use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete." Specimens were cast according to AASHTO R 39 / ASTM C 192 utilizing prisms of 4 in. square cross sections and approximately 11 ¼ in. long. Twelve specimens were cast for each mixture and consolidated by external vibration. Results shown in this report represent the average of the three specimens unless noted. Each set of three specimens were cured with one of the four curing methods which included; liquid membrane, 7-day soak, 14-day soak, and 28-day soak.

Sample Preparation

Specimens were cast and consolidated utilizing external vibration. Specimens were immediately placed in a moist curing room for a 24 hour initial curing period. Specimens were de-molded at an age of 23.5 ± 0.5 hours and labeled with identifying information. Specimens were then placed into a lime-saturated water curing bath maintained at 73 ± 1 degree Fahrenheit for 30 minutes before further processing (Figure 7).

Initial Testing

Specimens were removed from the lime-saturated curing bath and towel dried, leaving only a small amount of free water. Specimens were then placed in a comparator measuring to the nearest 0.0001 in. where initial measurements were taken and compared to a standard

reference bar (Figure 8). Specimens were removed from the comparator and returned to the lime-saturated curing bath where they cured for the remainder of their assigned 7, 14 or 28-day curing period. One set received an application of liquid membrane and immediately began its drying cycle (Figure 9). The liquid membrane was applied with a brush and the weight of each specimen was recorded in order to ensure a minimum application rate of 200 ft^2 per gallon. At the conclusion of the initial curing period all specimens received a second comparator reading (Figure 10) and began the drying portion of the test.

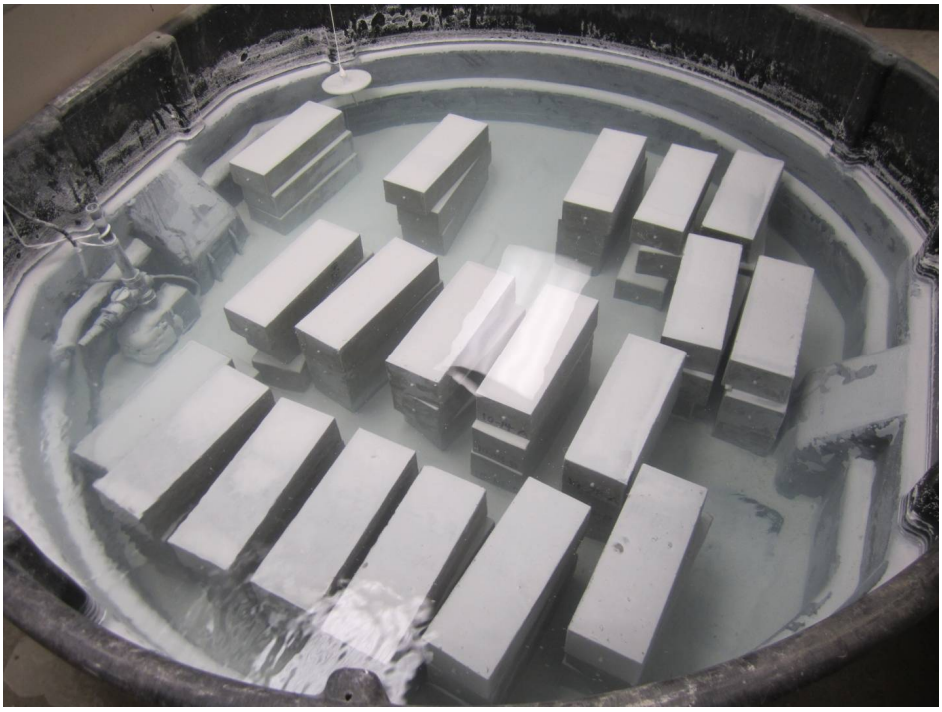


Figure 7: Curing Bath

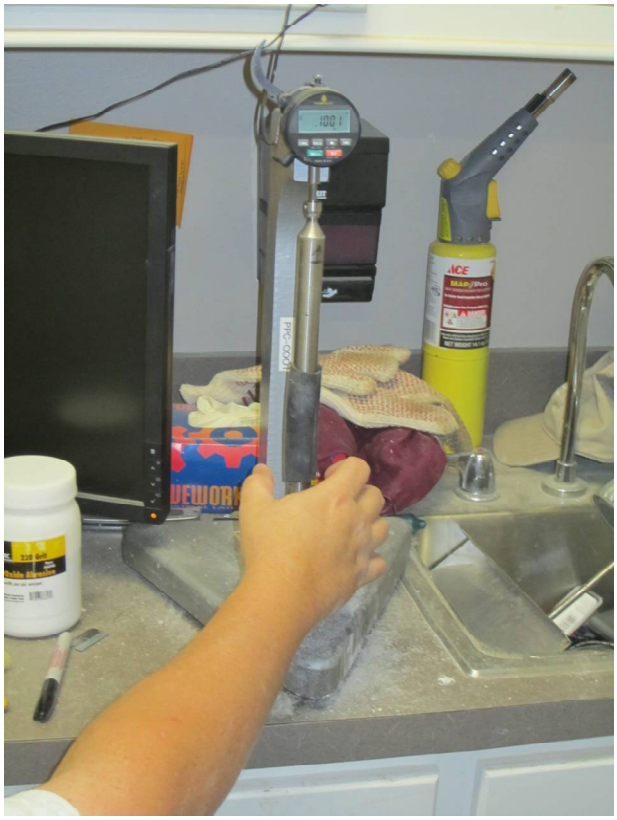


Figure 8: Comparator Reading of Standard Bar

Figure 9: Liquid membrane Application

Figure 10: Comparator Reading of Specimen

Specimen Dry Storage and Testing

Specimens were stored after the second reading in a temperature and humidity controlled environment of 50% ± 4% relative humidity and 73 ± 3 º F (Figure 11). Specimens were stacked on shelves with a clearance of at least 1 inch on all sides. Comparator readings were taken at 1 day after casting, at the conclusion of the curing period, and at drying days 0, 3, 7, 14, 28, 56, 112, 224, and 448. Tables and figures in this report will indicate length change based on days spent in the temperature and humidity controlled (shrinkage) room.

Figure 11: Temperature and Humidity Controlled Room

Calculations

Length change results were calculated and reported as a positive number if expansion occurred and a negative number (-) if shrinkage occurred. These data are reported to the nearest 0.0001% herein. AASHTO M 210 / ASTM C 490 "Standard Practice for use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete" states that the percent shrinkage or expansion of individual specimens is to be calculated to the nearest 0.001% and the average of the three specimens is to be reported to the nearest 0.01%. All shrinkage and expansion percentages herein are calculated and reported to the nearest 0.0001% in an effort to capture slight changes in length change. The equation for calculating length change of specimens at any age as a percent of the standard reference bar length (10 in.) is as follows:

$$L = \frac{L_x - L_i}{G} * 100 \qquad (4)$$

Where:

L = change in length at X age, %

L_X = comparator reading of specimen at X age minus comparator reading of reference bar at X age; in inches[2]

L_i = initial comparator reading of specimen minus comparator readings of reference bar at that same time; in inches

G = nominal gauge length; 10 inches. This nominal gage length is the length between inside ends of gauge studs cast into the prism specimens and is 10 ± 0.1 in.

> **Note 2:** In this study, the initial comparator reading (L_i) is the comparator reading minus the reference bar at the end of the curing. There were four curing methods used for each experimental mixture and these include; the use of liquid membrane, or moist curing for 7, 14, or 28 days in a lime treated water bath.

CHAPTER 5 - RESULTS

PLASTIC PROPERTIES

Plastic properties of each concrete mixture are presented in Table 12. The slump ranged from 2 ¾ in. (Mix 1) to 8 ½ in. (Mix 10). Entrapped air ranged from 1.25 percent (Mix 13) to 3.00 percent (Mix 14, 15, 16). Temperature ranged from 64.4 ° F (Mix 15) to 78.7 ° F (Mix 1). Unit weight ranged from 144.40 pcf (Mix 16) to 147.08 pcf (Mix 4).

Table 12: Plastic Properties

Mix No.	Cementitious Materials	Slump (in.)	Air (%)	Temp (°F)	Unit Wt (lbs/ft^3)
1	100% CS-1	2.75	2.00	78.7	146.16
2	15% C-1	4.25	2.00	71.0	146.80
3	20% C-1	6.50	1.50	69.6	147.00
4	25% C-1	6.00	1.25	75.7	147.08
5	15% C-2	6.25	2.00	75.0	146.04
6	20% C-2	7.25	2.00	74.5	146.88
7	25% C-2	8.25	2.00	71.7	146.80
8	15% F-1	6.00	1.50	77.1	146.04
9	20% F-1	6.50	2.00	77.5	145.40
10	25% F-1	8.50	1.25	71.4	145.80
11	15% F-2	7.50	2.00	70.9	146.20
12	20% F-2	6.00	1.75	69.6	146.20
13	25% F-2	8.50	1.25	79.1	146.00
14	40% S-1	3.50	3.00	74.8	145.20
15	45% S-1	5.75	3.00	64.4	145.40
16	50% S-1	3.00	3.00	71.5	144.40

COMPRESSIVE STRENGTH

Results from testing eleven compressive strength specimens per mixture are presented in this section. These specimens were tested as follows; 2 at 1 day, 2 at 7 days, 2 at 14 days, 3 at 28 days, and 2 at 56 days. Results shown in this report are calculated as the average of specimens tested for each age. Compressive strength results of each specimen were rounded to the nearest 10 pounds per square inch (psi). These individual tests at each test age were averaged and rounded to the nearest 1 psi for reporting. Each mixture has an average compressive strength that exceeds MDOT's specified 28 day strength requirement of 4,000 psi for bridge deck

concrete except for the mixtures with Class F fly ash used at 20 and 25 percent replacement rates.

Average 28 day compressive strengths ranged from 3,807 psi (Mix 10) to 5,213 psi (Mix 1). Table 13 presents the average compressive strengths and rankings for Mixes 1 through 16. A ranking of 1 indicates the highest compressive strength and a ranking of 16 indicates the lowest compressive strength.

PERCENT LENGTH CHANGE

Testing was performed on all mixtures to determine unrestrained length change. The ages given in the tables and figures are not from time of casting, but for the time specimens spent in the controlled room (shrinkage room) at a temperature of 73º ± 3º F and 50 ± 4 percent humidity. Data indicate that ultimate shrinkage occurred at 448 days of storage in the temperature and humidity controlled room. Ultimate shrinkage ranged from a low of (-) 0.0247 percent (Mix 15) for specimens soaked for 28 days to a high of (-) 0.0420 percent (Mix 13) for specimens soaked for 7 days. The average percent length change and rankings for Mixes 1 through 16 are shown in Table 14. These averages are calculated and reported to the nearest 0.0001 percent. Table 15 presents these same data except rounded to the nearest 0.01 percent as described in AASHTO M 210 / ASTM C 490. When calculating to the nearest 0.01 percent, shrinkage values determined in this study ranged from a low of (-) 0.02 percent to a high of (-) 0.04 percent. A ranking of 1 represents the lowest average ultimate shrinkage and a ranking of 16 represents the highest 448 day ultimate shrinkage.

PERCENT WEIGHT LOSS

The combined weight of each set of prism specimens was determined during the initial comparator reading. These specimens were additionally weighted each time comparator readings were taken. Comparator readings were made after the specimens had been stored in the humidity and temperature controlled room for 0, 4, 7, 14, 28, 56, 112, 224, and 448 days. The percent change in weight of these specimens was calculated to determine the percent weight loss due to drying. A summary of percent weight loss results is presented in Table 16.

A summary of mixture parameters, plastic properties, and test results is presented in Table 17.

Table 13: Average Compressive Strength

Mix No.	Cementitious Materials	1 Day		28 Day		56 Day	
		Avg. (psi)	Rank	Avg. (psi)	Rank	Avg. (psi)	Rank
1	100% CS-1	2250	1	5213	1	5635	2
2	15% C-1	1590	2	4773	4	5020	11
3	20% C-1	1440	6	4787	3	5270	6
4	25% C-1	1375	9	5020	2	5050	9
5	15% C-2	1540	3	4363	11	4945	13
6	20% C-2	1460	5	4690	6	4605	15
7	25% C-2	1235	12	4490	10	4820	14
8	15% F-1	1415	7	4527	9	5140	7
9	20% F-1	1270	10	3990	13	5360	4
10	25% F-1	1130	13	3807	16	4495	16
11	15% F-2	1525	4	4567	8	5075	8
12	20% F-2	1410	8	3990	13	5050	9
13	25% F-2	1270	10	3850	15	5010	12
14	40% S-1	890	14	4630	7	5600	3
15	45% S-1	885	15	4710	5	5915	1
16	50% S-1	590	16	4117	12	5290	5

Table 14: Average Length Change at 448 Days of Drying (0.0001%)

Mix No.	Cementitious Materials	Liquid membrane		7-Day Soak		14-Day Soak		28-Day Soak	
		Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank
1	100% CS-1	-0.0370	11	-0.0330	7	-0.0337	9	-0.0360	12
2	15% C-1	-0.0310	4	-0.0327	6	-0.0327	7	-0.0343	9
3	20% C-1	-0.0363	10	-0.0360	12	-0.0327	8	-0.0353	11
4	25% C-1	-0.0300	1	-0.0363	13	-0.0323	5	-0.0393	16
5	15% C-2	-0.0360	9	-0.0303	3	-0.0357	16	-0.0390	15
6	20% C-2	-0.0317	6	-0.0350	10	-0.0337	9	-0.0377	13
7	25% C-2	-0.0340	7	-0.0353	11	-0.0357	15	-0.0380	14
8	15% F-1	-0.0380	13	-0.0350	9	-0.0323	6	-0.0310	4
9	20% F-1	-0.0373	12	-0.0320	5	-0.0337	11	-0.0325	5
10	25% F-1	-0.0350	8	-0.0347	8	-0.0310	4	-0.0350	10
11	15% F-2	-0.0410	15	-0.0390	14	-0.0337	11	-0.0340	7
12	20% F-2	-0.0410	15	-0.0397	15	-0.0343	13	-0.0330	6
13	25% F-2	-0.0395	14	-0.0420	16	-0.0343	14	-0.0340	8
14	40% S-1	-0.0300	2	-0.0303	4	-0.0237	1	-0.0250	2
15	45% S-1	-0.0300	2	-0.0287	2	-0.0265	2	-0.0247	1
16	50% S-1	-0.0310	5	-0.0277	1	-0.0297	3	-0.0280	3

Table 15: Average Length Change at 448 Days of Drying (0.01%)

Mix No.	Cementitious Materials	Liquid membrane		7-Day Soak		14-Day Soak		28-Day Soak	
		Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank
1	100% CS-1	-0.04	11	-0.03	7	-0.03	9	-0.04	12
2	15% C-1	-0.03	4	-0.03	6	-0.03	7	-0.03	9
3	20% C-1	-0.04	10	-0.04	12	-0.03	8	-0.04	11
4	25% C-1	-0.03	1	-0.04	13	-0.03	5	-0.04	16
5	15% C-2	-0.04	9	-0.03	3	-0.04	16	-0.04	15
6	20% C-2	-0.03	6	-0.03	10	-0.03	9	-0.04	13
7	25% C-2	-0.03	7	-0.04	11	-0.04	15	-0.04	14
8	15% F-1	-0.04	13	-0.03	9	-0.03	6	-0.03	4
9	20% F-1	-0.04	12	-0.03	5	-0.03	11	-0.03	5
10	25% F-1	-0.04	8	-0.03	8	-0.03	4	-0.03	10
11	15% F-2	-0.04	15	-0.04	14	-0.03	11	-0.03	7
12	20% F-2	-0.04	15	-0.04	15	-0.03	13	-0.03	6
13	25% F-2	-0.04	14	-0.04	16	-0.03	14	-0.03	8
14	40% S-1	-0.03	2	-0.03	4	-0.02	1	-0.03	2
15	45% S-1	-0.03	2	-0.03	2	-0.03	2	-0.02	1
16	50% S-1	-0.03	5	-0.03	1	-0.03	3	-0.03	3

Table 16: Average Weight Change at 448 Days of Drying (Percent)

Mix No.	Cementitious Materials	w/cm ratio	Liquid membrane		7-Day Soak		14-Day Soak		28-Day Soak	
			Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank
1	100% CS-1	0.450	-2.56	1	-2.21	3	-2.17	4	-2.13	4
2	15% C-1	0.463	-2.73	2	-2.57	6	-2.29	5	-2.31	5
3	20% C-1	0.468	-2.87	3	-2.76	8	-2.56	6	-2.39	6
4	25% C-1	0.472	-3.09	7	-2.98	12	-2.78	12	-2.70	12
5	15% C-2	0.465	-2.93	4	-2.56	5	-2.57	7	-2.53	7
6	20% C-2	0.469	-3.03	5	-2.75	7	-2.61	8	-2.58	9
7	25% C-2	0.474	-3.23	11	-2.90	10	-2.75	11	-2.65	11
8	15% F-1	0.470	-3.07	6	-2.88	9	-2.74	10	-2.54	8
9	20% F-1	0.477	-3.26	13	-3.09	14	-3.02	14	-2.85	14
10	25% F-1	0.484	-3.42	15	-3.31	15	-3.02	15	-2.91	15
11	15% F-2	0.471	-3.26	12	-2.98	11	-2.68	9	-2.62	10
12	20% F-2	0.478	-3.31	14	-3.09	13	-2.98	13	-2.79	13
13	25% F-2	0.484	-3.57	16	-3.32	16	-3.13	16	-3.04	16
14	40% S-1	0.466	-3.15	9	-2.30	4	-2.03	3	-1.82	3
15	45% S-1	0.468	-3.13	8	-2.17	2	-1.89	2	-1.70	1
16	50% S-1	0.470	-3.18	10	-2.17	1	-1.88	1	-1.75	2

Table 17: Mixture Parameters, Plastic Properties, Test Results

Mix Number	Cementitious Materials	Paste Properties					Test Results						
		w/cm ratio	Cement (lbs)	SCM (lbs)	Total Cementitious (lbs)	Water (lbs)	Slump (in.)	Air (%)	Temperate (º F)	Unit Weight (pcf)	28 Day (psi)	448 Day Shrinkage 28-Day Soak (%)	448 Day Weight Loss 28-Day Soak (%)
1	100% CS-1	0.450	526.40	0.00	526.40	236.88	2.75	2.00	78.7	146.16	5213	-0.0360	-2.13
2	15% C-1	0.463	434.55	76.69	511.24	236.88	4.25	2.00	71.0	146.80	4773	-0.0343	-2.31
3	20% C-1	0.468	405.10	101.28	506.38	236.88	6.50	1.50	69.6	147.00	4787	-0.0353	-2.39
4	25% C-1	0.472	376.20	125.40	501.60	236.88	6.00	1.25	75.7	147.08	5020	-0.0393	-2.70
5	15% C-2	0.465	433.38	76.48	509.86	236.88	6.25	2.00	75.0	146.04	4363	-0.0390	-2.53
6	20% C-2	0.469	403.66	100.92	504.58	236.88	7.25	2.00	74.5	146.88	4690	-0.0377	-2.58
7	25% C-2	0.474	374.55	124.85	499.40	236.88	8.25	2.00	71.7	146.80	4490	-0.0380	-2.65
8	15% F-1	0.470	428.07	75.54	503.65	236.88	6.00	1.50	77.1	146.04	4527	-0.0310	-2.54
9	20% F-1	0.477	397.16	99.29	496.45	236.88	6.50	2.00	77.5	145.40	3990	-0.0325	-2.85
10	25% F-1	0.484	367.11	122.37	489.48	236.88	8.50	1.25	71.4	145.80	3807	-0.0350	-2.91
11	15% F-2	0.471	427.74	75.48	503.22	236.88	7.50	2.00	70.9	146.20	4567	-0.0340	-2.62
12	20% F-2	0.478	396.76	99.19	495.95	236.88	6.00	1.75	69.6	146.20	3990	-0.0330	-2.79
13	25% F-2	0.485	366.65	122.22	488.87	236.88	8.50	1.25	79.1	146.00	3850	-0.0340	-3.04
14	40% S-1	0.466	304.87	203.25	508.12	236.88	3.50	3.00	74.8	145.20	4630	-0.0250	-1.82
15	45% S-1	0.468	278.26	227.66	505.92	236.88	5.75	3.00	64.4	145.40	4710	-0.0247	-1.70
16	50% S-1	0.470	251.87	251.87	503.45	236.88	3.00	3.00	71.5	144.40	4117	-0.0280	-1.75

CHAPTER 6 – DISCUSSION OF RESULTS

FRESH PROPERTIES

Slump

The slump of the control mix (Mix 1) was 2 ¾ in. This mixture was proportioned with 100 percent portland cement. All other mixtures that used either fly ash or slag cement as a replacement for portland cement had an increase in slump relative to the control mixture. The slump of each mixture using supplementary cementitious materials is presented in Figure 12. Mixtures that used either Class C or Class F fly ash experienced that greatest change in slump. The slump was increase from 2 3/4 in. for the control mixture to between 4 ½ and 8 ½ in. with mixtures that used either 25 percent Class C or 25 percent Class F fly ash. There were also notable changes in slump between the two sources of Class C fly ash. On average, changing from Class C fly ash source 1 (C-1) to Class C fly ash source 2 (C-2) produced an increase slump of approximately 1 ½ in.

In general, the slump increased as the replacement rate of Class C and Class F increased from 15 percent to 25 percent. This did not occur in all cases, but this was the general trend. The most notable mix that did not follow this trend was Mix 12 proportioned with Class F fly ash source 2 (F-2) at a 20 percent replacement rate and this slump is considered an outlier. The mixtures proportioned with slag cement (Mixes 14, 15, and 16) also had a slight increase in slump over the control mixture. In the cases of 40 percent (Mix 14) and 50 percent (Mix 16) replacement rates this increase was ¼ in. and ¾ in., respectively. This indicates that slag cement does not have significant influence on slump when compared to a similar mixture made with 100 percent portland cement. The 45 percent slag cement mixture (Mix 15) was dissimilar to the other mixtures with slag cement because this mixture had a slump of 5 ¾ in. This slump is considered a possible outlier.

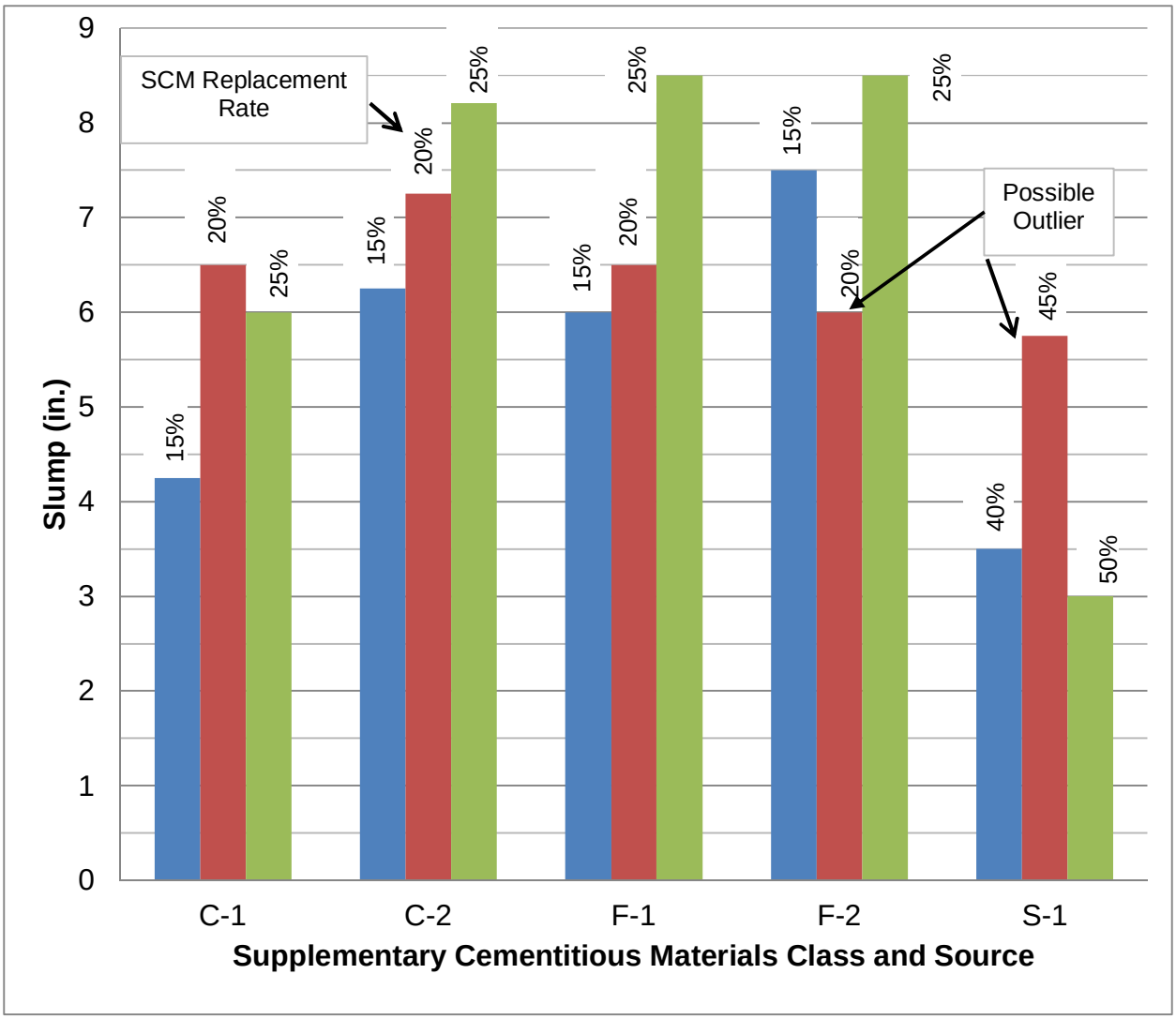


Figure 12: Slump vs Supplementary Cementitious Material

HARDENED PROPERTIES

Compressive Strength

Compressive strength of concrete is influenced by all aspects of the concrete mixture. Some of the most common aspects of concrete that influence compressive strength are water cementitious ratio; type, amount and source of cementitious material; and type of aggregate. In this study, the absolute volume of cementitious paste and aggregate remained constant for all mixtures. The weight of cementitious materials changed as well as the replacement rate of portland cement with supplementary cementitious materials. Therefore, the compressive

strength data of this study is useful in determining the influence of replacement rate and source of supplementary cementitious materials on compressive strength.

Adjusting Average Compressive Strength for Outliers

All sets of companion cylinders were evaluated to determine if the range of compressive strength for companion cylinders for each set was acceptable. AASHTO T 22 / ASTM is the standard providing acceptable ranges for companion cylinders including 9.0 percent for 2 cylinder sets and 10.6 percent for 3 cylinder sets. There were nineteen out of eighty (23.8 percent) sets of companion cylinders in this study that exceeded the acceptable range. One test result was removed from five of these nineteen sets based on our engineering judgment after evaluating these data and reviewing all compressive strength data. A summary of these outliers removed from the data presented in this report is presented in Table 18. All other individual test results are included in average values presented herein.

Table 18: Compressive Strength Outliers

Mix No.	Age (Days)	Compressive Strength (psi)
3.0	56	4670
4.0	56	4240
6.0	7	3750
8.0	7	3310
9.0	7	3600

All Mixes

The average 28-day compressive strengths ranged from 3,807 psi (Mix 10) to 5,213 psi (Mix 1). Mix 10 used 25 percent Class F fly ash (F-1) and had the highest w/cm ratio (0.484). Mix 1 had the lowest w/cm ratio (0.450) along with the highest strength. The general trend for compressive strength in this study was that using supplementary cementitious materials to replace portland cement produced lower compressive strengths at a given age. The exception to this trend was the 56-day compressive strength for Mix 15 that was proportioned with 45 percent slag cement. The compressive strength of this mix was 5,915 psi exceeding the strength of the control mix by 5 percent. However, w/cm ratio increased with respect to the control mix with the use of SCMs and this is one reason for the lower compressive strengths for mixtures

proportioned with SCMs. See w/cm ratio discussion in this chapter. A graph of compressive strength versus age is presented in Figure 13 for all mixtures.

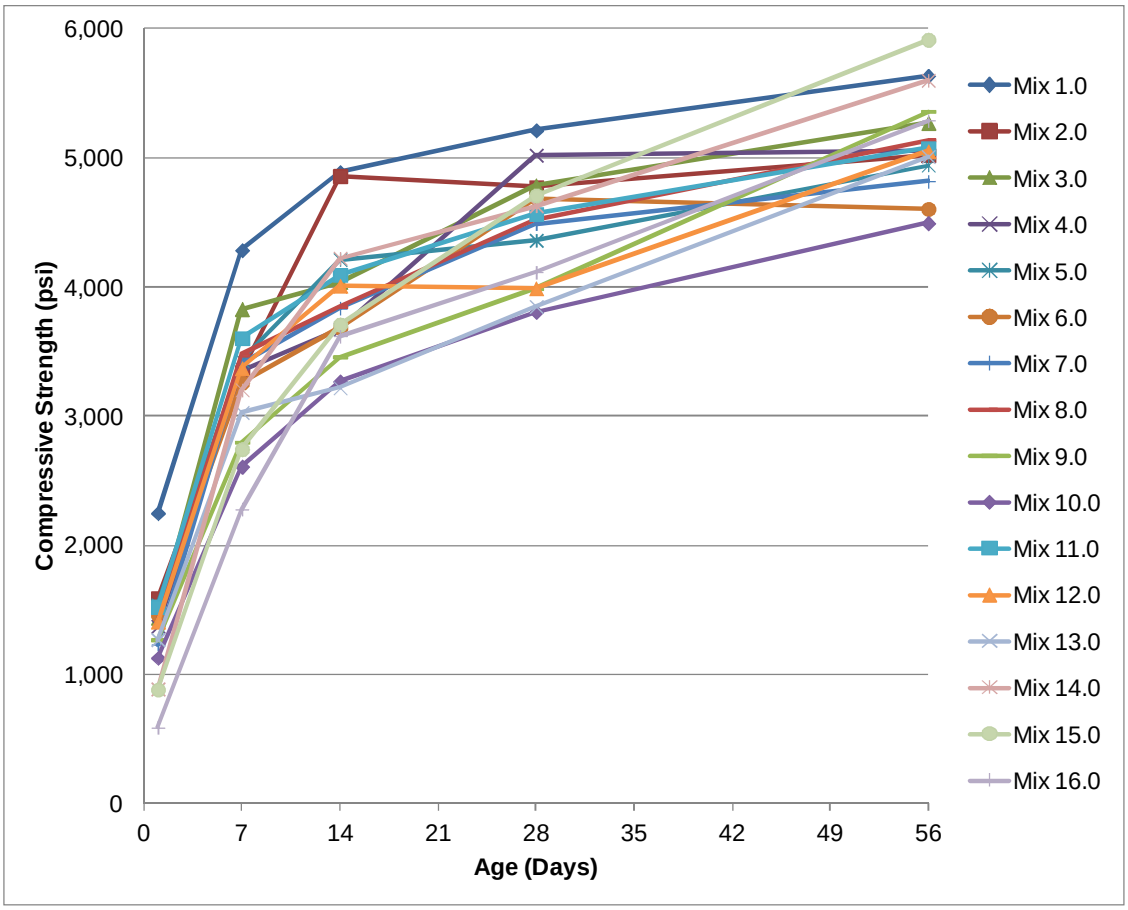


Figure 13: Compressive Strength vs Age - All Mixes

Compressive Strength of Mixes with Class C Fly Ash

Two sources of Class C fly ash were used in proportioning mixes 2 through 7. Source 1 was used in mixes 2, 3, and 4 and source 2 was used in mixes 5, 6, and 7. Compressive strength versus age graphs for source 1 and source 2 are presented in Figures 14 and 15, respectfully. The 28-day compressive strengths ranged from 4,363 psi (Mix 5) to 5,020 psi (Mix 4). The 56-day compressive strengths ranged from 4,605 psi (Mix 6) to 5,270 psi (Mix 3). Compressive strengths from mixes made with Class C fly ash from source 1 (C-1) were higher than compressive strengths made with Class C fly ash source 2 (C-2). This percent increase in compressive strength ranged from 2 percent to 12 percent for 28-day results and 2 to 14 percent

for 56-day results. The lower compressive strengths associated with Class C fly ash source 2 may have been due to fact that mixes that used Class C fly ash from source 2 had higher w/cm ratios than mixes proportioned with Class C fly ash from source 1. This increase in w/cm ratio ranged from 0.0013 to 0.0021 and w/cm ratio increased as the replacement rate increased. All ages of compressive strengths from mixes containing Class C fly ash were less than compressive strengths achieved with the control mix (Mix 1). The average 28-day compressive strength of all mixes proportioned with Class C fly ash from source 1 was 93.2 percent of the control mix and the 56 day compressive strength results was 90.7 percent of the control mix. The average 28-day compressive strength of all mixes proportioned with Class C fly ash from source 2 was 86.6 percent of the control mix and the 56-day compressive strength was 85.0 percent of the control mix. There were no apparent tends established between compressive strength versus age with respect to replacement rate of portland cement with Class C fly ash.

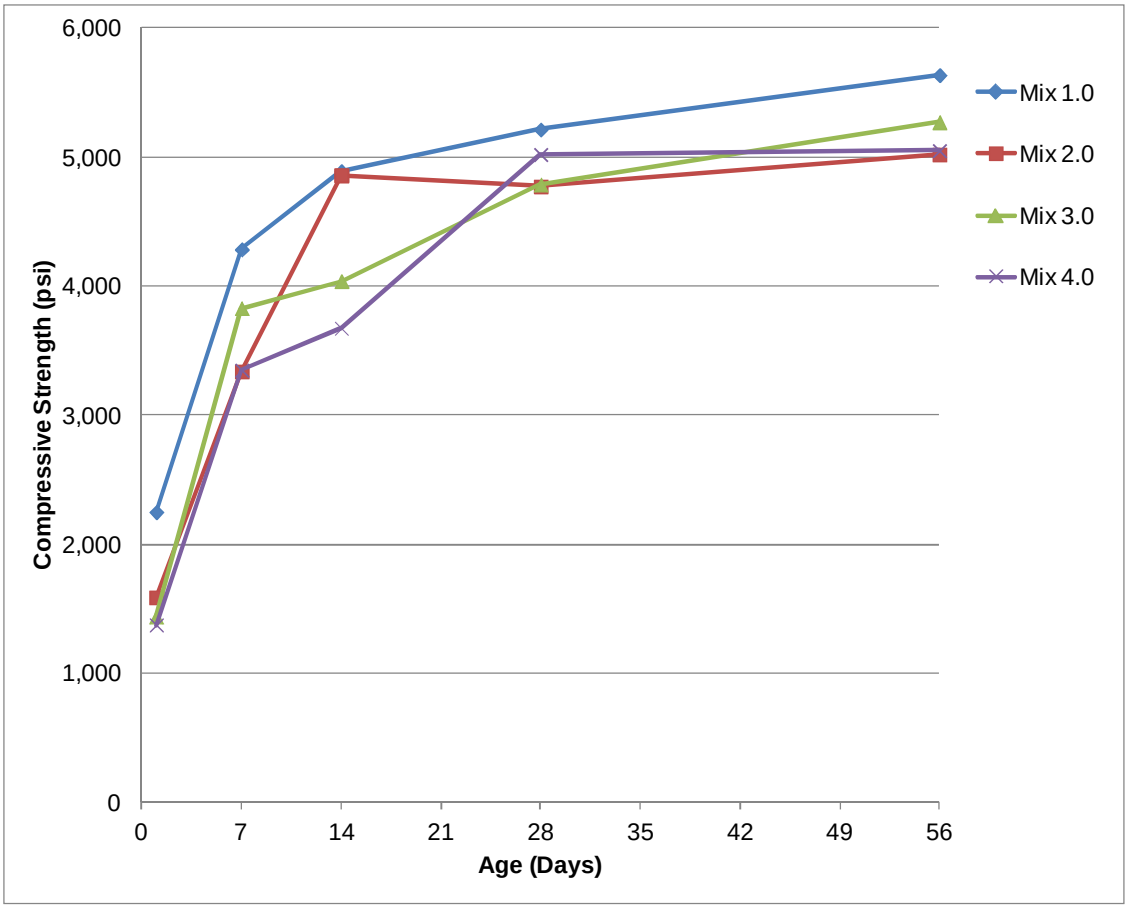


Figure 14: Compressive Strength vs Age Class C Fly Ash - Source 1 (C-1)

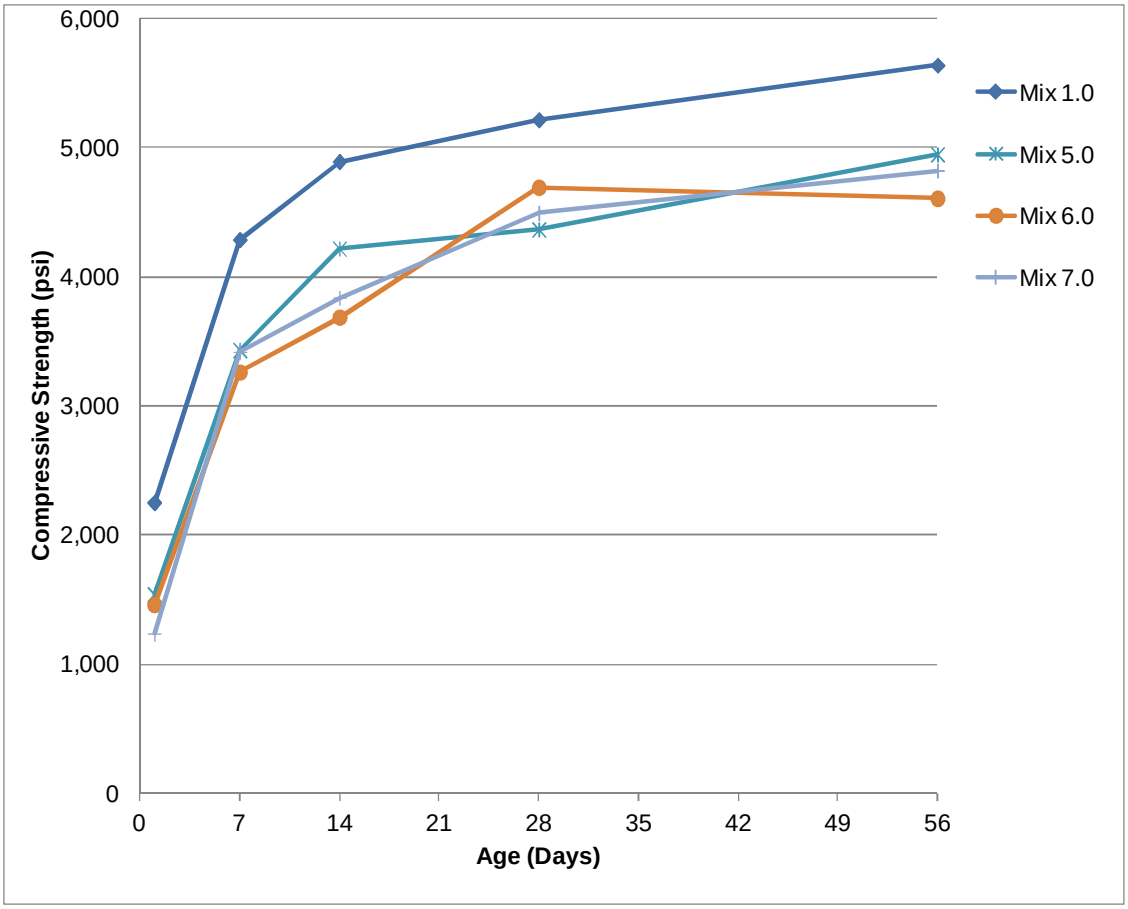


Figure 15: Compressive Strength vs Age Class C Fly Ash - Source 2 (C-2)

Compressive Strength of Mixes with Class F Fly Ash

Two sources of Class F fly ash were used in proportioning mixes 8 through 13. Class F fly ash from Source 1 (F-1) was used in mixes 8, 9, and 10 and source 2 (F-2) was used in mixes 11, 12, and 13. Compressive strength versus age graphs for source 1 and source 2 are presented in Figures 16 and 17, respectfully. The 28-day compressive strengths ranged from 3,807 psi (Mix 10) to 4,567 psi (Mix 11). The 56-day compressive strengths ranged from 4,495 psi (Mix 10) to 5,360 psi (Mix 9). All ages of compressive strengths from mixes containing Class F fly ash were less than compressive strengths achieved with the control mix (Mix 1). The average 28-day compressive strength of all mixes proportioned with Class F fly ash from source 1 was 78.8 percent of the control mix and the 56 day compressive strength result was 88.7 percent of the control mix. The average 28-day compressive strength of all mixes proportioned with Class

F fly ash from source 2 (F-2) was 79.3 percent of the control mix and the 56-day compressive strength was 89.5 percent of the control mix. The trend between compressive strength versus age with Class F fly ash with respect to replacement rate of portland cement was that compressive strength decreased as replacement rate increased. This trend was typical except for 56-day compressive strength results for Mix 9 where the strength using Class F fly ash from source 1 (F-1) to replace 20 percent of the portland cement produced higher strengths than the 15 percent replacement rate. Another interesting observation was that the 56-day compressive strength results for Class F fly ash from source 2 (F-2) was approximate the same value regardless of replacement rate.

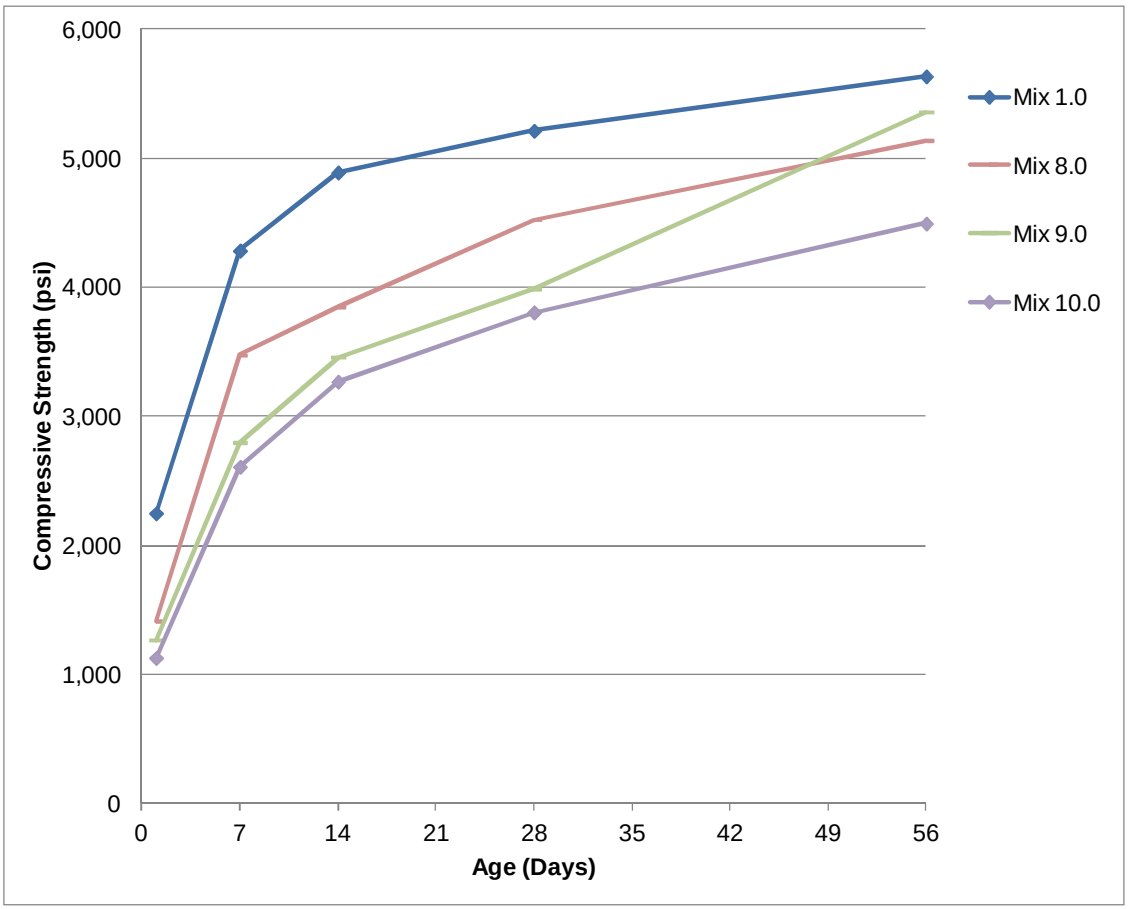


Figure 16: Compressive Strength vs Age Class F Fly Ash - Source 1

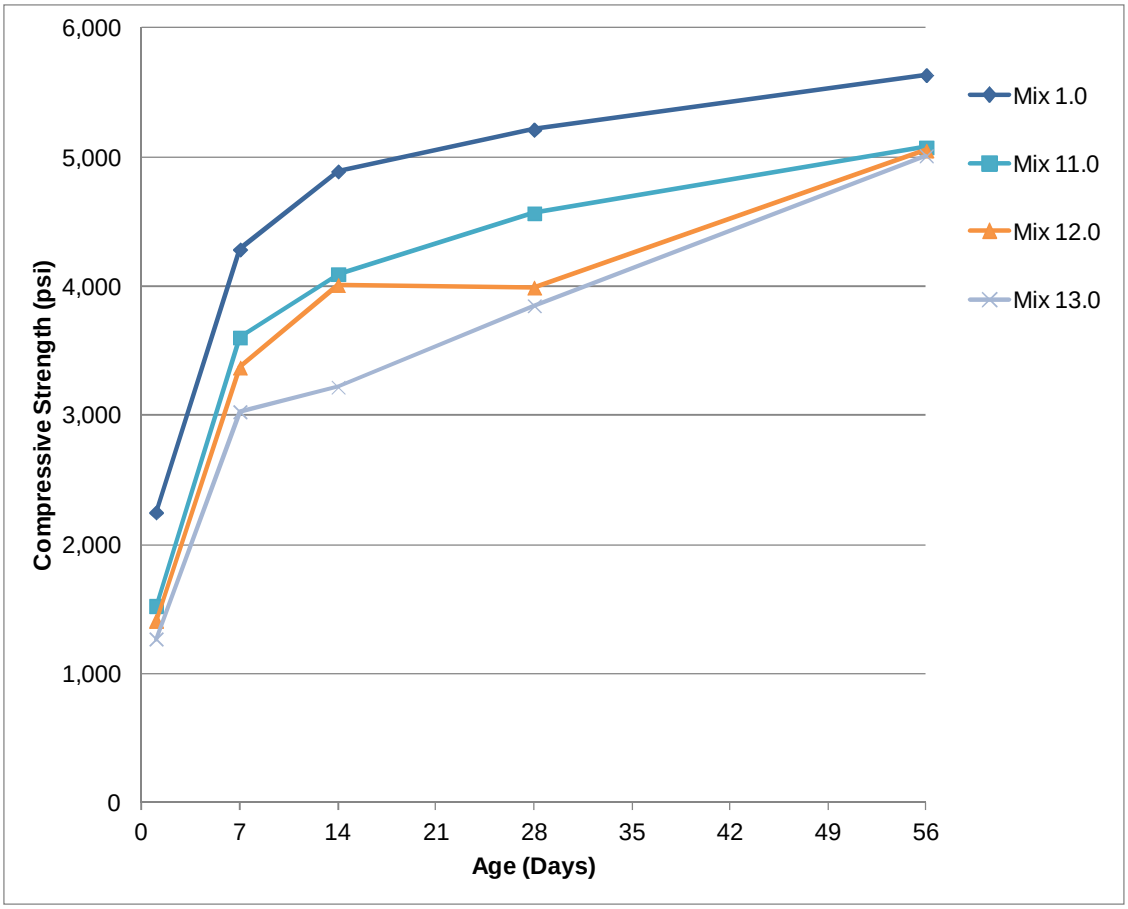


Figure 17: Compressive Strength vs Age Class F Fly Ash - Source 2

Compressive Strength of Mixes with Slag Cement

Only one source of slag cement was used in this study. This source was used to proportion mixes 14 through 16. Compressive strengths versus age graphs are presented in Figure 18. The 28-day compressive strengths ranged from 4,117 psi (Mix 16) to 4,710 psi (Mix 15). The 56-day compressive strengths ranged from 5,290 psi (Mix 16) to 5,915 psi (Mix 15). All ages of compressive strengths from mixes containing slag cement were less than compressive strengths achieved with the control mix (Mix 1) except for Mix 15. Mix 15 used a replacement rate of 45 percent and achieved a 56-day compressive strength of 5,915 psi which was 5 percent higher than the control mix (Mix 1). This higher compressive strength was achieved with slag cement although the w/cm ratio was 0.0182 higher than the control mix. The average 28-day compressive strength of all mixes proportioned with slag cement was 86.0 percent of the control mix and the 56-day compressive strength result was 99.4 percent of the control mix.

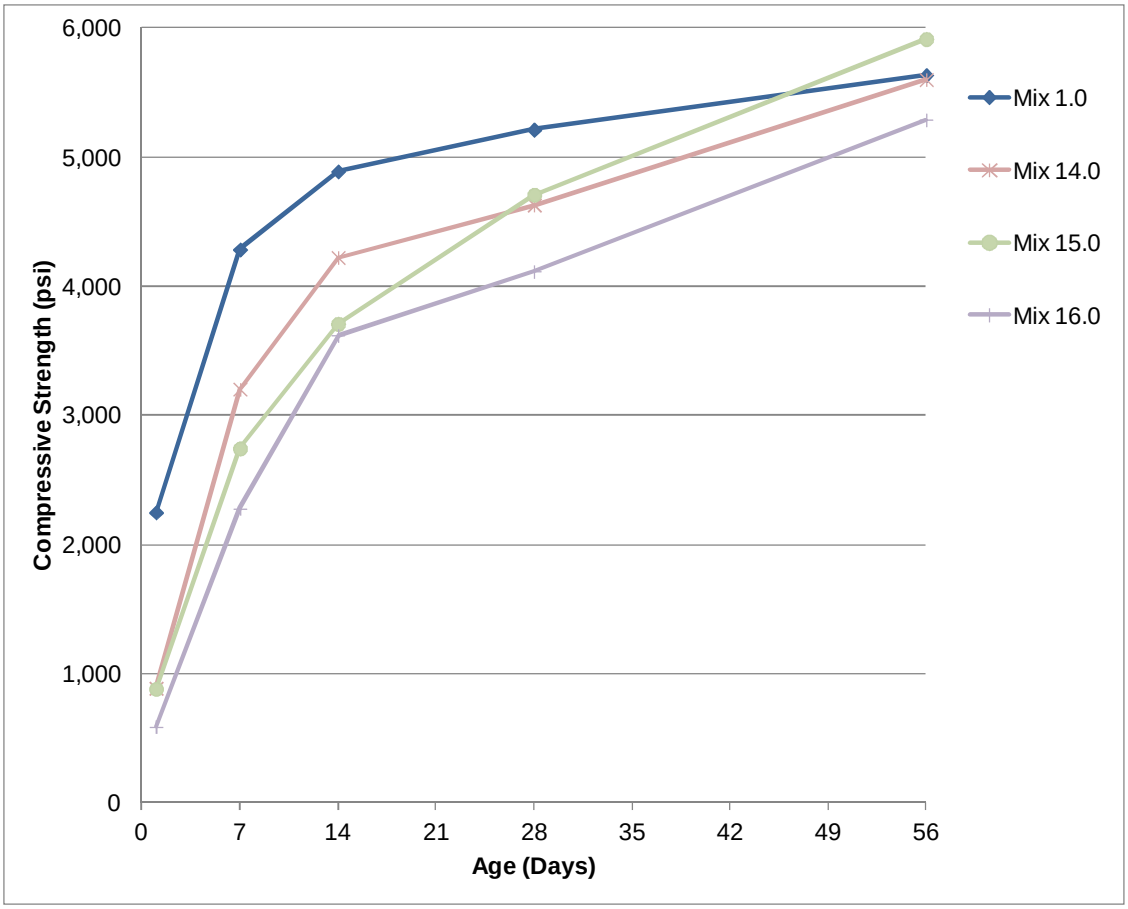


Figure 18: Compressive Strength vs Age Slag Cement

Average Compressive Strengths of SCM Mixes

In order to compare all mixes with the same SCM type to the control mix (Mix 1), mixes were divided into categories according to the type of SCM. The average compressive strengths were then calculated for each category. For example, all mixes that were proportioned with Class C fly ash were grouped together regardless of source or replacement rate and average compressive strengths were determined for all mixtures that included Class C fly ash (Mix 2,3,4,5,6, and 7). The same was done for Class F fly ash and slag cement. Results from these calculations are presented in Figures 19 and 20. The average 28-day compressive strength for the control mix (Mix 1) was 5,213 psi, Class C fly ash 4,687 psi, slag cement 4486 psi, and Class F fly ash 4,122 psi. Therefore, if SCMs are used to replace portland cement at replacement rates of 15 to 25 percent for fly ash and 40 to 50 percent for slag cement and the absolute volume of cementitious materials remains constant for all mixes, the expected percent of the compressive

strength of a mixture proportioned with 100 percent portland cement is 79.1 percent for Class F fly ash, 86.0 percent for Class C fly ash, and 89.9 percent for slag cement. The compressive strength of mixtures proportioned with SCMs as a percentage of the 100 percent portland cement control mix versus time is presented in Figure 20.

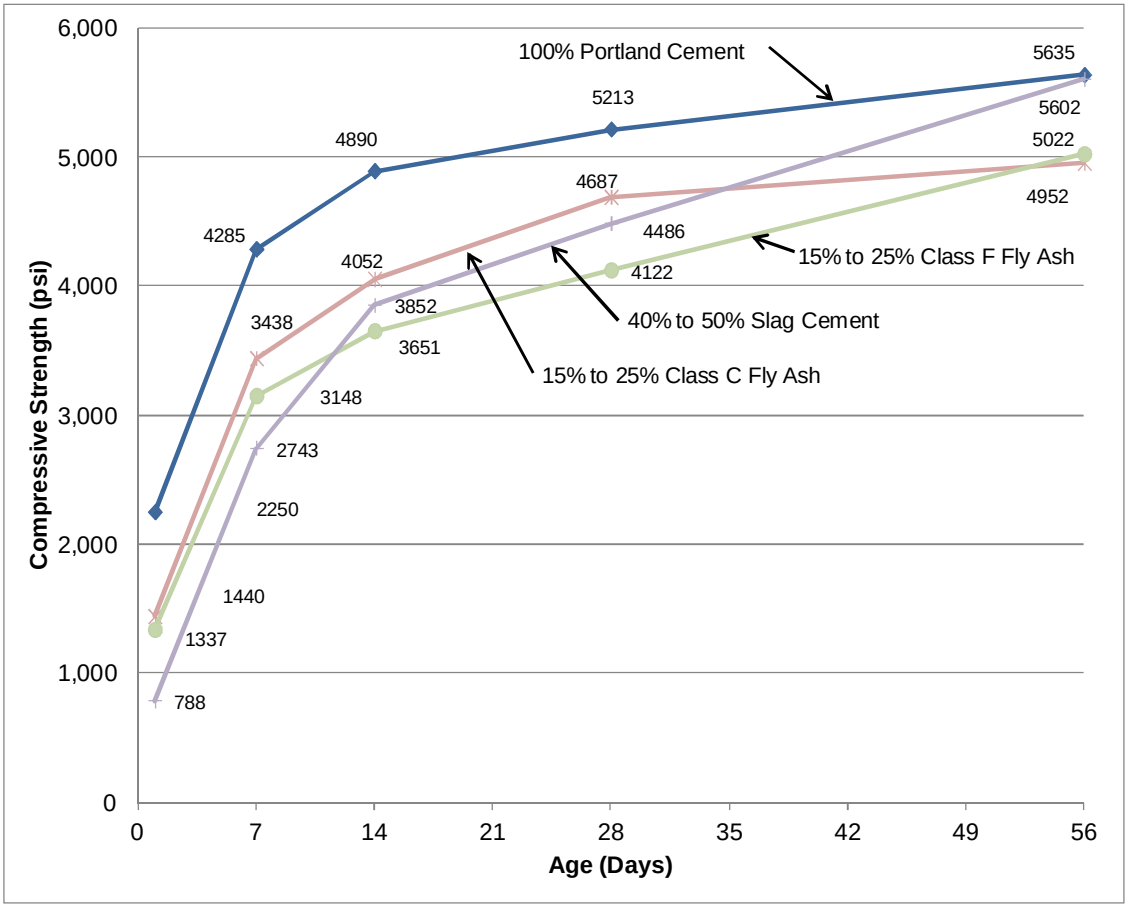


Figure 19: Average SCM Compressive Strength vs Age

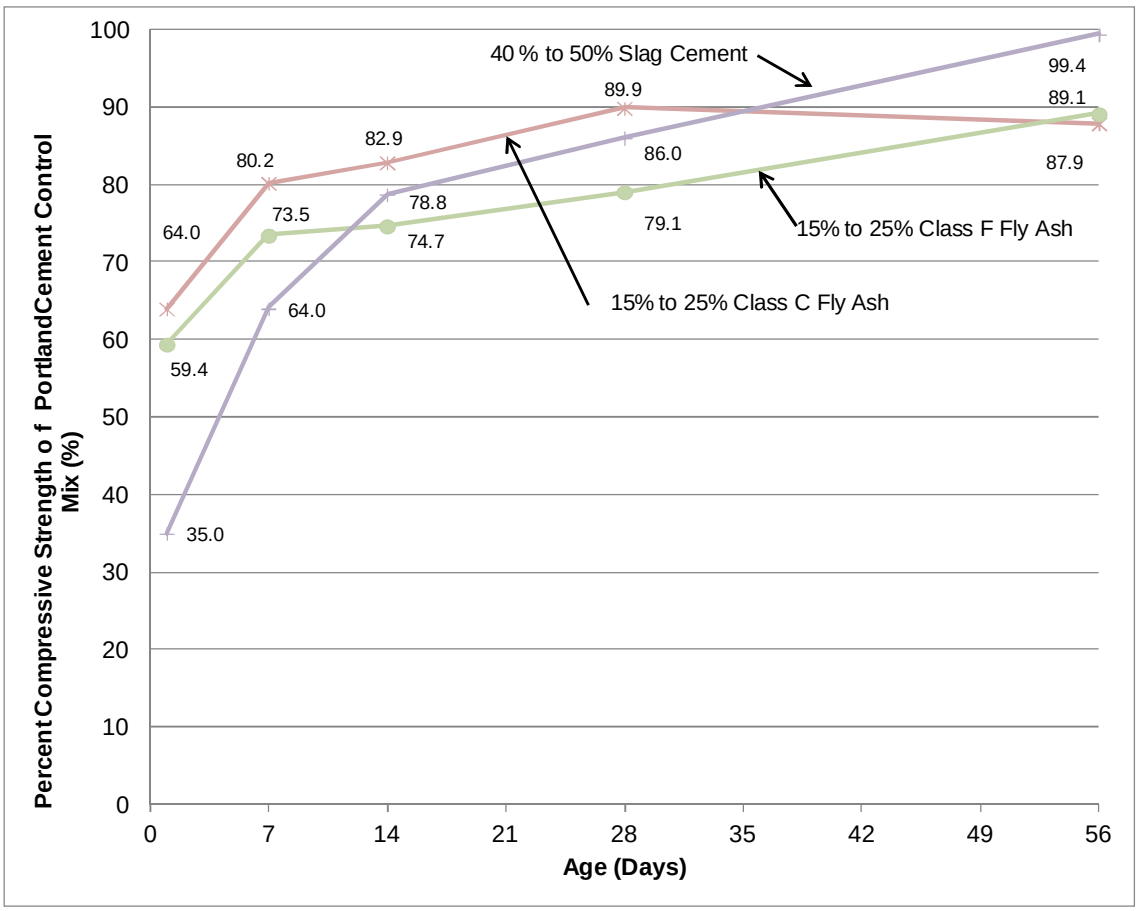


Figure 20: Average SCM Compressive Strength as a Percent of Control Mix

Compressive Strength – Influence of Water Cementitious Ratio (w/cm)

Water cementitious (w/cm) ratio ranged from 0.450 (Mix 1, control mix) to 0.484 (Mix 10, 75/25 F-1) for mixes of this study. Mixes 1 and 10 had 28-day compressive strengths of 5,213 psi (highest) and 3,807 psi (lowest), respectfully. Figure 21 presents 28-day compressive strengths versus w/cm ratio for all mixes in this study. The absolute volume of cementitious materials was held constant. Therefore, w/cm ratio increased as specific gravity of SCMs (2.41 to 2.89) decreased with respect to the specific gravity of portland cement (3.15). Figure 21 indicates that w/cm ratio influenced the compressive strength and is most likely the primary reason that mixtures proportioned with SCMs had lower strength than the control mix (Mix 1) proportioned with 100 percent portland cement. In addition, mixtures proportioned with SCM's had less total cementitious material by weight per unit volume than mixtures proportioned with 100 percent cement and this may have influenced compressive strength.

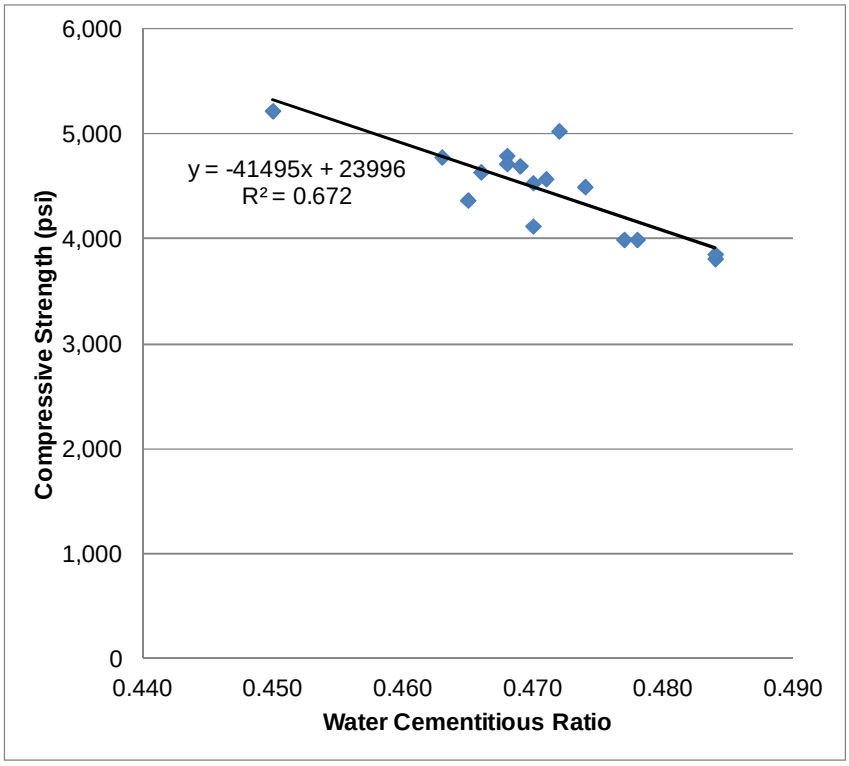


Figure 21: Compressive Strength (28-Day) vs Water Cementitious Ratio

Length Change

Length Change Outliers

This study includes producing and evaluating sixteen experimental mixes to investigate the influence of supplementary cementitious material and curing method on length change of concrete specimens. Three prism specimens were fabricated for each mixture in accordance with AASHTO T 160 / ASTM C 157 "Length Change of Hardened Hydraulic-Cement Mortar and Concrete" for each curing method making a total of 192 specimens. Curing methods included the use of liquid membrane and moist curing for 7, 14, and 28 days.

After the first few comparator readings, we determined that there were some obvious outliers indicating a problem with the initial comparator readings. We believe that we had slight movement in the pins on these specimens. We do not have definitive conclusions on the cause of the movement, but it could be a result of external vibration. In addition, specimens cured with liquid membrane were supported with large clamps in contact with the gauge studs for mixes 1 through mix 4 and this may also have caused movement of the gauge studs. These outliers were

identified and slight adjustments were made to the initial comparator reading based on our experience with similar mixtures and the amount of expected length change between the initial comparator readings and the second comparator reading. Table 19 presents adjustments to the initial comparator readings for mixes 1 through 4 for specimens cured with liquid membrane.

Length change readings were also evaluated to determine if percent length change between companion specimens exceeded one standard deviation (1s) as described in AASHTO T 160 / ASTM C 157. According to this standard, the 1s for replicate specimens is 0.0048 percent. Standard deviation was calculated for all length change calculations and each one that exceeded 0.0048 was evaluated to determine whether or not to include the individual specimen in length change calculations. Table 20 presents a list of length change specimens that were considered erratic and these data were removed and not included in average length change calculations.

Table 19: Adjustment Comparator Readings for Specimens Cured with Liquid Membrane

Mix No.	Specimen A		Specimen B		Specimen C	
	Original Reading	Adjusted Reading	Original Reading	Adjusted Reading	Original Reading	Adjusted Reading
1	0.1093	0.1088	0.1113	0.1078	0.1171	0.1152
2	0.1079	0.0988	0.0974	0.0812	0.1045	0.0959
3	0.1302	0.1043	0.1227	0.1141	0.1142	0.1184
4	0.1083	0.0955	0.0965	0.0879	0.1163	0.1038

Table 20: Length Change Specimens - Erratic Results

Mix No.	Liquid membrane	14-Day Soak
5	5A	
7	7A,7C	
8	8A	
10	10C	
11	11A	
12	12A	
13	13B	
14	14B	
15	15A	15C
16	16A,16B	

Length Change and Weight Change

Each length change specimen was measured with a comparator to determined percent length change compared to a 10 in. reference bar. These specimens were also weighed each time comparator reads were made to determine percent weight loss of the specimens compared to the weight determined upon demolding. These data are presented together so that similarities between length change and weight change could be discussed. Length change and weight change will be presented in this chapter and grouped according to type of cementitious materials used in the mixtures and the source of cementitious material.

Length and Weight Change Mix 1 (100/0 CS-1)

Mix 1 is the control mixture for this study and uses portland cement without SCMs. Length change versus drying day results are presented in Figure 22 for all curing conditions including liquid membrane, 7-day soak, 14-day soak, and 28-day soak. These data show a slight increase in shrinkage with increase in time spend in the curing bath. For example, the ultimate shrinkage of specimens exposed to 7-day soak was (-) 0.0330 percent while the ultimate shrinkage of specimens exposed to 28-day soak was (-) 0.0360 percent.

Figure 23 provides data showing that as length of time spent in curing bath increases the weight of the specimen increases and the percent weight loss due to drying decreases. For example, the maximum weight gained was 0.46 percent for the 7-day soak specimens while the weight loss was (-) 2.21 percent. The maximum weight gained was 0.55 percent for the 28-day soak specimens while the weight loss was (-) 2.13 percent. Because the results are so close for the shrinkage and weight loss, caution should be exercised is making definitive conclusions. However, based on data provided by our control mixture, shrinkage increased slightly with an increase in exposure to moist curing. The 7-day soak specimens had the least amount shrinkage and the most amount of weight loss when comparing specimens that were moist cured. When comparing data presented in Figures 22 and 23, one may conclude that moist curing provides additional water for additional hydration that may result in additional shrinkage. Specimens cured with liquid membrane had shrinkage of (-) 0.0370 percent and a percent weight loss of 2.56 percent which is the highest values for the control mix.

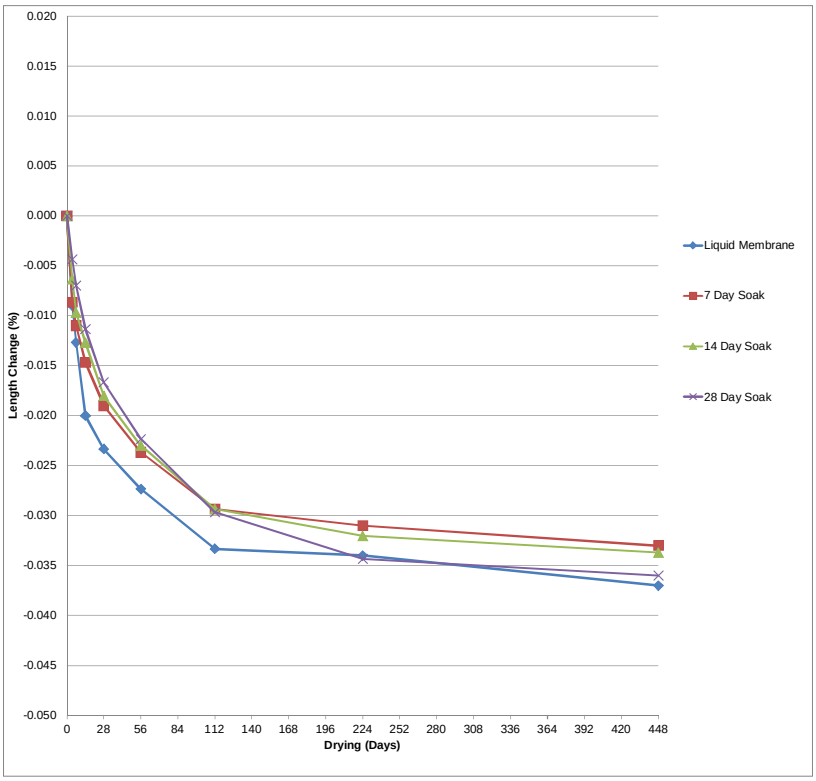


Figure 22: Percent Length Change vs Drying Days - Mix 1 (100/0 CS-1)

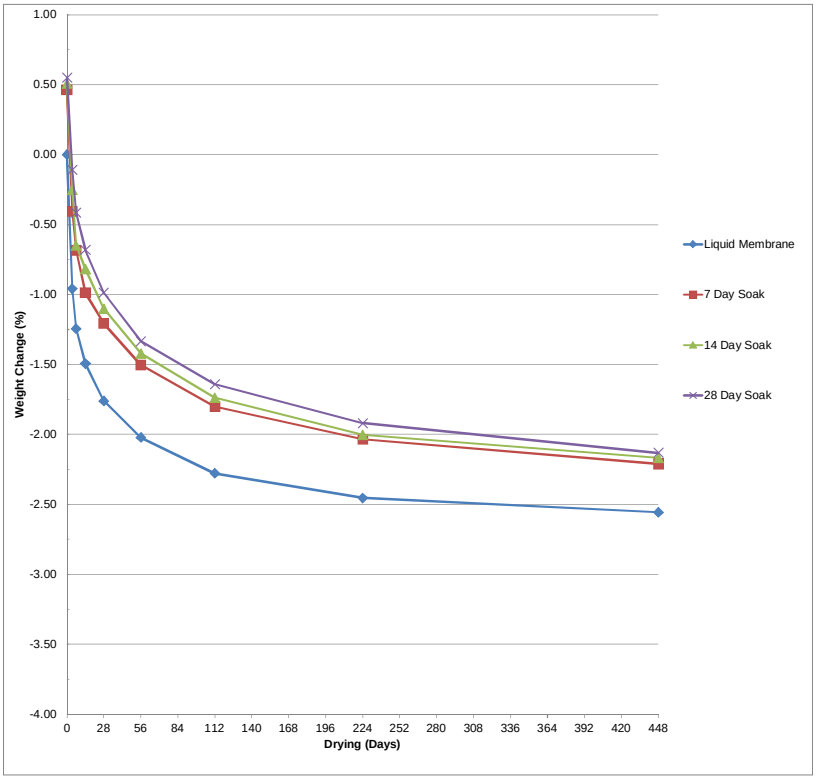


Figure 23: Percent Weight Loss Drying Days - Mix 1 (100/0 CS-1)

Length Change Mixes 2, 3, and 4 - Class C Fly Ash Source 1 (C-1)

Mixes 2, 3, and 4 are similar to the control mix (Mix 1) except portland cement is replaced with 15, 20, or 25 percent Class C fly ash sampled from source 1 (C-1), respectfully. Enough specimens were made for each mixture to test each mixture for four curing conditions including; liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Length changes versus drying day results for each curing condition are presented in Figures 24, 26, and 28. Weight change vs drying day results for each curing condition are presented in Figures 25, 27, and 29. Length change versus drying day results for each replacement rate and each curing condition are presented in Figures 30, 32, 34, and 36. Weight change vs drying day results for each replacement rate and each curing condition are presented in Figures 31, 33, 35, and 37.

The ultimate shrinkage for mixes proportioned with Class C fly ash from source 1 (C-1) ranged from (-) 0.0300 of Mix 4 (75/25, C-1, liquid membrane) to (-) 0.0393 of Mix 4 (75/25, C-1, 28-day soak). There were no apparent trends between length change and curing method or length change and replacement rate for mixes proportioned with Class C fly ash sampled from source 1 (C-1) except for specimens cured with 7-day soak and 28-day soak presented in Figures 32 and 36, respectively. These two figures show that shrinkage increased as replacement rate increased. This was not the case for specimens cured with liquid membrane or 14-day soak. All mixes with Class C fly ash from source 1 had less ultimate shrinkage when compared to ultimate shrinkage of the control mixture except for Mix 3 (80/20, C-1, 7-day), Mix 4 (75/25, C-1, 7-day soak) and Mix 4 (75/25, C-1, 28-day soak). Therefore, nine out of twelve (75 percent) of ultimate shrinkage measurements of mixes proportioned with Class C fly ash from sample 1 had less ultimate shrinkage than the control mix. In general, class C fly ash sampled from source 1 has less shrinkage than the control mix and the shrinkage increased with increase in replacement rate.

There was a definitive trend established in weight change versus drying days. As moist curing increased, percent weight loss decreased. As replacement rate of Class C fly ash source 1 increased, percent weight loss increased. These trends are typical in all cases where Class C fly ash from source 1 was used except for Mix 2 (85/15, C-1, 14-day soak) and Mix 2 (85/15, C-1, 28-day soak) as presented in Figure 25. In these cases, there was more weight loss for the 28-day soak specimens than with the 14-day soak specimens, (-) 2.31 percent and (-) 2.28 percent, respectively. Therefore, data of this study show that percent weight loss is proportional to

replacement rate of Class C fly ash sample from source 1. Shrinkage and weight loss increased as replacement rate of Class C fly ash from source 1 for portland cement increased. This increase in shrinkage and weight loss that occurred as replacement rate increased may have been influenced more by the increase in w/cm ratio than the replacement rate of SCM.

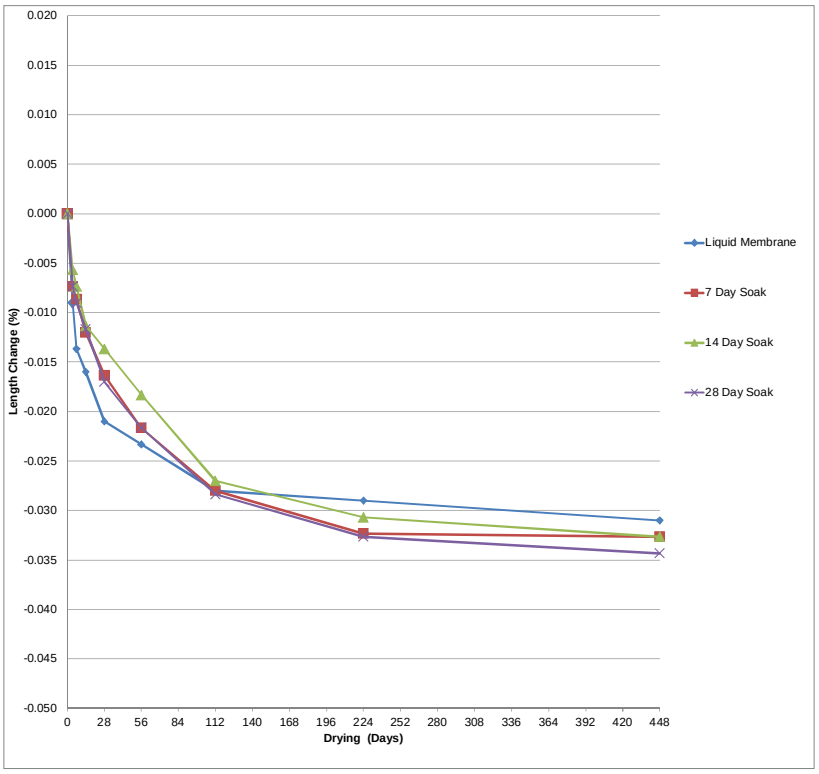


Figure 24: Length Change vs Drying Days - Mix 2 (85/15 C-1)

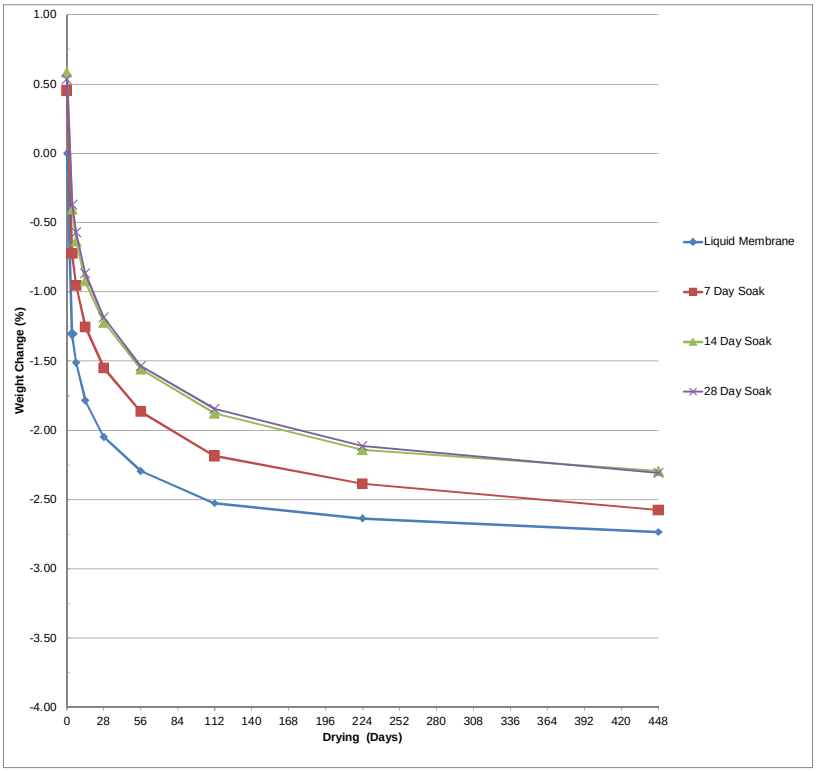


Figure 25: Weight Change vs Drying Days - Mix 2 (85/15 C-1)

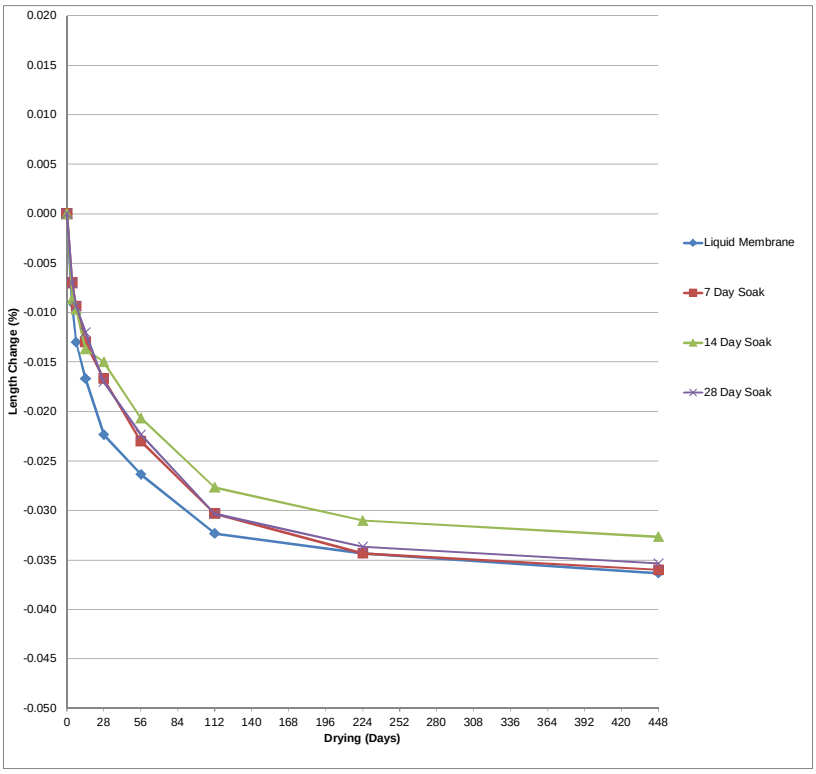


Figure 26: Length Change vs Drying Days - Mix 3 (80/20 C-1)

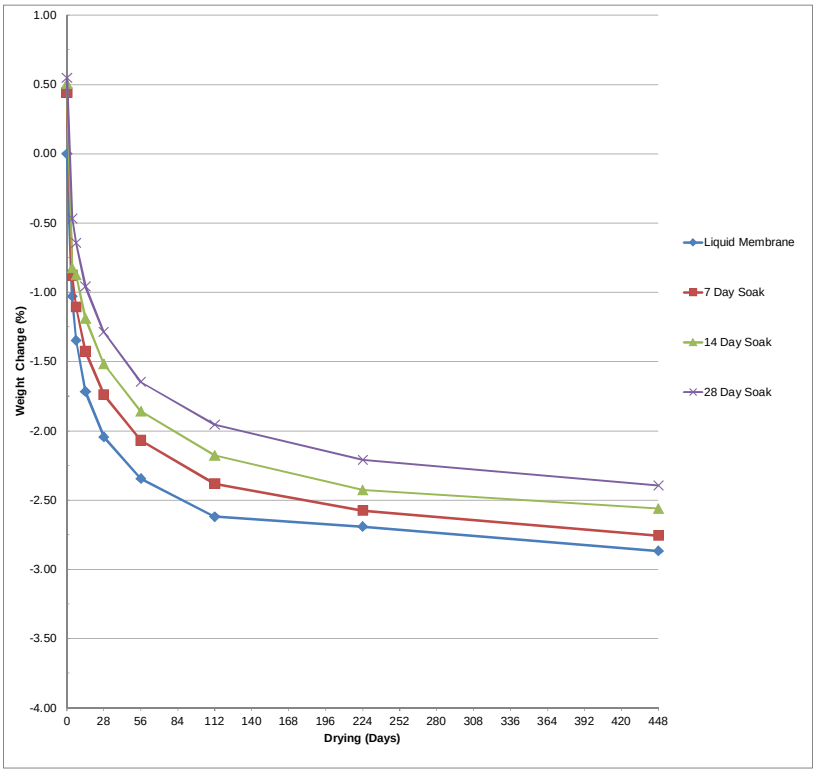


Figure 27: Weight Change vs Drying Days - Mix 3 (80/20 C-1)

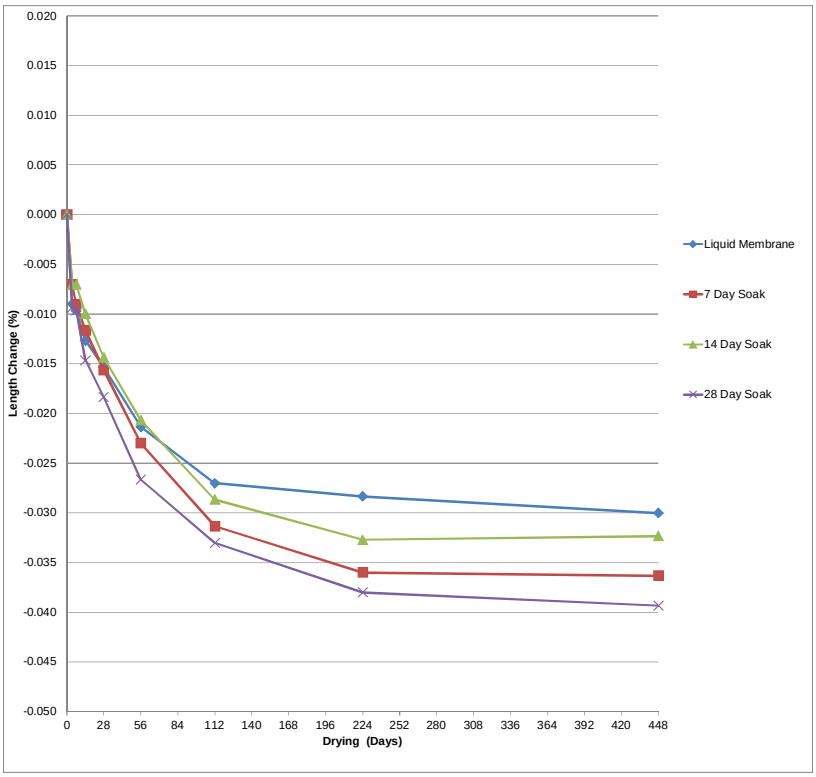


Figure 28: Length Change vs Drying Days - Mix 4 (75/25 C-1)

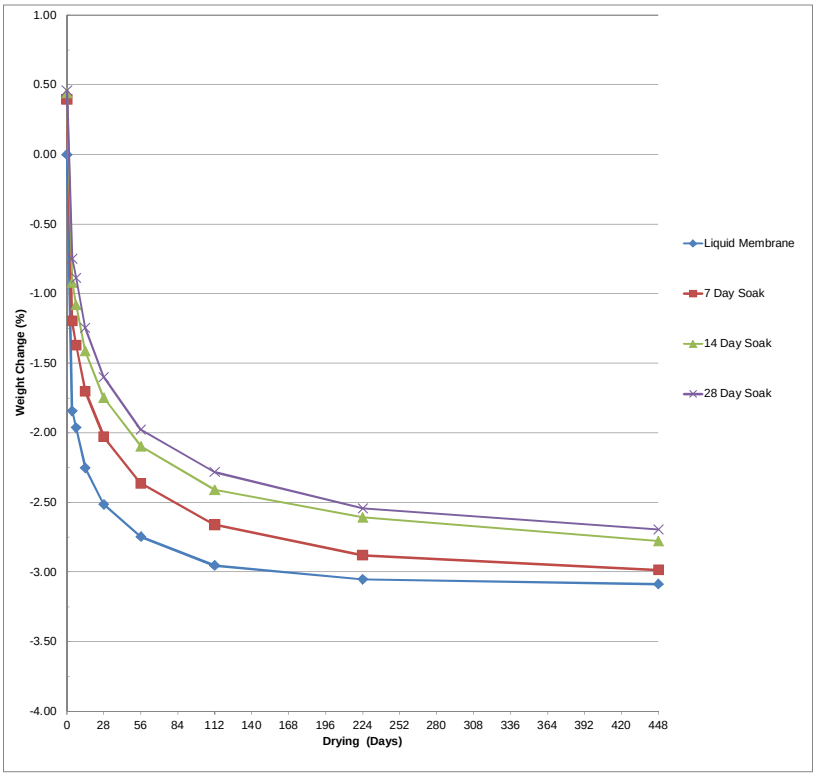


Figure 29: Weight Change vs Drying Days - Mix 4 (75/25 C-1)

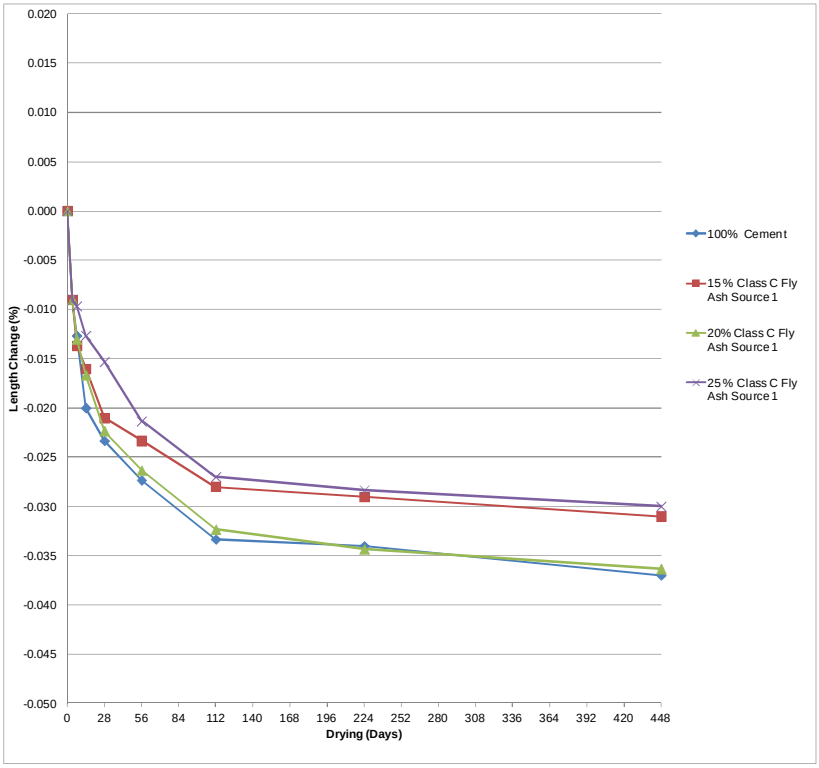


Figure 30: Length Change vs Drying Days - Mixes 2 thru 4 (Liquid membrane)

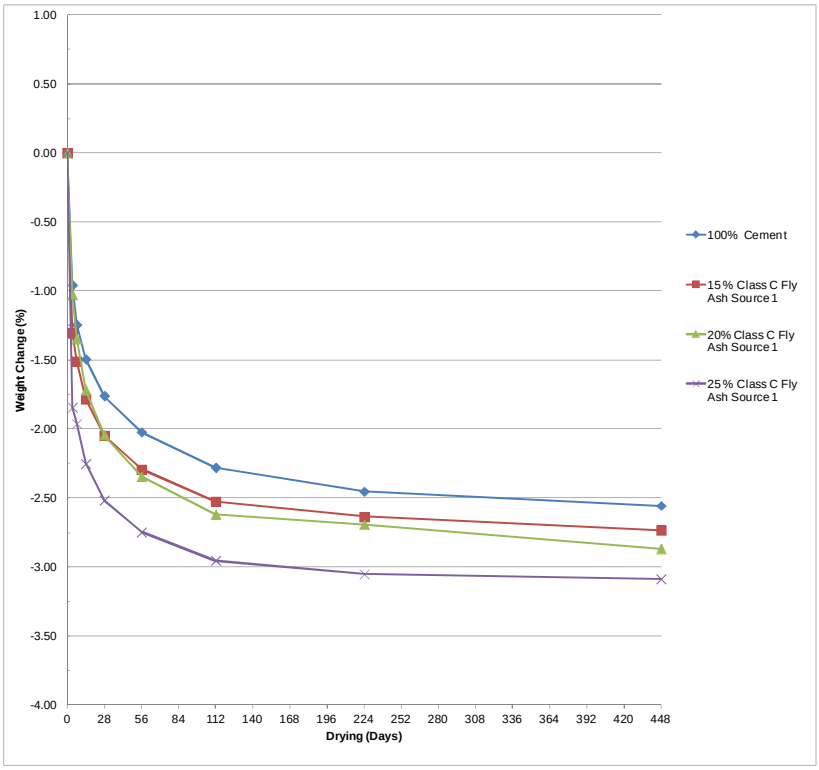


Figure 31: Weight Change vs Drying Days - Mixes 2 thru 4 (Liquid membrane)

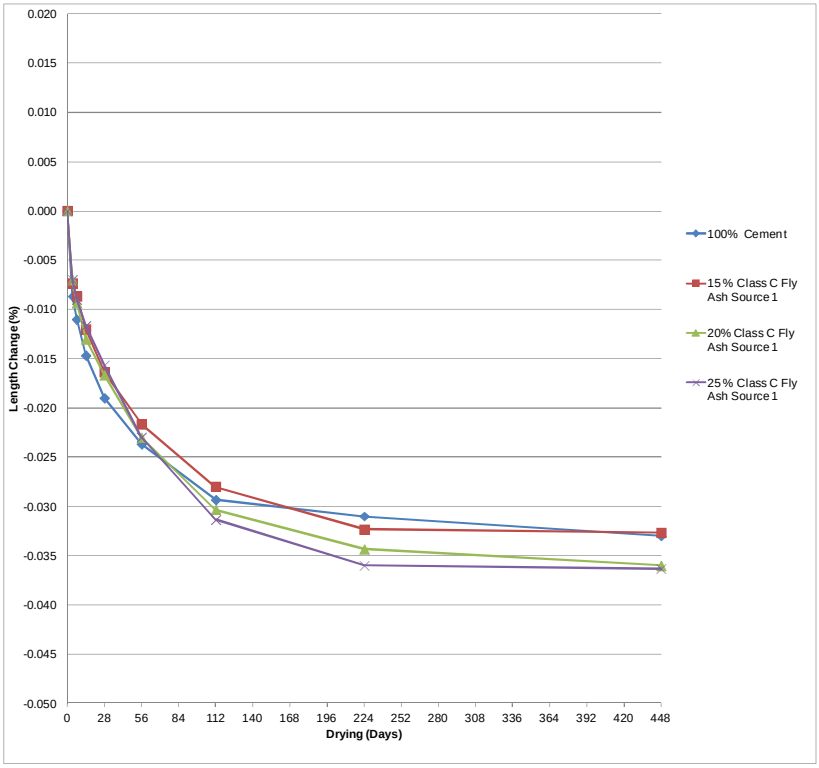


Figure 32: Length Change vs Drying Days - Mixes 2 thru 4 (7-Day Soak)

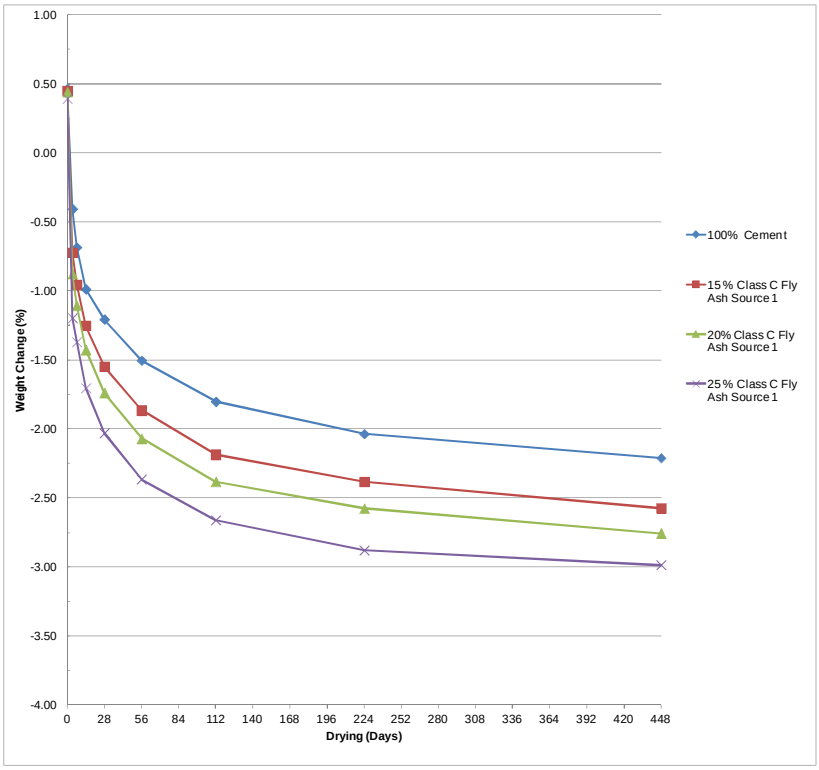


Figure 33: Weight Change vs Drying Days - Mixes 2 thru 4 (7-Day Soak)

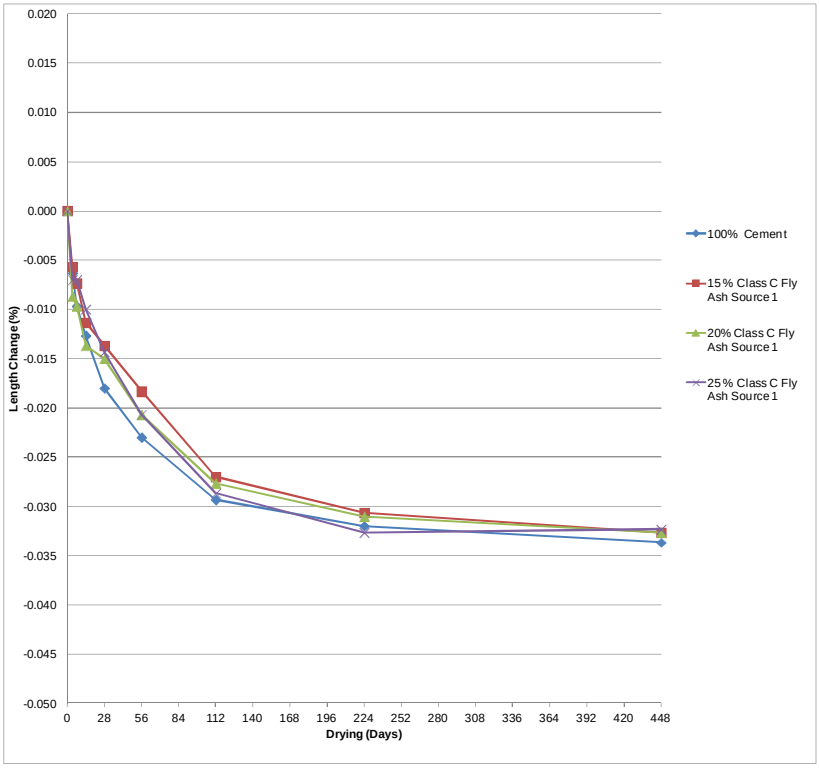


Figure 34: Length Change vs Drying Days (14-Day Soak)

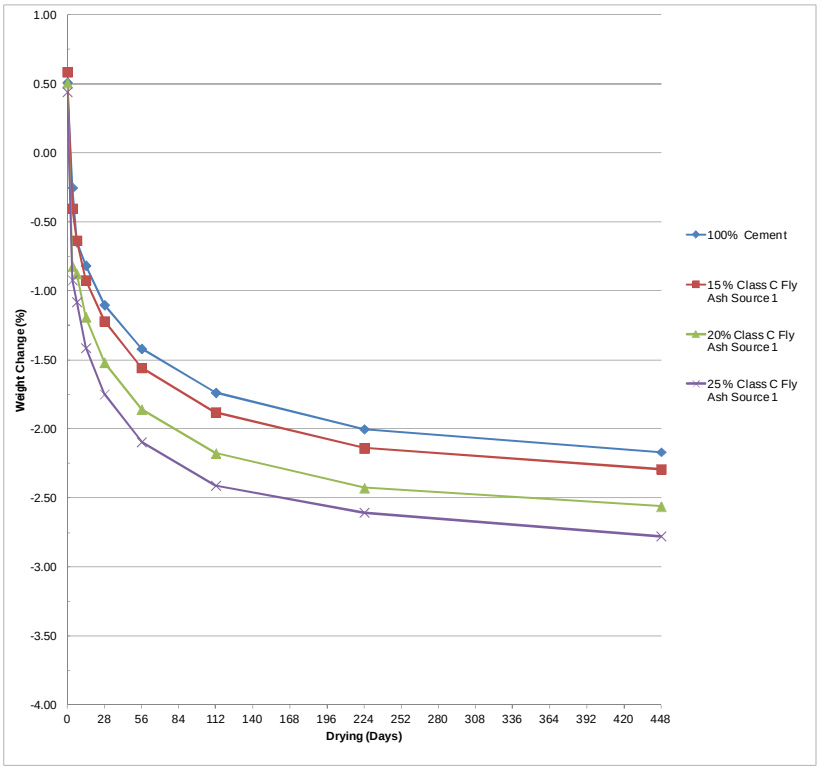


Figure 35: Weight Change vs Drying Days (14-Day Soak)

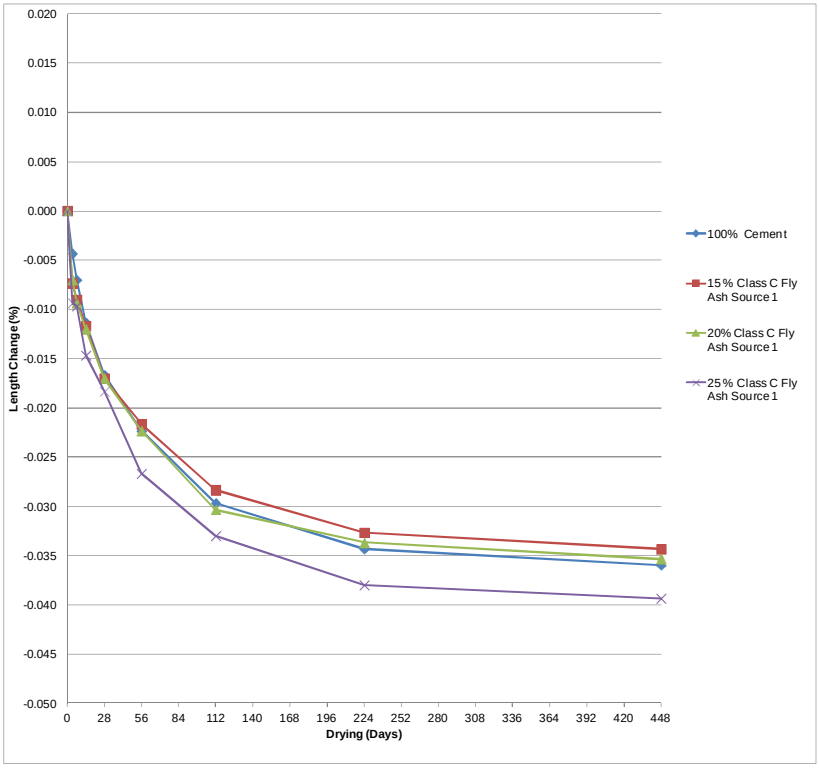


Figure 36: Length Change vs Drying Days - Mixes 2 thru 4 (28-Day Soak)

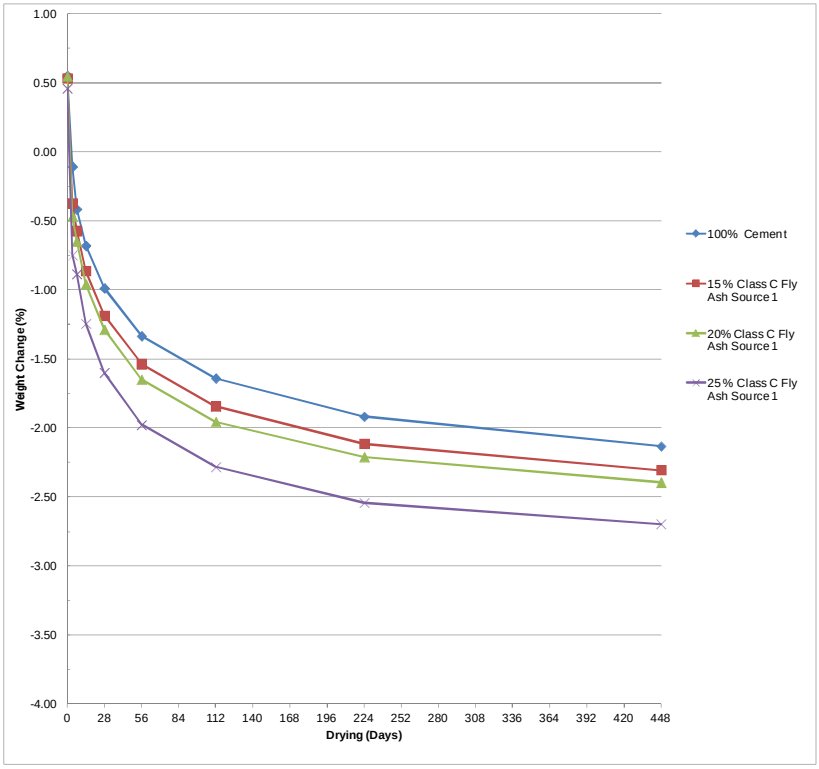


Figure 37: Weight Change vs Drying Days - Mixes 2 thru 4 (28-Day Soak)

Length Change Mixes 5, 6, and 7 – Class C Fly Ash Source 2 (C-2)

Mixes 5, 6, and 7 are similar to the control mix (Mix 1) except portland cement is replaced with 15, 20, or 25 percent Class C fly ash sampled from source 2 (C-2), respectfully. Enough specimens were made for each mixture to test specimens under four curing conditions including; liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Length changes versus drying day results for each curing condition are presented in Figures 38, 40, and 42. Weight change vs drying age for each curing condition are presented in Figures 39, 41, and 43. Length changes versus drying day results for each replacement rate are presented in Figures 44, 46, 48, and 50 for each curing condition. Weight change vs drying day results for each replacement rate are presented in Figures 45, 47, 49, and 51 for each curing condition.

The ultimate shrinkage for mixes proportioned with Class C fly ash from source 2 ranged from (-) 0.0303 for Mix 5 (85/15, C-2, 7-day soak) to (-) 0.0390 for Mix 5 (85/15, C-2, 28-day soak). There were no apparent trends between length change and curing method or length change and replacement rate for mixes proportioned with Class C fly ash sampled from source 2 expect for specimens made from Mix 7 (75/25, C-2) as presented in Figure 42. This figure shows that shrinkage increased as moist curing increased. Seven out of twelve or 58 percent of ultimate shrinkage measurements were more than ultimate shrinkage of the control mix. Therefore, the general trend was that shrinkage increased when using Class C fly ash from source 2 compared to the control mix. This increase in shrinkage may also be attributed to the higher w/cm ratios for mixes proportioned with Class C fly ash from source 2 than w/cm ratios of mixes proportioned with Class C fly ash from source 1 or the control mix.

There is a definitive trend established in weight change versus drying days. As moist curing increased, percent weight loss decreased. As replacement rate of Class C fly ash source 2 increased, percent weight loss increases. These trends are typical in all cases where Class C fly ash from source 2 was used except for Mix 5 (85/15, C-2, 7-day soak) and Mix 5 (85/15, C-2, 14-day soak as presented in Figure 38. In these cases, there was more weight loss for the 14-day soak specimens than with the 7-day soak specimens, (-) 2.57 percent and (-) 2.56 percent, respectively. Therefore, data of this study show that percent weight loss is proportional to replacement rate of Class C fly ash sample from source 2. Weight loss increased as replacement rate of Class C fly ash from source 2 for portland cement increased. This increase in weight loss with increase in replacement rate may also be attributed to increase in w/cm ratio.

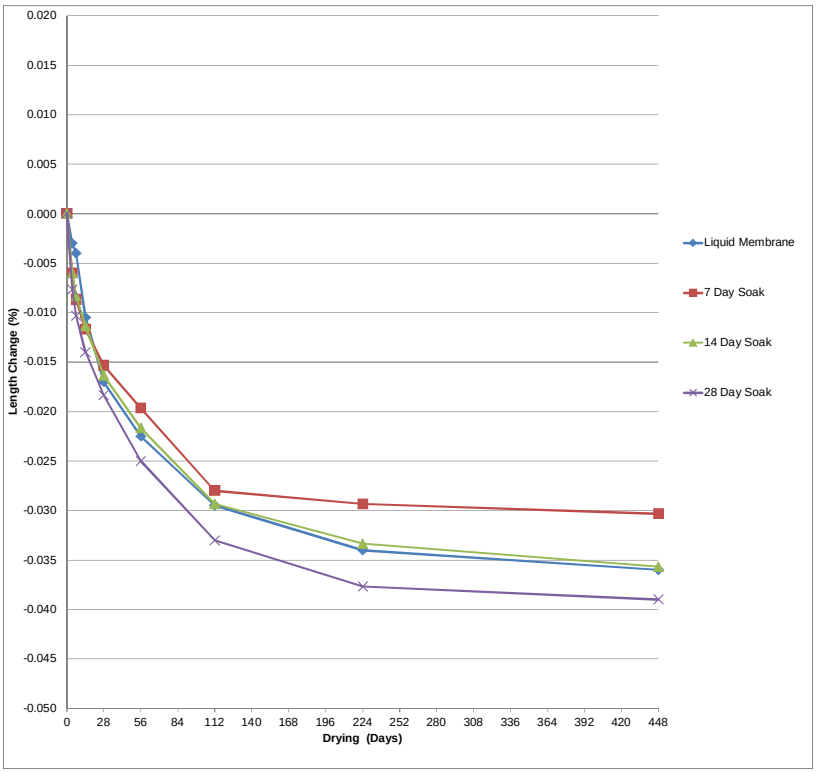


Figure 38: Length Change vs Drying Days - Mix 5 (85/15 C-2)

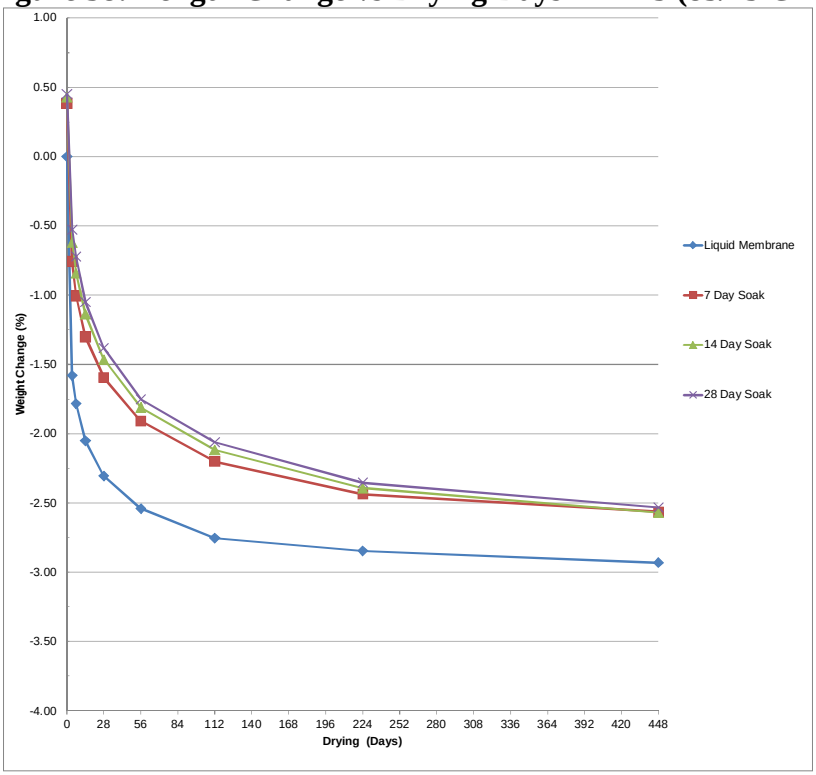


Figure 39: Weight Change vs Drying Days - Mix 5 (85/15 C-2)

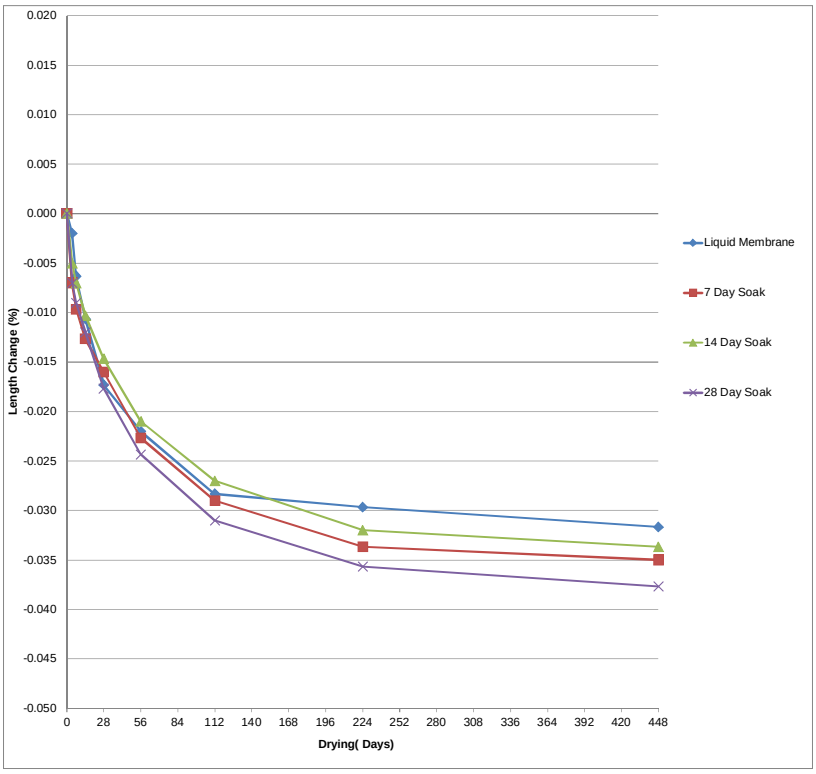


Figure 40: Length Change vs Drying Days - Mix 6 (80/20 C-2)

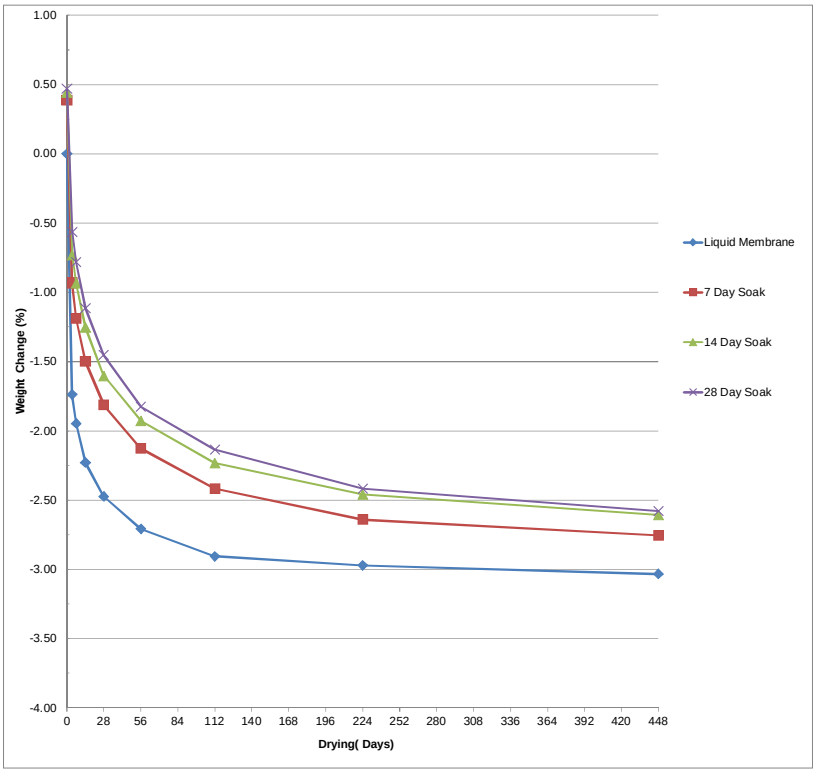


Figure 41: Weight Change vs Drying Days - Mix 6 (80/20 C-2)

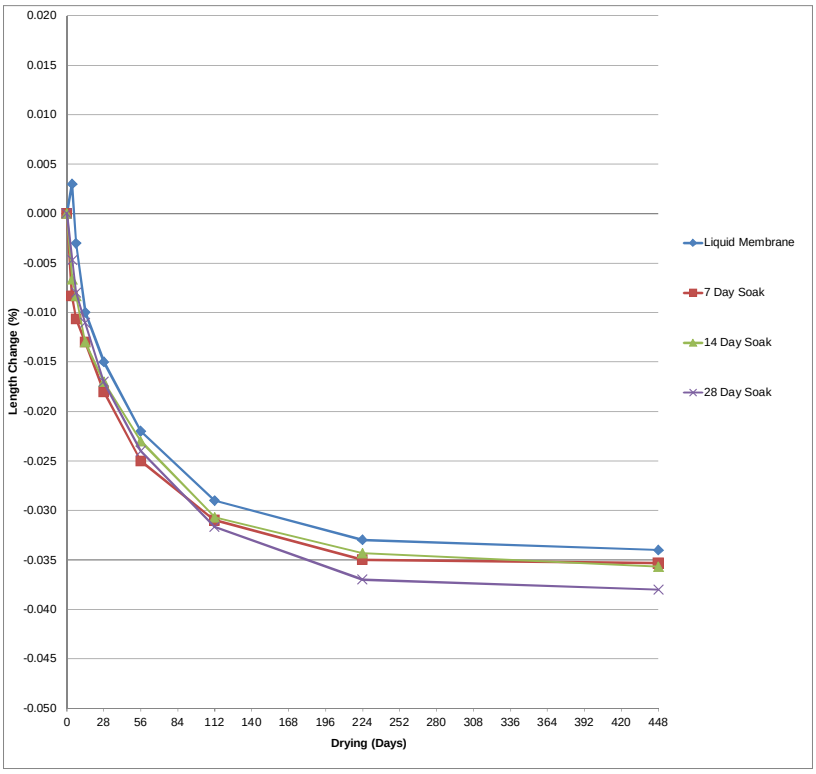


Figure 42: Length Change vs Drying Days - Mix 7 (75/25 C-2)

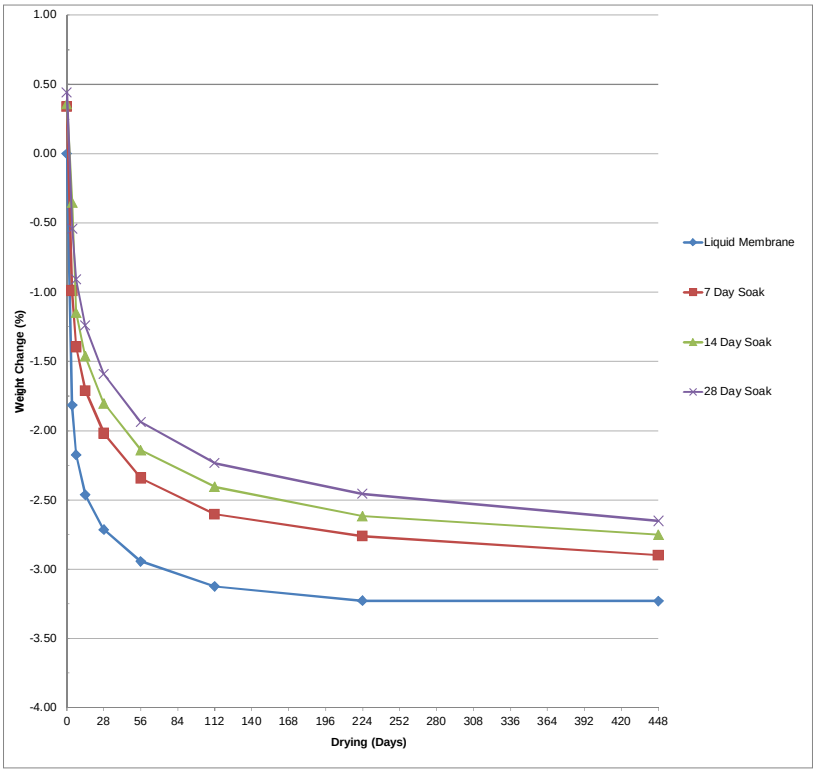


Figure 43: Weight Change vs Drying Days - Mix 7 (75/25 C-2)

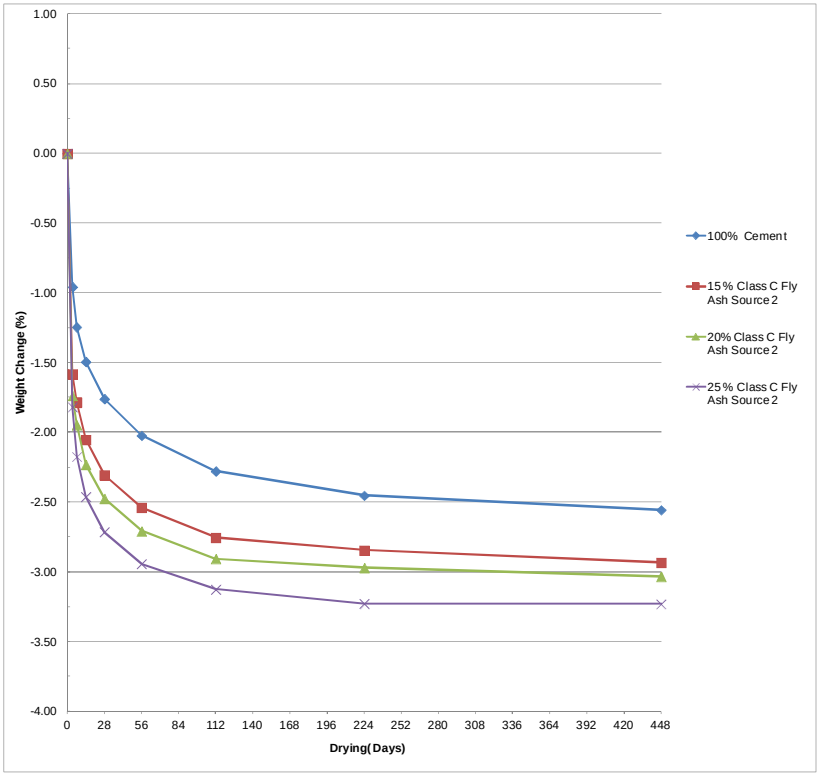


Figure 44: Length Change vs Drying Days - Mixes 5 thru 7 (Liquid membrane)

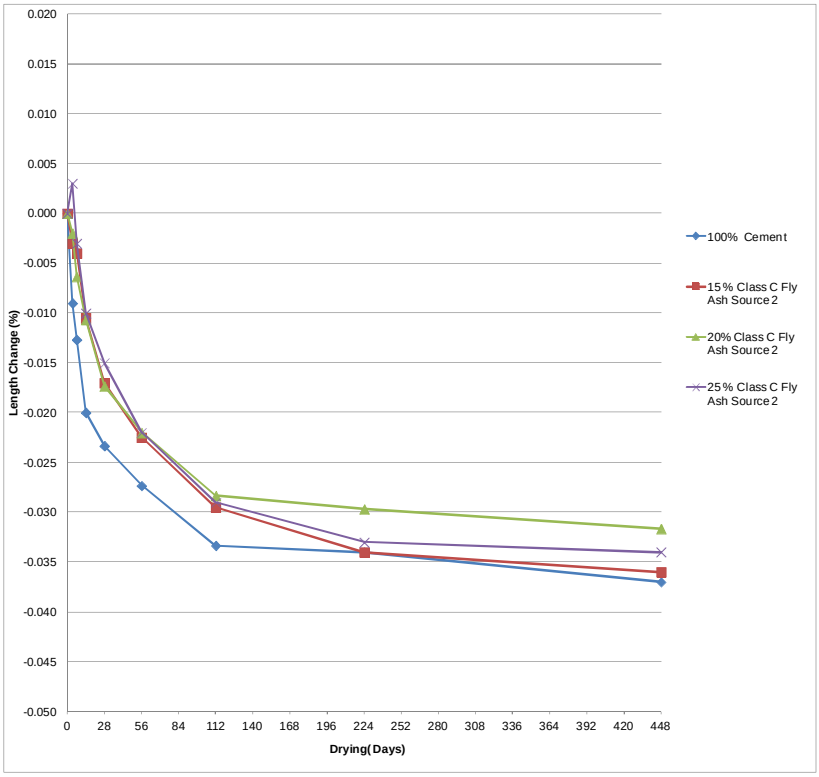


Figure 45: Weight Change vs Drying Days - Mixes 5 thru 7 (Liquid membrane)

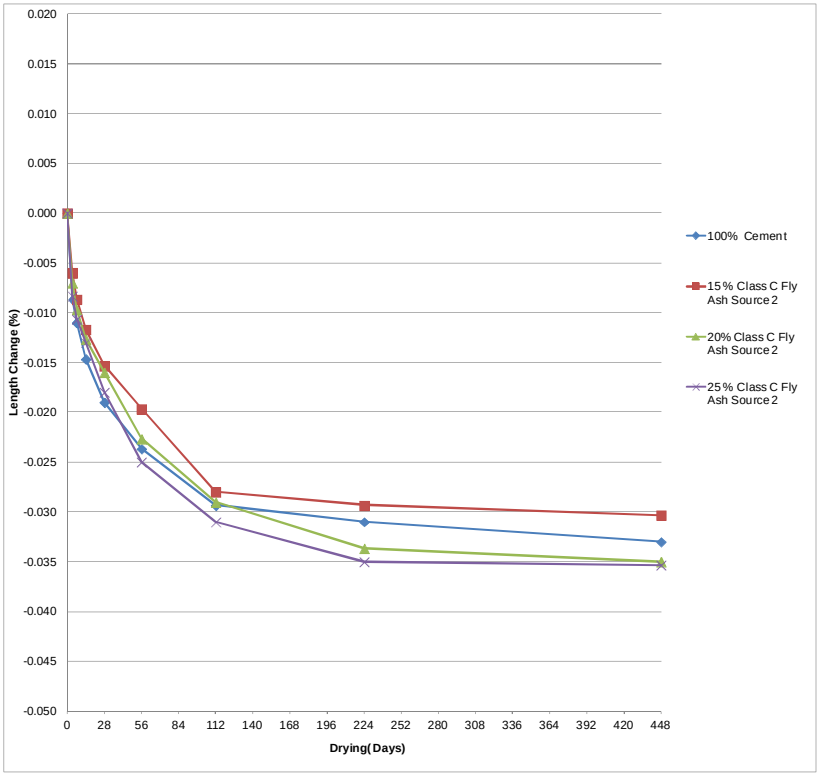


Figure 46: Length Change vs Drying Days - Mixes 5 thru 7 (7-Day Soak)

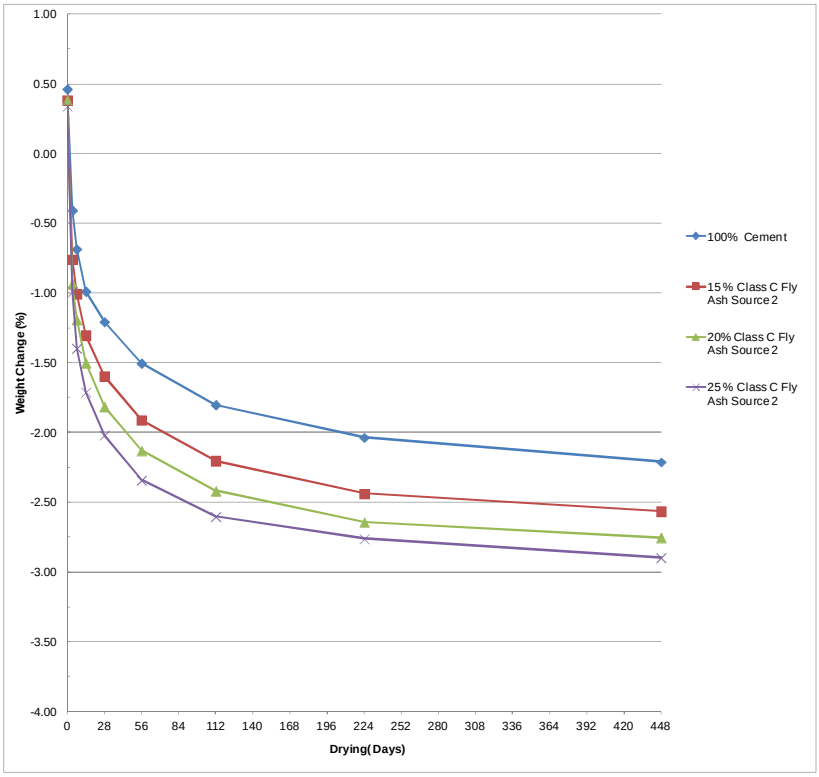


Figure 47: Weight Change vs Drying Days - Mixes 5 thru 7 (7-Day Soak)

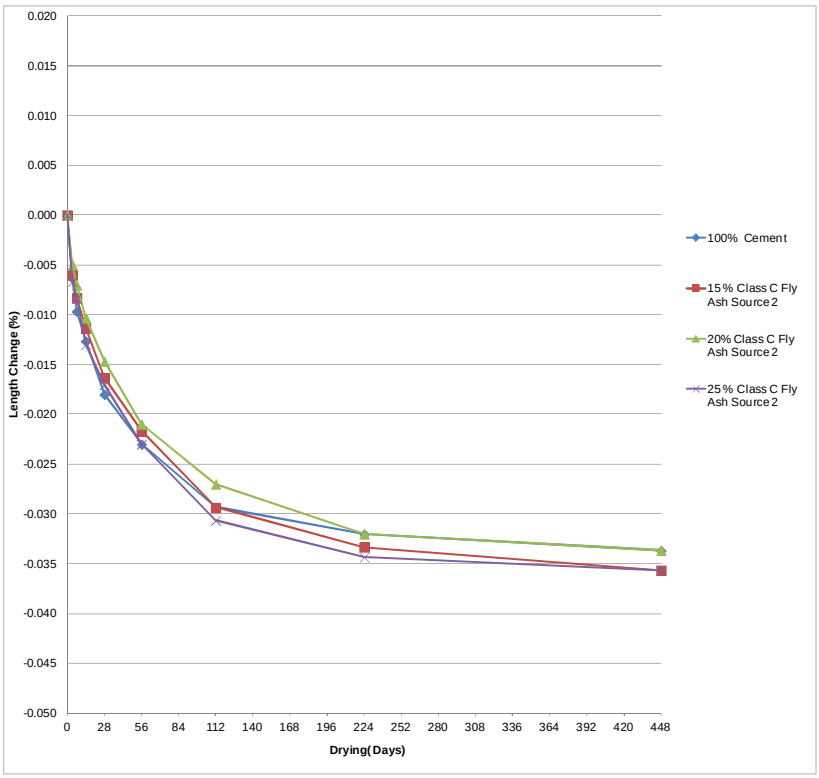


Figure 48: Length Change vs Drying Days - Mixes 5 thru 7 (14-Day Soak)

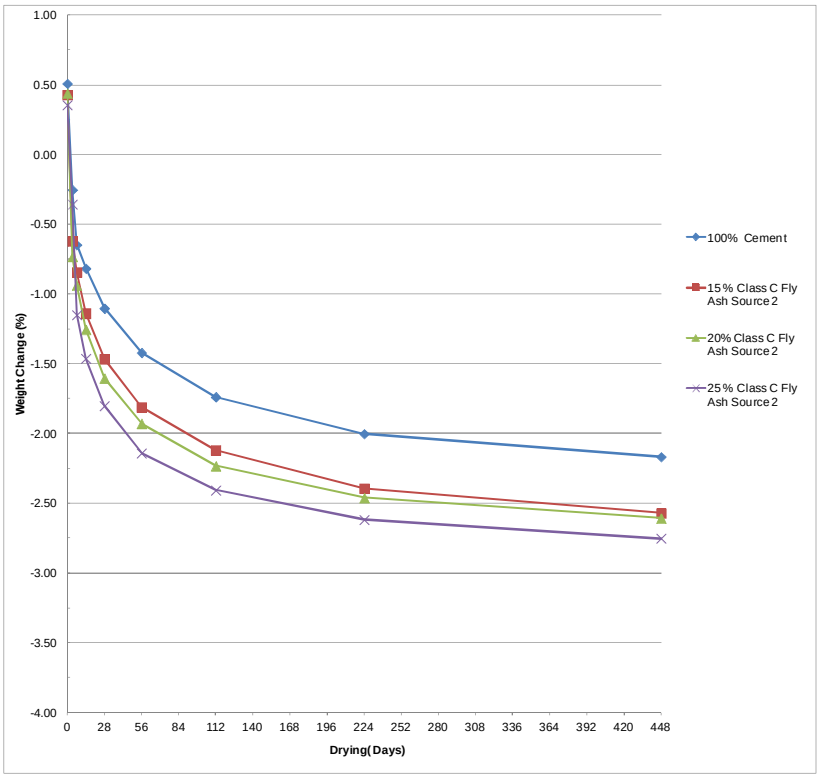


Figure 49: Weight Change vs Drying Days - Mixes 5 thru 7 (14-Day Soak)

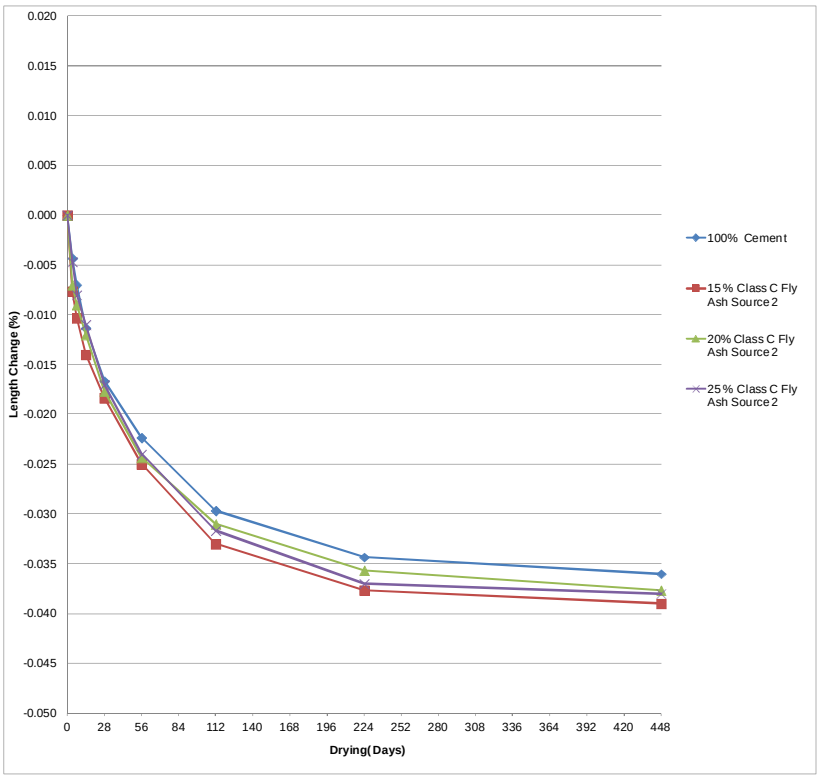


Figure 50: Length Change vs Drying Days - Mixes 5 thru 7 (28-Day Soak)

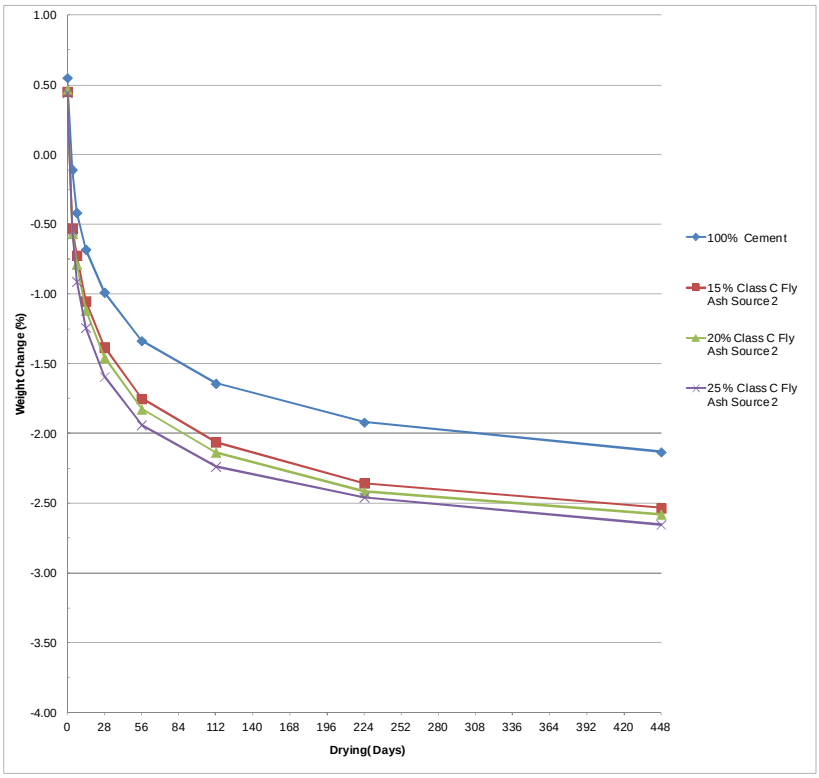


Figure 51: Weight Change vs Drying Days - Mixes 5 thru 7 (28-Day Soak)

Length Change Mixes 8, 9, and 10 – Class F Fly Ash Source 1 (F-1)

Mixes 8, 9, and 10 are similar to the control mix (Mix 1) except portland cement is replaced with 15, 20, or 25 percent Class F fly ash sampled from source 1 (F-1), respectfully. Enough specimens were made for each mixture to test specimens for four curing conditions including; liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Length changes versus drying day results for each curing condition are presented in Figures 52, 54, and 56. Weight change vs drying day results for each curing condition are presented in Figures 53, 55, and 57. Length changes versus drying day results for each replacement rate are presented in Figures 58, 60, 62, and 64 for each curing condition. Weight change vs drying age results for each replacement rate are presented in Figures 59, 61, 63, and 65 for each curing condition.

The ultimate shrinkage for mixes proportioned with Class F fly ash from source 1 ranged from (-) 0.0310 for Mix 8 (85/15, F-1, 28-day soak) and (-) 0.0310 for Mix 10 (75/25, F-1, 14-day soak) to (-) 0.0380 for Mix 8 (85/15, F-1, liquid membrane). There were three trends observed between length change and curing method or length change and replacement rate for mixes proportioned with Class F fly ash sampled from source 1; 1) shrinkage decreased as moist curing increased for Mix 8 (85/15, F-1) as presented in Figure 52; 2) shrinkage decreased with increase in replacement rate for specimens cured with liquid membrane as presented in Figure 58; 3) shrinkage increased with increase in replacement rate for specimens cured with 28-day soak presented in Figure 64.

There was a definitive trend established in weight change versus drying days. As moist curing increased, percent weight loss decreased. As replacement rate of Class F fly ash source 1 increased, percent weight loss increased. These trends are typical in all cases where Class F fly ash from source 1 was used except for Mix 9 (85/20, F-1) and Mix 10 (75/25, F-1) cured with 14-day soak where the percent weight loss of (-) 3.02 percent did not change as presented in Figure 63. Therefore, data of this study show that percent weight loss is proportional to replacement rate of Class F fly ash sample from source 1. Weight loss increased as replacement rate of Class F fly ash from source 1 for portland cement increased. This increase in weight loss with increase in replacement rate is most likely caused by the increase in w/cm ratio.

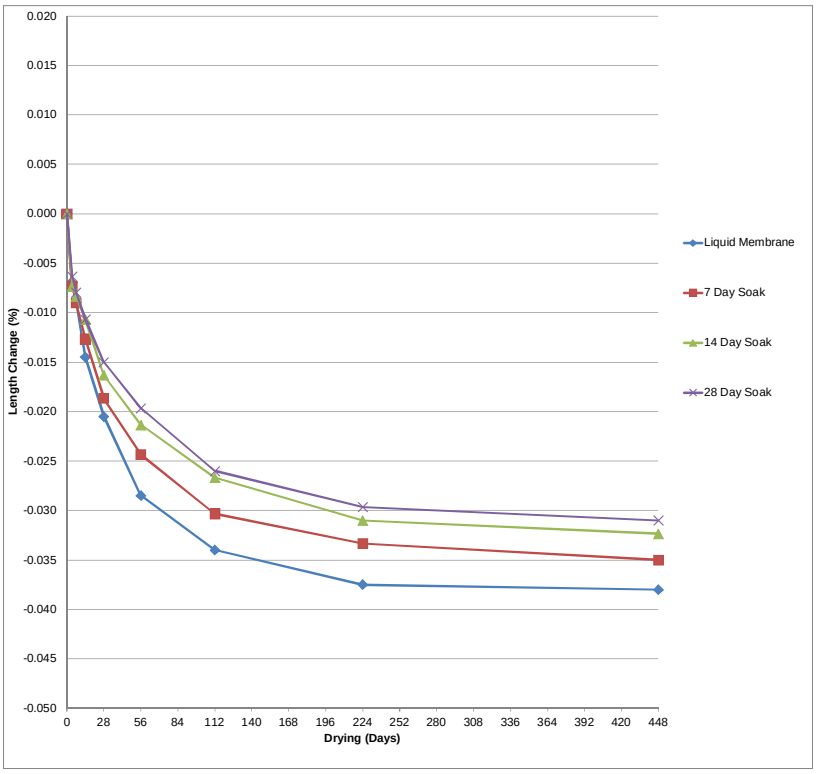


Figure 52: Length Change vs Drying Days - Mix 8 (85/15 F-1)

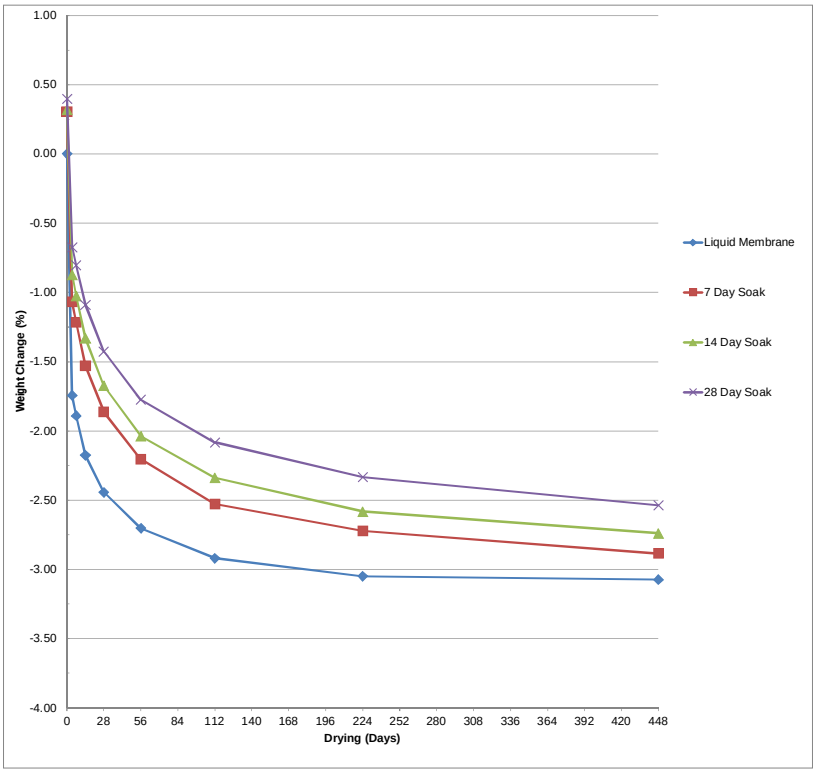


Figure 53: Weight Change vs Drying Days - Mix 8 (85/15 F-1)

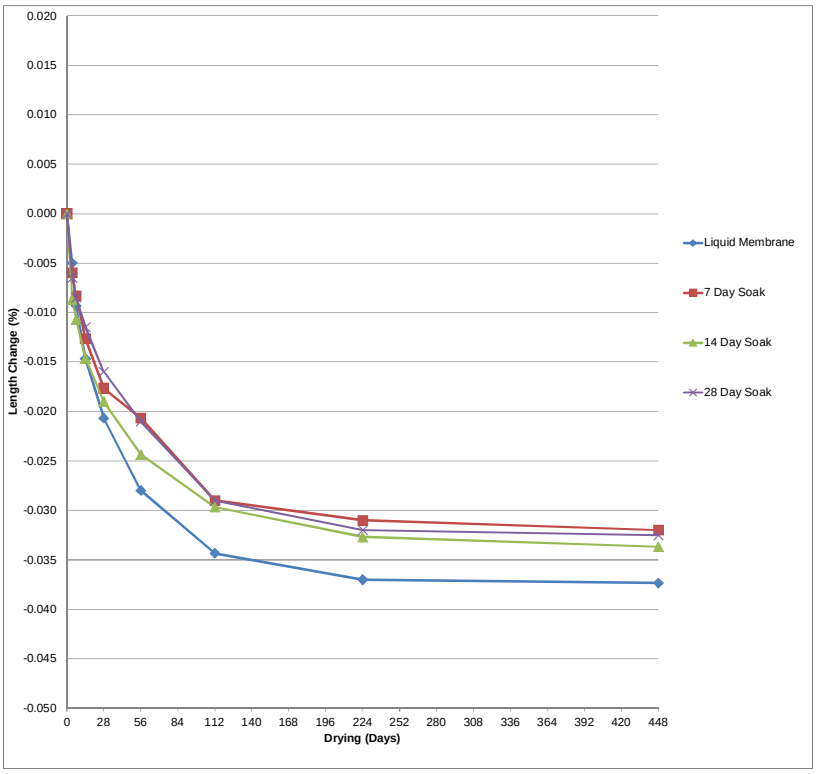


Figure 54: Length Change vs Drying Days - Mix 9 (80/20 F-1)

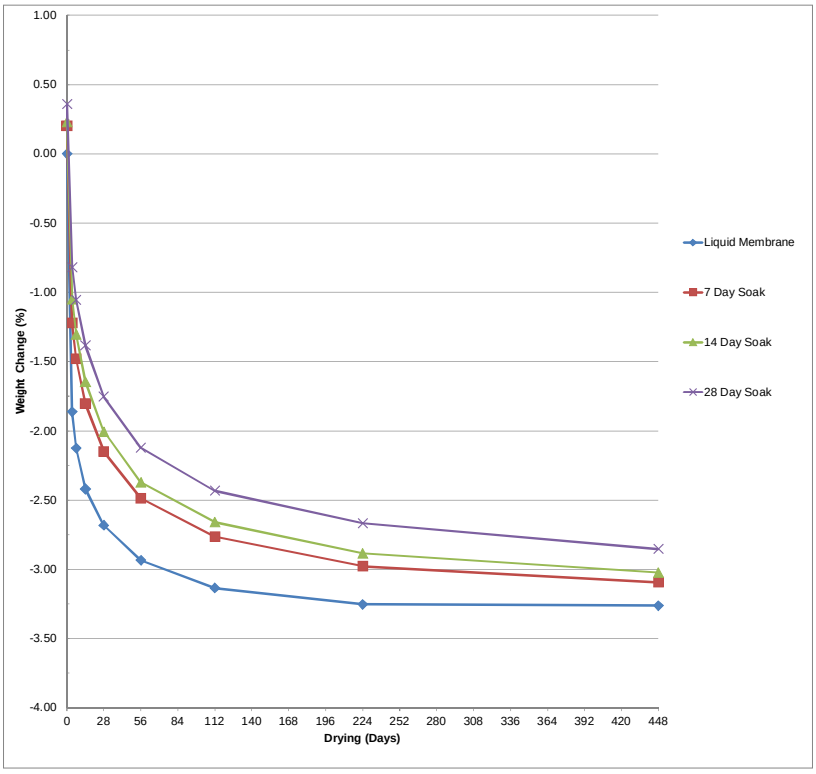


Figure 55: Weight Change vs Drying Days - Mix 9 (80/20 F-1)

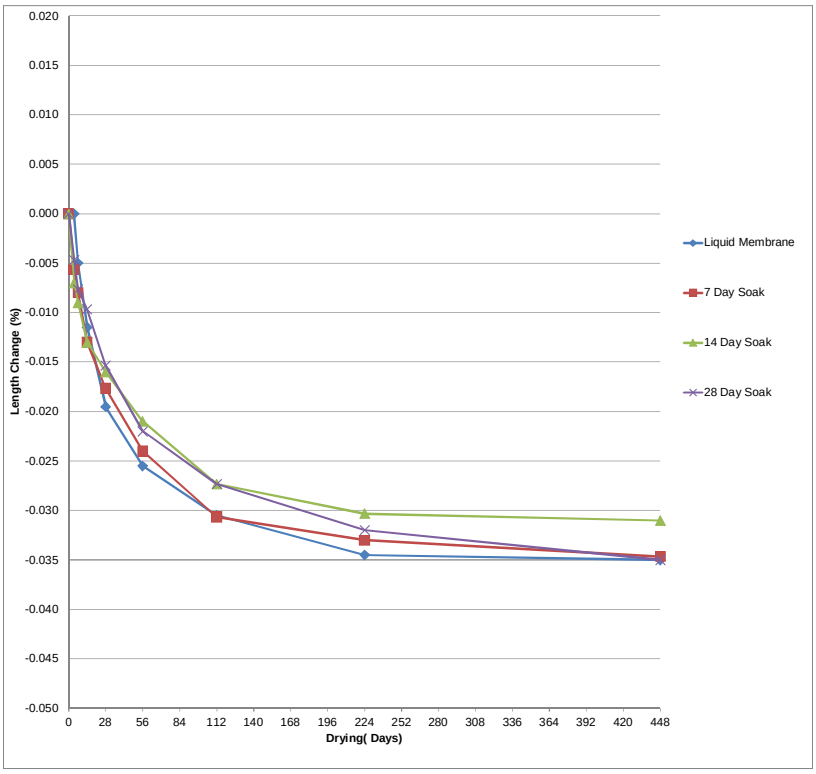


Figure 56: Length Change vs Drying Days - Mix 10 (75/25 F-1)

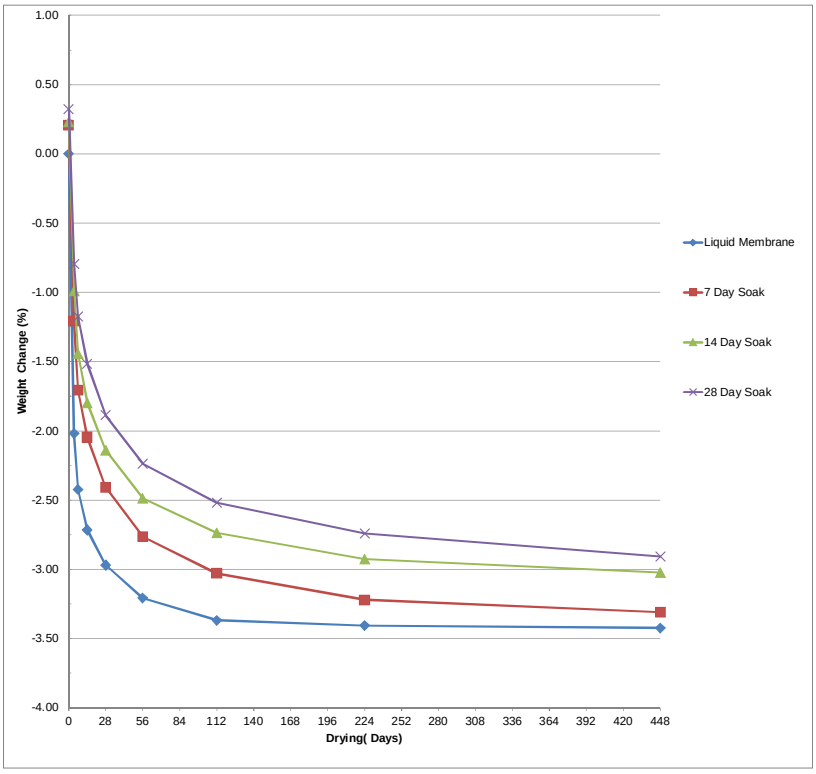


Figure 57: Weight Change vs Drying Days - Mix 10 (75/25 F-1)

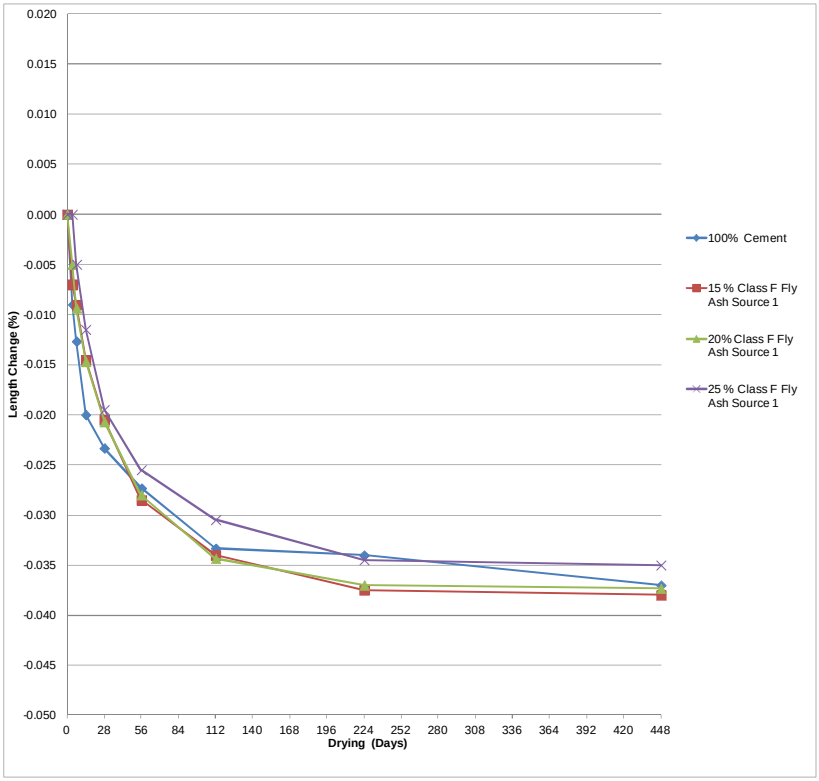


Figure 58: Length Change vs Drying Days - Mixes 8 thru 10 (Liquid membrane)

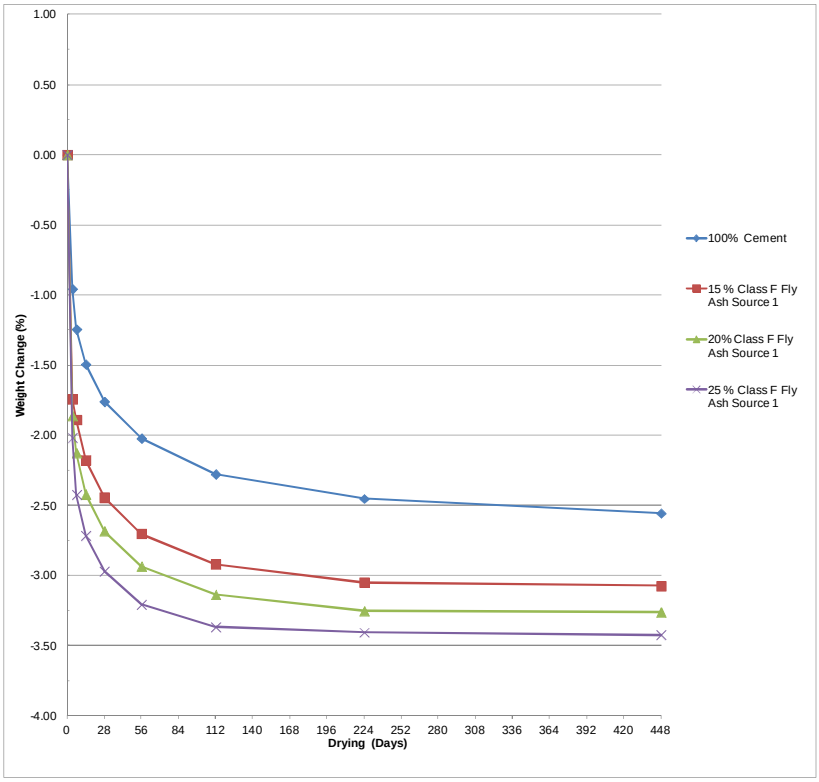


Figure 59: Weight Change vs Drying Days - Mixes 8 thru 10 (Liquid membrane)

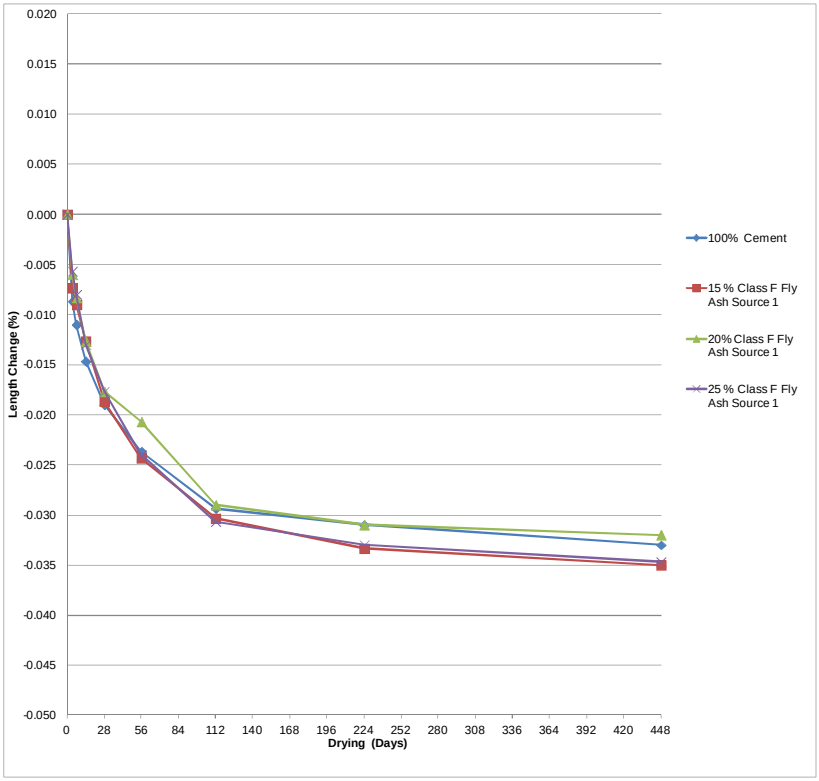


Figure 60: Length Change vs Drying Days - Mixes 8 thru 10 (7-Day Soak)

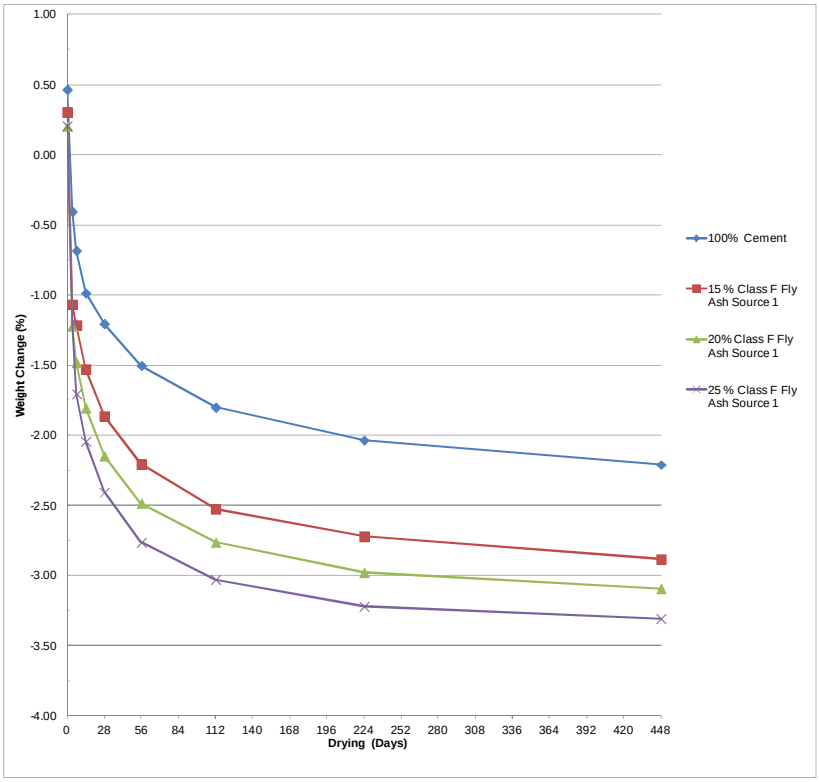


Figure 61: Weight Change vs Drying Days - Mixes 8 thru 10 (7-Day Soak)

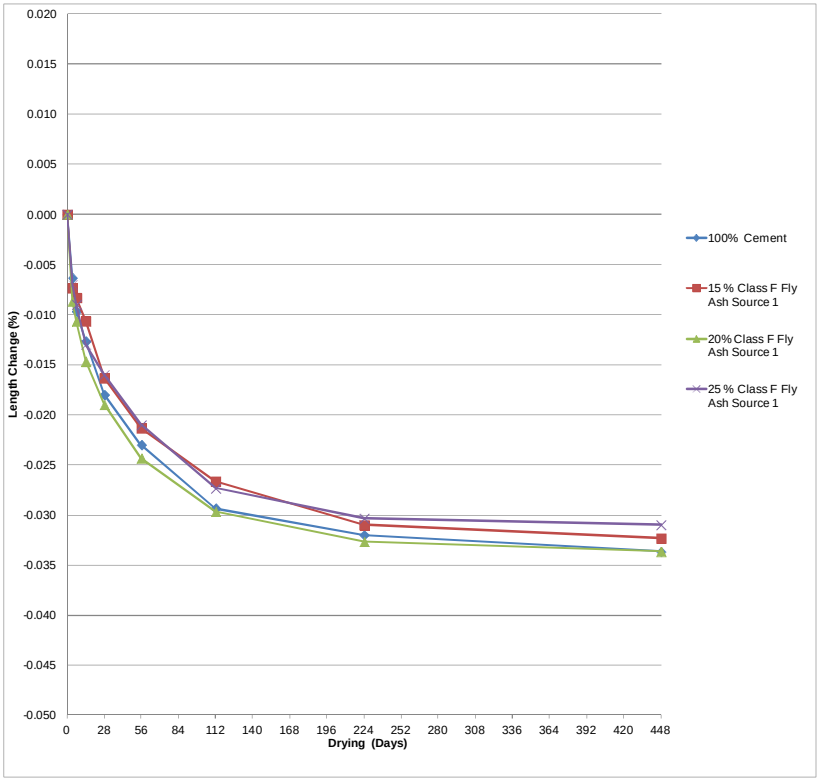


Figure 62: Length Change vs Drying Days - Mixes 8 thru 10 (14-Day Soak)

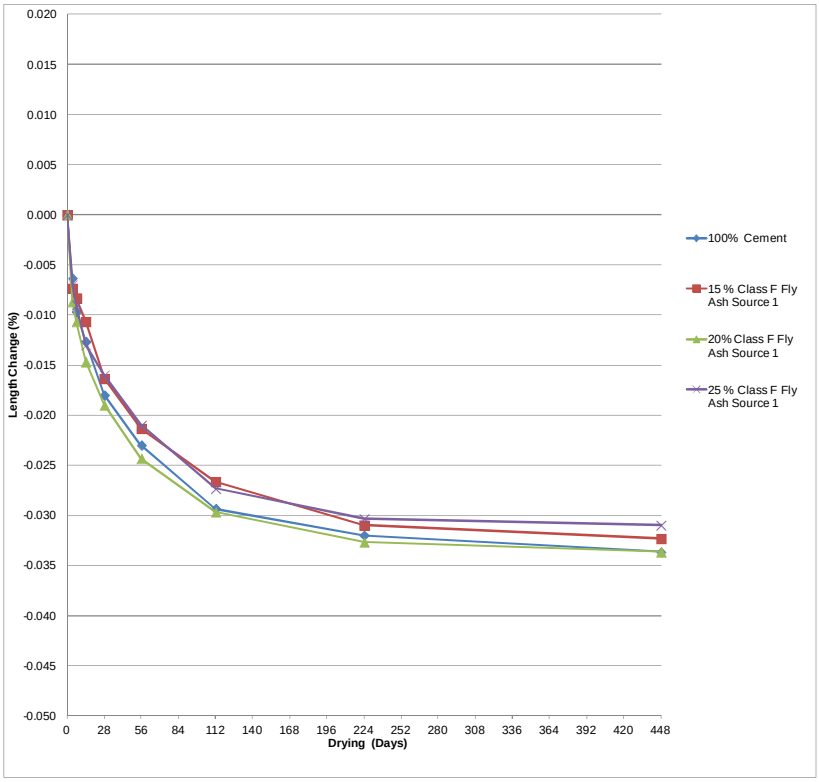


Figure 63: Weight Change vs Drying Days - Mixes 8 thru 10 (14-Day Soak)

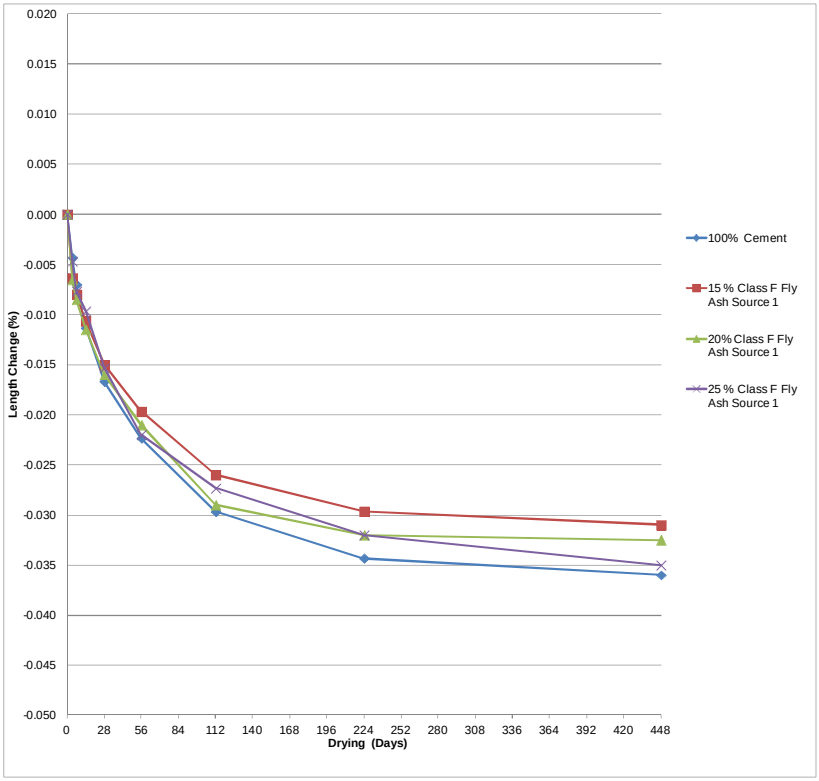


Figure 64: Length Change vs Drying Days - Mixes 8 thru 10 (28-Day Soak)

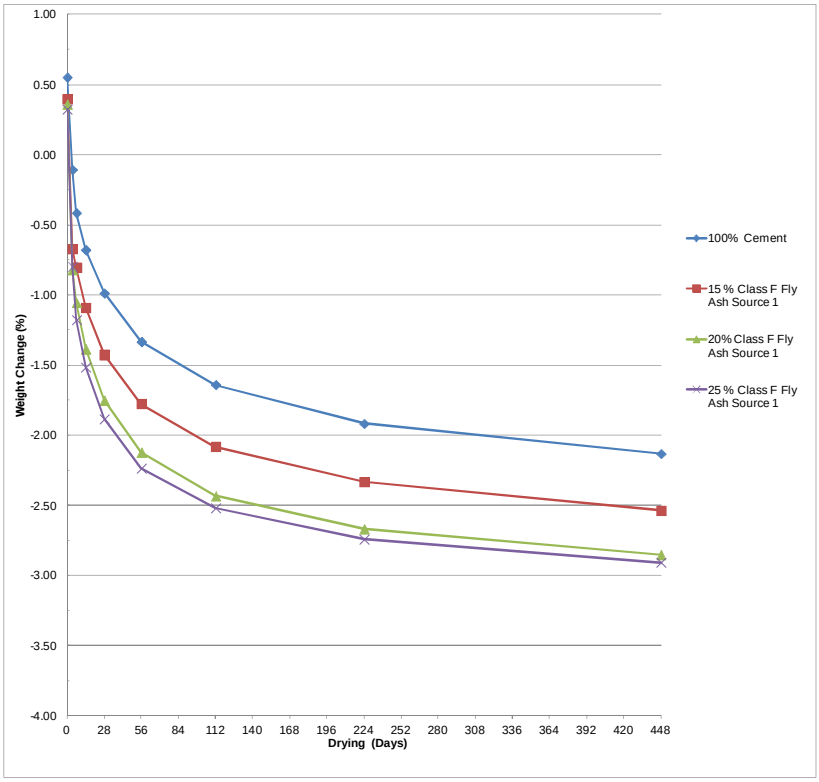


Figure 65: Weight Change vs Drying Days - Mixes 8 thru 10 (28-Day Soak)

Length Change Mixes 11, 12, and 13 – Class F Fly Ash Source 2 (F-2)

Mixes 11, 12, and 13 are similar to the control mix (Mix 1) except portland cement is replaced with 15, 20, or 25 percent Class F fly ash sampled from source 2, respectfully. Enough specimens were made for each mixture to test specimens for four curing conditions including; liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Length changes versus drying day results for each curing condition are presented in Figures 66, 68, and 70. Weight change vs drying day results for each curing condition are presented in Figures 67, 69, and 71. Length changes versus drying day results for each replacement rate are presented in Figures 72, 74, 76, and 78 for each curing condition. Weight change vs drying day results for each replacement rate are presented in Figures 73, 75, 77, and 79 for each curing condition.

The ultimate shrinkage ranged from (-) 0.0330 for Mix 12 (80/20, F-2, 28-day soak) to (-) 0.0420 for Mix 13 (75/25, F-2, 7-day soak). There was an increase in shrinkage when using Class F ash from source 2 when compared to the control mixture with the same curing conditions. This trend was typical for each curing method except for 28-day soak where there was a decrease in shrinkage. This decrease in shrinkage is presented in Figure 78. The only other exception is Mix 11 (85/15, F-2) where the shrinkage of the 14-day soak specimens was the same as the control mix. This exception is presented in Figure 76. In general, shrinkage increased with respect to the control mix when using Class F fly ash from source 2 to replace portland cement. This increase in shrinkage may have been a result of the higher w/cm ratio of these mixes compared to the w/cm ratio of the control mix.

There is a definitive trend established in weight change versus drying days. As moist curing increased, percent weight loss decreased. As replacement rate of Class F fly ash source 2 increased, percent weight loss increased. This trend is typical in all cases where Class F fly ash from source 2 was used. These trends are presented in Figures 73, 75, 77, and 79 for each curing condition. Therefore, data of this study show that percent weight loss is proportional to replacement rate of Class F fly ash sample from source 2. Weight loss increased as replacement rate of Class F fly ash from source 2 for portland cement increased. This increase in weight loss with increase in replacement rate is most likely caused by the increase in w/cm ratio.

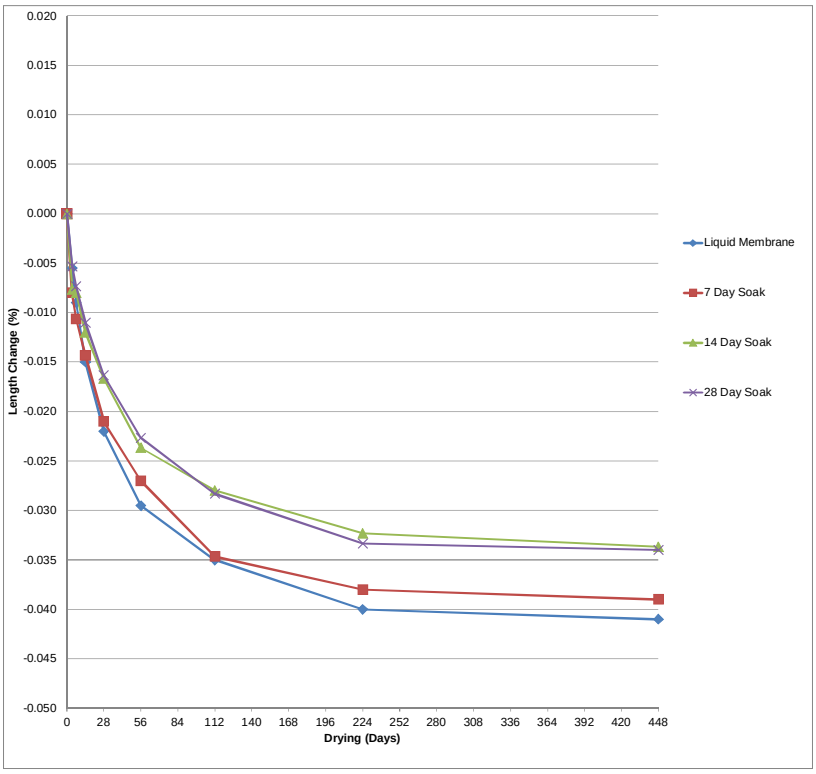


Figure 66: Length Change vs Drying Days - Mix 11 (85/15 F-2)

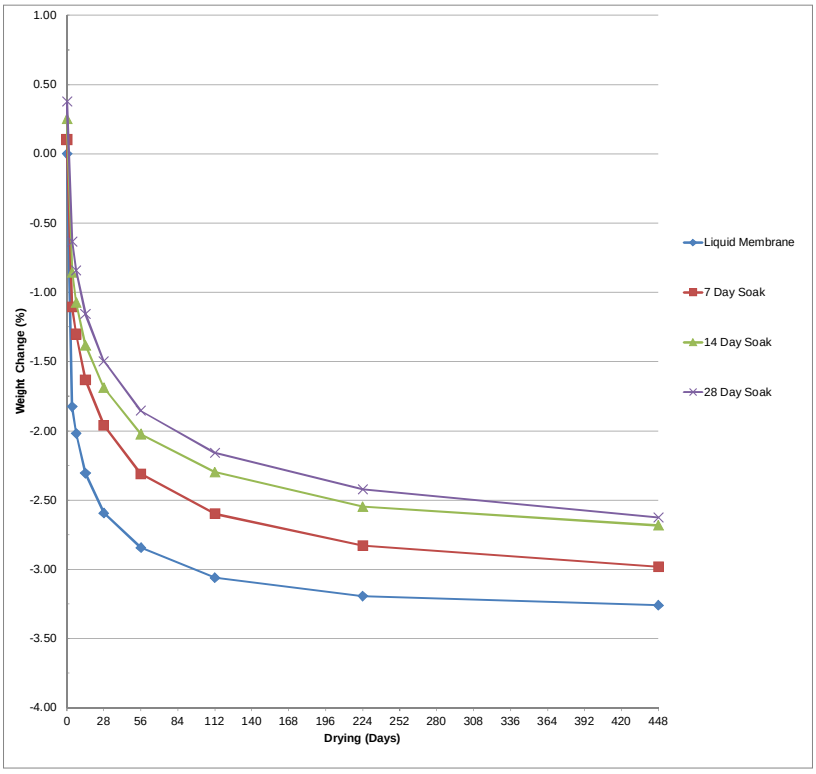


Figure 67: Weight Change vs Drying Days - Mix 11 (85/15 F-2)

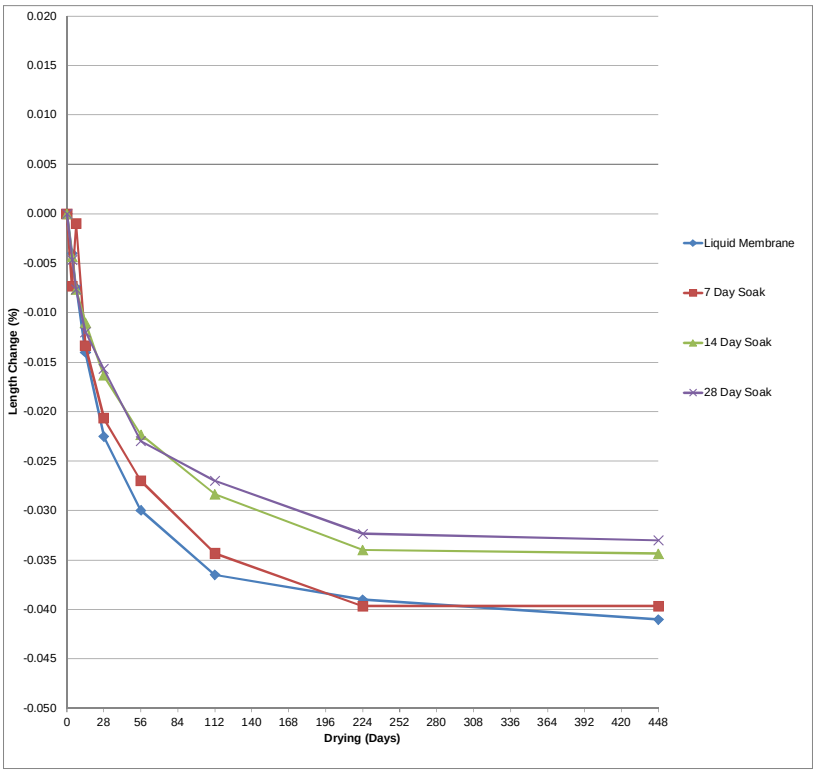


Figure 68: Length Change vs Drying Days - Mix 12 (80/20 F-2)

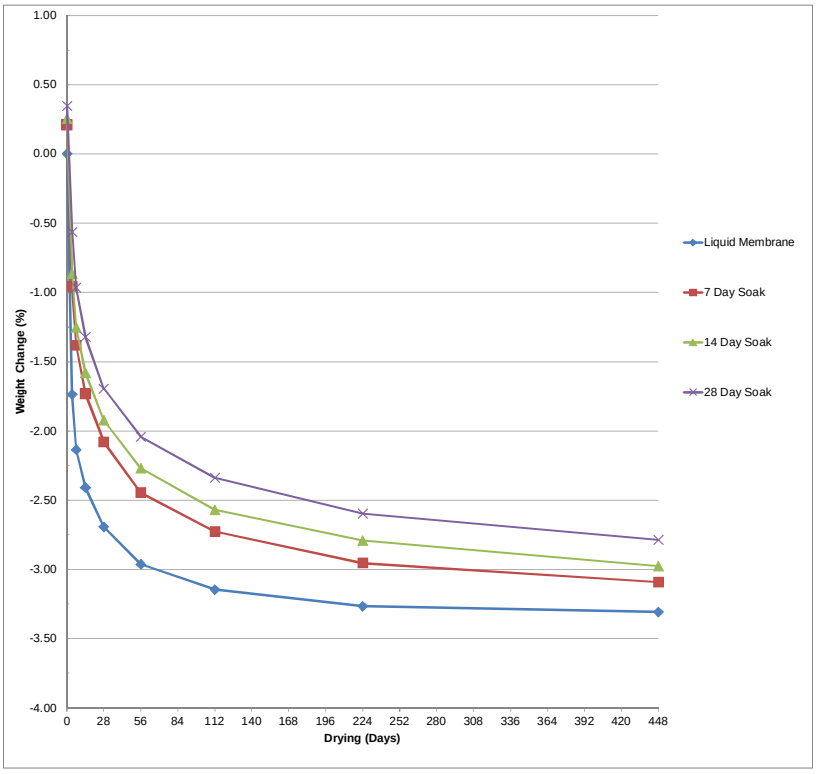


Figure 69: Weight Change vs Drying Days - Mix 12 (80/20 F-2)

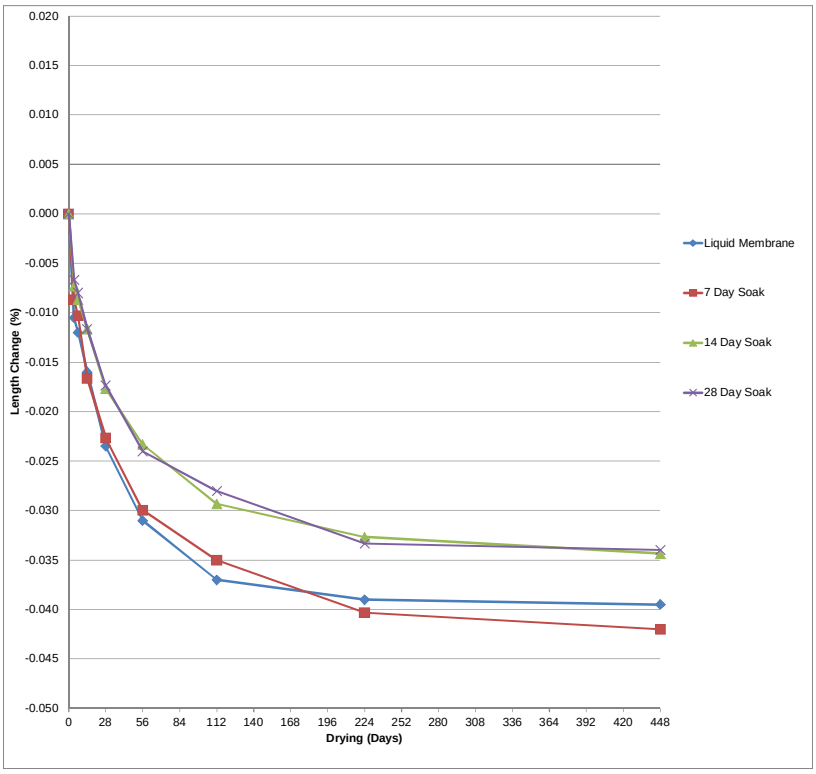


Figure 70: Length Change vs Drying Days - Mix 13 (75/25 F-2)

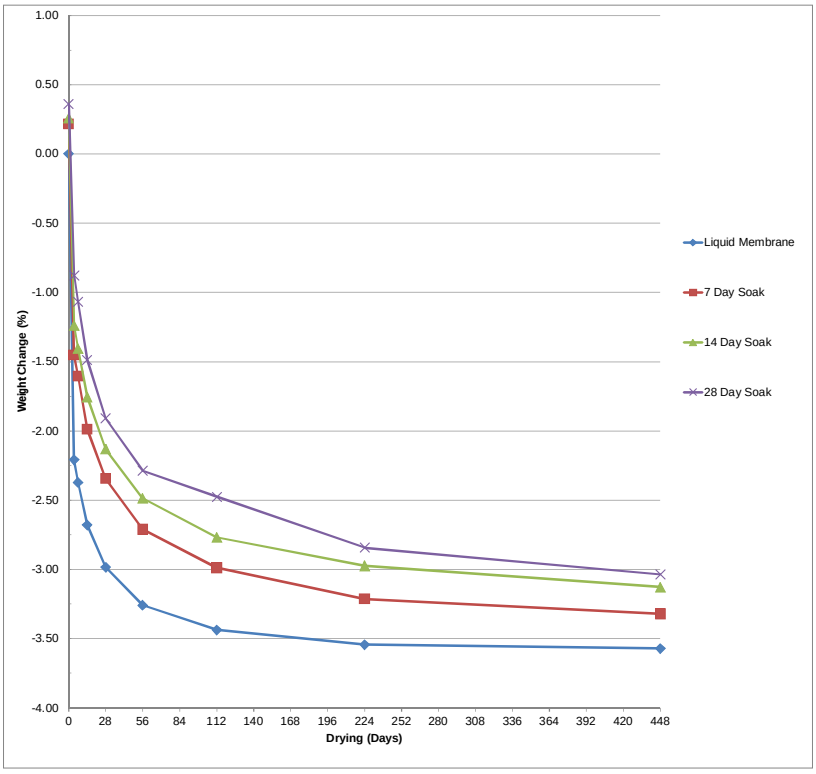


Figure 71: Weight Change vs Drying Days - Mix 13 (75/25 F-2)

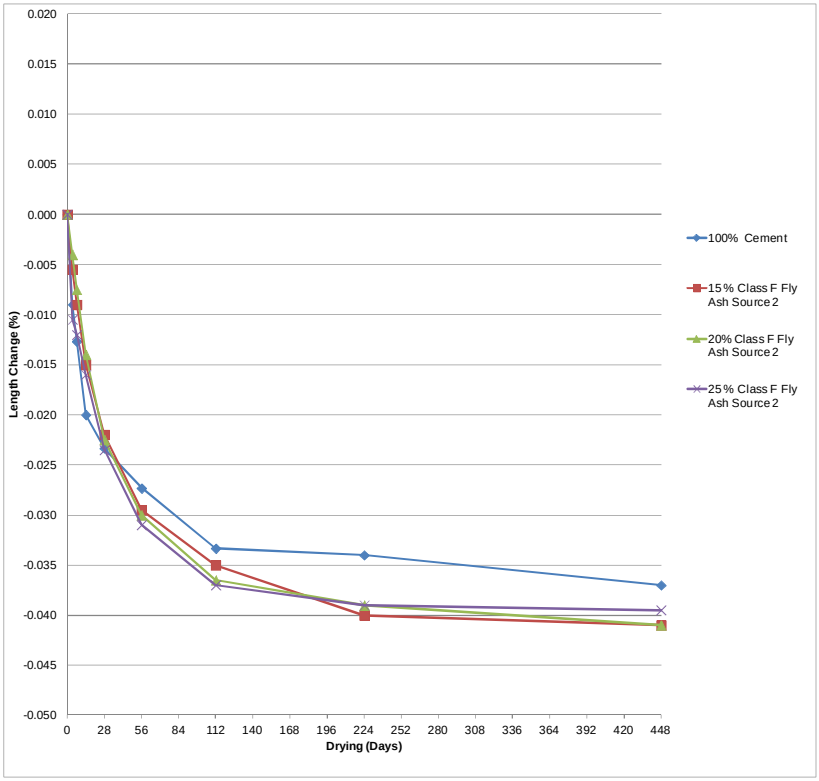


Figure 72: Length Change vs Drying Days - Mixes 11 thru 13 (Liquid membrane)

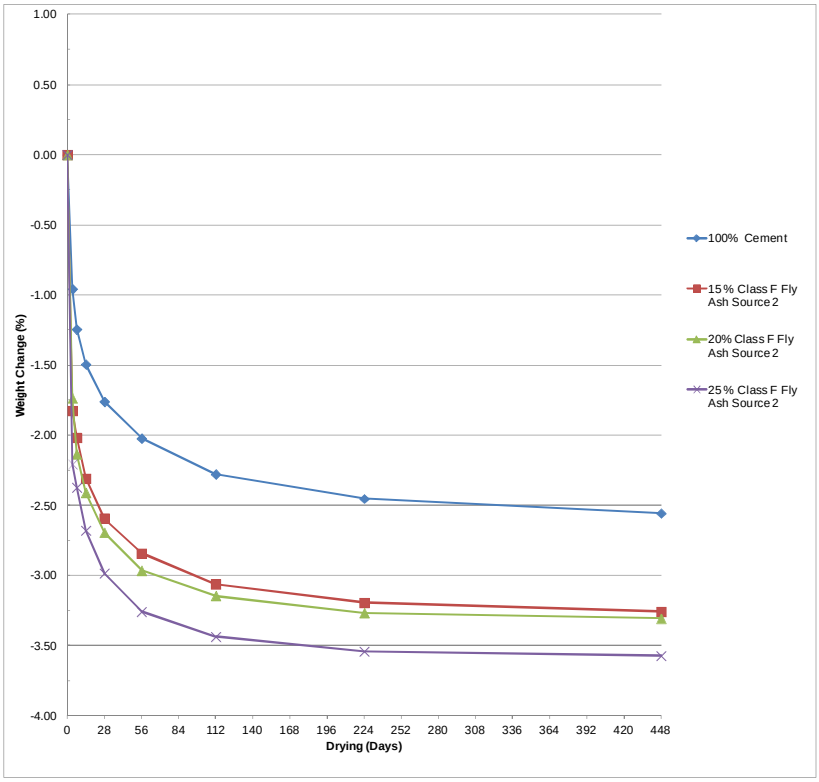


Figure 73: Weight Change vs Drying Days - Mixes 11 thru 13 (Liquid membrane)

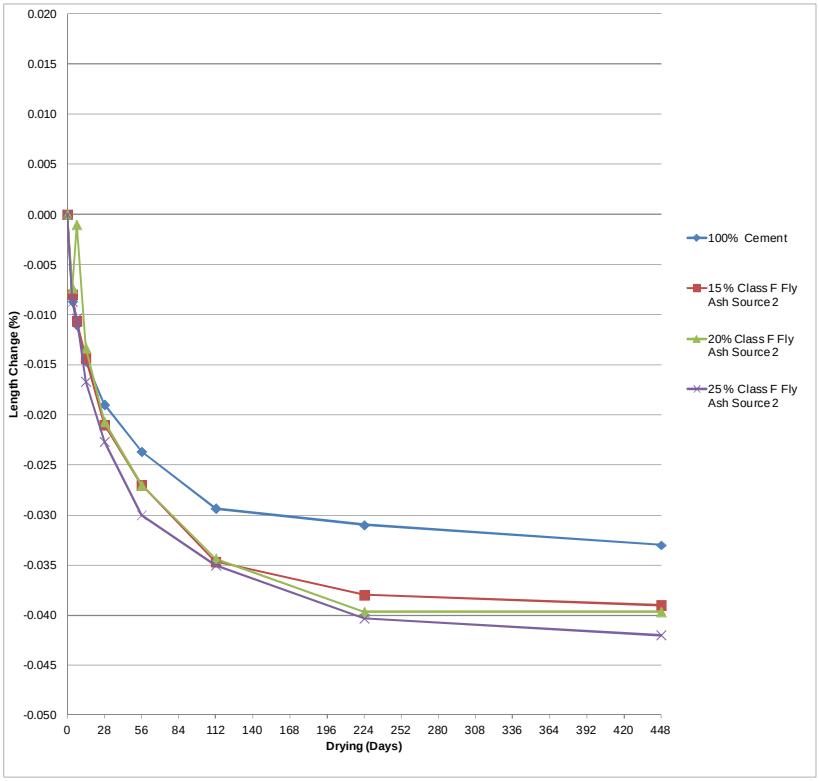


Figure 74: Length Change vs Drying Days - Mixes 11 thru 13 (7-Day Soak)

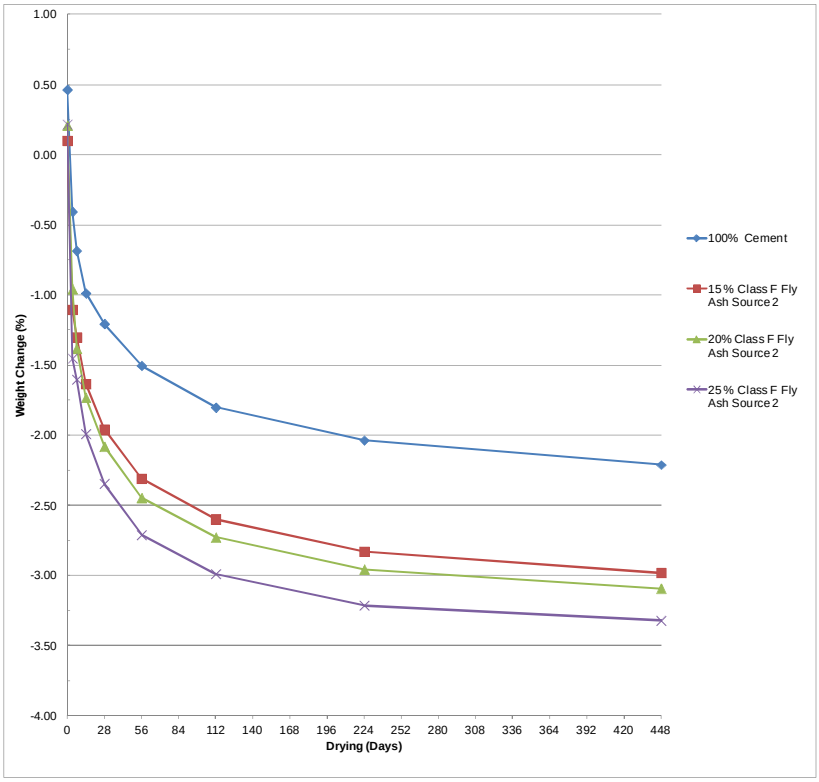


Figure 75: Weight Change vs Drying Days - Mixes 11 thru 13 (7-Day Soak)

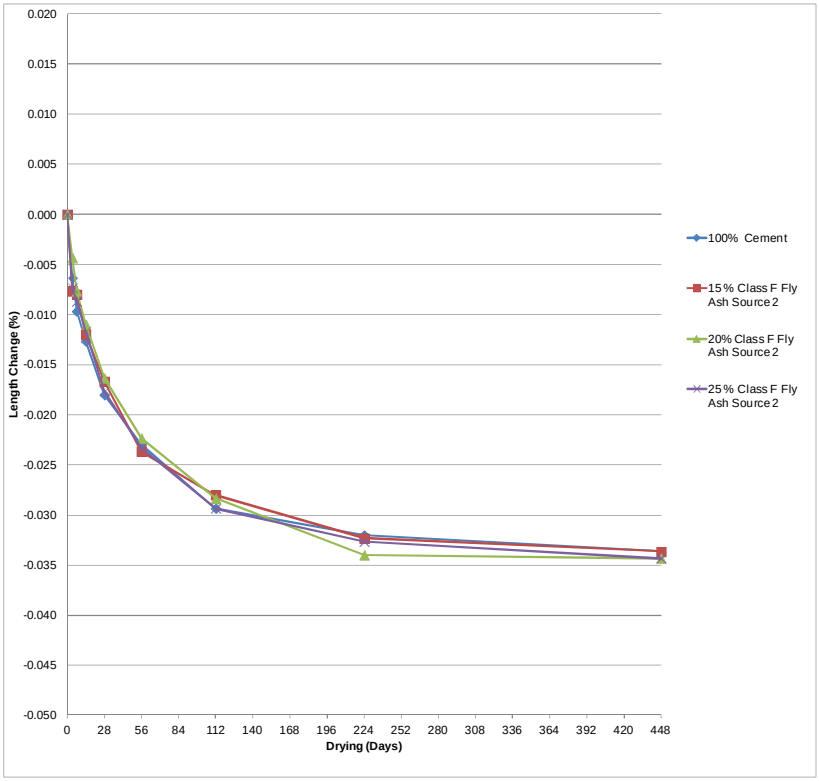


Figure 76: Length Change vs Drying Days - Mixes 11 thru 13 (14-Day Soak)

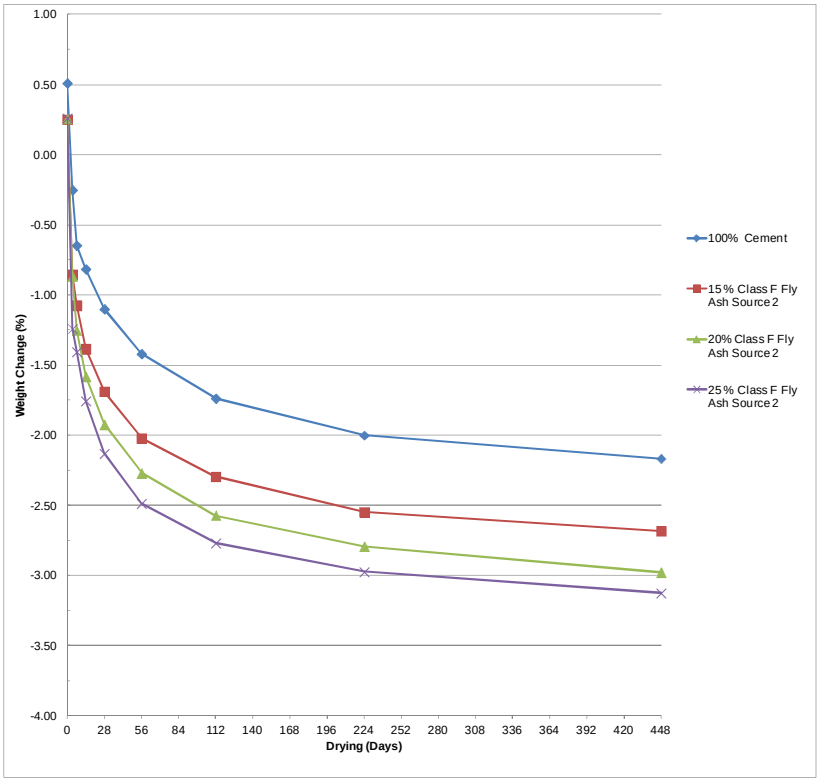


Figure 77: Weight Change vs Drying Days - Mixes 11 thru 13 (14-Day Soak)

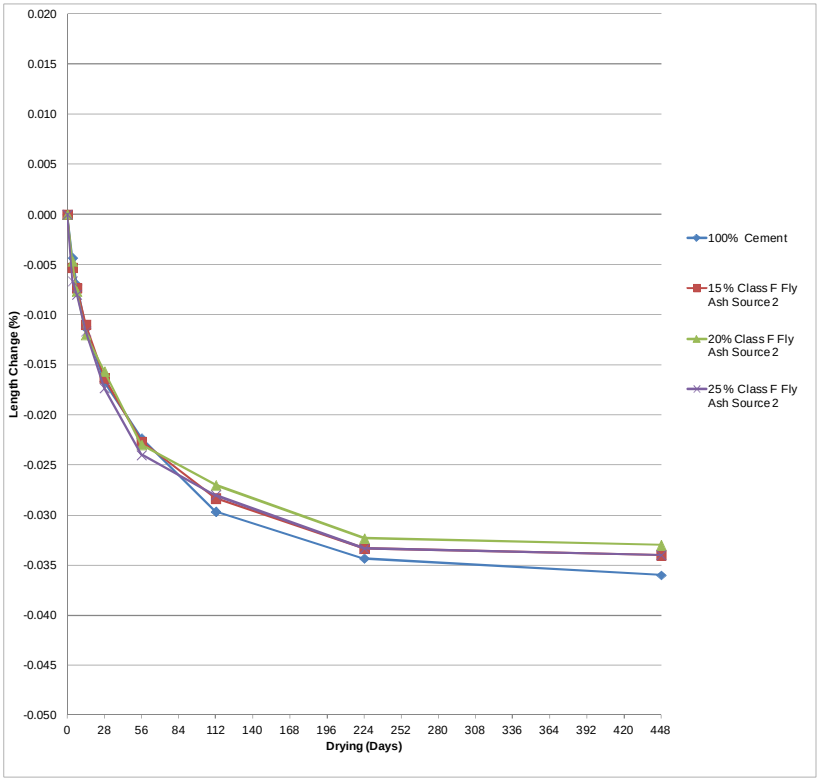


Figure 78: Length Change vs Drying Age - Mixes 11 thru 13 (28-Day Soak)

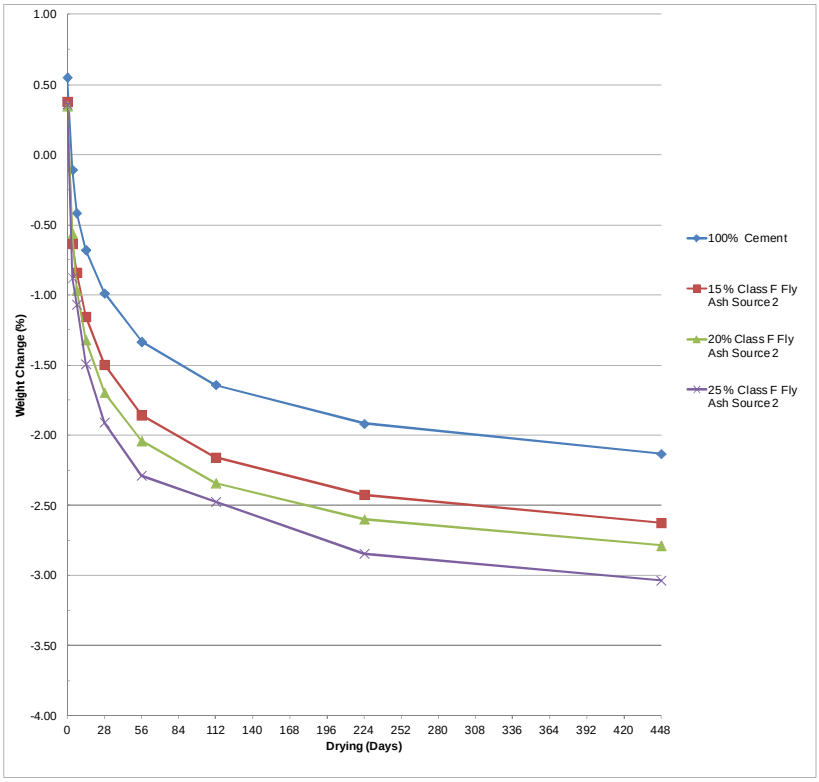


Figure 79: Weight Change vs Drying Age - Mixes 11 thru 13 (28-Day Soak)

Length Change Mixes 14, 15, and 16 – Slag Cement Source (S-1)

Mixes 14, 15, and 16 are similar to the control mix (Mix 1) except portland cement is replaced with 40, 45, or 50 percent slag cement sampled from source S-1, respectfully. Enough specimens were made for each mixture to test specimens for four curing conditions including; liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Length changes versus drying day results for each curing condition are presented in Figures 80, 82, and 84. Weight change vs drying day results for each curing condition are presented in Figures 81, 83, and 85. Length changes versus drying day results for each replacement rate are presented in Figures 86, 88, 90, and 92 for each curing condition. Weight change versus drying day results each replacement rate are presented in Figures 87, 89, 91, and 93 for each curing condition.

The ultimate shrinkage for mixes proportioned with slag cement ranged from (-) 0.0237 for Mix 14 (60/40, S-1, 14-day soak) to (-) 0.0310 for Mix 16 (50/50, S-1, liquid membrane). There was a decrease in shrinkage when using slag cement from source S-1 when compared to the control mixture. This trend was typical for each curing method. This decrease in shrinkage is presented in Figures 86 through 92. There are two other trends associated with replacement rate of slag cement. Shrinkage decreased as replacement rate increased when specimens were cured with 7-day soak as presented in Figure 88. Shrinkage increased as replacement rate increased when specimens were cured with 14-day soak Figure 90. Mixes proportioned with slag cement provided the lowest shrinkage values compared to mixes proportioned with Class C fly ash, Class F fly ash, and the control mix.

There is a definitive trend established in weight change versus drying days. As moist curing increased, percent weight loss decreased. This trend is presented in Figures 81, 83, and 85. There were no obvious trends associated with replacement rate and weight change. However, mixes proportioned with slag cement provided the lowest weight loss values compared to mixes proportioned with Class C fly ash, Class F fly ash, and the control mix.

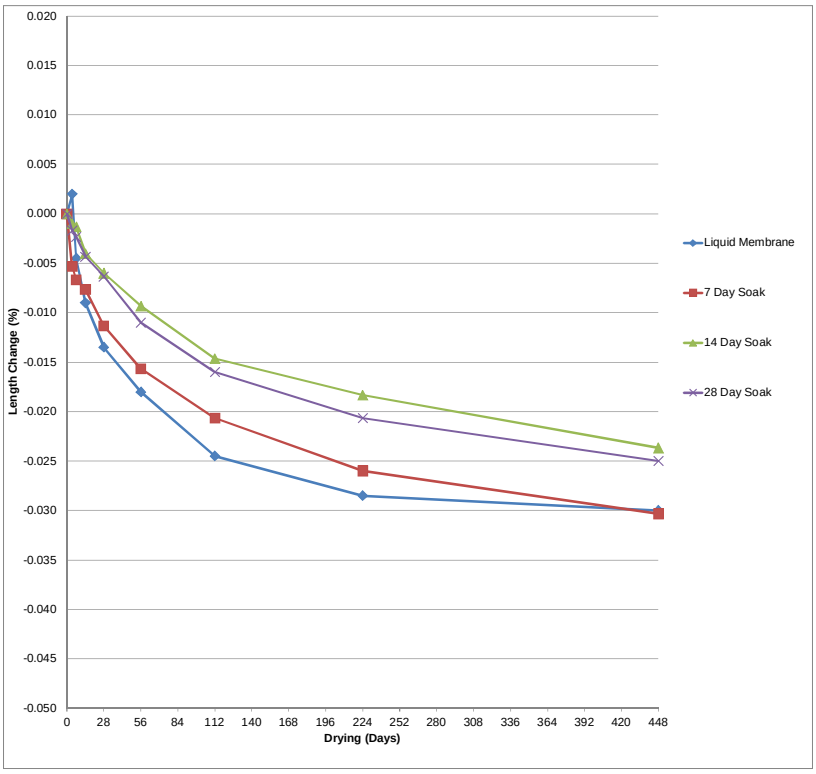


Figure 80: Length Change vs Drying Days - Mix 14 (60/40 S-1)

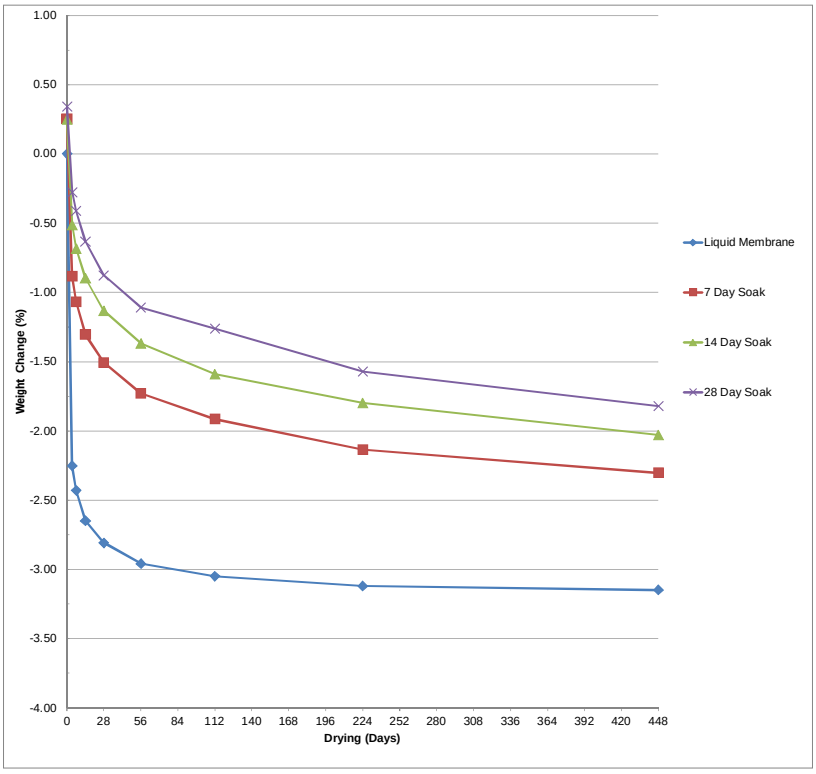


Figure 81: Weight Change vs Drying Days - Mix 14 (60/40 - S-1)

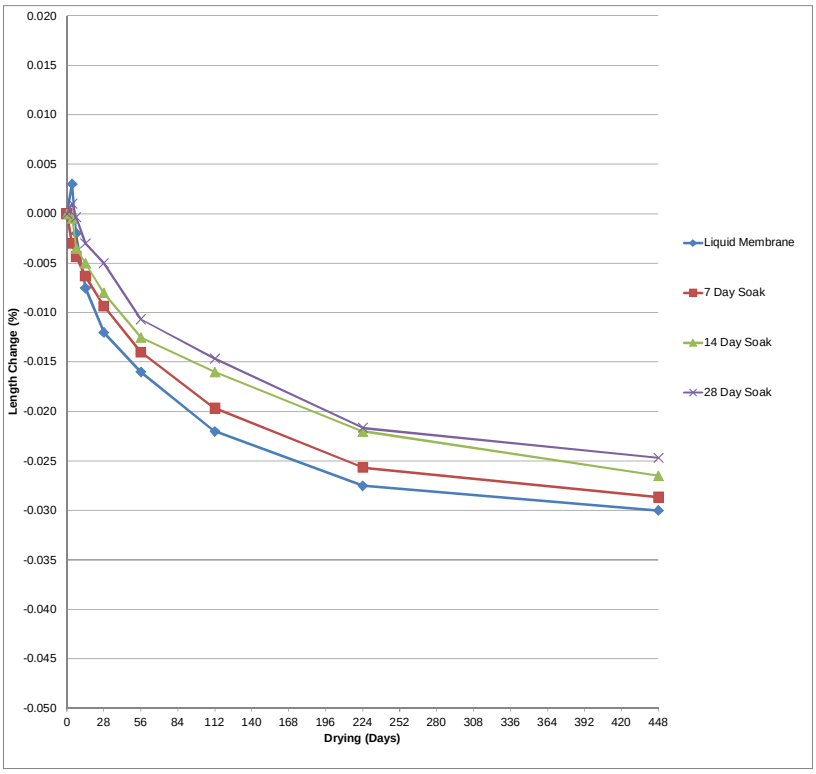


Figure 82: Length Change vs Drying Days - Mix 15 (55/45 S-1)

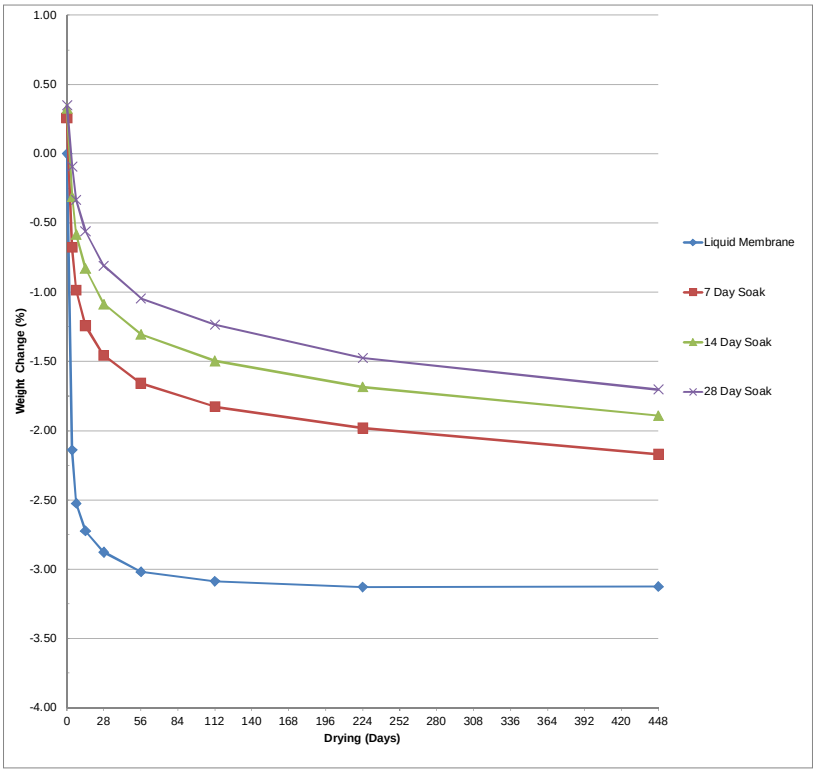


Figure 83: Weight Change vs Drying Days - Mix 15 (55/45 S-1)

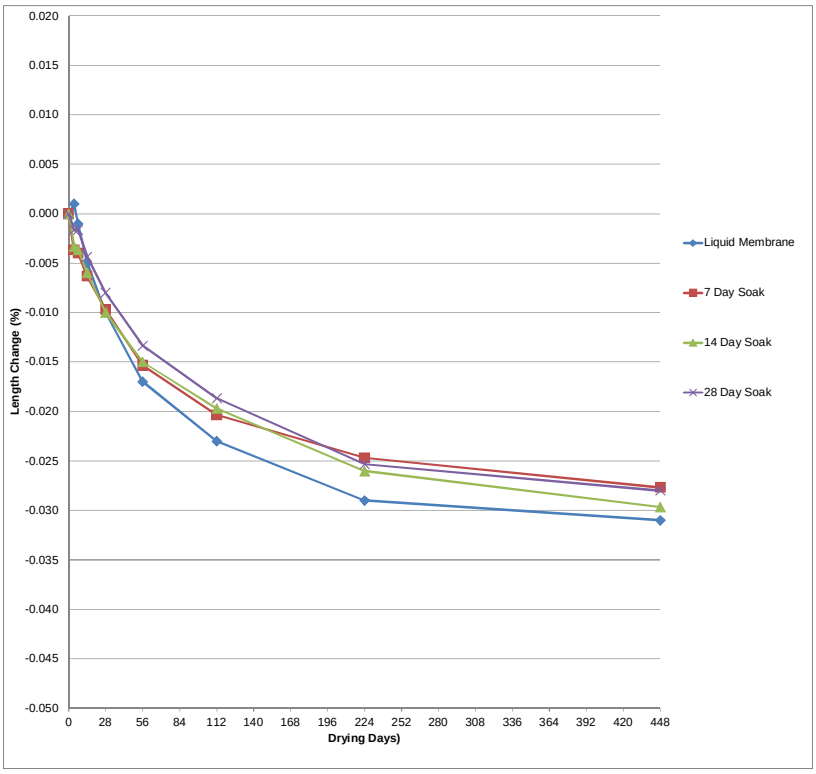


Figure 84: Length Change vs Drying Days - Mix 16 (50/50 S-1)

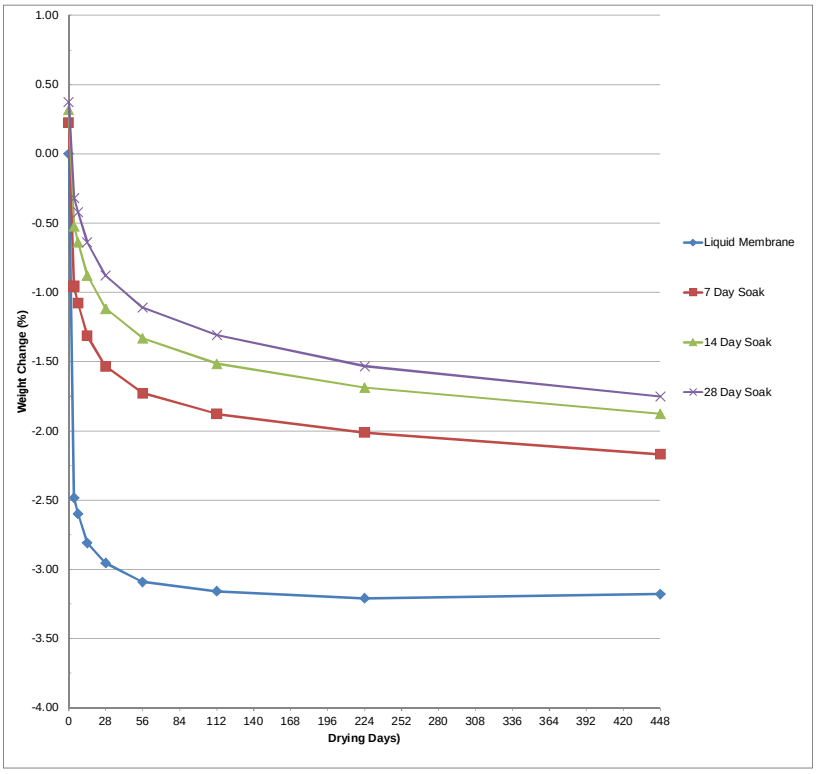


Figure 85: Weight Change vs Drying Days - Mix 16 (50/50 S-1)

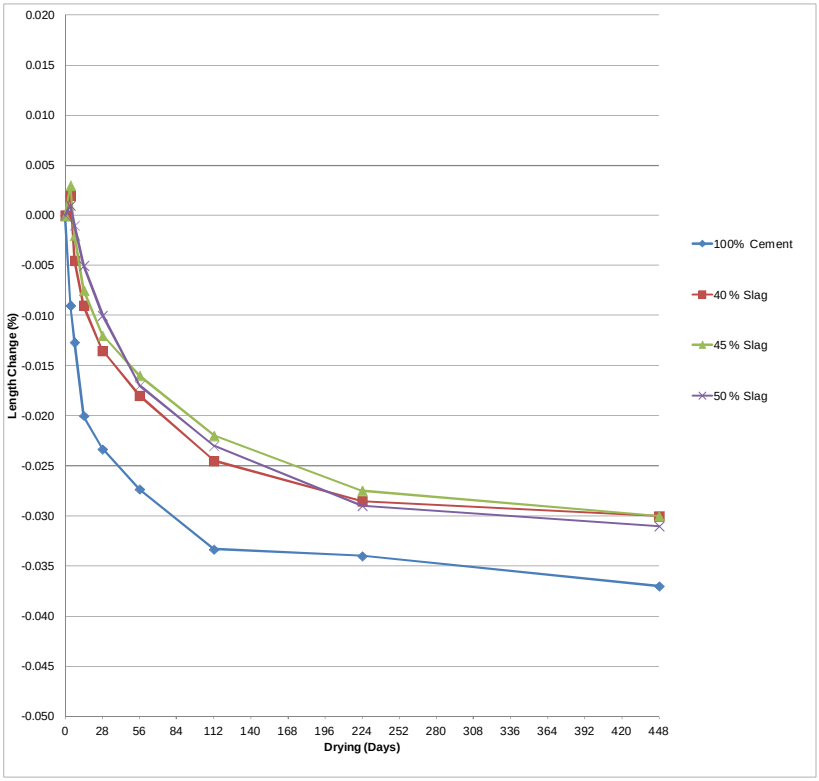


Figure 86: Length Change vs Drying Days - Mixes 14 thru 16 (Liquid membrane)

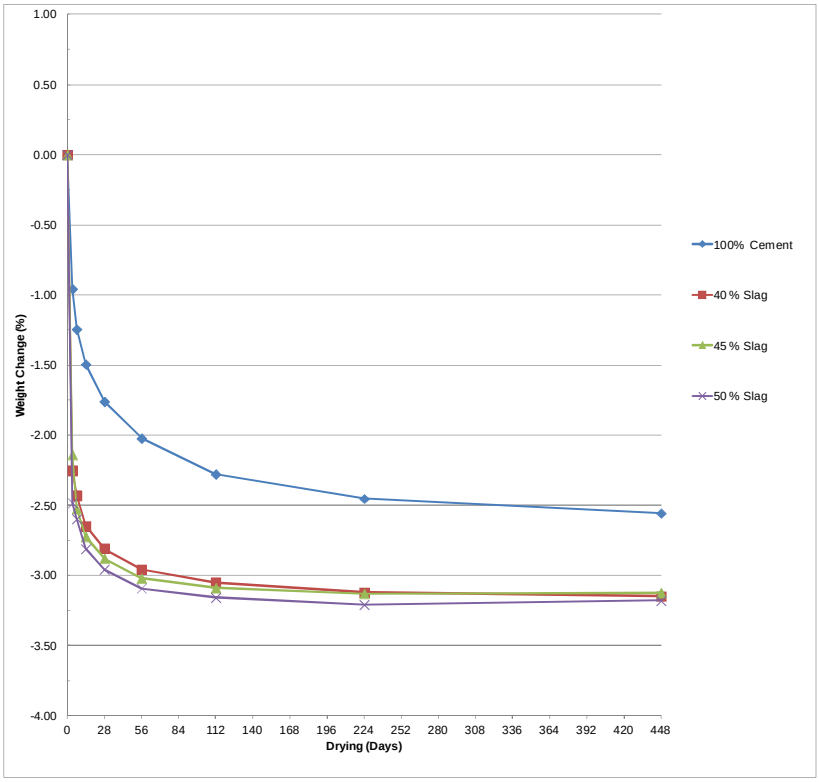


Figure 87: Weight Change vs Drying Days - Mixes 14 thru 16 (Liquid membrane)

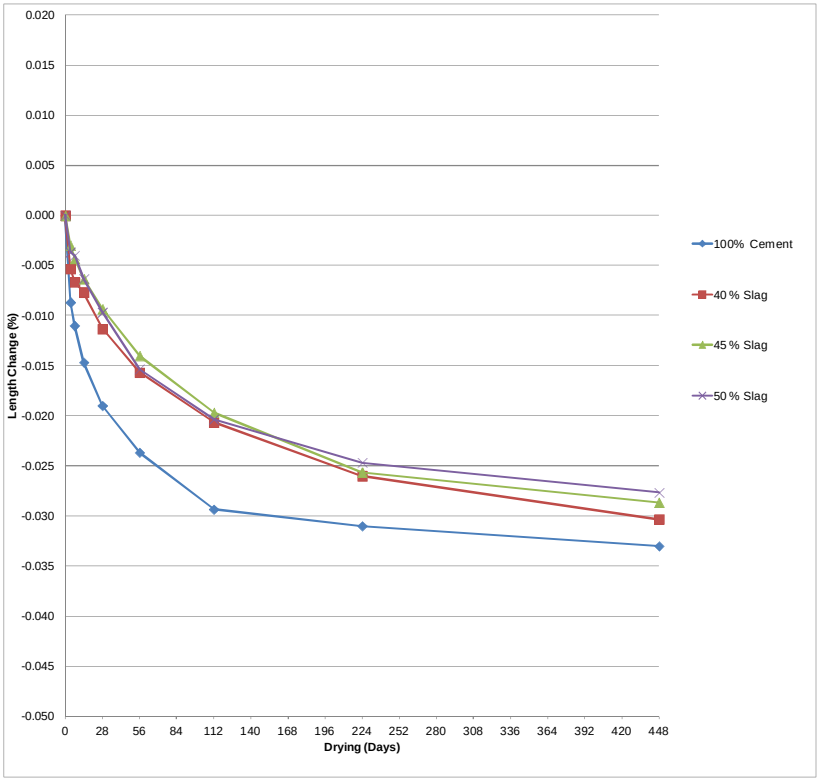


Figure 88: Length Change vs Drying Days - Mixes 14 thru 16 (7-Day Soak)

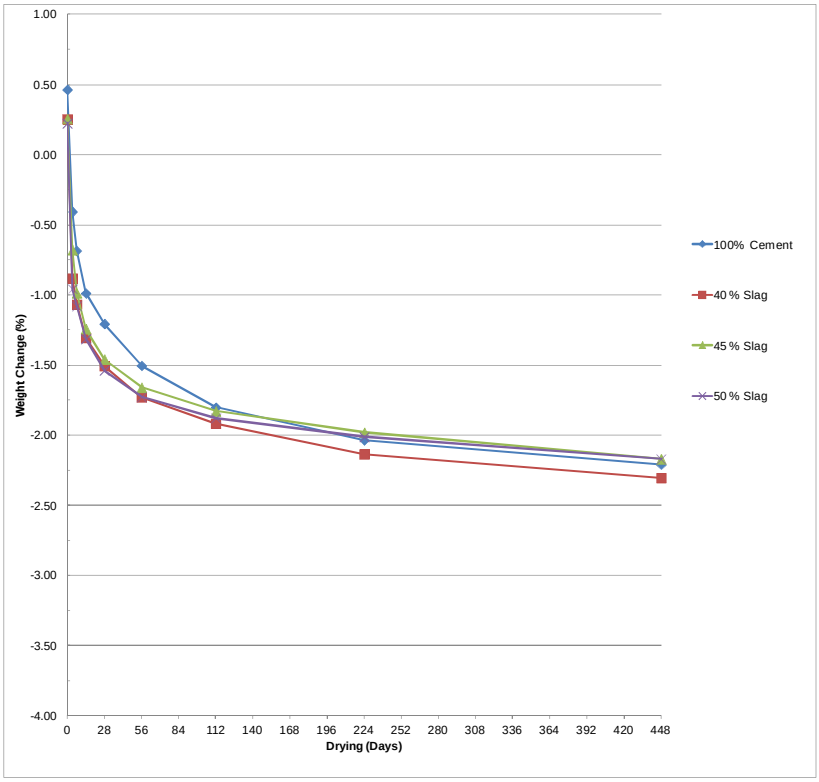


Figure 89: Weight Change vs Drying Days - Mixes 14 thru 16 (7-Day Soak)

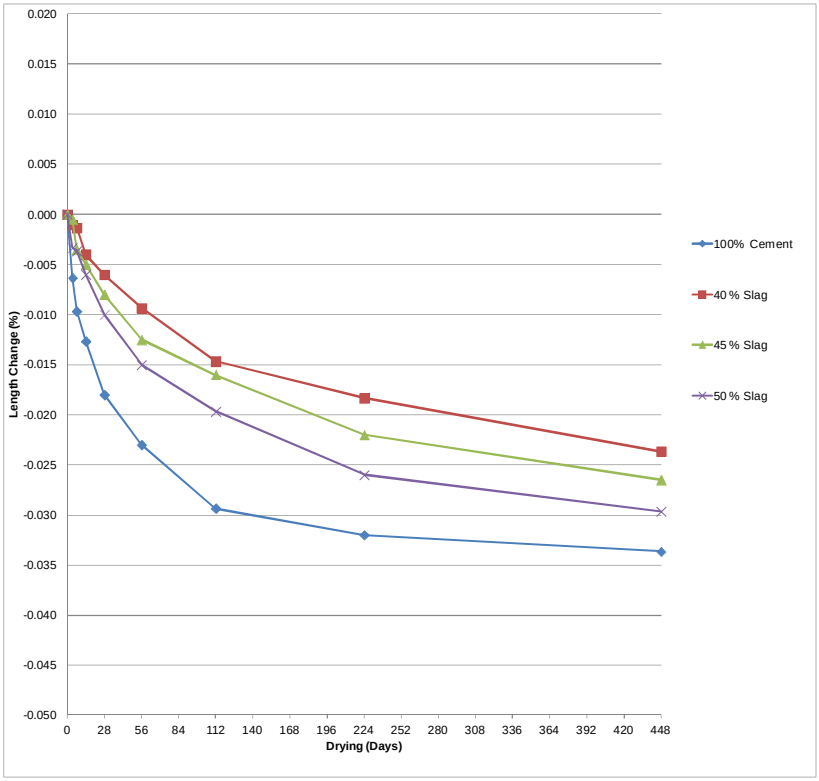


Figure 90: Length Change vs Drying Days - Mixes 14 thru 16 (14-Day Soak)

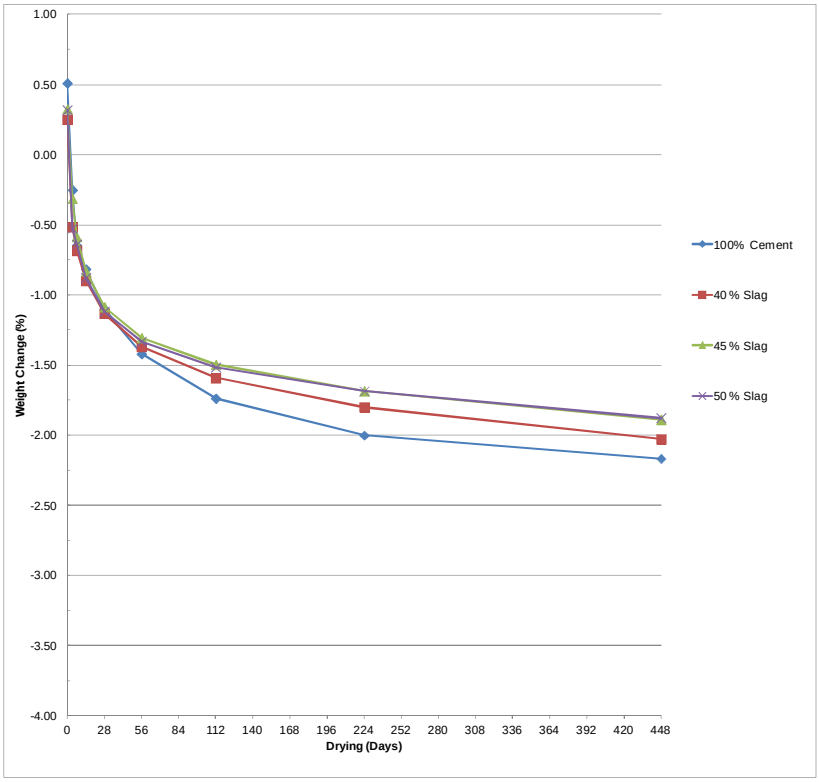


Figure 91: Weight Change vs Drying Days - Mixes 14 thru 16 (14-Day Soak)

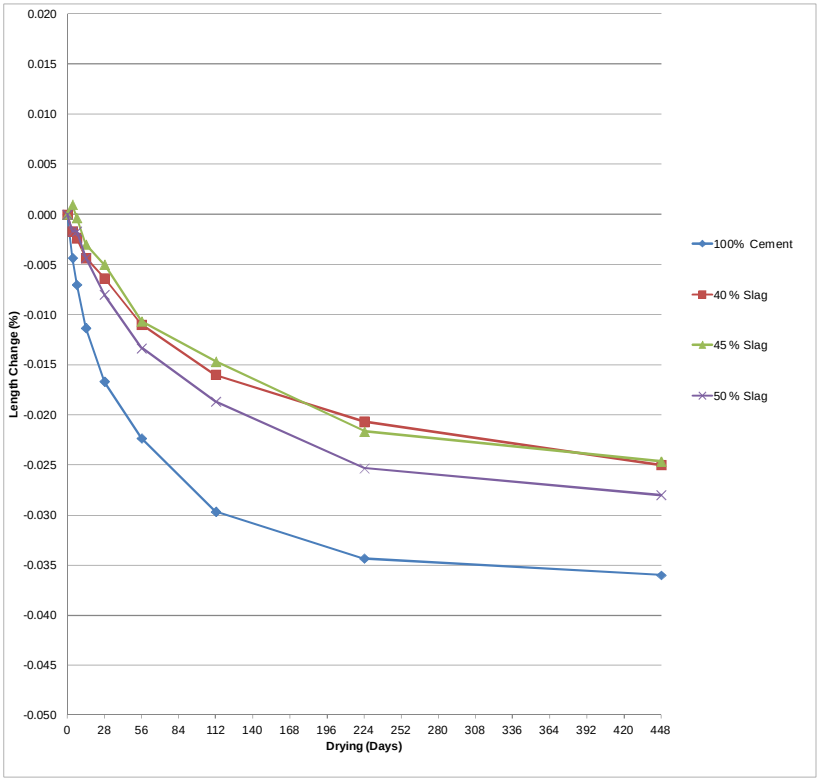


Figure 92: Length Change vs Drying Age - Mixes 14 thru 16 (28-Day Soak)

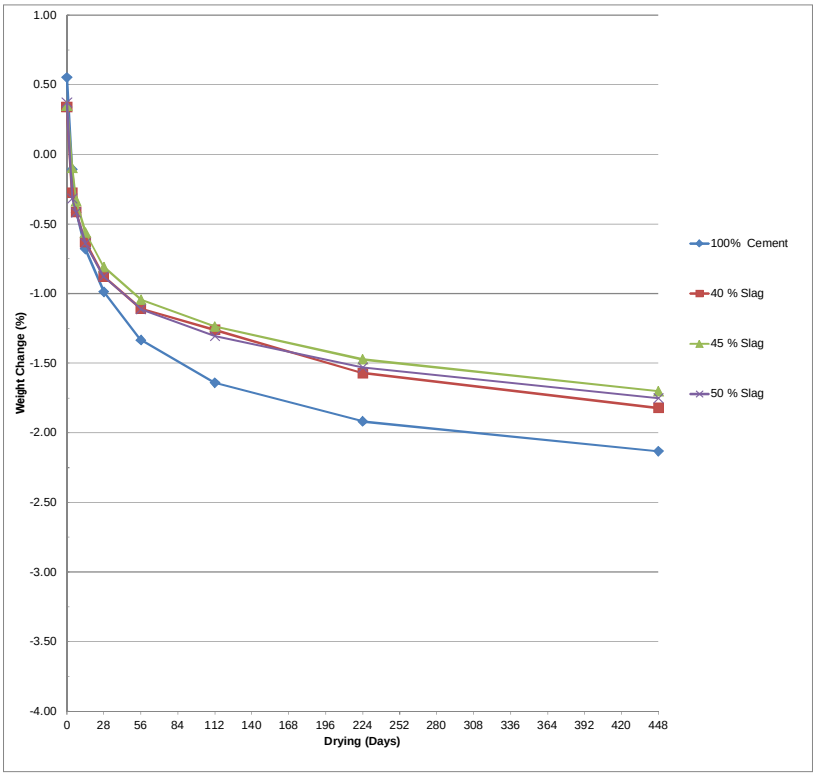


Figure 93: Weight Change vs Drying Age - Mixes 14 thru 16 (28-Day Soak)

Length Change and Weight Change - Average Values for Each SCM Type

All experimental mixes were divided into categories according to type of SCM in order to calculate average length and weight change for each type SCM regardless of the replacement rate. Types of SCMs in this study include Class C fly ash, Class F fly ash, and slag cement. Figures 94 through 101 present results of these averages grouped by the method of curing. These average values are also tabulated in Tables 21 and 22.

Length and Weight Change - Liquid membrane

Figure 94 presents results from averaging length change data for each SCM type and comparing this average to the control mix. The average ultimate length change in order of increasing shrinkage was (-) 0.0303 with slag, (-) 0.0332 with Class C fly ash, (-) 0.0370 with 100 percent portland cement, and (-) 0.0386 with Class F fly ash. Class F fly ash was the only SCM type that had more shrinkage of average than the control mix. Slag cement was the best performing SCM type with an ultimate shrinkage of 81.9 percent of the control mix.

Figure 95 present results from averaging weight change data for each SCM type and comparing this average to the control mix. Weight change in order of increasing percent weight change was (-) 2.56 with 100 percent portland cement, (-) 2.98 with Class C fly ash, (-) 3.15 with slag cement, and (-) 3.32 with Class F fly ash. All SCM types had more weight loss than the control mix. Class C fly ash was the SCM that had the least percent weight loss.

Length and Weight Change - 7-Day Soak

Figure 96 presents results from averaging length change data for each SCM type and comparing this average to the control mix. The average ultimate length change in order of increasing shrinkage was (-) 0.0289 with slag, (-) 0.0330 with 100 percent portland cement, (-) 0.03343 with Class C fly ash, and (-) 0.0371 with Class F fly ash. Class C and Class F fly ash had more shrinkage than the control mix. Slag cement was the best performing SCM type with an ultimate shrinkage of 87.6 percent of the control mix.

Figure 97 present results from averaging weight change data for each SCM type and comparing this average to the control mix. Weight change in order of increasing percent weight change was (-) 2.21 with portland cement, (-) 2.21 with slag cement, (-) 2.76 Class C fly ash and (-) 3.11 with Class F fly ash. All SCM types had more weight loss than the control mix except

for slag cement which had the same weight loss as the control mix. Slag cement has the least weight loss of all SCMs and this weight loss was equal to the weight loss of the control mix.

Length and Weight Change - 14-Day Soak

Figure 98 presents results from averaging length change data for each SCM type and comparing this average to the control mix. The ultimate length change in order of increasing shrinkage was (-) 0.0266 with slag, (-) 0.0332 with Class F fly ash, (-) 0.0337 with 100 percent portland cement, and (-) 0.0338 with Class C fly ash. These data indicate that there is little difference in ultimate shrinkage between 100 percent portland cement and Class C and F fly ash. Slag cement was the best performing SCM type with an ultimate shrinkage of 78.9 percent of the control mix.

Figure 99 present results from averaging weight change data for each SCM type and comparing this average to the control mix. Weight change in order of increasing percent weight change (-) 1.93 slag cement, (-) 2.17 with 100 percent cement, (-) 2.59 with Class C fly ash, and (-) 2.93 with Class F fly ash. All SCM types had more weight loss than the control mix except for slag cement which had 88.9 percent of the weight loss of the control mix.

Length and Weight Change - 28-Day Soak

Figure 100 presents results from averaging length change data for each SCM type and comparing this average to the control mix. The ultimate length change in order of increasing shrinkage was (-) 0.0259 with slag, (-) 0.0333 with Class F fly ash, (-) 0.0360 with 100 percent portland cement, and (-) 0.0373 with Class C fly ash. Mixes with Class F fly ash and slag cement had less shrinkage than the control mix. Class C fly ash had more shrinkage than the control mix. Slag cement was the best performing SCM type with an ultimate shrinkage 71.9 percent of the control mix.

Figure 101 present results from averaging weight change data for each SCM type and comparing this average to the control mix. Weight change in order of increasing percent weight change (-) 1.76 slag cement, (-) 2.13 with 100% cement, (-) 2.53 with Class C fly ash, and (-) 2.79 with Class F fly ash. All SCM types had more weight loss than the control mix except for slag cement which had 82.6 percent of the weight loss of the control mix.

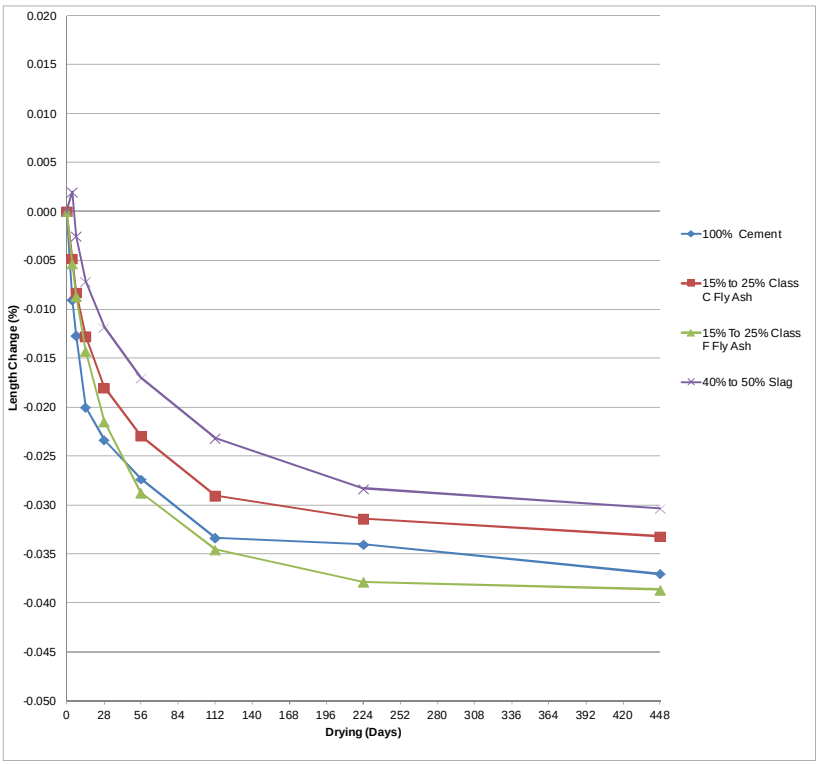


Figure 94: Length Change vs Drying Days - All Mixes (Liquid membrane)

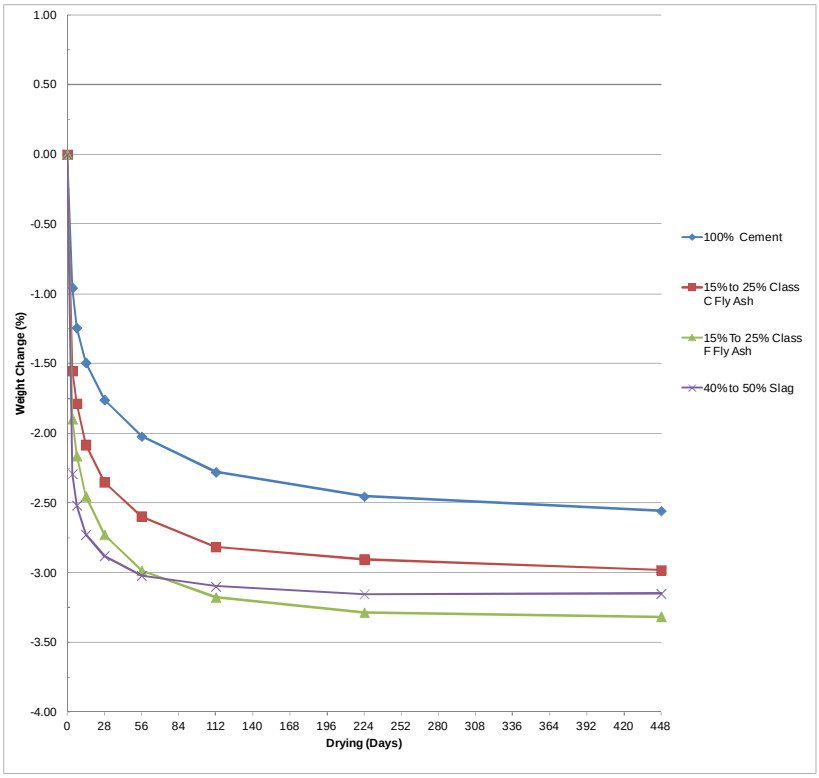


Figure 95: Weight Change vs Drying Days - All Mixtures (Liquid membrane)

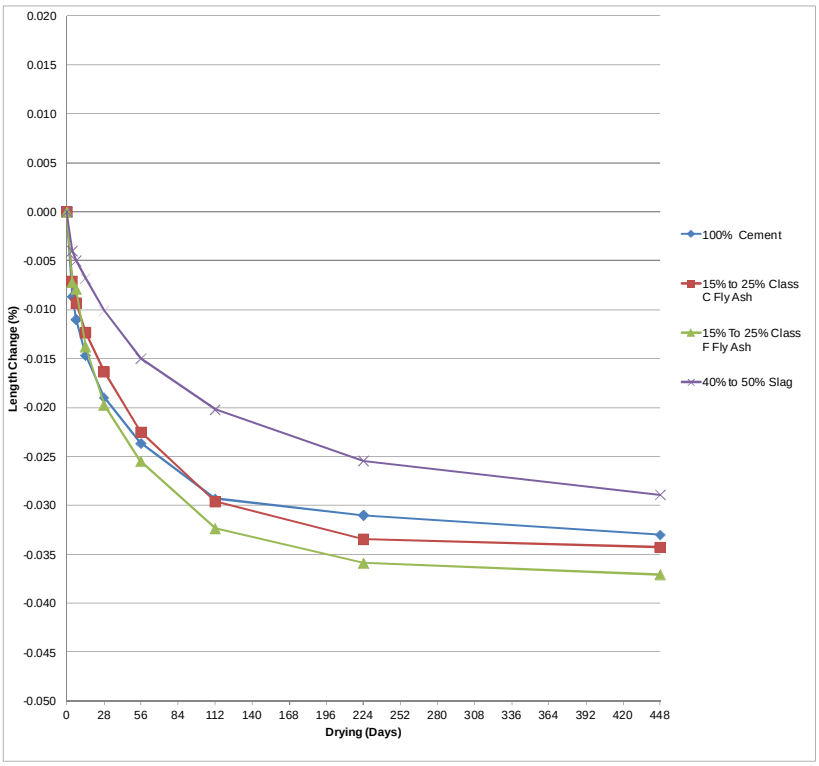


Figure 96: Length Changes vs Drying Days - All Mixes (7-Day Soak)

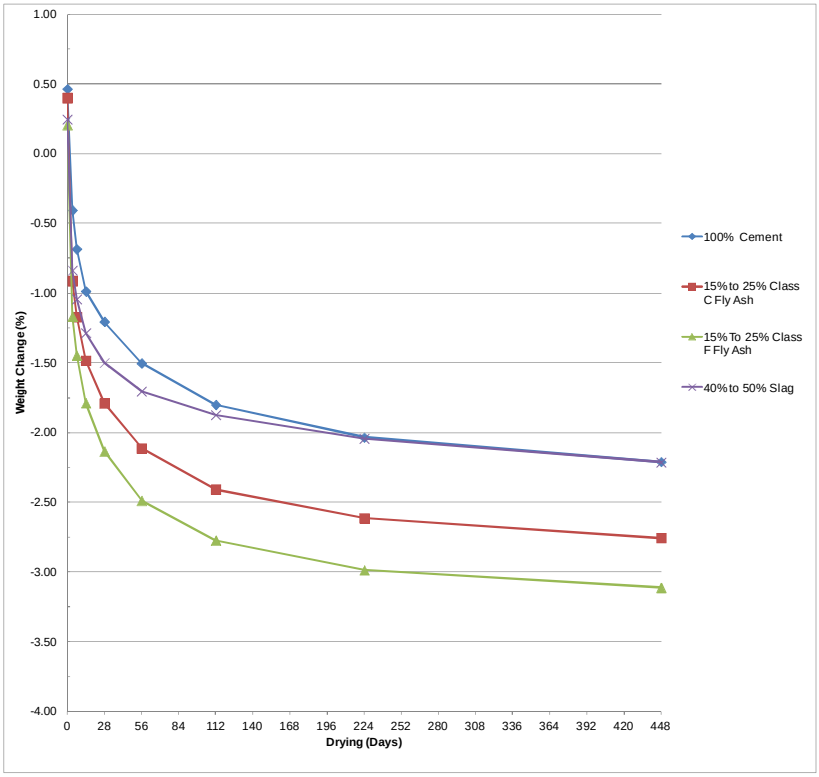


Figure 97: Weight Change vs Drying Days - All Mixes (7-Day Soak)

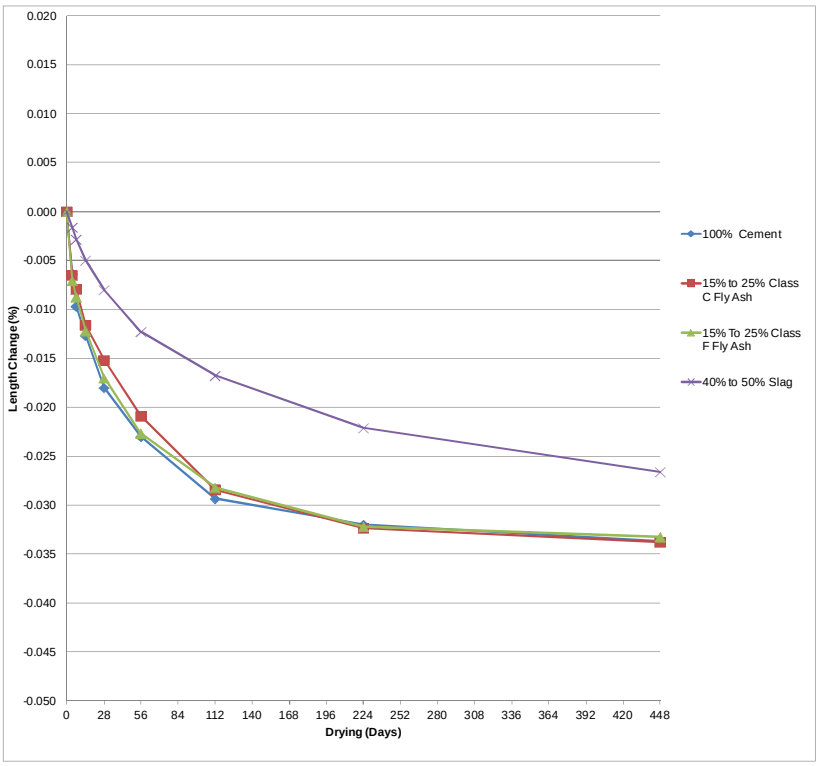


Figure 98: Length Change vs Drying Days - All Mixes (14-Day Soak)

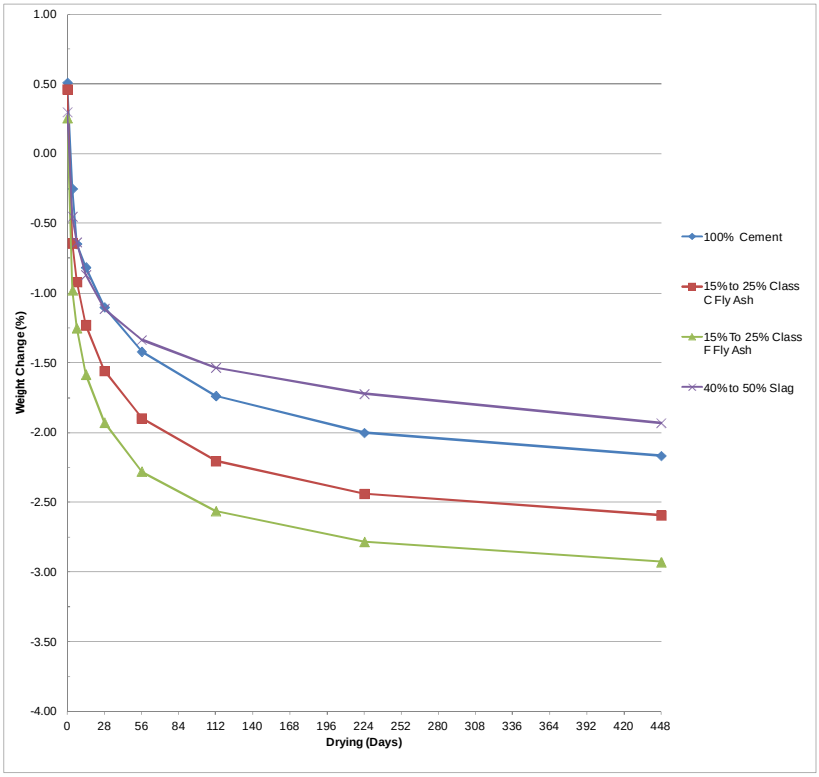


Figure 99: Weight Change vs Drying Days - All Mixes (14-Day Soak)

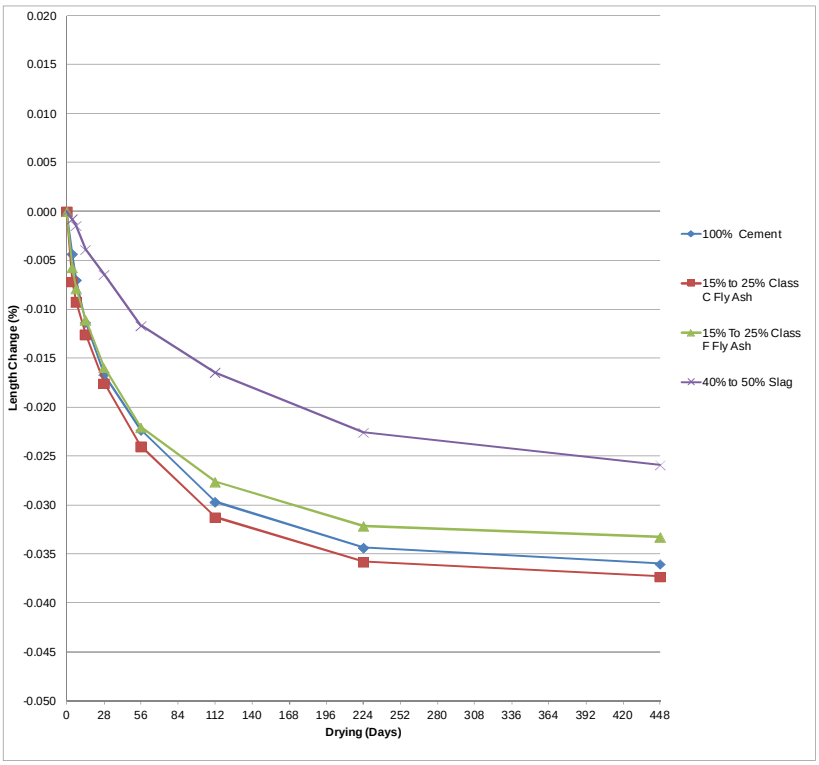


Figure 100: Length Change vs Drying Days - All Mixes (28-Day Soak)

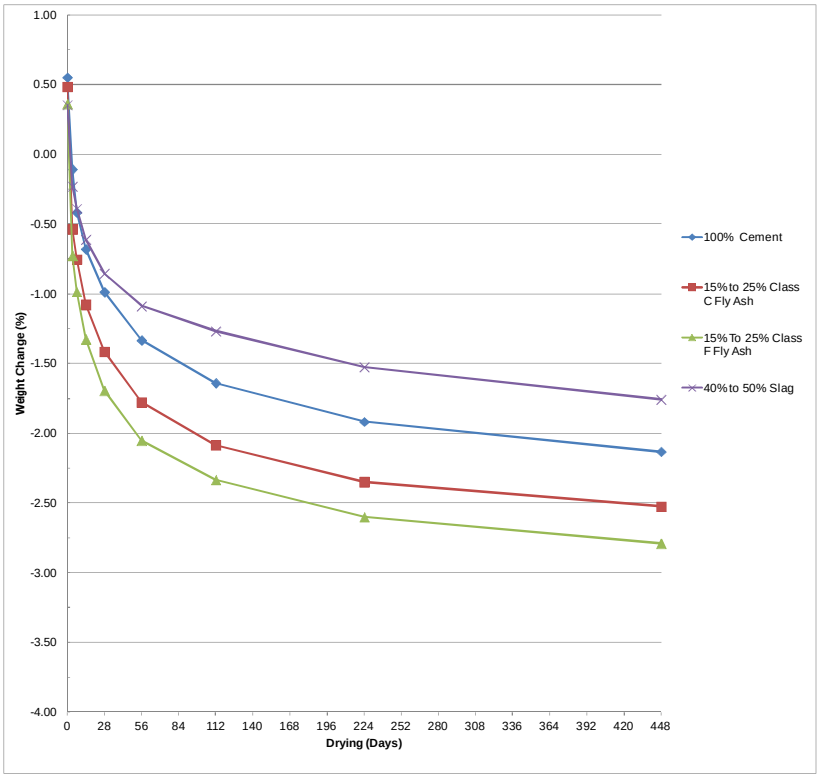


Figure 101: Weight Change vs Drying Days - All Mixes (28-Day Soak)

Table 21: Average Length Change at 448 Days of Drying (0.0001%)

Cementitious Materials	Liquid membrane		7-Day Soak		14-Day Soak		28-Day Soak	
	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank
Portland Cement	-0.0370	3	-0.0330	2	-0.0337	3	-0.0360	3
Class C Fly Ash	-0.0332	2	-0.0343	3	-0.0338	4	-0.0373	4
Class F Fly Ash	-0.0386	4	-0.0371	4	-0.0332	2	-0.0333	2
Slag Cement	-0.0303	1	-0.0289	1	-0.0266	1	-0.0259	1

Table 22: Average Weight Change at 448 Days of Drying (0.01%)

Cementitious Materials	Liquid membrane		7-Day Soak		14-Day Soak		28-Day Soak	
	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank	Avg. (%)	Rank
Portland Cement	-2.56	1	-2.21	1	-2.17	2	-2.13	2
Class C Fly Ash	-2.98	2	-2.76	3	-2.59	3	-2.53	3
Class F Fly Ash	-3.32	4	-3.11	4	-2.93	4	-2.79	4
Slag Cement	-3.15	3	-2.21	1	-1.93	1	-1.76	1

Length Change and Weight Change – Influence of Water Cementitious Ratio

Water cementitious (w/cm) ratio ranged from 0.450 (Mix 1, control mix) to 0.484 (Mix 10, 75/25 F-1) for mixes of this study. Mixes of the study were proportioned so that the absolute volume of aggregate, absolute volume of cementitious paste, and absolute volume of cementitious materials was held constant for all mixes. While these volumes were held constant, the weight of cementitious materials was then controlled by the specific gravities of the SCMs. As the specific gravity of the SCM decreased, the weight of cementitious materials decreased and the w/cm ratio increased. In addition, as the percent replacement rate of portland cement with SCMs increased, the w/cm also increased. This increase in w/cm had influence on the ultimate shrinkage and ultimate weight loss of the concrete specimens. Figure 102 presents graphs of length change versus w/cm ratio for each curing condition. Length change did not correlate well with w/cm ratio although the tendency was that length change in the form shrinkage increased as w/cm ratio increased. Figure 103 presents graphs of weight change versus w/cm ratio for each curing condition. Weight loss did correlate well with w/cm ratio. Weight loss increased as w/cm ratio increased. There was also a decrease in weight loss with increase in time of moist curing.

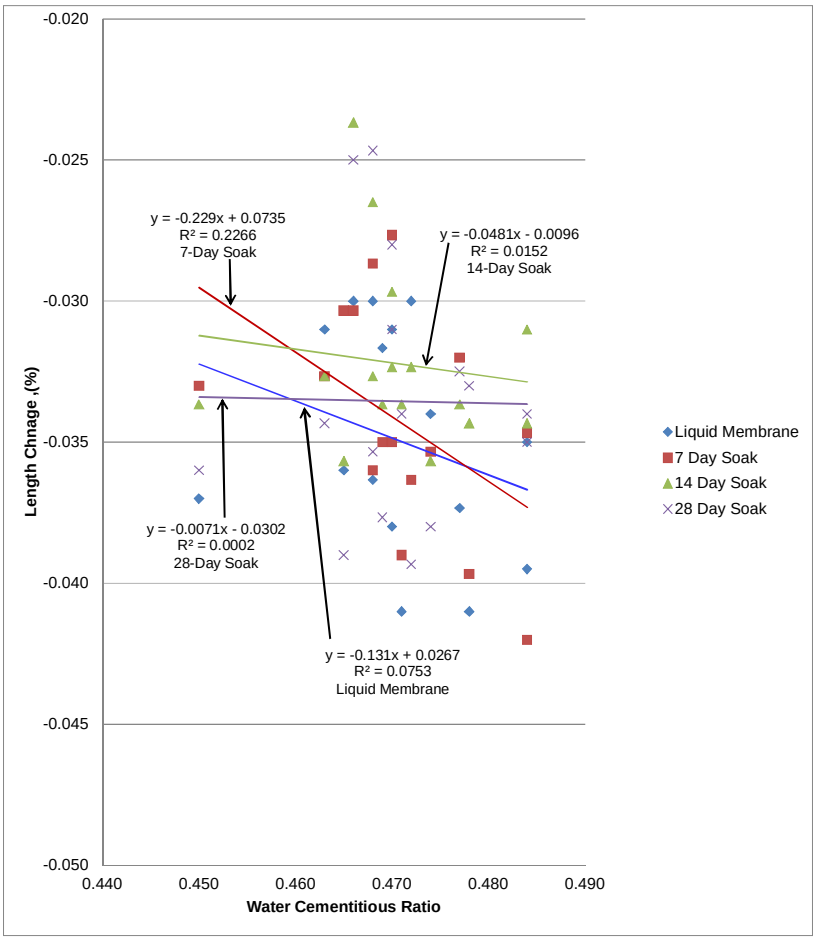


Figure 102 - Length Change vs Water Cementitious Ratio

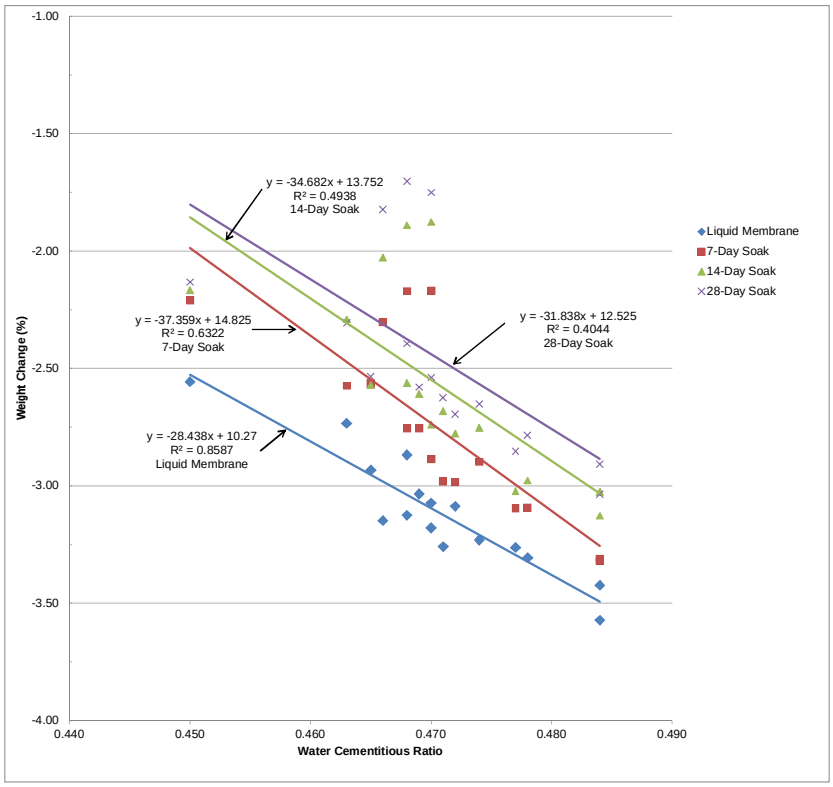


Figure 103 - Weight Change vs Water Cementitious Ratio

CHAPTER 7 – STATISTICAL ANALYSIS OF LENGTH CHANGE DATA

The experimental design for the evaluation of ultimate shrinkage is presented in Table 23 which includes three factors; supplementary cementitious material (SCM) source, curing method, and replacement rate. The source of SCM had five levels including: CS-1 (portland cement), C-1 (Class C fly ash source 1), C-2 (Class C fly ash source 2), F-1 (Class F fly ash source 1), F-2 (Class F fly ash source 2), and S-1 (slag cement). Curing method had four levels including: liquid membrane, 7-day soak, 14-day soak, and 28-day soak. Replacement rate had four levels including: 0, 15, 20, and 25 percent for sources C-1, C-2, F-1, F-2 and 0, 40, 45, and 50 percent for source S-1. While there were different replacement rates for mixes proportioned with slag cement than with mixes proportioned with fly ash, replacement rates were included in these analyses because the absolute volume of the cementitious materials remained constant for all mixes and the replacement rates shown were based on percent by weight.

An analysis of variance (ANOVA) was conducted to determine the effect of SCM source, curing method, and replacement rate on the measured response variables for ultimate shrinkage. Table 24 presents the results of the ANOVA for the 448-day length change results. Results of this ANOVA show that SCM source and curing method were the only two factors that had significant effect on the ultimate shrinkage test results.

One benefit of utilizing an ANOVA to evaluate test results is that the relative importance of the various factors within the data set can be ranked in order of importance by utilizing the F-ratio statistic. With regards to the three main factors within the experimental design, the SCM source had the most impact on the resulting ultimate shrinkage (highest F-statistic ratio). The factor having the next highest impact on the ultimate shrinkage was curing method. The replacement rate of portland cement with SCM was not significant according to this analysis.

Table 23: Experimental Design Including Factors and Levels

Mix Number	Supplementary Cementitious Source	Replacement Rate	Liquid Membrane			
1	CS-1	0	Liquid membrane	7-Day Soak	14-Day Soak	28-Day Soak
2	C-1	15				
3		20				
4		25				
5	C-2	15				
6		20				
7		25				
8	F-1	15				
9		20				
10		25				
11	F-2	15				
12		20				
13		25				
14	S-1	40				
15		45				
16		50				

Table 24: ANOVA Results for 448 Day Length Change Test Results

Factor	Degrees of Freedom	Sum of Squares	Mean Squares	F-statistic	F-critical	Significant * Y/N
A: SCM Source	4	0.00128	0.00032	12.238	2.41	Y
B: Curing Method	3	0.00024	0.00008	3.080	2.64	Y
C: Replacement Rate	3	0.00010	0.00003	1.238	2.64	N
AB	12	0.00047	0.00004	1.514	1.86	N
AC	12	0.00048	0.00004	1.516	1.86	N
BC	9	0.00018	0.00002	0.756	1.98	N
ABC	36	0.00041	0.00001	0.436	1.54	N
Error	160	0.00418	0.00003			
Total	239	0.00102				

*level of significance = 0.05

Once ANOVA has shown factors that significantly impact a response variable, another useful statistical tool is a Tukey's Multiple Comparison Test (Tukey's). Tukey's is useful for ranking the impact of levels within a main factor and showing which levels are significantly different. Table 25 presents results of the Tukey's rankings for ultimate shrinkage test results. Within the rankings, means having different letter designations are significantly different. Likewise, means having the same letter are statistically similar.

Table 25: Results of DMRT Rankings for 448 Day Length Change Test Results

Factor	Level	Mean Result (%)	Tukey's Ranking **
SCM Source	S-1	-0.0297	A
	F-1	-0.0342	B
	C-1	-0.0343	B
	C-2	-0.0351	B
	F-2	-0.0366	B
Curing Method	14-Day Soak	-0.0325	A
	7-Day Soak	-0.0340	A
	28-Day Soak	-0.0340	A
	Liquid membrane	-0.0353	B
** Rankings with the same letter are similar			

Figure 104 graphically illustrates the results of the average ultimate shrinkage tests for each SCM source. As shown by the Tukey's rankings in Table 25 and Figure 102, mixes proportioned with SCM source S-1 had the lowest ultimate shrinkage. These are the mixes that utilized slag cement to replace either 40, 45, or 50 percent by weight of the portland cement. The Tukey's rankings and Figure 104 also show that mixes prepared with the SCM sources C-1, C-2, F-1, and F-2 produced ultimate shrinkage results that are statistically similar. In addition, this analysis showed that the control mix with no SCMs was statistically similar to mixes that used Class C or Class F fly ash.

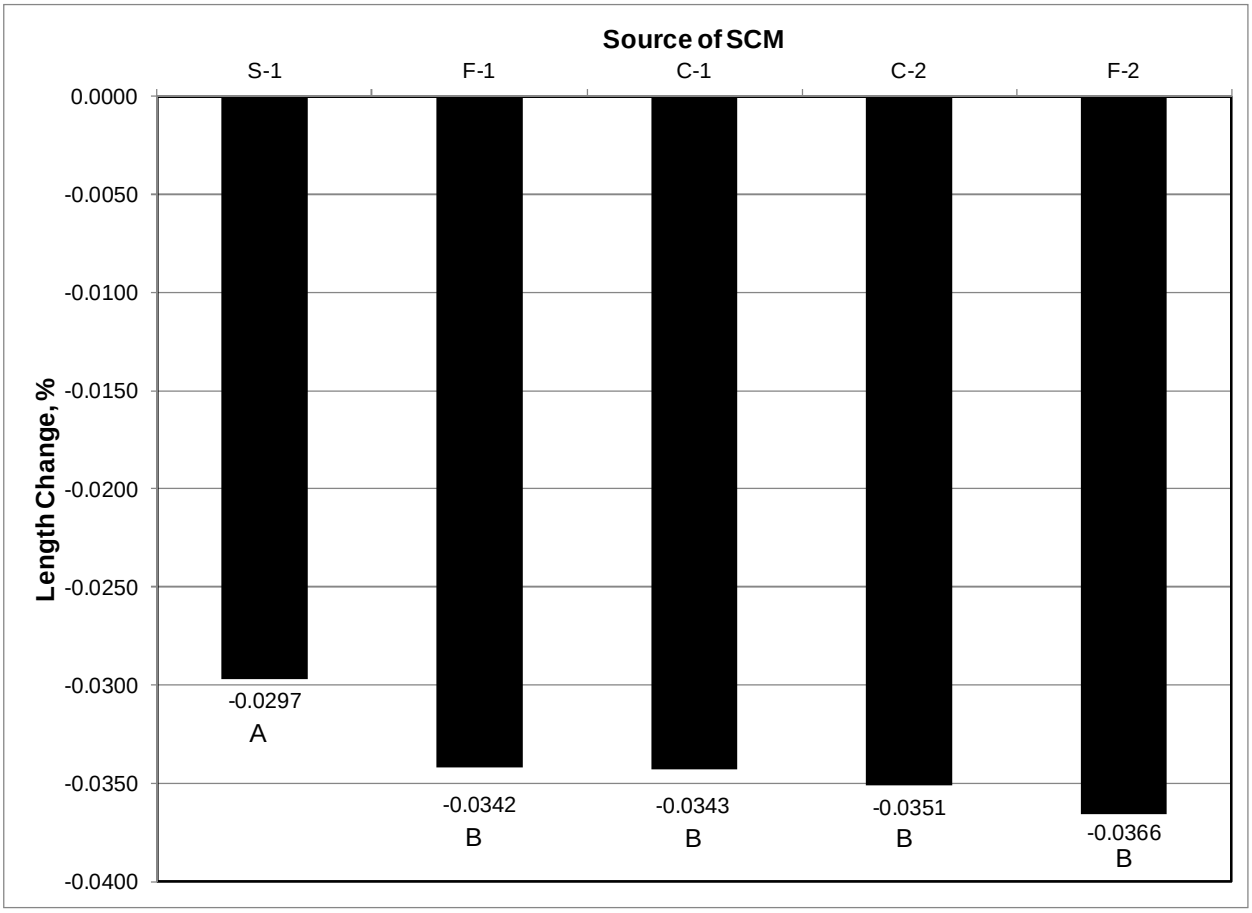


Figure 104: Means and Tukey's Rankins for Supplementary Cementitious Material Source (Ultimate Shrinkage)

Figure 105 shows that Tukey's results graphically for the curing method used for the specimens. Based upon the Tukey's rankings, the specimens that were moist cured with either 7-day, 14-day, or 28-day soaking produced lower shrinkage results than specimens cured with liquid membrane. Results from all the moist curing periods were statistically similar. Specimens cured with liquid membrane had higher shrinkage results than specimens that were moist cured.

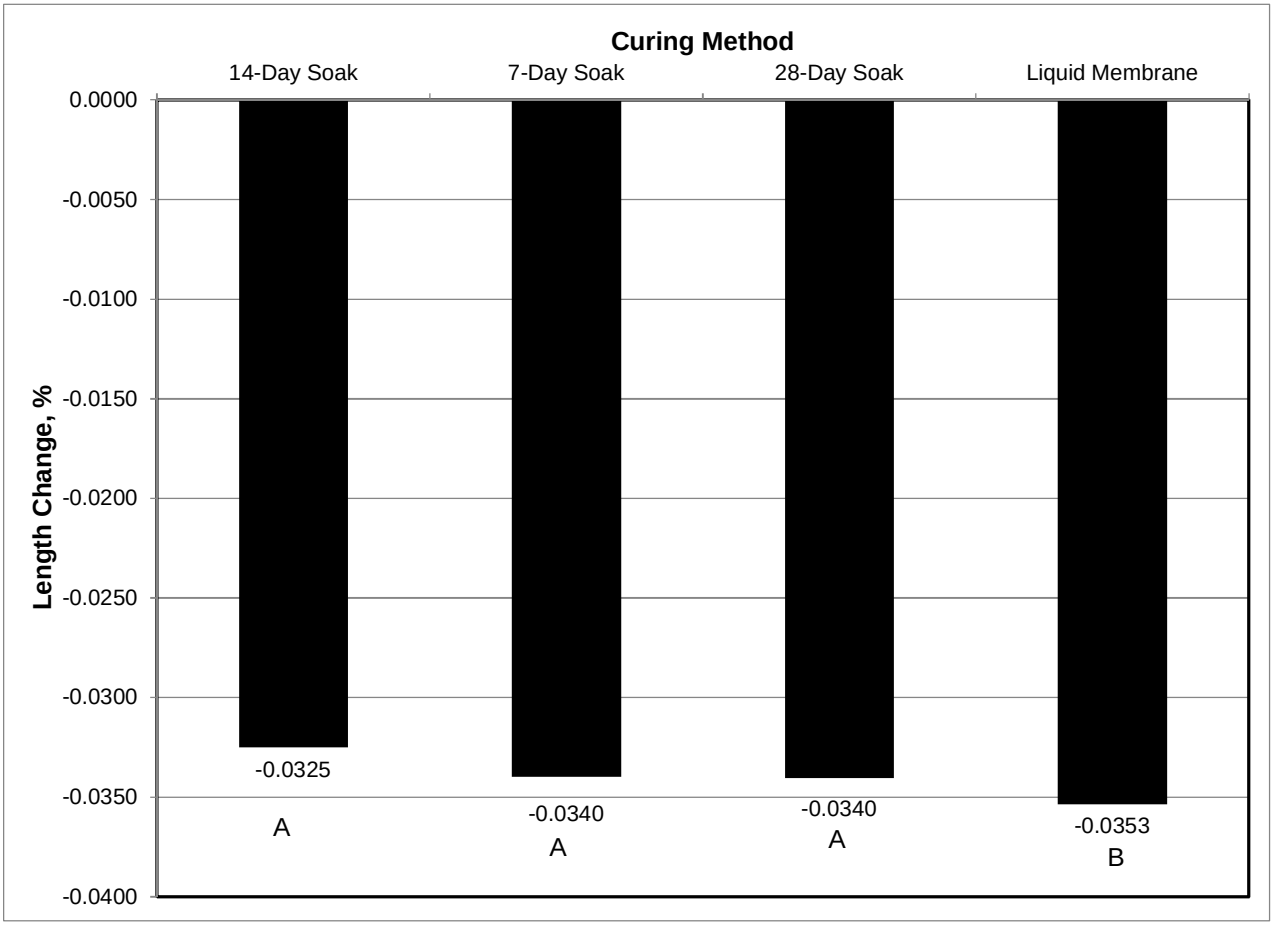


Figure 105: Means and Tukey's Rankins for Curing Method (Ultimate Shrinkage)

CHAPTER 8 – CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations herein are based on data sets generated from mixture proportions and materials used in this study. These data are from mixtures that used one source of portland cement (CS-1), one source of fine and coarse aggregates, two sources of Class C fly ash (C-1,C-2), two sources of Class F fly ash (F-1,F-2), one source of slag cement (S-1), and no chemical admixture. Conclusions and recommendations may not be applicable for mixtures made with any other sources of materials or any other mixture proportions than those used in this study. In addition, mixtures of this study were proportioned such that the absolute volume of cementitious materials, absolute volume of aggregate, and absolute volume of cementitious paste remained constant while the water cementitious (w/cm) ratio varied as influenced by specific gravity of the supplemental cementitious materials (SCMs).

CONCLUSIONS

Slump

Data in the study show that mixes proportioned with Class C and Class F fly ash produce higher slumps than the control mix (Mix 1) proportioned with 100 percent portland cement. Slump was increased from 2 3/4 in. for the control mix to 8 ½ in. with mixtures using either 25 percent Class C or 25 percent Class F fly ash. There was also a notable change in slump between the two sources of Class C fly ash. On average, when comparing slumps from mixes proportioned with Class C fly ash source C-1 to mixes proportioned with Class C fly ash source C-2, slump increased by approximately 1 ½ in. Higher slumps of mixes proportioned with Class C or Class F fly ash indicates that these mixes require less water to produce a given slump than a mixture proportioned with 100 percent portland cement. Therefore, fly ash can be used to reduce the amount of water required for a given slump and reduce drying shrinkage as influenced by free mix water. The mixtures proportioned with slag cement did not increase slump by more than ¾ in. over the control mix. Therefore slag cement had little influence on water demand for mixes in this study.

Compressive Strength

Average twenty-eight day compressive strengths ranged from 3,807 psi (Mix 10) to 5,915 psi (Mix 1). Mix 10 used 25 percent Class C fly ash and had the highest w/cm ratio (0.484). Mix 1 had the lowest w/cm ratio (0.45) along with the highest strength. Mixes of this study that were proportioned with SCMs had lower compressive strength at a given age than the control mix with 100 percent portland cement. The exception to this trend was Mix 15 which was proportioned with 45 percent slag cement. The 56-day compressive strength for Mix 15 was 5 percent higher than the control mix. One reason that mixtures proportioned with SCMs had lower compressive strengths than the control mix was because mixes with SCMs had higher w/cm ratios. The reason SCM mixes had higher w/cm ratios than the control mix was that the volume of cementitious materials remained constant for all mixes. As a result, the lower specific gravities of the SCMs generated higher w/cm ratios.

Percent Length Change

Data from this study indicates that length change is influenced by type of SCM, curing method, and w/cm ratio. The replacement rate of SCM for portland cement as a percent by weight did not have significant influence on length change according to our statistical evaluation of the data. The use of slag cement produced the lowest shrinkage values in this study and was the best performing type of SCM with respect to shrinkage. This trend included the control mixture that had a lower w/cm ratio than the mixtures proportioned with slag cement. There was no significant difference in the performance of the control mix, Class C fly ash, and Class F fly ash with respect to shrinkage according to our statistical evaluation. It is our opinion that the reason our data did not show that mixtures proportioned with Class C fly ash and Class F fly ash did not perform better than the control mixture was that the w/cm ratio increased with Class C and Class F fly ash with respect to the control mixture.

Moist curing performed better with respect to shrinkage than the use of liquid membrane. There was no significant difference in shrinkage values based on the length of time in moist curing according to our statistical evaluation of the data. However, our data also showed that weight loss decreased as moist curing increased (7-day, 14-day, 28-day). The lower weight loss associated with increased moist curing time indicates that less shrinkage due to drying occurred with increased moist curing.

Water cementitious ratio also had influence of the length change data in this study. We did not observe a strong correlation between length change and w/cm ratio, but our data showed a tendency for the length change (shrinkage) to increase as w/cm ratio increased. It is the author's opinion that R squared values greater than or equal to 0.5 indicates a strong correlation. However, the general trend was that shrinkage increased as w/cm ratio increased.

Percent Weight Change

Weight change was influenced by w/cm ratio and length of moist curing. As w/cm ratio increased, weight loss increased. We did observe a strong correlation between weight loss and w/cm ratio. Slag cement was the best performer with respect to weight loss. Mixes proportioned with slag cement (Mixes 14, 15, and 16) generally had less weight loss than the control mix (Mix 1) even though the w/cm ratio of the mixes proportioned with slag cement was higher than the w/cm ratio of the control mix. This general trend was observed in specimens that were moist cured but was not observed in specimens cured with liquid membrane. Weight loss is also influenced by length of moist curing. Data in this study show a slight decrease in weight loss with an increase in time of moist curing. Specimens cured with liquid membrane experienced more weight loss than replicate specimens cured with 7-day soak, 14-day soak, or 28-day soak. Concrete cured with liquid membrane was the worst performer with respect to weight loss.

RECOMMENDATIONS

We recommend that MDOT continue the use of Class C and Class F fly ash in bridge deck concrete. Based on the data from this study, fly ash mixes require less water to produce a given slump than mixes proportioned with only portland cement. This will provide for lower water content mixtures than mixes with only portland cement. Lower water content mixes will result in less free water to leave the mix and increase concrete shrinkage.

We recommend that MDOT use slag cement in a test project to evaluate its use in bridge deck concrete. Slag cement mixtures have performed best with respect to shrinkage is all recent studies performed by Burns Cooley Dennis. Slag cement could reduce shrinkage cracking in bridge decks to the extent that MDOT requires its use in future projects.

We recommend that MDOT use moist curing in a test project to evaluate the use of 7-day moist curing versus liquid membrane. Our statistical analysis showed that there is a significant reduction in shrinkage of specimens cured with moist curing than specimens cured with liquid

membrane. Our data also showed that less weight loss occurs in specimens cured with 7-day moist curing than specimens cured with liquid membrane.

The combination of the use of a mix proportioned with slag cement and implementation of moist curing for bridge decks will provide low shrinkage concrete materials and could produce bridge decks with the lowest practical amount of shrinkage cracks.

RESEARCH OPPORTUNITIES

A research project should be conducted to investigate length change of mixtures proportioned with supplementary cementitious materials and proportioned to produce similar slumps and compressive strengths as the control mix with 100 percent portland cement.

REFERENCES

1. Kosmatka, Steven H., Beatrix Kerkhoff, and William C. Panarese. Design and Control of Concrete Mixtures. 15th ed. Skokie: Portland Cement Association, 2002.
2. Mindess, Sidney, and J. Francis Young. Concrete. Englwood Cliffs: Prentice-Hall, Inc., 1981.

Appendix A

Raw Data:

Concrete Mixtures and Length Change

Burns Cooley Dennis, Inc - State Study No. 247

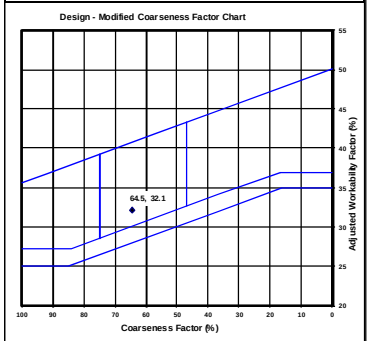
Customer: **MDOT** | Project: **110375** | MIX **1**

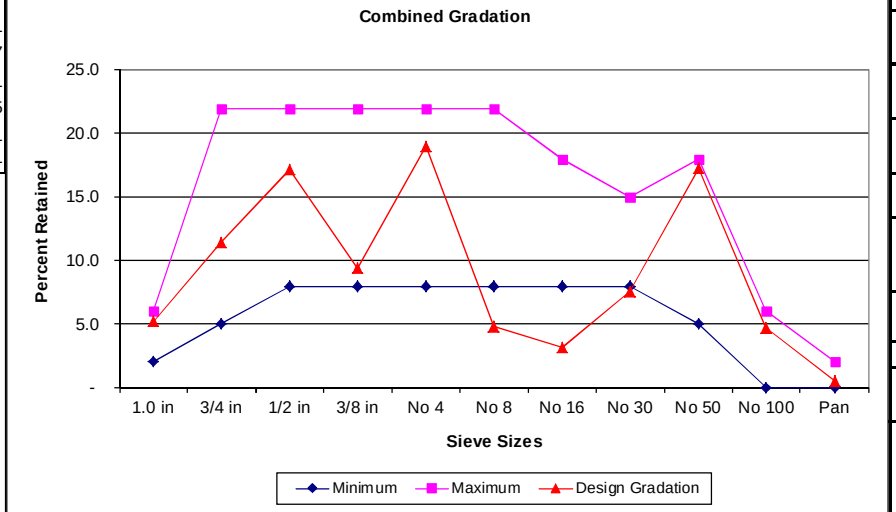
MIX NUMBER Mix 1 | Notes: | Set #:

MIX DESIGN INFO | Date: 8/27/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	% Retained MDOT Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.6781	526.4000	43.8670	43.87	43.87	Paste
SCM 1				1.000						0.0000	0.0000	0.0000	0.00	0.00	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9984	3896.8967	324.7410	328.60	328.60	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	34.0	32.7	32.1





Plastic Test Results

Batch Time	12:22 PM	% Air	2.00	Unit Wt w/o Air	148.04	Design w/c	0.450
Sample Time	12:31 PM	Bucket Weight	7.69	Unit Wt (pcf)	146.16	Actual w/c	0.450
Air Temp.	89.1	Bucket Full	44.23	Theorectial Air	1.27	Design Unit Wt	144.34
Mix Temp.	78.7	Bucket Volume	0.250	Yield	2.25	Fine/Coarse	0.65
Slump, in.	2.75	Cmt+Wtr Vol(%)	23.98	Relative Yield	1.00	Bag Factor	5.60

Reviewed by: Robert Varner, P.E.

Comments / Notes / Observations

100% Cement

100% Cement

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
08/28/12	1	2200	2250
	1	2300	
09/03/12	7	4280	4285
	7	4290	
09/10/12	14	4760	4890
	14	5020	
09/24/12	28	5460	5213
	28	5110	
	28	5070	
10/22/12	56	5740	5635
	56	5530	

Technician who conducted tests: GP, SB, MR, RV

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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 1
Mix Date Monday, August 27, 2012 Mix Time: 12:22 PM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8135	0.8120	11.63000	1.6255	10.0045
B	10.0000	0.8170	0.8190	11.63450	1.6360	9.9985
C	10.0000	0.8145	0.8165	11.63250	1.6310	10.0015

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	**INITIAL READINGS**										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Tuesday, August 28, 2012	**0.1088**	**0.1005**	0.0083	**0.1078**	**0.1005**	0.0073	**0.1152**	**0.1004**	0.0148	0.0101	**M/Rm**
	Curing Compound	**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, August 28, 2012	**0.1088**	**0.1005**	0.0000	**0.1078**	**0.1005**	0.0000	**0.1152**	**0.1004**	0.0000	0.0000	
3	Friday, August 31, 2012	**0.1080**	**0.1006**	-0.0090	**0.1070**	**0.1006**	-0.0090	**0.1145**	**0.1006**	-0.0090	-0.0090	**Shrinkage Room**
7	Tuesday, September 04, 2012	**0.1075**	**0.1005**	-0.0130	**0.1065**	**0.1005**	-0.0130	**0.1141**	**0.1005**	-0.0120	-0.0127	
14	Tuesday, September 11, 2012	**0.1069**	**0.1006**	-0.0200	**0.1058**	**0.1006**	-0.0210	**0.1135**	**0.1006**	-0.0190	-0.0200	
28	Tuesday, September 25, 2012	**0.1061**	**0.1002**	-0.0240	**0.1051**	**0.1002**	-0.0240	**0.1128**	**0.1002**	-0.0220	-0.0233	
56	Tuesday, October 23, 2012	**0.1049**	**0.0995**	-0.0290	**0.1039**	**0.0995**	-0.0290	**0.1119**	**0.0995**	-0.0240	-0.0273	
112	Tuesday, December 18, 2012	**0.1042**	**0.0995**	-0.0360	**0.1034**	**0.0995**	-0.0340	**0.1113**	**0.0995**	-0.0300	-0.0333	
224	Tuesday, April 09, 2013	**0.1038**	**0.0991**	-0.0360	**0.1029**	**0.0991**	-0.0350	**0.1108**	**0.0991**	-0.0310	-0.0340	
448	Tuesday, November 19, 2013	**0.1030**	**0.0986**	-0.0390	**0.1021**	**0.0986**	-0.0380	**0.1100**	**0.0986**	-0.0340	-0.0370	

Note: Initial reading of specimen "A" was changed from 0.1093 to 0.1088, "B" from 0.1113 to 0.1078 and "C" from 0.1171 to 0.1152.

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

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BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 1

Mix Date Monday, August 27, 2012 Mix Time: 12:22 PM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8230	11.61950	1.6385	9.9810
B	10.0000	0.8195	0.8120	11.62900	1.6315	9.9975
C	10.0000	0.8155	0.8170	11.62550	1.6325	9.9930

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Tuesday, September 04, 2012	**0.1130**	**0.1005**	0.0125	**0.1086**	**0.1005**	0.0081	**0.1047**	**0.1005**	0.0042	0.0083	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 04, 2012	**0.1130**	**0.1005**	0.0000	**0.1086**	**0.1005**	0.0000	**0.1047**	**0.1005**	0.0000	0.0000	
4	Saturday, September 08, 2012	**0.1122**	**0.1006**	-0.0090	**0.1079**	**0.1006**	-0.0080	**0.1039**	**0.1006**	-0.0090	-0.0087	Shrinkage Room
7	Tuesday, September 11, 2012	**0.1118**	**0.1004**	-0.0110	**0.1075**	**0.1004**	-0.0100	**0.1034**	**0.1004**	-0.0120	-0.0110	
14	Tuesday, September 18, 2012	**0.1113**	**0.1002**	-0.0140	**0.1069**	**0.1002**	-0.0140	**0.1028**	**0.1002**	-0.0160	-0.0147	
28	Tuesday, October 02, 2012	**0.1108**	**0.1002**	-0.0190	**0.1065**	**0.1002**	-0.0180	**0.1024**	**0.1002**	-0.0200	-0.0190	
56	Tuesday, October 30, 2012	**0.1095**	**0.0994**	-0.0240	**0.1053**	**0.0994**	-0.0220	**0.1011**	**0.0994**	-0.0250	-0.0237	
112	Tuesday, December 25, 2012	**0.1090**	**0.0995**	-0.0300	**0.1048**	**0.0995**	-0.0280	**0.1007**	**0.0995**	-0.0300	-0.0293	
224	Tuesday, April 16, 2013	**0.1085**	**0.0991**	-0.0310	**0.1042**	**0.0991**	-0.0300	**0.1001**	**0.0991**	-0.0320	-0.0310	
448	Tuesday, November 26, 2013	**0.1077**	**0.0986**	-0.0340	**0.1035**	**0.0986**	-0.0320	**0.0995**	**0.0986**	-0.0330	-0.0330	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

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RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 1

Mix Date Monday, August 27, 2012 Mix Time: 12:22 PM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8160	0.8160	11.62300	1.6320	9.9910
B	10.0000	0.8160	0.8135	11.62000	1.6295	9.9905
C	10.0000	0.8140	0.8150	11.62350	1.6290	9.9945

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Tuesday, September 11, 2012	**0.1092**	**0.1003**	0.0089	**0.0994**	**0.1003**	-0.0009	**0.1040**	**0.1003**	0.0037	0.0039	**M/Rm**
		LENGTH CHANGE CALCULATIONS										
14 Day Soak		**Specimen A**	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	**Soak**
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 11, 2012	**0.1092**	**0.1003**	0.0000	**0.0994**	**0.1003**	0.0000	**0.1040**	**0.1003**	0.0000	0.0000	
3	Friday, September 14, 2012	**0.1087**	**0.1003**	-0.0050	**0.0986**	**0.1003**	-0.0080	**0.1034**	**0.1003**	-0.0060	-0.0063	**Shrinkage Room**
9	Thursday, September 20, 2012	**0.1083**	**0.1002**	-0.0080	**0.0981**	**0.1002**	-0.0120	**0.1030**	**0.1002**	-0.0090	-0.0097	
14	Tuesday, September 25, 2012	**0.1080**	**0.1002**	-0.0110	**0.0978**	**0.1002**	-0.0150	**0.1027**	**0.1002**	-0.0120	-0.0127	
28	Tuesday, October 09, 2012	**0.1071**	**0.0998**	-0.0160	**0.0967**	**0.0998**	-0.0220	**0.1019**	**0.0998**	-0.0160	-0.0180	
56	Tuesday, November 06, 2012	**0.1063**	**0.0994**	-0.0200	**0.0958**	**0.0994**	-0.0270	**0.1009**	**0.0994**	-0.0220	-0.0230	
112	Tuesday, January 01, 2013	**0.1054**	**0.0992**	-0.0270	**0.0949**	**0.0992**	-0.0340	**0.1002**	**0.0992**	-0.0270	-0.0293	
224	Tuesday, April 23, 2013	**0.1048**	**0.0990**	-0.0310	**0.0944**	**0.0989**	-0.0360	**0.0997**	**0.0989**	-0.0290	-0.0320	
448	Tuesday, December 03, 2013	**0.1044**	**0.0986**	-0.0310	**0.0939**	**0.0986**	-0.0380	**0.0991**	**0.0986**	-0.0320	-0.0337	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

Curing Method:
28 Day Soak

BCD JOB NO. 110375

Mix Number Mix 1

Mix Date Monday, August 27, 2012 Mix Time: 12:22 PM

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8180	0.8185	11.62400	1.6365	9.9875
B	10.0000	0.8145	0.8160	11.61950	1.6305	9.9890
C	10.0000	0.8150	0.8165	11.63450	1.6315	10.0030

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Tuesday, September 25, 2012	**0.1086**	**0.1002**	0.0084	**0.0959**	**0.1002**	-0.0043	**0.1076**	**0.1002**	0.0074	0.0038	M/Rm
		LENGTH CHANGE CALCULATIONS										
28 Day Soak		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	Soak
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 25, 2012	**0.1086**	**0.1002**	0.0000	**0.0959**	**0.1002**	0.0000	**0.1076**	**0.1002**	0.0000	0.0000	
3	Friday, September 28, 2012	**0.1080**	**0.1001**	-0.0050	**0.0954**	**0.1001**	-0.0040	**0.1071**	**0.1001**	-0.0040	-0.0043	
7	Tuesday, October 02, 2012	**0.1077**	**0.1001**	-0.0080	**0.0951**	**0.1001**	-0.0070	**0.1069**	**0.1001**	-0.0060	-0.0070	
14	Tuesday, October 09, 2012	**0.1070**	**0.0998**	-0.0120	**0.0943**	**0.0998**	-0.0120	**0.1062**	**0.0998**	-0.0100	-0.0113	
28	Tuesday, October 23, 2012	**0.1062**	**0.0995**	-0.0170	**0.0935**	**0.0995**	-0.0170	**0.1053**	**0.0995**	-0.0160	-0.0167	
56	Tuesday, November 20, 2012	**0.1054**	**0.0993**	-0.0230	**0.0927**	**0.0993**	-0.0230	**0.1046**	**0.0993**	-0.0210	-0.0223	
112	Tuesday, January 15, 2013	**0.1045**	**0.0991**	-0.0300	**0.0918**	**0.0991**	-0.0300	**0.1036**	**0.0991**	-0.0290	-0.0297	
224	Tuesday, May 07, 2013	**0.1039**	**0.0990**	-0.0350	**0.0912**	**0.0990**	-0.0350	**0.1031**	**0.0990**	-0.0330	-0.0343	
448	Tuesday, December 17, 2013	**0.1034**	**0.0986**	-0.0360	**0.0907**	**0.0986**	-0.0360	**0.1024**	**0.0986**	-0.0360	-0.0360	Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

Burns Cooley Dennis, Inc - State Study No. 247

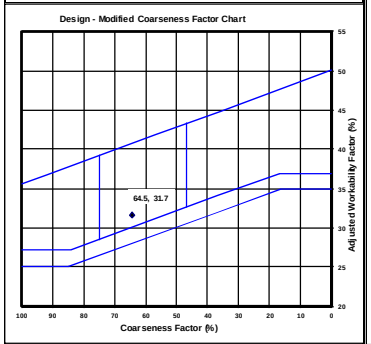
Customer: **MDOT** | Project: **110375** | MIX **2** | Set #:

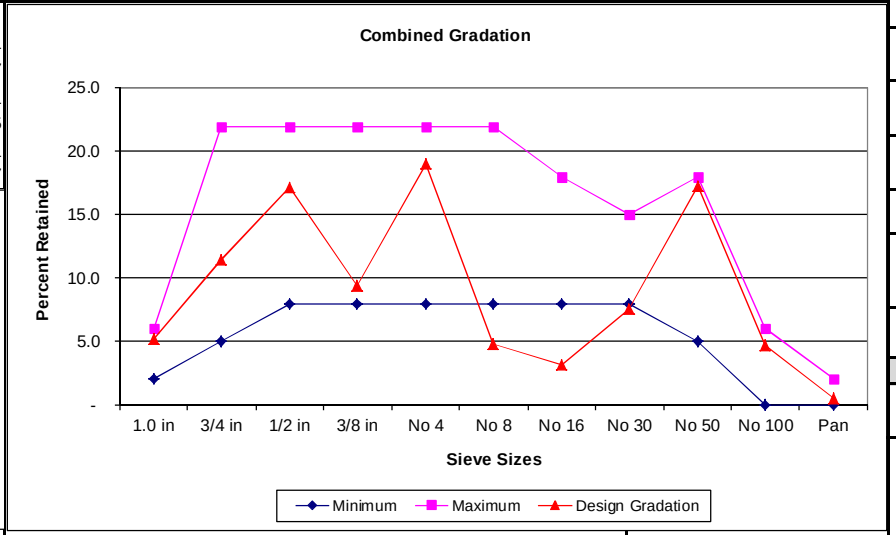
MIX NUMBER Mix 2 | Notes:

MIX DESIGN INFO | Date: 8/29/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.2108	434.5521	36.2130	36.21	36.21	Paste
SCM 1				2.630						0.4673	76.6857	6.3900	6.39	6.39	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9984	3881.7345	323.4770	327.33	327.33	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.6	32.3	31.7





Plastic Test Results

Batch Time	7:39 AM	% Air	2.00	Unit Wt w/o Air	147.46	Design w/c	0.463
Sample Time	7:48 AM	Bucket Weight	7.70	Unit Wt (pcf)	146.80	Actual w/c	0.463
Air Temp.	79.0	Bucket Full	44.40	Theorectial Air	0.45	Design Unit Wt	143.78
Mix Temp.	71	Bucket Volume	0.250	Yield	2.23	Fine/Coarse	0.65
Slump, in.	4.25	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.44

Comments / Notes / Observations

C Ash Source 1

85/15

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
08/30/12	1	1460	1590
	1	1720	
09/05/12	7	3280	3340
	7	3400	
09/12/12	14	4870	4860
	14	4850	
09/26/12	28	4330	4773
	28	4830	
	28	5160	
10/24/12	56	5000	5020
	56	5040	

Technician who conducted tests:

Reviewed by: Robert Varner, P.E.

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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 2
Mix Date Wednesday, August 29, 2012 Mix Time: 7:39 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8145	11.62200	1.6270	9.9950
B	10.0000	0.8150	0.8135	11.60700	1.6285	9.9785
C	10.0000	0.8120	0.8155	11.60100	1.6275	9.9735

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Thursday, August 30, 2012	**0.0988**	**0.1007**	-0.0019	**0.0812**	**0.1006**	-0.0194	**0.0959**	**0.1006**	-0.0047	#NUM!	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, August 30, 2012	**0.0988**	**0.1007**	0.0000	**0.0812**	**0.1006**	0.0000	**0.0959**	**0.1006**	0.0000	0.0000	
4	Monday, September 03, 2012	**0.0978**	**0.1006**	-0.0090	**0.0803**	**0.1006**	-0.0090	**0.0950**	**0.1006**	-0.0090	-0.0090	Shrinkage Room
7	Thursday, September 06, 2012	**0.0973**	**0.1006**	-0.0140	**0.0799**	**0.1006**	-0.0130	**0.0945**	**0.1006**	-0.0140	-0.0137	
14	Thursday, September 13, 2012	**0.0967**	**0.1003**	-0.0170	**0.0793**	**0.1003**	-0.0160	**0.0941**	**0.1003**	-0.0150	-0.0160	
28	Thursday, September 27, 2012	**0.0962**	**0.1002**	-0.0210	**0.0787**	**0.1002**	-0.0210	**0.0935**	**0.1003**	-0.0210	-0.0210	
56	Thursday, October 25, 2012	**0.0952**	**0.0995**	-0.0240	**0.0777**	**0.0995**	-0.0240	**0.0926**	**0.0995**	-0.0220	-0.0233	
112	Thursday, December 20, 2012	**0.0946**	**0.0994**	-0.0290	**0.0771**	**0.0994**	-0.0290	**0.0921**	**0.0994**	-0.0260	-0.0280	
224	Thursday, April 11, 2013	**0.0942**	**0.0991**	-0.0300	**0.0766**	**0.0991**	-0.0310	**0.0918**	**0.0991**	-0.0260	-0.0290	
448	Thursday, November 21, 2013	**0.0935**	**0.0986**	-0.0320	**0.0759**	**0.0986**	-0.0330	**0.0911**	**0.0986**	-0.0280	-0.0310	
		-0.0009			**-0.0009**			**-0.0009**				

Note: Initial reading of specimen "A" was changed from 0.1079 to 0.0988, "B" from 0.0974 to 0.0812 and "C" from 0.1045 to 0.0959.

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 2

Mix Date Wednesday, August 29, 2012 Mix Time: 7:39 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8165	0.8140	11.61500	1.6305	9.9845
B	10.0000	0.8155	0.8125	11.61800	1.6280	9.9900
C	10.0000	0.8125	0.8130	11.60400	1.6255	9.9785

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Thursday, September 06, 2012	**0.1034**	**0.1006**	0.0028	**0.1149**	**0.1006**	0.0143	**0.1058**	**0.1006**	0.0052	0.0074	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 06, 2012	**0.1034**	**0.1006**	0.0000	**0.1149**	**0.1006**	0.0000	**0.1058**	**0.1006**	0.0000	0.0000	
4	Monday, September 10, 2012	**0.1026**	**0.1005**	-0.0070	**0.1140**	**0.1005**	-0.0080	**0.1050**	**0.1005**	-0.0070	-0.0073	Shrinkage Room
7	Thursday, September 13, 2012	**0.1022**	**0.1003**	-0.0090	**0.1136**	**0.1003**	-0.0100	**0.1047**	**0.1002**	-0.0070	-0.0087	
14	Thursday, September 20, 2012	**0.1019**	**0.1003**	-0.0120	**0.1133**	**0.1003**	-0.0130	**0.1044**	**0.1003**	-0.0110	-0.0120	
28	Thursday, October 04, 2012	**0.1010**	**0.0999**	-0.0170	**0.1124**	**0.0998**	-0.0170	**0.1035**	**0.0998**	-0.0150	-0.0163	
56	Thursday, November 01, 2012	**0.1000**	**0.0993**	-0.0210	**0.1114**	**0.0994**	-0.0230	**0.1025**	**0.0994**	-0.0210	-0.0217	
112	Thursday, December 27, 2012	**0.0994**	**0.0994**	-0.0280	**0.1108**	**0.0994**	-0.0290	**0.1019**	**0.0994**	-0.0270	-0.0280	
224	Thursday, April 18, 2013	**0.0987**	**0.0991**	-0.0320	**0.1101**	**0.0991**	-0.0330	**0.1011**	**0.0991**	-0.0320	-0.0323	
448	Thursday, November 28, 2013	**0.0982**	**0.0986**	-0.0320	**0.1095**	**0.0986**	-0.0340	**0.1006**	**0.0986**	-0.0320	-0.0327	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/22/2014

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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 2

Mix Date Wednesday, August 29, 2012 Mix Time: 7:39 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8130	0.8125	11.63300	1.6255	10.0075
B	10.0000	0.8155	0.8135	11.61300	1.6290	9.9840
C	10.0000	0.8175	0.8155	11.74600	1.6330	10.1130

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Thursday, September 13, 2012	**0.1066**	**0.1002**	0.0064	**0.0997**	**0.1003**	-0.0006	**0.2332**	**0.1003**	0.1329	0.0462	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 13, 2012	**0.1066**	**0.1002**	0.0000	**0.0997**	**0.1003**	0.0000	**0.2332**	**0.1003**	0.0000	0.0000	
4	Monday, September 17, 2012	**0.1059**	**0.1001**	-0.0060	**0.0990**	**0.1002**	-0.0060	**0.2326**	**0.1002**	-0.0050	-0.0057	Shrinkage Room
7	Thursday, September 20, 2012	**0.1059**	**0.1003**	-0.0080	**0.0990**	**0.1003**	-0.0070	**0.2325**	**0.1003**	-0.0070	-0.0073	
14	Thursday, September 27, 2012	**0.1055**	**0.1002**	-0.0110	**0.0984**	**0.1002**	-0.0120	**0.2320**	**0.1002**	-0.0110	-0.0113	
28	Thursday, October 11, 2012	**0.1047**	**0.0997**	-0.0140	**0.0977**	**0.0997**	-0.0140	**0.2313**	**0.0997**	-0.0130	-0.0137	
56	Thursday, November 08, 2012	**0.1037**	**0.0992**	-0.0190	**0.0968**	**0.0992**	-0.0180	**0.2303**	**0.0992**	-0.0180	-0.0183	
112	Thursday, January 03, 2013	**0.1029**	**0.0993**	-0.0280	**0.0960**	**0.0993**	-0.0270	**0.2296**	**0.0993**	-0.0260	-0.0270	
224	Thursday, April 25, 2013	**0.1023**	**0.0991**	-0.0320	**0.0954**	**0.0991**	-0.0310	**0.2291**	**0.0991**	-0.0290	-0.0307	
448	Thursday, December 05, 2013	**0.1017**	**0.0986**	-0.0330	**0.0947**	**0.0986**	-0.0330	**0.2283**	**0.0986**	-0.0320	-0.0327	

Note: One gauge stud vibrated out of the end of specimen C.

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/24/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 2

Mix Date Wednesday, August 29, 2012 Mix Time: 7:39 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8095	0.8145	11.60800	1.6240	9.9840
B	10.0000	0.8150	0.8160	11.60500	1.6310	9.9740
C	10.0000	0.8130	0.8150	11.60800	1.6280	9.9800

SHRINKAGE TESTING - ASTM C157

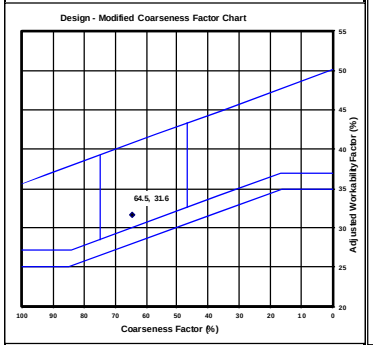
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Thursday, September 27, 2012	**0.1056**	**0.1001**	0.0055	**0.1062**	**0.1000**	0.0062	**0.0998**	**0.1000**	-0.0002	0.0038	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	Soak
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 27, 2012	**0.1056**	**0.1001**	0.0000	**0.1062**	**0.1000**	0.0000	**0.0998**	**0.1000**	0.0000	0.0000	
4	Monday, October 01, 2012	**0.1051**	**0.1002**	-0.0060	**0.1055**	**0.1002**	-0.0090	**0.0992**	**0.1001**	-0.0070	-0.0073	
7	Thursday, October 04, 2012	**0.1046**	**0.0998**	-0.0070	**0.1051**	**0.0998**	-0.0090	**0.0986**	**0.0999**	-0.0110	-0.0090	
14	Thursday, October 11, 2012	**0.1041**	**0.0997**	-0.0110	**0.1047**	**0.0997**	-0.0120	**0.0983**	**0.0997**	-0.0120	-0.0117	
28	Thursday, October 25, 2012	**0.1035**	**0.0995**	-0.0150	**0.1039**	**0.0995**	-0.0180	**0.0975**	**0.0995**	-0.0180	-0.0170	
56	Thursday, November 22, 2012	**0.1029**	**0.0994**	-0.0200	**0.1034**	**0.0994**	-0.0220	**0.0969**	**0.0994**	-0.0230	-0.0217	
112	Thursday, January 17, 2013	**0.1019**	**0.0991**	-0.0270	**0.1025**	**0.0991**	-0.0280	**0.0959**	**0.0991**	-0.0300	-0.0283	
224	Thursday, May 09, 2013	**0.1014**	**0.0990**	-0.0310	**0.1019**	**0.0990**	-0.0330	**0.0954**	**0.0990**	-0.0340	-0.0327	
448	Thursday, December 19, 2013	**0.1008**	**0.0985**	-0.0320	**0.1012**	**0.0985**	-0.0350	**0.0947**	**0.0985**	-0.0360	-0.0343	Shrinkage Room

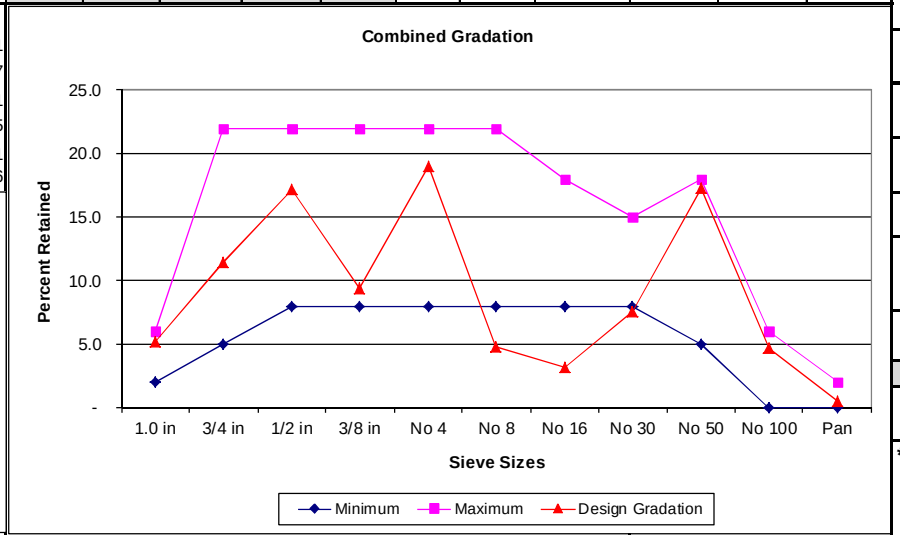
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/24/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT	Project:	110375									MIX	3		
MIX NUMBER	Mix 3	Notes:										Set #:			
MIX DESIGN INFO	Date: 8/30/2012		f'c: 4,000 psi							Size(c.f.): 2.25			Factor: 0.0833		
	% Retained MDOT			DRY Specific	AGG Absorp-		AGG Moisture	Free H20	Batch Free	Volume	DRY Mix 1 cu yd	DRY Mix lab batch	Adjusted lab batch	Actual lab batch	
Material	Min	Max	Design	Gravity	tion		Content	Content	H2O	(c.f.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.0610	405.1008	33.7580	33.76	33.76	Paste
SCM 1				2.630						0.6171	101.2752	8.4400	8.44	8.44	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	
Total Grad%			100.0						-3.84	26.9984	3876.8727	323.0720	326.93	326.93	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.5	32.2	31.6





Plastic Test Results

Batch Time	10:54 AM	% Air	1.50	Unit Wt w/o Air	147.28	Design w/c	0.468
Sample Time	11:03 AM	Bucket Weight	7.70	Unit Wt (pcf)	147.00	Actual w/c	0.468
Air Temp.	75.4	Bucket Full	44.45	Theorectial Air	0.19	Design Unit Wt	143.60
Mix Temp.	69.6	Bucket Volume	0.250	Yield	2.22	Fine/Coarse	0.65
Slump, in.	6.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.39

Comments / Notes / Observations

C Ash Source 1

80/20

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
08/31/12	1	1420	1440
	1	1460	
09/06/12	7	3900	3830
	7	3760	
09/13/12	14	3950	4040
	14	4130	
09/27/12	28	4780	4787
	28	5010	
	28	4570	
10/25/12	56	5270	5270
	56	*4670	

Technician who conducted tests:

* Denotes erratic results.

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 3
Mix Date Thursday, August 30, 2012 Mix Time: 10:54 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8130	0.8130	11.63650	1.6260	10.0105
B	10.0000	0.8155	0.8160	11.64600	1.6315	10.0145
C	10.0000	0.8145	0.8165	11.65600	1.6310	10.0250

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Friday, August 31, 2012	**0.1043**	**0.1006**	0.0037	**0.1141**	**0.1006**	0.0135	**0.1184**	**0.1006**	0.0178	0.0117	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, August 31, 2012	**0.1043**	**0.1006**	0.0000	**0.1141**	**0.1006**	0.0000	**0.1184**	**0.1006**	0.0000	0.0000	
4	Tuesday, September 04, 2012	**0.1033**	**0.1005**	-0.0090	**0.1131**	**0.1005**	-0.0090	**0.1173**	**0.1004**	-0.0090	-0.0090	**Shrinkage Room**
7	Friday, September 07, 2012	**0.1030**	**0.1006**	-0.0130	**0.1129**	**0.1006**	-0.0120	**0.1170**	**0.1006**	-0.0140	-0.0130	
14	Friday, September 14, 2012	**0.1022**	**0.1003**	-0.0180	**0.1122**	**0.1003**	-0.0160	**0.1165**	**0.1003**	-0.0160	-0.0167	
28	Friday, September 28, 2012	**0.1015**	**0.1002**	-0.0240	**0.1115**	**0.1002**	-0.0220	**0.1158**	**0.1001**	-0.0210	-0.0223	
56	Friday, October 26, 2012	**0.1004**	**0.0995**	-0.0280	**0.1104**	**0.0995**	-0.0260	**0.1148**	**0.0995**	-0.0250	-0.0263	
112	Friday, December 21, 2012	**0.0997**	**0.0994**	-0.0340	**0.1096**	**0.0994**	-0.0330	**0.1142**	**0.0994**	-0.0300	-0.0323	
224	Friday, April 12, 2013	**0.0991**	**0.0991**	-0.0370	**0.1091**	**0.0991**	-0.0350	**0.1138**	**0.0991**	-0.0310	-0.0343	
448	Friday, November 22, 2013	**0.0984**	**0.0986**	-0.0390	**0.1084**	**0.0986**	-0.0370	**0.1131**	**0.0986**	-0.0330	-0.0363	

Note: Initial reading of specimen "A" was changed from 0.1302 to 0.1043, "B" from 0.1227 to 0.1141 and "C" from 0.1142 to 0.1184.

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 10/24/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 3
Mix Date Thursday, August 30, 2012 Mix Time: 10:54 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8135	0.8150	11.62550	1.6285	9.9970
B	10.0000	0.8165	0.8150	11.63050	1.6315	9.9990
C	10.0000	0.8160	0.8145	11.62500	1.6305	9.9945

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Friday, September 07, 2012	**0.1023**	**0.1006**	0.0017	**0.1100**	**0.1006**	0.0094	**0.1044**	**0.1006**	0.0038	0.0050	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 07, 2012	**0.1023**	**0.1006**	0.0000	**0.1100**	**0.1006**	0.0000	**0.1044**	**0.1006**	0.0000	0.0000	
4	Tuesday, September 11, 2012	**0.1014**	**0.1004**	-0.0070	**0.1091**	**0.1004**	-0.0070	**0.1035**	**0.1004**	-0.0070	-0.0070	Shrinkage Room
7	Friday, September 14, 2012	**0.1012**	**0.1003**	-0.0080	**0.1087**	**0.1003**	-0.0100	**0.1031**	**0.1003**	-0.0100	-0.0093	
14	Friday, September 21, 2012	**0.1007**	**0.1003**	-0.0130	**0.1084**	**0.1003**	-0.0130	**0.1028**	**0.1003**	-0.0130	-0.0130	
28	Friday, October 05, 2012	**0.0999**	**0.0998**	-0.0160	**0.1074**	**0.0998**	-0.0180	**0.1020**	**0.0998**	-0.0160	-0.0167	
56	Friday, November 02, 2012	**0.0987**	**0.0993**	-0.0230	**0.1063**	**0.0994**	-0.0250	**0.1011**	**0.0994**	-0.0210	-0.0230	
112	Friday, December 28, 2012	**0.0980**	**0.0994**	-0.0310	**0.1057**	**0.0994**	-0.0310	**0.1003**	**0.0994**	-0.0290	-0.0303	
224	Friday, April 19, 2013	**0.0973**	**0.0991**	-0.0350	**0.1049**	**0.0991**	-0.0360	**0.0997**	**0.0991**	-0.0320	-0.0343	
448	Friday, November 29, 2013	**0.0965**	**0.0986**	-0.0380	**0.1043**	**0.0986**	-0.0370	**0.0991**	**0.0986**	-0.0330	-0.0360	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/24/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 3

Mix Date Thursday, August 30, 2012 Mix Time: 10:54 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8140	0.8145	11.65200	1.6285	10.0235
B	10.0000	0.8155	0.8145	11.62700	1.6300	9.9970
C	10.0000	0.8135	0.8145	11.63550	1.6280	10.0075

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Friday, September 14, 2012	**0.1360**	**0.1003**	0.0357	**0.1069**	**0.1003**	0.0066	**0.1186**	**0.1003**	0.0183	0.0202	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 14, 2012	**0.1360**	**0.1003**	0.0000	**0.1069**	**0.1003**	0.0000	**0.1186**	**0.1003**	0.0000	0.0000	
6	Thursday, September 20, 2012	**0.1351**	**0.1002**	-0.0080	**0.1061**	**0.1002**	-0.0070	**0.1174**	**0.1002**	-0.0110	-0.0087	Shrinkage Room
7	Friday, September 21, 2012	**0.1351**	**0.1003**	-0.0090	**0.1061**	**0.1003**	-0.0080	**0.1174**	**0.1003**	-0.0120	-0.0097	
14	Friday, September 28, 2012	**0.1346**	**0.1002**	-0.0130	**0.1055**	**0.1002**	-0.0130	**0.1169**	**0.1001**	-0.0150	-0.0137	
28	Friday, October 12, 2012	**0.1339**	**0.0996**	-0.0140	**0.1048**	**0.0996**	-0.0140	**0.1162**	**0.0996**	-0.0170	-0.0150	
56	Friday, November 09, 2012	**0.1332**	**0.0994**	-0.0190	**0.1041**	**0.0994**	-0.0190	**0.1153**	**0.0994**	-0.0240	-0.0207	
112	Friday, January 04, 2013	**0.1325**	**0.0993**	-0.0250	**0.1033**	**0.0993**	-0.0260	**0.1144**	**0.0993**	-0.0320	-0.0277	
224	Friday, April 26, 2013	**0.1318**	**0.0990**	-0.0290	**0.1027**	**0.0990**	-0.0290	**0.1138**	**0.0990**	-0.0350	-0.0310	
448	Friday, December 06, 2013	**0.1313**	**0.0986**	-0.0300	**0.1021**	**0.0986**	-0.0310	**0.1132**	**0.0986**	-0.0370	-0.0327	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/24/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 3

Mix Date Thursday, August 30, 2012 Mix Time: 10:54 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8145	11.61550	1.6270	9.9885
B	10.0000	0.8135	0.8140	11.63450	1.6275	10.0070
C	10.0000	0.8155	0.8125	11.61700	1.6280	9.9890

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Friday, September 28, 2012	**0.0943**	**0.1001**	-0.0058	**0.1059**	**0.1001**	0.0058	**0.1023**	**0.1001**	0.0022	0.0007	**M/Rm**
28 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 28, 2012	**0.0943**	**0.1001**	0.0000	**0.1059**	**0.1001**	0.0000	**0.1023**	**0.1001**	0.0000	0.0000	**Soak**
4	Tuesday, October 02, 2012	**0.0935**	**0.1000**	-0.0070	**0.1052**	**0.1000**	-0.0060	**0.1014**	**0.1000**	-0.0080	-0.0070	
7	Friday, October 05, 2012	**0.0931**	**0.0998**	-0.0090	**0.1048**	**0.0998**	-0.0080	**0.1009**	**0.0998**	-0.0110	-0.0093	
14	Friday, October 12, 2012	**0.0927**	**0.0996**	-0.0110	**0.1043**	**0.0996**	-0.0110	**0.1004**	**0.0996**	-0.0140	-0.0120	
28	Friday, October 26, 2012	**0.0920**	**0.0995**	-0.0170	**0.1038**	**0.0995**	-0.0150	**0.0998**	**0.0995**	-0.0190	-0.0170	
56	Friday, November 23, 2012	**0.0915**	**0.0994**	-0.0210	**0.1031**	**0.0994**	-0.0210	**0.0991**	**0.0994**	-0.0250	-0.0223	
112	Friday, January 18, 2013	**0.0904**	**0.0991**	-0.0290	**0.1020**	**0.0991**	-0.0290	**0.0980**	**0.0991**	-0.0330	-0.0303	
224	Friday, May 10, 2013	**0.0900**	**0.0990**	-0.0320	**0.1016**	**0.0990**	-0.0320	**0.0975**	**0.0990**	-0.0370	-0.0337	
448	Friday, December 20, 2013	**0.0895**	**0.0985**	-0.0320	**0.1008**	**0.0985**	-0.0350	**0.0968**	**0.0985**	-0.0390	-0.0353	**Shrinkage Room**

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 10/24/2014

Burns Cooley Dennis, Inc - State Study No. 247

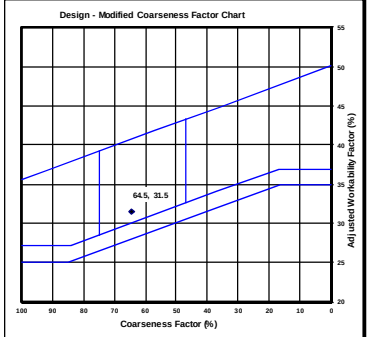
Customer: **MDOT** | Project: **110375** | MIX **4** | Set #:

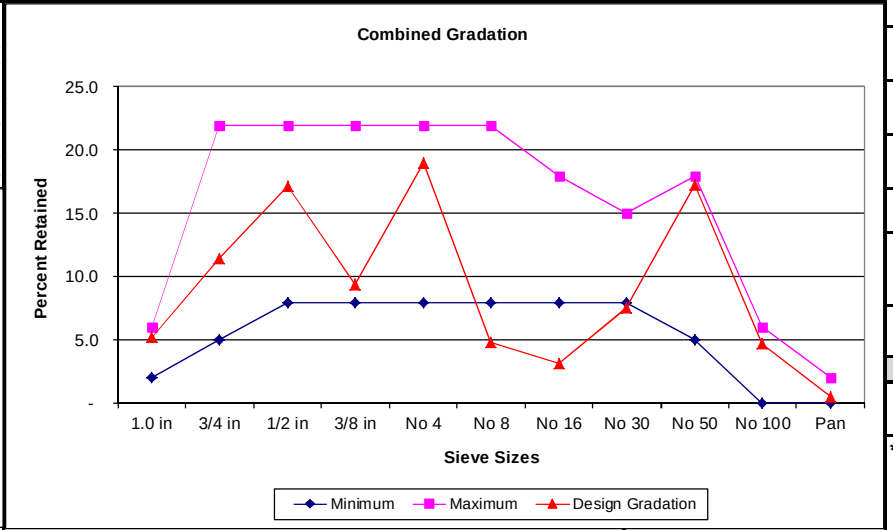
MIX NUMBER Mix 4 | Notes:

MIX DESIGN INFO | Date: 9/4/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.9139	376.2043	31.3500	31.35	31.35	Paste
SCM 1				2.630						0.7641	125.4014	10.4500	10.45	10.45	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9983	3872.1024	322.6740	326.53	326.53	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.3	32.1	31.5





Plastic Test Results

Batch Time	9:20 AM	% Air	1.25	Unit Wt w/o Air	147.10	Design w/c	0.472
Sample Time	9:28 AM	Bucket Weight	7.68	Unit Wt (pcf)	147.08	Actual w/c	0.472
Air Temp.	78.1	Bucket Full	44.45	Theorectial Air	0.01	Design Unit Wt	143.42
Mix Temp.	75.7	Bucket Volume	0.250	Yield	2.22	Fine/Coarse	0.65
Slump, in.	6.00	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.34

Comments / Notes / Observations

C Ash Source 1

75/25

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/05/12	1	1210	1375
	1	1540	
09/11/12	7	3320	3350
	7	3380	
09/18/12	14	3580	3675
	14	3770	
10/02/12	28	5070	5020
	28	5000	
	28	4990	
10/30/12	56	*4240	5050
	56	5050	

Technician who conducted tests:

* Denotes erratic results.

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 4
Mix Date Tuesday, September 04, 2012 Mix Time: 9:20 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8155	0.8130	11.63400	1.6285	10.0055
B	10.0000	0.8155	0.8155	11.62050	1.6310	9.9895
C	10.0000	0.8130	0.8155	11.63950	1.6285	10.0110

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	**INITIAL READINGS**										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Wednesday, September 05, 2012	**0.0955**	**0.1005**	-0.0050	**0.0879**	**0.1005**	-0.0126	**0.1038**	**0.1005**	0.0033	-0.0044	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	**Soak**
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 05, 2012	**0.0955**	**0.1005**	0.0000	**0.0879**	**0.1005**	0.0000	**0.1038**	**0.1005**	0.0000	0.0000	
5	Monday, September 10, 2012	**0.0946**	**0.1005**	-0.0090	**0.0870**	**0.1005**	-0.0090	**0.1029**	**0.1005**	-0.0090	-0.0090	**Shrinkage Room**
7	Wednesday, September 12, 2012	**0.0944**	**0.1004**	-0.0100	**0.0868**	**0.1004**	-0.0100	**0.1028**	**0.1004**	-0.0090	-0.0097	
14	Wednesday, September 19, 2012	**0.0940**	**0.1003**	-0.0130	**0.0864**	**0.1003**	-0.0130	**0.1024**	**0.1003**	-0.0120	-0.0127	
28	Wednesday, October 03, 2012	**0.0934**	**0.1000**	-0.0160	**0.0858**	**0.1000**	-0.0160	**0.1019**	**0.1000**	-0.0140	-0.0153	
56	Wednesday, October 31, 2012	**0.0922**	**0.0994**	-0.0220	**0.0846**	**0.0994**	-0.0220	**0.1007**	**0.0994**	-0.0200	-0.0213	
112	Wednesday, December 26, 2012	**0.0917**	**0.0995**	-0.0280	**0.0841**	**0.0995**	-0.0280	**0.1003**	**0.0995**	-0.0250	-0.0270	
224	Wednesday, April 17, 2013	**0.0911**	**0.0991**	-0.0300	**0.0836**	**0.0991**	-0.0290	**0.0998**	**0.0991**	-0.0260	-0.0283	
448	Wednesday, November 27, 2013	**0.0904**	**0.0986**	-0.0320	**0.0830**	**0.0986**	-0.0300	**0.0991**	**0.0986**	-0.0280	-0.0300	

Note: Initial reading of specimen "A" was changed from 0.1083 to 0.0955, "B" from 0.0965 to 0.0879 and "C" from 0.1163 to 0.1038.

Note: Lowest Reading Value Recorded. Reviewed By: Robet Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 4

Mix Date Tuesday, September 04, 2012 Mix Time: 9:20 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8160	0.8160	11.64200	1.6320	10.0100
B	10.0000	0.8140	0.8160	11.61700	1.6300	9.9870
C	10.0000	0.8140	0.8160	11.64500	1.6300	10.0150

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Wednesday, September 12, 2012	**0.1148**	**0.1004**	0.0144	**0.0878**	**0.1004**	-0.0126	**0.1230**	**0.1004**	0.0226	0.0081	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 12, 2012	**0.1148**	**0.1004**	0.0000	**0.0878**	**0.1004**	0.0000	**0.1230**	**0.1004**	0.0000	0.0000	
5	Monday, September 17, 2012	**0.1138**	**0.1002**	-0.0080	**0.0869**	**0.1002**	-0.0070	**0.1222**	**0.1002**	-0.0060	-0.0070	Shrinkage Room
7	Wednesday, September 19, 2012	**0.1138**	**0.1004**	-0.0100	**0.0868**	**0.1004**	-0.0100	**0.1222**	**0.1003**	-0.0070	-0.0090	
14	Wednesday, September 26, 2012	**0.1133**	**0.1001**	-0.0120	**0.0863**	**0.1001**	-0.0120	**0.1216**	**0.1001**	-0.0110	-0.0117	
28	Wednesday, October 10, 2012	**0.1123**	**0.0996**	-0.0170	**0.0855**	**0.0996**	-0.0150	**0.1207**	**0.0996**	-0.0150	-0.0157	
56	Wednesday, November 07, 2012	**0.1113**	**0.0994**	-0.0250	**0.0846**	**0.0994**	-0.0220	**0.1198**	**0.0994**	-0.0220	-0.0230	
112	Wednesday, January 02, 2013	**0.1102**	**0.0992**	-0.0340	**0.0836**	**0.0992**	-0.0300	**0.1188**	**0.0992**	-0.0300	-0.0313	
224	Wednesday, April 24, 2013	**0.1095**	**0.0990**	-0.0390	**0.0831**	**0.0990**	-0.0330	**0.1179**	**0.0989**	-0.0360	-0.0360	
448	Wednesday, December 04, 2013	**0.1091**	**0.0986**	-0.0390	**0.0827**	**0.0986**	-0.0330	**0.1175**	**0.0986**	-0.0370	-0.0363	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 4
Mix Date Tuesday, September 04, 2012 Mix Time: 9:20 AM

Curing Method: 14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8170	11.63850	1.6320	10.0065
B	10.0000	0.8150	0.8165	11.64250	1.6315	10.0110
C	10.0000	0.8150	0.8155	11.62950	1.6305	9.9990

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Wednesday, September 19, 2012	**0.1168**	**0.1003**	0.0165	**0.1184**	**0.1003**	0.0181	**0.1056**	**0.1003**	0.0053	0.0133	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 19, 2012	**0.1168**	**0.1003**	0.0000	**0.1184**	**0.1003**	0.0000	**0.1056**	**0.1003**	0.0000	0.0000	
5	Monday, September 24, 2012	**0.1159**	**0.1001**	-0.0070	**0.1175**	**0.1001**	-0.0070	**0.1047**	**0.1001**	-0.0070	-0.0070	Shrinkage Room
7	Wednesday, September 26, 2012	**0.1159**	**0.1001**	-0.0070	**0.1175**	**0.1001**	-0.0070	**0.1047**	**0.1001**	-0.0070	-0.0070	
14	Wednesday, October 03, 2012	**0.1155**	**0.1000**	-0.0100	**0.1171**	**0.1000**	-0.0100	**0.1043**	**0.1000**	-0.0100	-0.0100	
28	Wednesday, October 17, 2012	**0.1146**	**0.0996**	-0.0150	**0.1163**	**0.0996**	-0.0140	**0.1035**	**0.0996**	-0.0140	-0.0143	
56	Wednesday, November 14, 2012	**0.1138**	**0.0994**	-0.0210	**0.1155**	**0.0994**	-0.0200	**0.1026**	**0.0994**	-0.0210	-0.0207	
112	Wednesday, January 09, 2013	**0.1127**	**0.0991**	-0.0290	**0.1144**	**0.0991**	-0.0280	**0.1015**	**0.0991**	-0.0290	-0.0287	
224	Wednesday, May 01, 2013	**0.1123**	**0.0991**	-0.0330	**0.1140**	**0.0991**	-0.0320	**0.1011**	**0.0991**	-0.0330	-0.0327	
448	Wednesday, December 11, 2013	**0.1118**	**0.0986**	-0.0330	**0.1136**	**0.0986**	-0.0310	**0.1006**	**0.0986**	-0.0330	-0.0323	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 4

Mix Date Tuesday, September 04, 2012 Mix Time: 9:20 AM

Curing Method: 28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8100	0.8145	11.60000	1.6245	9.9755
B	10.0000	0.8150	0.8155	11.63900	1.6305	10.0085
C	10.0000	0.8140	0.8165	11.63050	1.6305	10.0000

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Wednesday, October 03, 2012	**0.0835**	**0.0998**	-0.0163	**0.1147**	**0.0998**	0.0149	**0.1061**	**0.0998**	0.0063	0.0016	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 03, 2012	**0.0835**	**0.0998**	0.0000	**0.1147**	**0.0998**	0.0000	**0.1061**	**0.0998**	0.0000	0.0000	
5	Monday, October 08, 2012	**0.0825**	**0.0998**	-0.0100	**0.1137**	**0.0997**	-0.0090	**0.1051**	**0.0997**	-0.0090	-0.0093	Shrinkage Room
7	Wednesday, October 10, 2012	**0.0823**	**0.0996**	-0.0100	**0.1136**	**0.0996**	-0.0090	**0.1049**	**0.0996**	-0.0100	-0.0097	
14	Wednesday, October 17, 2012	**0.0818**	**0.0998**	-0.0170	**0.1132**	**0.0996**	-0.0130	**0.1045**	**0.0996**	-0.0140	-0.0147	
28	Wednesday, October 31, 2012	**0.0812**	**0.0994**	-0.0190	**0.1125**	**0.0994**	-0.0180	**0.1039**	**0.0994**	-0.0180	-0.0183	
56	Wednesday, November 28, 2012	**0.0804**	**0.0994**	-0.0270	**0.1116**	**0.0994**	-0.0270	**0.1031**	**0.0994**	-0.0260	-0.0267	
112	Wednesday, January 23, 2013	**0.0795**	**0.0991**	-0.0330	**0.1107**	**0.0991**	-0.0330	**0.1021**	**0.0991**	-0.0330	-0.0330	
224	Wednesday, May 15, 2013	**0.0790**	**0.0990**	-0.0370	**0.1100**	**0.0990**	-0.0390	**0.1015**	**0.0990**	-0.0380	-0.0380	
448	Wednesday, December 25, 2013	**0.0785**	**0.0986**	-0.0380	**0.1094**	**0.0986**	-0.0410	**0.1010**	**0.0986**	-0.0390	-0.0393	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

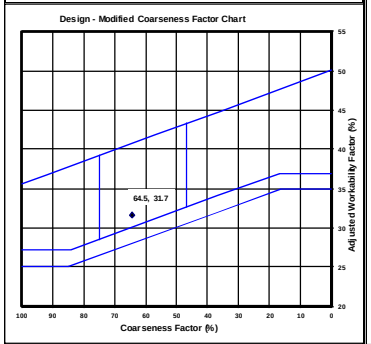
Customer: **MDOT** | Project: **110375** | MIX **5** | Set #:

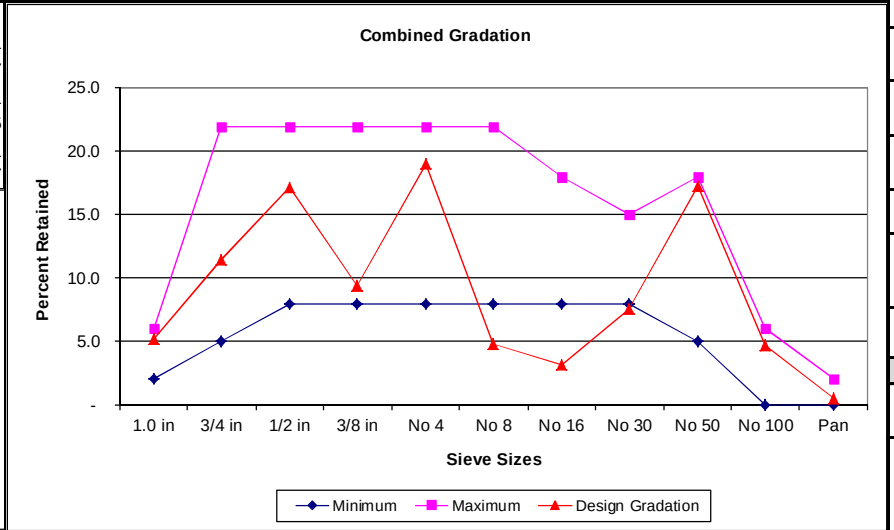
MIX NUMBER Mix 5 | Notes:

MIX DESIGN INFO | Date: 9/5/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.2048	433.3843	36.1150	36.12	36.12	Paste
SCM 1				2.590						0.4732	76.4796	6.3730	6.37	6.37	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9983	3880.3606	323.3620	327.22	327.22	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.6	32.3	31.7





Comments / Notes / Observations

C Ash Source 2

85/15

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/06/12	1	1560	1540
	1	1520	
09/12/12	7	3280	3430
	7	3580	
09/19/12	14	4200	4215
	14	4230	
10/03/12	28	4460	4363
	28	4510	
	28	4120	
10/31/12	56	5220	4945
	56	4670	

Technician who conducted tests:

Plastic Test Results

Batch Time	10:08 AM	% Air	2.00	Unit Wt w/o Air	147.41	Design w/c	0.465
Sample Time	10:16 AM	Bucket Weight	7.69	Unit Wt (pcf)	146.04	Actual w/c	0.465
Air Temp.	76.0	Bucket Full	44.20	Theorectial Air	0.93	Design Unit Wt	143.73
Mix Temp.	75	Bucket Volume	0.250	Yield	2.24	Fine/Coarse	0.65
Slump, in.	6.25	Cmt+Wtr Vol(%)	23.98	Relative Yield	1.00	Bag Factor	5.42

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 5

Mix Date Wednesday, September 05, 2012 Mix Time: 10:08 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8145	0.8160	11.62650	1.6305	9.9960
B	10.0000	0.8155	0.8155	11.64250	1.6310	10.0115
C	10.0000	0.8120	0.8140	11.65150	1.6260	10.0255

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Thursday, September 06, 2012	**0.1025**	**0.1006**	0.0019	**0.1150**	**0.1006**	0.0144	**0.1240**	**0.1006**	0.0234	0.0132	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 06, 2012	**0.1025**	**0.1006**	0.0000	**0.1150**	**0.1006**	Erratic	**0.1240**	**0.1006**	0.0000	0.0000	
4	Monday, September 10, 2012	**0.1025**	**0.1005**	0.0010	**0.1146**	**0.1005**	Erratic	**0.1233**	**0.1006**	-0.0070	-0.0030	**Shrinkage Room**
7	Thursday, September 13, 2012	**0.1021**	**0.1003**	-0.0010	**0.1140**	**0.1003**	Erratic	**0.1230**	**0.1003**	-0.0070	-0.0040	
14	Thursday, September 20, 2012	**0.1015**	**0.1003**	-0.0070	**0.1135**	**0.1003**	Erratic	**0.1223**	**0.1003**	-0.0140	-0.0105	
28	Thursday, October 04, 2012	**0.1003**	**0.0998**	-0.0140	**0.1125**	**0.0998**	Erratic	**0.1213**	**0.0999**	-0.0200	-0.0170	
56	Thursday, November 01, 2012	**0.0994**	**0.0994**	-0.0190	**0.1116**	**0.0994**	Erratic	**0.1202**	**0.0994**	-0.0260	-0.0225	
112	Thursday, December 27, 2012	**0.0988**	**0.0994**	-0.0250	**0.1086**	**0.0994**	Erratic	**0.1194**	**0.0994**	-0.0340	-0.0295	
224	Thursday, April 18, 2013	**0.0978**	**0.0991**	-0.0320	**0.1079**	**0.0991**	Erratic	**0.1189**	**0.0991**	-0.0360	-0.0340	
448	Thursday, November 28, 2013	**0.0973**	**0.0986**	-0.0320	**0.1072**	**0.0986**	Erratic	**0.1180**	**0.0986**	-0.0400	-0.0360	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 5

Mix Date Wednesday, September 05, 2012 Mix Time: 10:08 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8140	11.63100	1.6295	10.0015
B	10.0000	0.8135	0.8150	11.60750	1.6285	9.9790
C	10.0000	0.8165	0.8165	11.63450	1.6330	10.0015

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Thursday, September 13, 2012	**0.1033**	**0.1003**	0.0030	**0.0853**	**0.1003**	-0.0150	**0.1119**	**0.1003**	0.0116	-0.0001	**M/Rm**
7 Day Soak		LENGTH CHANGE CALCULATIONS										**Soak**
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 13, 2012	**0.1033**	**0.1003**	0.0000	**0.0853**	**0.1003**	0.0000	**0.1119**	**0.1003**	0.0000	0.0000	
4	Monday, September 17, 2012	**0.1026**	**0.1002**	-0.0060	**0.0846**	**0.1002**	-0.0060	**0.1112**	**0.1002**	-0.0060	-0.0060	**Shrinkage Room**
7	Thursday, September 20, 2012	**0.1024**	**0.1003**	-0.0090	**0.0844**	**0.1003**	-0.0090	**0.1111**	**0.1003**	-0.0080	-0.0087	
14	Thursday, September 27, 2012	**0.1019**	**0.1001**	-0.0120	**0.0839**	**0.1001**	-0.0120	**0.1106**	**0.1001**	-0.0110	-0.0117	
28	Thursday, October 11, 2012	**0.1011**	**0.0997**	-0.0160	**0.0832**	**0.0997**	-0.0150	**0.1098**	**0.0997**	-0.0150	-0.0153	
56	Thursday, November 08, 2012	**0.1002**	**0.0992**	-0.0200	**0.0823**	**0.0992**	-0.0190	**0.1088**	**0.0992**	-0.0200	-0.0197	
112	Thursday, January 03, 2013	**0.0994**	**0.0993**	-0.0290	**0.0816**	**0.0993**	-0.0270	**0.1081**	**0.0993**	-0.0280	-0.0280	
224	Thursday, April 25, 2013	**0.0990**	**0.0991**	-0.0310	**0.0815**	**0.0991**	-0.0260	**0.1076**	**0.0991**	-0.0310	-0.0293	
448	Thursday, December 05, 2013	**0.0985**	**0.0986**	-0.0310	**0.0808**	**0.0986**	-0.0280	**0.1070**	**0.0986**	-0.0320	-0.0303	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 5

Mix Date Wednesday, September 05, 2012 Mix Time: 10:08 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8125	11.63850	1.6280	10.0105
B	10.0000	0.8150	0.8160	11.65250	1.6310	10.0215
C	10.0000	0.8130	0.8150	11.62550	1.6280	9.9975

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Thursday, September 20, 2012	**0.1187**	**0.1003**	0.0184	**0.1373**	**0.1002**	0.0371	**0.1015**	**0.1002**	0.0013	0.0189	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 20, 2012	**0.1187**	**0.1003**	0.0000	**0.1373**	**0.1002**	0.0000	**0.1015**	**0.1002**	0.0000	0.0000	
4	Monday, September 24, 2012	**0.1181**	**0.1002**	-0.0050	**0.1367**	**0.1002**	-0.0060	**0.1008**	**0.1002**	-0.0070	-0.0060	Shrinkage Room
7	Thursday, September 27, 2012	**0.1179**	**0.1002**	-0.0070	**0.1363**	**0.1001**	-0.0090	**0.1005**	**0.1001**	-0.0090	-0.0083	
14	Thursday, October 04, 2012	**0.1173**	**0.1000**	-0.0110	**0.1358**	**0.0998**	-0.0110	**0.0999**	**0.0998**	-0.0120	-0.0113	
28	Thursday, October 18, 2012	**0.1167**	**0.0997**	-0.0140	**0.1349**	**0.0996**	-0.0180	**0.0992**	**0.0996**	-0.0170	-0.0163	
56	Thursday, November 15, 2012	**0.1158**	**0.0993**	-0.0190	**0.1340**	**0.0993**	-0.0240	**0.0984**	**0.0993**	-0.0220	-0.0217	
112	Thursday, January 10, 2013	**0.1149**	**0.0992**	-0.0270	**0.1331**	**0.0992**	-0.0320	**0.0976**	**0.0992**	-0.0290	-0.0293	
224	Thursday, May 02, 2013	**0.1143**	**0.0990**	-0.0310	**0.1324**	**0.0990**	-0.0370	**0.0971**	**0.0990**	-0.0320	-0.0333	
448	Thursday, December 12, 2013	**0.1136**	**0.0986**	-0.0340	**0.1318**	**0.0986**	-0.0390	**0.0965**	**0.0986**	-0.0340	-0.0357	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 5

Mix Date Wednesday, September 05, 2012 Mix Time: 10:08 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8150	0.8165	11.65200	1.6315	10.0205
B	10.0000	0.8140	0.8165	11.62950	1.6305	9.9990
C	10.0000	0.8145	0.8130	11.62100	1.6275	9.9935

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Thursday, October 04, 2012	**0.1278**	**0.0999**	0.0279	**0.1091**	**0.0999**	0.0092	**0.0993**	**0.0999**	-0.0006	0.0122	**M/Rm**
28 Day Soak		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, October 04, 2012	**0.1278**	**0.0999**	0.0000	**0.1091**	**0.0999**	0.0000	**0.0993**	**0.0999**	0.0000	0.0000	
4	Monday, October 08, 2012	**0.1268**	**0.0997**	-0.0080	**0.1082**	**0.0997**	-0.0070	**0.0983**	**0.0997**	-0.0080	-0.0077	**Shrinkage Room**
7	Thursday, October 11, 2012	**0.1266**	**0.0997**	-0.0100	**0.1079**	**0.0997**	-0.0100	**0.0980**	**0.0997**	-0.0110	-0.0103	
14	Thursday, October 18, 2012	**0.1261**	**0.0996**	-0.0140	**0.1075**	**0.0996**	-0.0130	**0.0975**	**0.0996**	-0.0150	-0.0140	
28	Thursday, November 01, 2012	**0.1255**	**0.0994**	-0.0180	**0.1068**	**0.0994**	-0.0180	**0.0969**	**0.0994**	-0.0190	-0.0183	
56	Thursday, November 29, 2012	**0.1250**	**0.0995**	-0.0240	**0.1063**	**0.0995**	-0.0240	**0.0962**	**0.0995**	-0.0270	-0.0250	
112	Thursday, January 24, 2013	**0.1239**	**0.0992**	-0.0320	**0.1052**	**0.0992**	-0.0320	**0.0951**	**0.0992**	-0.0350	-0.0330	
224	Thursday, May 16, 2013	**0.1232**	**0.0990**	-0.0370	**0.1046**	**0.0990**	-0.0360	**0.0944**	**0.0990**	-0.0400	-0.0377	
448	Thursday, December 26, 2013	**0.1226**	**0.0985**	-0.0380	**0.1039**	**0.0985**	-0.0380	**0.0937**	**0.0984**	-0.0410	-0.0390	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 11/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

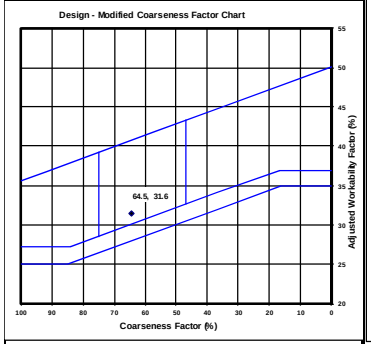
Customer: **MDOT** | Project: **110375** | MIX **6** | Set #:

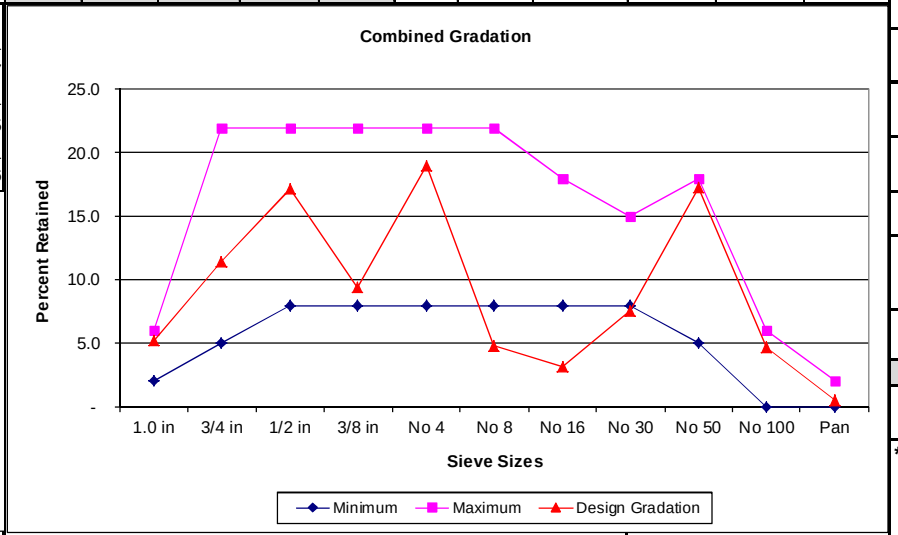
MIX NUMBER Mix 6 | Notes:

MIX DESIGN INFO | Date: 9/6/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	% Retained MDOT Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.0536	403.6642	33.6390	33.64	33.64	Paste
SCM 1				2.590						0.6244	100.9161	8.4100	8.41	8.41	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9983	3875.0770	322.9230	326.78	326.78	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.4	32.1	31.6





Plastic Test Results

Batch Time	9:02 AM	% Air	2.00	Unit Wt w/o Air	147.21	Design w/c	0.469
Sample Time	9:10 AM	Bucket Weight	7.68	Unit Wt (pcf)	146.88	Actual w/c	0.469
Air Temp.	74.2	Bucket Full	44.40	Theorectial Air	0.22	Design Unit Wt	143.53
Mix Temp.	74.5	Bucket Volume	0.250	Yield	2.22	Fine/Coarse	0.65
Slump, in.	7.25	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.37

Comments / Notes / Observations

C Ash Source 2

80/20

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/07/12	1	1470	1460
	1	1450	
09/13/12	7	*3750	3260
	7	3260	
09/20/12	14	3720	3685
	14	3650	
10/04/12	28	4530	4690
	28	4660	
	28	4880	
11/01/12	56	4410	4605
	56	4800	

Technician who conducted tests:

* Denotes erratic results.

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 6
Mix Date Thursday, September 06, 2012 Mix Time: 9:02 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8150	0.8145	11.63700	1.6295	10.0075
B	10.0000	0.8130	0.8160	11.62250	1.6290	9.9935
C	10.0000	0.8130	0.8150	11.62800	1.6280	10.0000

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	**INITIAL READINGS**										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Friday, September 07, 2012	**0.1107**	**0.1006**	0.0101	**0.1040**	**0.1006**	0.0034	**0.1110**	**0.1006**	0.0104	0.0080	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 07, 2012	**0.1107**	**0.1006**	0.0000	**0.1040**	**0.1006**	0.0000	**0.1110**	**0.1006**	0.0000	0.0000	
4	Tuesday, September 11, 2012	**0.1101**	**0.1004**	-0.0040	**0.1037**	**0.1004**	-0.0010	**0.1107**	**0.1004**	-0.0010	-0.0020	**Shrinkage Room**
7	Friday, September 14, 2012	**0.1096**	**0.1003**	-0.0080	**0.1031**	**0.1003**	-0.0060	**0.1102**	**0.1003**	-0.0050	-0.0063	
14	Friday, September 21, 2012	**0.1091**	**0.1002**	-0.0120	**0.1027**	**0.1003**	-0.0100	**0.1097**	**0.1003**	-0.0100	-0.0107	
28	Friday, October 05, 2012	**0.1082**	**0.0998**	-0.0170	**0.1014**	**0.0998**	-0.0180	**0.1085**	**0.0998**	-0.0170	-0.0173	
56	Friday, November 02, 2012	**0.1072**	**0.0994**	-0.0230	**0.1006**	**0.0994**	-0.0220	**0.1077**	**0.0994**	-0.0210	-0.0220	
112	Friday, December 28, 2012	**0.1066**	**0.0994**	-0.0290	**0.0999**	**0.0994**	-0.0290	**0.1071**	**0.0994**	-0.0270	-0.0283	
224	Friday, April 19, 2013	**0.1060**	**0.0991**	-0.0320	**0.0996**	**0.0990**	-0.0280	**0.1065**	**0.0990**	-0.0290	-0.0297	
448	Friday, November 29, 2013	**0.1055**	**0.0986**	-0.0320	**0.0988**	**0.0986**	-0.0320	**0.1059**	**0.0986**	-0.0310	-0.0317	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 11/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 6
Mix Date Thursday, September 06, 2012 Mix Time: 9:02 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8130	11.62750	1.6275	10.0000
B	10.0000	0.8155	0.8145	11.62650	1.6300	9.9965
C	10.0000	0.8170	0.8150	11.63300	1.6320	10.0010

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Friday, September 14, 2012	**0.1053**	**0.1002**	0.0051	**0.0986**	**0.1002**	-0.0016	**0.1085**	**0.1002**	0.0083	0.0039	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 14, 2012	**0.1053**	**0.1002**	0.0000	**0.0986**	**0.1002**	0.0000	**0.1085**	**0.1002**	0.0000	0.0000	
4	Tuesday, September 18, 2012	**0.1047**	**0.1003**	-0.0070	**0.0980**	**0.1003**	-0.0070	**0.1079**	**0.1003**	-0.0070	-0.0070	Shrinkage Room
7	Friday, September 21, 2012	**0.1043**	**0.1002**	-0.0100	**0.0977**	**0.1002**	-0.0090	**0.1075**	**0.1002**	-0.0100	-0.0097	
14	Friday, September 28, 2012	**0.1039**	**0.1001**	-0.0130	**0.0973**	**0.1000**	-0.0110	**0.1070**	**0.1001**	-0.0140	-0.0127	
28	Friday, October 12, 2012	**0.1031**	**0.0996**	-0.0160	**0.0965**	**0.0996**	-0.0150	**0.1062**	**0.0996**	-0.0170	-0.0160	
56	Friday, November 09, 2012	**0.1022**	**0.0994**	-0.0230	**0.0957**	**0.0994**	-0.0210	**0.1053**	**0.0994**	-0.0240	-0.0227	
112	Friday, January 04, 2013	**0.1015**	**0.0993**	-0.0290	**0.0950**	**0.0993**	-0.0270	**0.1045**	**0.0993**	-0.0310	-0.0290	
224	Friday, April 26, 2013	**0.1007**	**0.0991**	-0.0350	**0.0943**	**0.0990**	-0.0310	**0.1038**	**0.0990**	-0.0350	-0.0337	
448	Friday, December 06, 2013	**0.1000**	**0.0986**	-0.0370	**0.0939**	**0.0986**	-0.0310	**0.1032**	**0.0986**	-0.0370	-0.0350	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 6

Mix Date Thursday, September 06, 2012 Mix Time: 9:02 AM

Curing Method: 14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8145	11.66500	1.6295	10.0355
B	10.0000	0.8140	0.8150	11.64800	1.6290	10.0190
C	10.0000	0.8140	0.8145	11.63350	1.6285	10.0050

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Friday, September 21, 2012	**0.1465**	**0.1002**	0.0463	**0.1264**	**0.1002**	0.0262	**0.1096**	**0.1002**	0.0094	0.0273	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 21, 2012	**0.1465**	**0.1002**	0.0000	**0.1264**	**0.1002**	0.0000	**0.1096**	**0.1002**	0.0000	0.0000	
4	Tuesday, September 25, 2012	**0.1458**	**0.1001**	-0.0060	**0.1258**	**0.1001**	-0.0050	**0.1091**	**0.1001**	-0.0040	-0.0050	Shrinkage Room
7	Friday, September 28, 2012	**0.1455**	**0.1000**	-0.0080	**0.1255**	**0.1000**	-0.0070	**0.1088**	**0.1000**	-0.0060	-0.0070	
14	Friday, October 05, 2012	**0.1449**	**0.0998**	-0.0120	**0.1250**	**0.0998**	-0.0100	**0.1083**	**0.0998**	-0.0090	-0.0103	
28	Friday, October 19, 2012	**0.1443**	**0.0996**	-0.0160	**0.1243**	**0.0996**	-0.0150	**0.1077**	**0.0996**	-0.0130	-0.0147	
56	Friday, November 16, 2012	**0.1433**	**0.0993**	-0.0230	**0.1234**	**0.0993**	-0.0210	**0.1068**	**0.0993**	-0.0190	-0.0210	
112	Friday, January 11, 2013	**0.1425**	**0.0991**	-0.0290	**0.1225**	**0.0991**	-0.0280	**0.1061**	**0.0991**	-0.0240	-0.0270	
224	Friday, May 03, 2013	**0.1419**	**0.0990**	-0.0340	**0.1219**	**0.0990**	-0.0330	**0.1055**	**0.0990**	-0.0290	-0.0320	
448	Friday, December 13, 2013	**0.1413**	**0.0986**	-0.0360	**0.1213**	**0.0986**	-0.0350	**0.1050**	**0.0986**	-0.0300	-0.0337	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 6

Mix Date Thursday, September 06, 2012 Mix Time: 9:02 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8150	11.64350	1.6275	10.0160
B	10.0000	0.8145	0.8170	11.63650	1.6315	10.0050
C	10.0000	0.8160	0.8125	11.62100	1.6285	9.9925

SHRINKAGE TESTING - ASTM C157

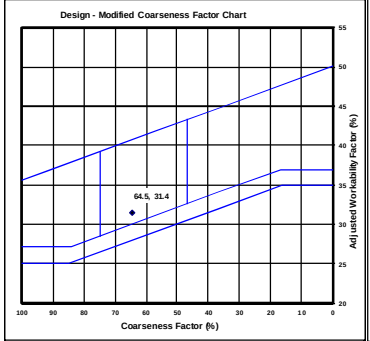
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Friday, October 05, 2012	**0.1135**	**0.0998**	0.0137	**0.1130**	**0.0998**	0.0132	**0.0956**	**0.0998**	-0.0042	0.0076	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 05, 2012	**0.1135**	**0.0998**	0.0000	**0.1130**	**0.0998**	0.0000	**0.0956**	**0.0998**	0.0000	0.0000	
4	Tuesday, October 09, 2012	**0.1128**	**0.0998**	-0.0070	**0.1123**	**0.0998**	-0.0070	**0.0949**	**0.0998**	-0.0070	-0.0070	Shrinkage Room
7	Friday, October 12, 2012	**0.1123**	**0.0996**	-0.0100	**0.1120**	**0.0996**	-0.0080	**0.0945**	**0.0996**	-0.0090	-0.0090	
14	Friday, October 19, 2012	**0.1119**	**0.0996**	-0.0140	**0.1118**	**0.0996**	-0.0100	**0.0942**	**0.0996**	-0.0120	-0.0120	
28	Friday, November 02, 2012	**0.1112**	**0.0994**	-0.0190	**0.1109**	**0.0994**	-0.0170	**0.0935**	**0.0994**	-0.0170	-0.0177	
56	Friday, November 30, 2012	**0.1107**	**0.0995**	-0.0250	**0.1103**	**0.0995**	-0.0240	**0.0929**	**0.0995**	-0.0240	-0.0243	
112	Friday, January 25, 2013	**0.1097**	**0.0992**	-0.0320	**0.1094**	**0.0992**	-0.0300	**0.0919**	**0.0992**	-0.0310	-0.0310	
224	Friday, May 17, 2013	**0.1090**	**0.0990**	-0.0370	**0.1088**	**0.0990**	-0.0340	**0.0912**	**0.0990**	-0.0360	-0.0357	
448	Friday, December 27, 2013	**0.1083**	**0.0985**	-0.0390	**0.1081**	**0.0985**	-0.0360	**0.0905**	**0.0985**	-0.0380	-0.0377	

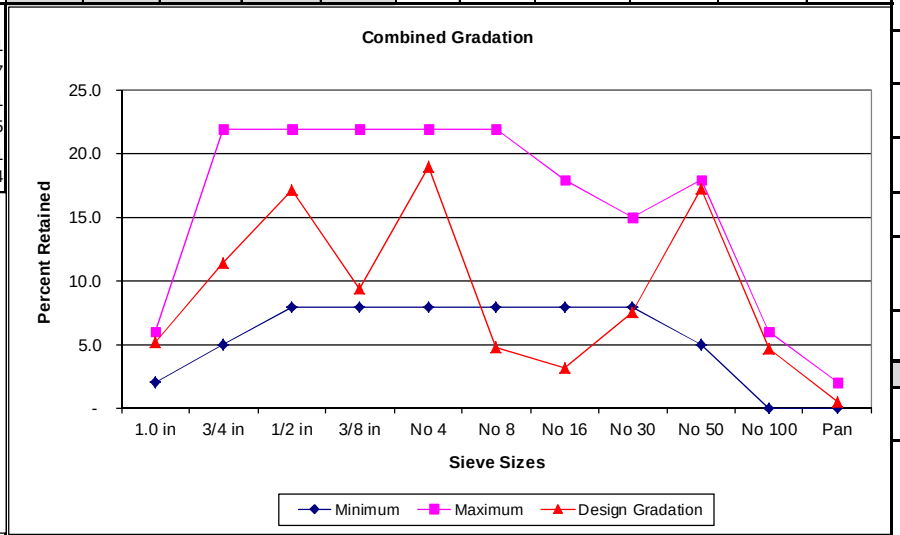
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375								MIX	7	Comments / Notes / Observations	
MIX NUMBER	Mix 7		Notes:									Set #:		C Ash Source 2	
MIX DESIGN INFO	Date: 9/10/2012			f'c: 4,000 psi						Size(c.f.): 2.25			Factor: 0.0833	75/25	
	% Retained MDOT			DRY Specific	AGG Absorp-		AGG Moisture	Free H20	Batch Free	Volume	DRY Mix 1 cu yd	DRY Mix lab batch	Adjusted lab batch	Actual lab batch	
Material	Min	Max	Design	Gravity	tion		Content	Content	H2O	(c.f.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.9055	374.5538	31.2130	31.21	31.21	Paste
SCM 1				2.590						0.7725	124.8513	10.4040	10.40	10.4	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)
Total Grad%			100.0						-3.84	26.9983	3869.9018	322.4910	326.34	326.34	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.3	32.0	31.4





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/11/12	1	1270	1235
	1	1200	
09/17/12	7	3560	3415
	7	3270	
09/24/12	14	4100	3835
	14	3570	
10/08/12	28	4300	4490
	28	4500	
	28	4670	
11/05/12	56	5260	4820
	56	4380	

Technician who conducted tests:

Plastic Test Results

Batch Time	10:22 AM	% Air	2.00	Unit Wt w/o Air	147.01	Design w/c	0.474
Sample Time	10:32 AM	Bucket Weight	7.70	Unit Wt (pcf)	146.80	Actual w/c	0.474
Air Temp.	79.1	Bucket Full	44.40	Theorectial Air	0.15	Design Unit Wt	143.34
Mix Temp.	71.7	Bucket Volume	0.250	Yield	2.22	Fine/Coarse	0.65
Slump, in.	8.25	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.31

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 7

Mix Date Monday, September 10, 2012 Mix Time: 10:22 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8165	11.61800	1.6315	9.9865
B	10.0000	0.8115	0.8110	11.60450	1.6225	9.9820
C	10.0000	0.8120	0.8120	11.61750	1.6240	9.9935

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Tuesday, September 11, 2012	**0.0907**	**0.1004**	-0.0097	**0.0851**	**0.1004**	-0.0153	**0.0928**	**0.1004**	-0.0076	-0.0109	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 11, 2012	**0.0907**	**0.1004**	Erratic	**0.0851**	**0.1004**	0.0000	**0.0928**	**0.1004**	Erratic	0.0000	
3	Friday, September 14, 2012	**0.0858**	**0.1003**	Erratic	**0.0853**	**0.1003**	0.0030	**0.0864**	**0.1002**	Erratic	0.0030	Shrinkage Room
7	Tuesday, September 18, 2012	**0.0857**	**0.1003**	Erratic	**0.0847**	**0.1003**	-0.0030	**0.0862**	**0.1003**	Erratic	-0.0030	
14	Tuesday, September 25, 2012	**0.0850**	**0.1002**	Erratic	**0.0839**	**0.1002**	-0.0100	**0.0855**	**0.1002**	Erratic	-0.0100	
28	Tuesday, October 09, 2012	**0.0842**	**0.0998**	Erratic	**0.0830**	**0.0998**	-0.0150	**0.0845**	**0.0998**	Erratic	-0.0150	
56	Tuesday, November 06, 2012	**0.0834**	**0.0994**	Erratic	**0.0819**	**0.0994**	-0.0220	**0.0836**	**0.0994**	Erratic	-0.0220	
112	Tuesday, January 01, 2013	**0.0826**	**0.0992**	Erratic	**0.0810**	**0.0992**	-0.0290	**0.0827**	**0.0992**	Erratic	-0.0290	
224	Tuesday, April 23, 2013	**0.0823**	**0.0989**	Erratic	**0.0803**	**0.0989**	-0.0330	**0.0822**	**0.0989**	Erratic	-0.0330	
448	Tuesday, December 03, 2013	**0.0816**	**0.0986**	Erratic	**0.0799**	**0.0986**	-0.0340	**0.0816**	**0.0986**	Erratic	-0.0340	

Note: Lowest Reading Value Recorded. Reviewed By Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 7
Mix Date Monday, September 10, 2012 Mix Time: 10:22 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8135	0.8105	11.60350	1.6240	9.9795
B	10.0000	0.8120	0.8130	11.60050	1.6250	9.9755
C	10.0000	0.8155	0.8140	11.61750	1.6295	9.9880

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Tuesday, September 18, 2012	**0.0830**	**0.1003**	-0.0173	**0.0809**	**0.1003**	-0.0194	**0.0925**	**0.1003**	-0.0078	-0.0148	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 18, 2012	**0.0830**	**0.1003**	0.0000	**0.0809**	**0.1003**	0.0000	**0.0925**	**0.1003**	0.0000	0.0000	
3	Friday, September 21, 2012	**0.0822**	**0.1003**	-0.0080	**0.0800**	**0.1003**	-0.0090	**0.0917**	**0.1003**	-0.0080	-0.0083	Shrinkage Room
7	Tuesday, September 25, 2012	**0.0818**	**0.1002**	-0.0110	**0.0798**	**0.1002**	-0.0100	**0.0913**	**0.1002**	-0.0110	-0.0107	
14	Tuesday, October 02, 2012	**0.0814**	**0.1000**	-0.0130	**0.0792**	**0.1000**	-0.0140	**0.0910**	**0.1000**	-0.0120	-0.0130	
28	Tuesday, October 16, 2012	**0.0805**	**0.0996**	-0.0180	**0.0783**	**0.0996**	-0.0190	**0.0901**	**0.0996**	-0.0170	-0.0180	
56	Tuesday, November 13, 2012	**0.0795**	**0.0994**	-0.0260	**0.0774**	**0.0994**	-0.0260	**0.0893**	**0.0994**	-0.0230	-0.0250	
112	Tuesday, January 08, 2013	**0.0785**	**0.0991**	-0.0330	**0.0765**	**0.0991**	-0.0320	**0.0885**	**0.0991**	-0.0280	-0.0310	
224	Tuesday, April 30, 2013	**0.0782**	**0.0991**	-0.0360	**0.0759**	**0.0991**	-0.0380	**0.0882**	**0.0991**	-0.0310	-0.0350	
448	Tuesday, December 10, 2013	**0.0774**	**0.0986**	-0.0390	**0.0754**	**0.0986**	-0.0380	**0.0879**	**0.0986**	-0.0290	-0.0353	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 7

Mix Date Monday, September 10, 2012 Mix Time: 10:22 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8130	11.63750	1.6280	10.0095
B	10.0000	0.8130	0.8130	11.62300	1.6260	9.9970
C	10.0000	0.8140	0.8135	11.63250	1.6275	10.0050

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Tuesday, September 25, 2012	**0.1112**	**0.1002**	0.0110	**0.0968**	**0.1002**	-0.0034	**0.1038**	**0.1002**	0.0036	0.0037	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 25, 2012	**0.1112**	**0.1002**	0.0000	**0.0968**	**0.1002**	0.0000	**0.1038**	**0.1002**	0.0000	0.0000	
3	Friday, September 28, 2012	**0.1103**	**0.1001**	-0.0080	**0.0960**	**0.1000**	-0.0060	**0.1030**	**0.1000**	-0.0060	-0.0067	Shrinkage Room
7	Tuesday, October 02, 2012	**0.1102**	**0.1001**	-0.0090	**0.0958**	**0.1000**	-0.0080	**0.1028**	**0.1000**	-0.0080	-0.0083	
14	Tuesday, October 09, 2012	**0.1095**	**0.0998**	-0.0130	**0.0951**	**0.0998**	-0.0130	**0.1021**	**0.0998**	-0.0130	-0.0130	
28	Tuesday, October 23, 2012	**0.1088**	**0.0995**	-0.0170	**0.0944**	**0.0995**	-0.0170	**0.1014**	**0.0995**	-0.0170	-0.0170	
56	Tuesday, November 20, 2012	**0.1080**	**0.0993**	-0.0230	**0.0936**	**0.0993**	-0.0230	**0.1006**	**0.0993**	-0.0230	-0.0230	
112	Tuesday, January 15, 2013	**0.1071**	**0.0991**	-0.0300	**0.0926**	**0.0991**	-0.0310	**0.0996**	**0.0991**	-0.0310	-0.0307	
224	Tuesday, May 07, 2013	**0.1066**	**0.0990**	-0.0340	**0.0922**	**0.0990**	-0.0340	**0.0991**	**0.0990**	-0.0350	-0.0343	
448	Tuesday, December 17, 2013	**0.1061**	**0.0986**	-0.0350	**0.0917**	**0.0986**	-0.0350	**0.0985**	**0.0986**	-0.0370	-0.0357	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 7

Mix Date Monday, September 10, 2012 Mix Time: 10:22 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8145	11.61000	1.6300	9.9800
B	10.0000	0.8130	0.8140	11.62700	1.6270	10.0000
C	10.0000	0.8165	0.8155	11.64700	1.6320	10.0150

SHRINKAGE TESTING - ASTM C157

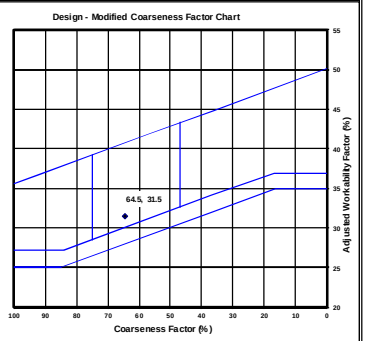
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Tuesday, October 09, 2012	**0.0864**	**0.0996**	-0.0132	**0.1214**	**0.0996**	0.0218	**0.1176**	**0.0997**	0.0179	0.0088	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 09, 2012	**0.0864**	**0.0996**	0.0000	**0.1214**	**0.0996**	0.0000	**0.1176**	**0.0997**	0.0000	0.0000	
3	Friday, October 12, 2012	**0.0859**	**0.0996**	-0.0050	**0.1209**	**0.0996**	-0.0050	**0.1171**	**0.0996**	-0.0040	-0.0047	Shrinkage Room
7	Tuesday, October 16, 2012	**0.0856**	**0.0996**	-0.0080	**0.1206**	**0.0996**	-0.0080	**0.1167**	**0.0996**	-0.0080	-0.0080	
14	Tuesday, October 23, 2012	**0.0852**	**0.0995**	-0.0110	**0.1202**	**0.0995**	-0.0110	**0.1163**	**0.0995**	-0.0110	-0.0110	
28	Tuesday, November 06, 2012	**0.0845**	**0.0994**	-0.0170	**0.1195**	**0.0994**	-0.0170	**0.1156**	**0.0994**	-0.0170	-0.0170	
56	Tuesday, December 04, 2012	**0.0838**	**0.0994**	-0.0240	**0.1189**	**0.0994**	-0.0230	**0.1148**	**0.0994**	-0.0250	-0.0240	
112	Tuesday, January 29, 2013	**0.0828**	**0.0992**	-0.0320	**0.1179**	**0.0992**	-0.0310	**0.1138**	**0.0991**	-0.0320	-0.0317	
224	Tuesday, May 21, 2013	**0.0822**	**0.0990**	-0.0360	**0.1171**	**0.0990**	-0.0370	**0.1131**	**0.0990**	-0.0380	-0.0370	
448	Tuesday, December 31, 2013	**0.0815**	**0.0984**	-0.0370	**0.1164**	**0.0984**	-0.0380	**0.1124**	**0.0984**	-0.0390	-0.0380	

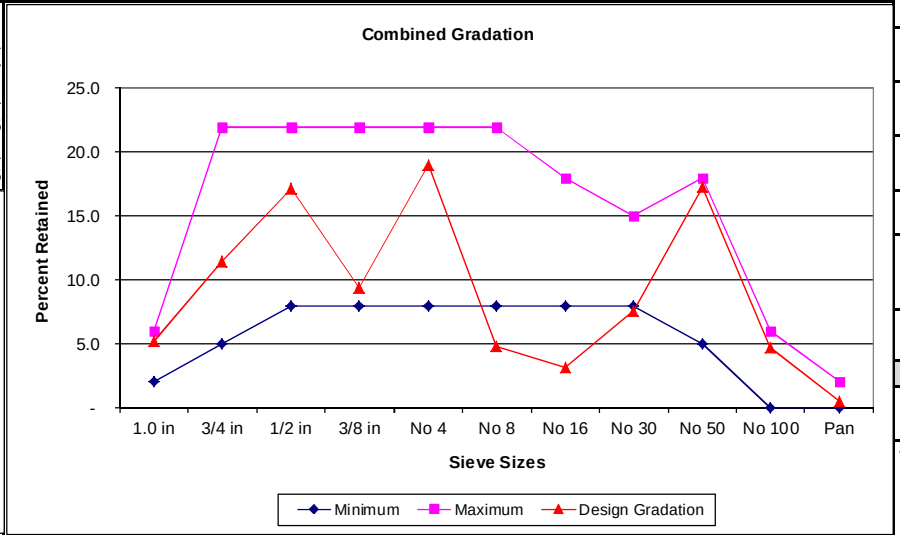
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375								MIX	8	Comments / Notes / Observations			
MIX NUMBER	Mix 8		Notes:									Set #:		F Ash Source 1			
MIX DESIGN INFO	Date: 9/11/2012			f'c: 4,000 psi							Size(c.f.): 2.25		Factor: 0.0833	85/15			
	% Retained MDOT			DRY Specific	AGG Absorp-		AGG Moisture	Free H20	Batch Free	Volume	DRY Mix 1 cu yd	DRY Mix lab batch	Adjusted lab batch	Actual lab batch			
Material	Min	Max	Design	Gravity	tion		Content	Content	H2O	(c.f.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)			
Entrapped Air			2.50%							0.6750							
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste		
Cementitious 1				3.150						2.1778	428.0707	35.6730	35.67	35.67			
SCM 1				2.420						0.5003	75.5419	6.2950	6.30	6.3		Headwaters - Dolet Hills	
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27			
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel		
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75			
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92			
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38			
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93			
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54			
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand		
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85			
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60			
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35		75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)	
Total Grad%			100.0						-3.84	26.9984	3874.1093	322.8420	326.70	326.70			

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.4	32.1	31.5





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/12/12	1	1350	1415
	1	1480	
09/18/12	7	3310	3475
	7	3640	
09/25/12	14	*3310	3850
	14	3850	
10/09/12	28	4590	4527
	28	4540	
	28	4450	
11/06/12	56	5280	5140
	56	5000	

Technician who conducted tests:

* Denotes erratic results.

Plastic Test Results

Batch Time	12:39 PM	% Air	1.50	Unit Wt w/o Air	147.17	Design w/c	0.470
Sample Time	12:49 PM	Bucket Weight	7.69	Unit Wt (pcf)	146.04	Actual w/c	0.470
Air Temp.	87.3	Bucket Full	44.20	Theorectial Air	0.77	Design Unit Wt	143.49
Mix Temp.	77.1	Bucket Volume	0.250	Yield	2.24	Fine/Coarse	0.65
Slump, in.	6.00	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.36

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 8

Mix Date Tuesday, September 11, 2012 Mix Time: 12:39 PM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8120	0.8120	11.61150	1.6240	9.9875
B	10.0000	0.8140	0.8150	11.60700	1.6290	9.9780
C	10.0000	0.8140	0.8145	11.62500	1.6285	9.9965

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	**INITIAL READINGS**										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Wednesday, September 12, 2012	**0.0882**	**0.1003**	-0.0121	**0.0820**	**0.1003**	-0.0183	**0.1036**	**0.1003**	0.0033	-0.0090	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	**Soak**
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 12, 2012	**0.0882**	**0.1003**	0.0000	**0.0820**	**0.1003**	Erratic	**0.1036**	**0.1003**	0.0000	0.0000	
5	Monday, September 17, 2012	**0.0873**	**0.1002**	-0.0080	**0.0803**	**0.1002**	Erratic	**0.1029**	**0.1002**	-0.0060	-0.0070	
7	Wednesday, September 19, 2012	**0.0872**	**0.1003**	-0.0100	**0.0801**	**0.1003**	Erratic	**0.1028**	**0.1003**	-0.0080	-0.0090	
14	Wednesday, September 26, 2012	**0.0863**	**0.1001**	-0.0170	**0.0794**	**0.1001**	Erratic	**0.1022**	**0.1001**	-0.0120	-0.0145	
28	Wednesday, October 10, 2012	**0.0851**	**0.0996**	-0.0240	**0.0782**	**0.0996**	Erratic	**0.1012**	**0.0996**	-0.0170	-0.0205	
56	Wednesday, November 07, 2012	**0.0839**	**0.0994**	-0.0340	**0.0773**	**0.0994**	Erratic	**0.1004**	**0.0994**	-0.0230	-0.0285	
112	Wednesday, January 02, 2013	**0.0831**	**0.0992**	-0.0400	**0.0765**	**0.0992**	Erratic	**0.0997**	**0.0992**	-0.0280	-0.0340	
224	Wednesday, April 24, 2013	**0.0824**	**0.0989**	-0.0440	**0.0759**	**0.0989**	Erratic	**0.0991**	**0.0989**	-0.0310	-0.0375	
448	Wednesday, December 04, 2013	**0.0820**	**0.0986**	-0.0450	**0.0753**	**0.0986**	Erratic	**0.0987**	**0.0985**	-0.0310	-0.0380	**Shrinkage Room**

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 8

Mix Date Tuesday, September 11, 2012 Mix Time: 12:39 PM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8130	0.8155	11.61450	1.6285	9.9860
B	10.0000	0.8135	0.8125	11.61350	1.6260	9.9875
C	10.0000	0.8155	0.8125	11.63900	1.6280	10.0110

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Wednesday, September 12, 2012	**0.0880**	**0.1003**	-0.0123	**0.0827**	**0.1003**	-0.0176	**0.1139**	**0.1003**	0.0136	-0.0054	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 19, 2012	**0.0880**	**0.1003**	0.0000	**0.0827**	**0.1003**	0.0000	**0.1139**	**0.1003**	0.0000	0.0000	Soak
5	Monday, September 24, 2012	**0.0871**	**0.1002**	-0.0080	**0.0819**	**0.1002**	-0.0070	**0.1131**	**0.1002**	-0.0070	-0.0073	Shrinkage Room
7	Wednesday, September 26, 2012	**0.0869**	**0.1001**	-0.0090	**0.0816**	**0.1001**	-0.0090	**0.1128**	**0.1001**	-0.0090	-0.0090	
14	Wednesday, October 03, 2012	**0.0863**	**0.0999**	-0.0130	**0.0810**	**0.0999**	-0.0130	**0.1123**	**0.0999**	-0.0120	-0.0127	
28	Wednesday, October 17, 2012	**0.0854**	**0.0996**	-0.0190	**0.0801**	**0.0996**	-0.0190	**0.1114**	**0.0996**	-0.0180	-0.0187	
56	Wednesday, November 14, 2012	**0.0846**	**0.0994**	-0.0250	**0.0793**	**0.0994**	-0.0250	**0.1107**	**0.0994**	-0.0230	-0.0243	
112	Wednesday, January 09, 2013	**0.0837**	**0.0991**	-0.0310	**0.0784**	**0.0991**	-0.0310	**0.1098**	**0.0991**	-0.0290	-0.0303	
224	Wednesday, May 01, 2013	**0.0832**	**0.0990**	-0.0350	**0.0781**	**0.0990**	-0.0330	**0.1094**	**0.0990**	-0.0320	-0.0333	
448	Wednesday, December 11, 2013	**0.0825**	**0.0986**	-0.0380	**0.0775**	**0.0986**	-0.0350	**0.1090**	**0.0986**	-0.0320	-0.0350	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

Curing Method:
14 Day Soak

BCD JOB NO. 110375

Mix Number Mix 8

Mix Date Tuesday, September 11, 2012 Mix Time: 12:39 PM

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8120	0.8155	11.62200	1.6275	9.9945
B	10.0000	0.8150	0.8135	11.64100	1.6285	10.0125
C	10.0000	0.8140	0.8155	11.70550	1.6295	10.0760

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Wednesday, September 26, 2012	**0.0964**	**0.1001**	-0.0037	**0.1139**	**0.1001**	0.0138	**0.1811**	**0.1001**	0.0810	0.0304	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 26, 2012	**0.0964**	**0.1001**	0.0000	**0.1139**	**0.1001**	0.0000	**0.1811**	**0.1001**	0.0000	0.0000	
5	Monday, October 01, 2012	**0.0958**	**0.1002**	-0.0070	**0.1132**	**0.1002**	-0.0080	**0.1804**	**0.1001**	-0.0070	-0.0073	Shrinkage Room
7	Wednesday, October 03, 2012	**0.0954**	**0.0999**	-0.0080	**0.1129**	**0.0999**	-0.0080	**0.1800**	**0.0999**	-0.0090	-0.0083	
14	Wednesday, October 10, 2012	**0.0949**	**0.0996**	-0.0100	**0.1123**	**0.0996**	-0.0110	**0.1795**	**0.0996**	-0.0110	-0.0107	
28	Wednesday, October 24, 2012	**0.0942**	**0.0995**	-0.0160	**0.1117**	**0.0995**	-0.0160	**0.1788**	**0.0995**	-0.0170	-0.0163	
56	Wednesday, November 21, 2012	**0.0937**	**0.0995**	-0.0210	**0.1112**	**0.0995**	-0.0210	**0.1783**	**0.0995**	-0.0220	-0.0213	
112	Wednesday, January 16, 2013	**0.0928**	**0.0991**	-0.0260	**0.1103**	**0.0991**	-0.0260	**0.1773**	**0.0991**	-0.0280	-0.0267	
224	Wednesday, May 08, 2013	**0.0923**	**0.0990**	-0.0300	**0.1098**	**0.0990**	-0.0300	**0.1767**	**0.0990**	-0.0330	-0.0310	
448	Wednesday, December 18, 2013	**0.0917**	**0.0986**	-0.0320	**0.1093**	**0.0986**	-0.0310	**0.1762**	**0.0986**	-0.0340	-0.0323	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 8

Mix Date Tuesday, September 11, 2012 Mix Time: 12:39 PM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8140	11.65300	1.6290	10.0240
B	10.0000	0.8150	0.8140	11.62200	1.6290	9.9930
C	10.0000	0.8140	0.8140	11.62150	1.6280	9.9935

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Wednesday, October 10, 2012	**0.1269**	**0.0996**	0.0273	**0.0974**	**0.0996**	-0.0022	**0.0974**	**0.0996**	-0.0022	0.0076	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 10, 2012	**0.1269**	**0.0996**	0.0000	**0.0974**	**0.0996**	0.0000	**0.0974**	**0.0996**	0.0000	0.0000	
5	Monday, October 15, 2012	**0.1263**	**0.0996**	-0.0060	**0.0968**	**0.0996**	-0.0060	**0.0967**	**0.0996**	-0.0070	-0.0063	Shrinkage Room
7	Wednesday, October 17, 2012	**0.1261**	**0.0996**	-0.0080	**0.0966**	**0.0996**	-0.0080	**0.0966**	**0.0996**	-0.0080	-0.0080	
14	Wednesday, October 24, 2012	**0.1257**	**0.0994**	-0.0100	**0.0960**	**0.0994**	-0.0120	**0.0962**	**0.0994**	-0.0100	-0.0107	
28	Wednesday, November 07, 2012	**0.1253**	**0.0994**	-0.0140	**0.0955**	**0.0994**	-0.0170	**0.0958**	**0.0994**	-0.0140	-0.0150	
56	Wednesday, December 05, 2012	**0.1247**	**0.0993**	-0.0190	**0.0951**	**0.0993**	-0.0200	**0.0952**	**0.0994**	-0.0200	-0.0197	
112	Wednesday, January 30, 2013	**0.1239**	**0.0991**	-0.0250	**0.0942**	**0.0991**	-0.0270	**0.0943**	**0.0991**	-0.0260	-0.0260	
224	Wednesday, May 22, 2013	**0.1233**	**0.0989**	-0.0290	**0.0935**	**0.0989**	-0.0320	**0.0939**	**0.0989**	-0.0280	-0.0297	
448	Wednesday, January 01, 2014	**0.1227**	**0.0984**	-0.0300	**0.0929**	**0.0984**	-0.0330	**0.0932**	**0.0984**	-0.0300	-0.0310	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

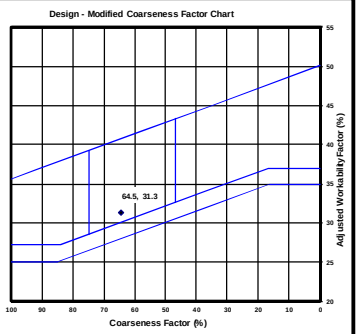
Customer: **MDOT** | Project: **110375** | MIX **9** | Set #:

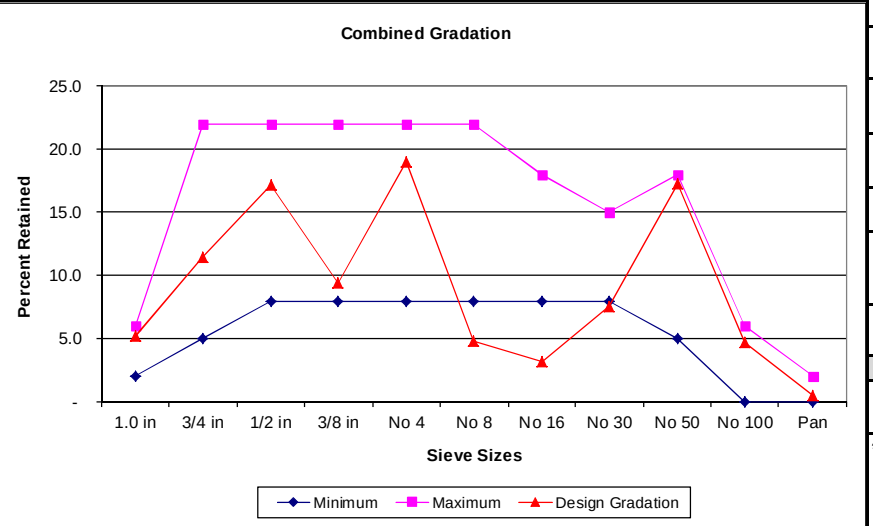
MIX NUMBER Mix 9 | Notes:

MIX DESIGN INFO | Date: 9/12/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.0205	397.1592	33.0970	33.10	33.1	Paste
SCM 1				2.420						0.6575	99.2898	8.2740	8.27	8.27	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9983	3866.9457	322.2450	326.10	326.10	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.2	31.9	31.3





Plastic Test Results

Batch Time	2:12 PM	% Air	2.00	Unit Wt w/o Air	146.90	Design w/c	0.477
Sample Time	2:22 PM	Bucket Weight	7.70	Unit Wt (pcf)	145.40	Actual w/c	0.477
Air Temp.	90.8	Bucket Full	44.05	Theorectial Air	1.02	Design Unit Wt	143.23
Mix Temp.	77.5	Bucket Volume	0.250	Yield	2.24	Fine/Coarse	0.65
Slump, in.	6.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	1.00	Bag Factor	5.28

Reviewed by: Robert Varner, P.E.

Comments / Notes / Observations

F Ash Source 1

80/20

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/13/12	1	1260	1270
	1	1280	
09/19/12	7	2800	2800
	7	*3600	
09/26/12	14	3390	3460
	14	3530	
10/10/12	28	3860	3990
	28	4170	
	28	3940	
11/07/12	56	5200	5360
	56	5520	

Technician who conducted tests:

* Denotes erratic results.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 9

Mix Date Wednesday, September 12, 2012 Mix Time: 2:12 PM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8150	0.8150	11.60700	1.6300	9.9770
B	10.0000	0.8145	0.8140	11.61550	1.6285	9.9870
C	10.0000	0.8155	0.8140	11.62700	1.6295	9.9975

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Thursday, September 13, 2012	**0.0884**	**0.1003**	-0.0119	**0.0890**	**0.1003**	-0.0113	**0.1053**	**0.1003**	0.0050	-0.0061	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 13, 2012	**0.0884**	**0.1003**	0.0000	**0.0890**	**0.1003**	0.0000	**0.1053**	**0.1003**	0.0000	0.0000	
4	Monday, September 17, 2012	**0.0881**	**0.1002**	-0.0020	**0.0882**	**0.1001**	-0.0060	**0.1044**	**0.1001**	-0.0070	-0.0050	**Shrinkage Room**
7	Thursday, September 20, 2012	**0.0878**	**0.1003**	-0.0060	**0.0879**	**0.1003**	-0.0110	**0.1042**	**0.1003**	-0.0110	-0.0093	
14	Thursday, September 27, 2012	**0.0870**	**0.1001**	-0.0120	**0.0872**	**0.1001**	-0.0160	**0.1035**	**0.1001**	-0.0160	-0.0147	
28	Thursday, October 11, 2012	**0.0861**	**0.0997**	-0.0170	**0.0862**	**0.0997**	-0.0220	**0.1024**	**0.0997**	-0.0230	-0.0207	
56	Thursday, November 08, 2012	**0.0850**	**0.0993**	-0.0240	**0.0850**	**0.0993**	-0.0300	**0.1013**	**0.0993**	-0.0300	-0.0280	
112	Thursday, January 03, 2013	**0.0843**	**0.0993**	-0.0310	**0.0844**	**0.0993**	-0.0360	**0.1007**	**0.0993**	-0.0360	-0.0343	
224	Thursday, April 25, 2013	**0.0838**	**0.0991**	-0.0340	**0.0839**	**0.0991**	-0.0390	**0.1003**	**0.0991**	-0.0380	-0.0370	
448	Thursday, December 05, 2013	**0.0831**	**0.0986**	-0.0360	**0.0834**	**0.0986**	-0.0390	**0.0999**	**0.0986**	-0.0370	-0.0373	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 9

Mix Date Wednesday, September 12, 2012 Mix Time: 2:12 PM

Curing Method: 7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8180	0.8145	11.63050	1.6325	9.9980
B	10.0000	0.8130	0.8105	11.60500	1.6235	9.9815
C	10.0000	0.8165	0.8135	11.62400	1.6300	9.9940

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Thursday, September 20, 2012	**0.1066**	**0.1003**	0.0063	**0.0800**	**0.1003**	-0.0203	**0.1024**	**0.1003**	0.0021	-0.0040	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 20, 2012	**0.1066**	**0.1003**	0.0000	**0.0800**	**0.1003**	0.0000	**0.1024**	**0.1003**	0.0000	0.0000	
4	Monday, September 24, 2012	**0.1059**	**0.1002**	-0.0060	**0.0793**	**0.1002**	-0.0060	**0.1017**	**0.1002**	-0.0060	-0.0060	Shrinkage Room
7	Thursday, September 27, 2012	**0.1055**	**0.1001**	-0.0090	**0.0790**	**0.1001**	-0.0080	**0.1014**	**0.1001**	-0.0080	-0.0083	
14	Thursday, October 04, 2012	**0.1048**	**0.0998**	-0.0130	**0.0782**	**0.0998**	-0.0130	**0.1007**	**0.0998**	-0.0120	-0.0127	
28	Thursday, October 18, 2012	**0.1041**	**0.0996**	-0.0180	**0.0775**	**0.0996**	-0.0180	**0.1000**	**0.0996**	-0.0170	-0.0177	
56	Thursday, November 15, 2012	**0.1034**	**0.0993**	-0.0220	**0.0767**	**0.0992**	-0.0220	**0.0995**	**0.0992**	-0.0180	-0.0207	
112	Thursday, January 10, 2013	**0.1026**	**0.0992**	-0.0290	**0.0759**	**0.0992**	-0.0300	**0.0985**	**0.0992**	-0.0280	-0.0290	
224	Thursday, May 02, 2013	**0.1022**	**0.0990**	-0.0310	**0.0754**	**0.0990**	-0.0330	**0.0982**	**0.0990**	-0.0290	-0.0310	
448	Thursday, December 12, 2013	**0.1018**	**0.0986**	-0.0310	**0.0749**	**0.0986**	-0.0340	**0.0976**	**0.0986**	-0.0310	-0.0320	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 9

Mix Date Wednesday, September 12, 2012 Mix Time: 2:12 PM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8125	11.60950	1.6275	9.9820
B	10.0000	0.8135	0.8145	11.62200	1.6280	9.9940
C	10.0000	0.8155	0.8130	11.62450	1.6285	9.9960

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Thursday, September 27, 2012	**0.0972**	**0.1000**	-0.0028	**0.1010**	**0.1000**	0.0010	**0.1005**	**0.1000**	0.0005	-0.0004	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, September 27, 2012	**0.0972**	**0.1000**	0.0000	**0.1010**	**0.1000**	0.0000	**0.1005**	**0.1000**	0.0000	0.0000	
4	Monday, October 01, 2012	**0.0965**	**0.1001**	-0.0080	**0.1003**	**0.1001**	-0.0080	**0.0996**	**0.1001**	-0.0100	-0.0087	Shrinkage Room
7	Thursday, October 04, 2012	**0.0960**	**0.0998**	-0.0100	**0.0998**	**0.0998**	-0.0100	**0.0991**	**0.0998**	-0.0120	-0.0107	
14	Thursday, October 11, 2012	**0.0956**	**0.0997**	-0.0130	**0.0992**	**0.0997**	-0.0150	**0.0986**	**0.0997**	-0.0160	-0.0147	
28	Thursday, October 25, 2012	**0.0950**	**0.0995**	-0.0170	**0.0986**	**0.0995**	-0.0190	**0.0979**	**0.0995**	-0.0210	-0.0190	
56	Thursday, November 22, 2012	**0.0944**	**0.0994**	-0.0220	**0.0979**	**0.0994**	-0.0250	**0.0973**	**0.0994**	-0.0260	-0.0243	
112	Thursday, January 17, 2013	**0.0936**	**0.0991**	-0.0270	**0.0971**	**0.0991**	-0.0300	**0.0964**	**0.0991**	-0.0320	-0.0297	
224	Thursday, May 09, 2013	**0.0933**	**0.0990**	-0.0290	**0.0967**	**0.0990**	-0.0330	**0.0959**	**0.0990**	-0.0360	-0.0327	
448	Thursday, December 19, 2013	**0.0928**	**0.0985**	-0.0290	**0.0959**	**0.0985**	-0.0360	**0.0954**	**0.0985**	-0.0360	-0.0337	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 9

Mix Date Wednesday, September 12, 2012 Mix Time: 2:12 PM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8140	0.8145	0.00000	1.6285	-1.6285
B	10.0000	0.8150	0.8145	11.64200	1.6295	10.0125
C	10.0000	0.8155	0.8160	11.63600	1.6315	10.0045

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Thursday, October 11, 2012	**0.0000**	**0.0000**	0.0000	**0.1146**	**0.0996**	0.0150	**0.1041**	**0.0996**	0.0045	0.0065	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Thursday, October 11, 2012				**0.1146**	**0.0996**	0.0000	**0.1041**	**0.0996**	0.0000	0.0000	
4	Monday, October 15, 2012				**0.1139**	**0.0996**	-0.0070	**0.1035**	**0.0996**	-0.0060	-0.0065	Shrinkage Room
7	Thursday, October 18, 2012				**0.1136**	**0.0996**	-0.0100	**0.1034**	**0.0996**	-0.0070	-0.0085	
14	Thursday, October 25, 2012				**0.1132**	**0.0995**	-0.0130	**0.1030**	**0.0995**	-0.0100	-0.0115	
28	Thursday, November 08, 2012				**0.1126**	**0.0993**	-0.0170	**0.1022**	**0.0992**	-0.0150	-0.0160	
56	Thursday, December 06, 2012				**0.1122**	**0.0994**	-0.0220	**0.1019**	**0.0994**	-0.0200	-0.0210	
112	Thursday, January 31, 2013				**0.1111**	**0.0992**	-0.0310	**0.1010**	**0.0992**	-0.0270	-0.0290	
224	Thursday, May 23, 2013				**0.1107**	**0.0991**	-0.0340	**0.1006**	**0.0991**	-0.0300	-0.0320	
448	Thursday, January 02, 2014				**0.1099**	**0.0984**	-0.0350	**0.0999**	**0.0984**	-0.0300	-0.0325	

Note: Specimen 'A" discarded.

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

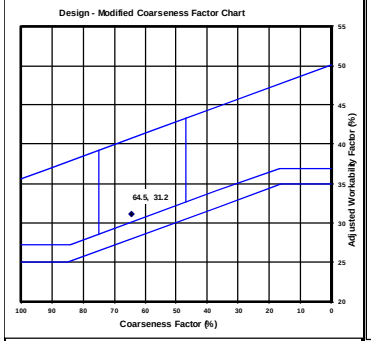
Customer: **MDOT** | Project: **110375** | MIX **10**

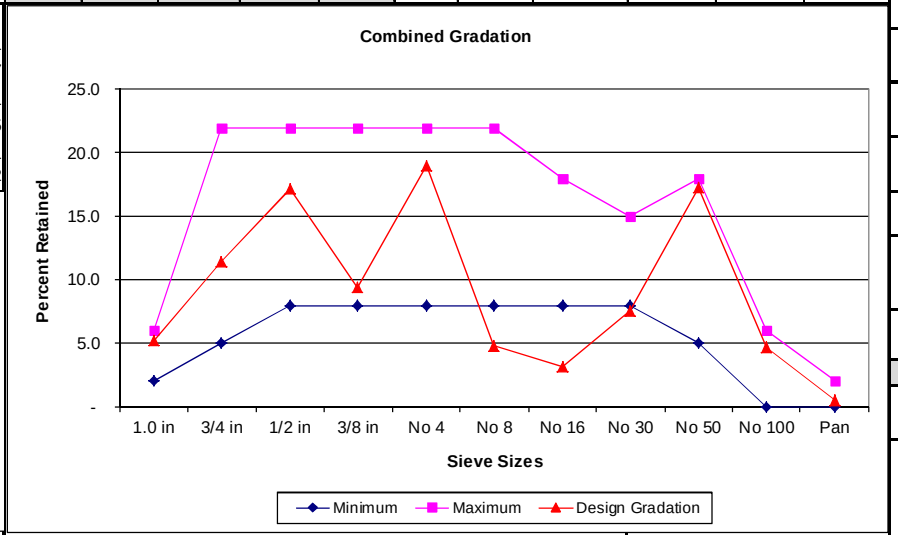
MIX NUMBER Mix 10 | Notes: | Set #:

MIX DESIGN INFO | Date: 9/17/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	% Retained MDOT Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.8677	367.1147	30.5930	30.59	30.59	Paste
SCM 1				2.420						0.8104	122.3716	10.1980	10.20	10.2	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9984	3859.9830	321.6650	325.52	325.52	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.0	31.7	31.2





Plastic Test Results

Batch Time	8:25 AM	% Air	1.25	Unit Wt w/o Air	146.64	Design w/c	0.484
Sample Time	8:34 AM	Bucket Weight	7.70	Unit Wt (pcf)	145.80	Actual w/c	0.484
Air Temp.	76.1	Bucket Full	44.15	Theorectial Air	0.57	Design Unit Wt	142.97
Mix Temp.	71.4	Bucket Volume	0.250	Yield	2.23	Fine/Coarse	0.65
Slump, in.	8.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.21

Comments / Notes / Observations

F Ash Source 1

75/25

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/18/12	1	1100	1130
	1	1160	
09/24/12	7	2590	2610
	7	2630	
10/01/12	14	3400	3270
	14	3140	
10/15/12	28	3700	3807
	28	3570	
	28	4150	
11/12/12	56	4520	4495
	56	4470	

Technician who conducted tests:

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 10

Mix Date Monday, September 17, 2012 Mix Time: 8:25 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8150	0.8140	11.62750	1.6290	9.9985
B	10.0000	0.8125	0.8155	11.61900	1.6280	9.9910
C	10.0000	0.8145	0.8160	11.63150	1.6305	10.0010

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Tuesday, September 18, 2012	**0.1054**	**0.1004**	0.0050	**0.0966**	**0.1003**	-0.0037	**0.1034**	**0.1003**	0.0031	0.0015	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 18, 2012	**0.1054**	**0.1004**	0.0000	**0.0966**	**0.1003**	0.0000	**0.1034**	**0.1003**	Erratic	0.0000	
3	Friday, September 21, 2012	**0.1052**	**0.1003**	-0.0010	**0.0967**	**0.1003**	0.0010	**0.1023**	**0.1003**	Erratic	0.0000	Shrinkage Room
7	Tuesday, September 25, 2012	**0.1046**	**0.1001**	-0.0050	**0.0959**	**0.1001**	-0.0050	**0.1017**	**0.1001**	Erratic	-0.0050	
14	Tuesday, October 02, 2012	**0.1039**	**0.1001**	-0.0120	**0.0953**	**0.1001**	-0.0110	**0.1010**	**0.1000**	Erratic	-0.0115	
28	Tuesday, October 16, 2012	**0.1026**	**0.0996**	-0.0200	**0.0940**	**0.0996**	-0.0190	**0.0997**	**0.0996**	Erratic	-0.0195	
56	Tuesday, November 13, 2012	**0.1018**	**0.0994**	-0.0260	**0.0932**	**0.0994**	-0.0250	**0.0988**	**0.0994**	Erratic	-0.0255	
112	Tuesday, January 08, 2013	**0.1011**	**0.0991**	-0.0300	**0.0923**	**0.0991**	-0.0310	**0.0981**	**0.0991**	Erratic	-0.0305	
224	Tuesday, April 30, 2013	**0.1007**	**0.0991**	-0.0340	**0.0919**	**0.0991**	-0.0350	**0.0976**	**0.0991**	Erratic	-0.0345	
448	Tuesday, December 10, 2013	**0.1001**	**0.0986**	-0.0350	**0.0914**	**0.0986**	-0.0350	**0.0971**	**0.0986**	Erratic	-0.0350	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 10
Mix Date Monday, September 17, 2012 Mix Time: 8:25 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8140	11.62100	1.6285	9.9925
B	10.0000	0.8130	0.8145	11.61000	1.6275	9.9825
C	10.0000	0.8120	0.8155	11.63050	1.6275	10.0030

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Tuesday, September 25, 2012	**0.0968**	**0.1002**	-0.0034	**0.0855**	**0.1002**	-0.0147	**0.1052**	**0.1002**	0.0050	-0.0044	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 25, 2012	**0.0968**	**0.1002**	0.0000	**0.0855**	**0.1002**	0.0000	**0.1052**	**0.1002**	0.0000	0.0000	
3	Friday, September 28, 2012	**0.0961**	**0.1001**	-0.0060	**0.0847**	**0.1000**	-0.0060	**0.1045**	**0.1000**	-0.0050	-0.0057	Shrinkage Room
7	Tuesday, October 02, 2012	**0.0959**	**0.1001**	-0.0080	**0.0846**	**0.1001**	-0.0080	**0.1043**	**0.1001**	-0.0080	-0.0080	
14	Tuesday, October 09, 2012	**0.0952**	**0.0998**	-0.0120	**0.0837**	**0.0998**	-0.0140	**0.1035**	**0.0998**	-0.0130	-0.0130	
28	Tuesday, October 23, 2012	**0.0945**	**0.0995**	-0.0160	**0.0829**	**0.0995**	-0.0190	**0.1027**	**0.0995**	-0.0180	-0.0177	
56	Tuesday, November 20, 2012	**0.0938**	**0.0993**	-0.0210	**0.0819**	**0.0993**	-0.0270	**0.1019**	**0.0993**	-0.0240	-0.0240	
112	Tuesday, January 15, 2013	**0.0930**	**0.0991**	-0.0270	**0.0811**	**0.0991**	-0.0330	**0.1010**	**0.0992**	-0.0320	-0.0307	
224	Tuesday, May 07, 2013	**0.0926**	**0.0990**	-0.0300	**0.0807**	**0.0990**	-0.0360	**0.1007**	**0.0990**	-0.0330	-0.0330	
448	Tuesday, December 17, 2013	**0.0922**	**0.0986**	-0.0300	**0.0801**	**0.0986**	-0.0380	**0.1000**	**0.0986**	-0.0360	-0.0347	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 10

Mix Date Monday, September 17, 2012 Mix Time: 8:25 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8110	0.8140	11.61600	1.6250	9.9910
B	10.0000	0.8135	0.8135	11.61050	1.6270	9.9835
C	10.0000	0.8140	0.8140	11.61500	1.6280	9.9870

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Tuesday, October 02, 2012	**0.0902**	**0.1001**	-0.0099	**0.0888**	**0.1001**	-0.0113	**0.0938**	**0.1000**	-0.0062	-0.0091	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 02, 2012	**0.0902**	**0.1001**	0.0000	**0.0888**	**0.1001**	0.0000	**0.0938**	**0.1000**	0.0000	0.0000	
3	Friday, October 05, 2012	**0.0893**	**0.0999**	-0.0070	**0.0880**	**0.0999**	-0.0060	**0.0929**	**0.0999**	-0.0080	-0.0070	Shrinkage Room
7	Tuesday, October 09, 2012	**0.0890**	**0.0998**	-0.0090	**0.0876**	**0.0998**	-0.0090	**0.0927**	**0.0998**	-0.0090	-0.0090	
14	Tuesday, October 16, 2012	**0.0883**	**0.0996**	-0.0140	**0.0871**	**0.0996**	-0.0120	**0.0921**	**0.0996**	-0.0130	-0.0130	
28	Tuesday, October 30, 2012	**0.0878**	**0.0994**	-0.0170	**0.0865**	**0.0994**	-0.0160	**0.0917**	**0.0994**	-0.0150	-0.0160	
56	Tuesday, November 27, 2012	**0.0871**	**0.0992**	-0.0220	**0.0858**	**0.0992**	-0.0210	**0.0910**	**0.0992**	-0.0200	-0.0210	
112	Tuesday, January 22, 2013	**0.0864**	**0.0992**	-0.0290	**0.0852**	**0.0992**	-0.0270	**0.0904**	**0.0992**	-0.0260	-0.0273	
224	Tuesday, May 14, 2013	**0.0860**	**0.0991**	-0.0320	**0.0847**	**0.0991**	-0.0310	**0.0901**	**0.0991**	-0.0280	-0.0303	
448	Tuesday, December 24, 2013	**0.0853**	**0.0985**	-0.0330	**0.0840**	**0.0985**	-0.0320	**0.0895**	**0.0985**	-0.0280	-0.0310	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 10

Mix Date Monday, September 17, 2012 Mix Time: 8:25 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8155	11.63750	1.6310	10.0065
B	10.0000	0.8155	0.8120	11.63300	1.6275	10.0055
C	10.0000	0.8140	0.8150	11.62150	1.6290	9.9925

SHRINKAGE TESTING - ASTM C157

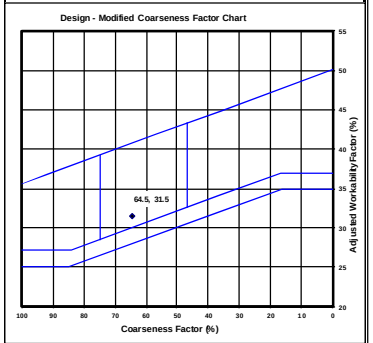
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Tuesday, October 16, 2012	**0.1104**	**0.0995**	0.0109	**0.0990**	**0.0995**	-0.0005	**0.0970**	**0.0995**	-0.0025	0.0026	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	Soak
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 16, 2012	**0.1104**	**0.0995**	0.0000	**0.0990**	**0.0995**	0.0000	**0.0970**	**0.0995**	0.0000	0.0000	
3	Friday, October 19, 2012	**0.1100**	**0.0996**	-0.0050	**0.0987**	**0.0996**	-0.0040	**0.0966**	**0.0996**	-0.0050	-0.0047	
7	Tuesday, October 23, 2012	**0.1096**	**0.0995**	-0.0080	**0.0983**	**0.0995**	-0.0070	**0.0962**	**0.0995**	-0.0080	-0.0077	
14	Tuesday, October 30, 2012	**0.1093**	**0.0994**	-0.0100	**0.0980**	**0.0994**	-0.0090	**0.0959**	**0.0994**	-0.0100	-0.0097	
28	Tuesday, November 13, 2012	**0.1087**	**0.0994**	-0.0160	**0.0975**	**0.0994**	-0.0140	**0.0953**	**0.0994**	-0.0160	-0.0153	
56	Tuesday, December 11, 2012	**0.1080**	**0.0994**	-0.0230	**0.0968**	**0.0994**	-0.0210	**0.0947**	**0.0994**	-0.0220	-0.0220	
112	Tuesday, February 05, 2013	**0.1073**	**0.0992**	-0.0280	**0.0960**	**0.0992**	-0.0270	**0.0939**	**0.0991**	-0.0270	-0.0273	
224	Tuesday, May 28, 2013	**0.1064**	**0.0988**	-0.0330	**0.0952**	**0.0988**	-0.0310	**0.0931**	**0.0988**	-0.0320	-0.0320	
448	Tuesday, January 07, 2014	**0.1059**	**0.0986**	-0.0360	**0.0946**	**0.0986**	-0.0350	**0.0927**	**0.0986**	-0.0340	-0.0350	Shrinkage Room

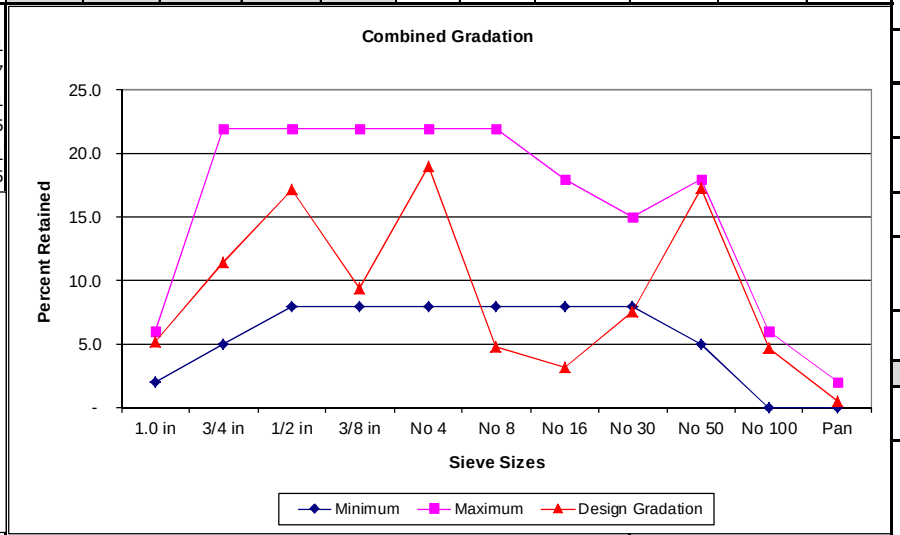
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT	Project:	110375								MIX	11	Comments / Notes / Observations		
MIX NUMBER	Mix 11	Notes:									Set #:		F Ash Source 2		
MIX DESIGN INFO	Date: 9/20/2012		f'c: 4,000 psi						Size(c.f.): 2.25			Factor: 0.0833	85/15		
	% Retained MDOT			DRY Specific	AGG Absorp-		AGG Moisture	Free H20	Batch Free	Volume	DRY Mix 1 cu yd	DRY Mix lab batch	Adjusted lab batch	Actual lab batch	
Material	Min	Max	Design	Gravity	tion		Content	Content	H2O	(c.f.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.1761	427.7392	35.6450	35.65	35.65	Paste
SCM 1				2.410						0.5019	75.4834	6.2900	6.29	6.29	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9983	3873.7193	322.8090	326.67	326.67	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.4	32.1	31.5





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/21/12	1	1550	1525
	1	1500	
09/27/12	7	3600	3605
	7	3610	
10/04/12	14	4130	4095
	14	4060	
10/18/12	28	4560	4567
	28	4670	
	28	4470	
11/15/12	56	4990	5075
	56	5160	

Technician who conducted tests:

Plastic Test Results

Batch Time	11:49 AM	% Air	2.00	Unit Wt w/o Air	147.16	Design w/c	0.471
Sample Time	11:59 AM	Bucket Weight	7.70	Unit Wt (pcf)	146.20	Actual w/c	0.471
Air Temp.	74.9	Bucket Full	44.25	Theorectial Air	0.65	Design Unit Wt	143.48
Mix Temp.	70.9	Bucket Volume	0.250	Yield	2.23	Fine/Coarse	0.65
Slump, in.	7.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.35

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 11
Mix Date Thursday, September 20, 2012 Mix Time: 11:49 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8145	11.65100	1.6300	10.0210
B	10.0000	0.8145	0.8140	11.64300	1.6285	10.0145
C	10.0000	0.8145	0.8135	11.63450	1.6280	10.0065

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Friday, September 21, 2012	**0.1246**	**0.1002**	0.0244	**0.1181**	**0.1002**	0.0179	**0.1111**	**0.1002**	0.0109	0.0177	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 21, 2012	**0.1246**	**0.1002**	Erratic	**0.1181**	**0.1002**	0.0000	**0.1111**	**0.1002**	0.0000	0.0000	
4	Tuesday, September 25, 2012	**0.1237**	**0.1001**	Erratic	**0.1176**	**0.1001**	-0.0040	**0.1103**	**0.1001**	-0.0070	-0.0055	Shrinkage Room
7	Friday, September 28, 2012	**0.1232**	**0.1000**	Erratic	**0.1171**	**0.1001**	-0.0090	**0.1101**	**0.1001**	-0.0090	-0.0090	
14	Friday, October 05, 2012	**0.1222**	**0.0998**	Erratic	**0.1163**	**0.0999**	-0.0150	**0.1093**	**0.0999**	-0.0150	-0.0150	
28	Friday, October 19, 2012	**0.1208**	**0.0995**	Erratic	**0.1152**	**0.0996**	-0.0230	**0.1083**	**0.0995**	-0.0210	-0.0220	
56	Friday, November 16, 2012	**0.1198**	**0.0993**	Erratic	**0.1143**	**0.0993**	-0.0290	**0.1072**	**0.0993**	-0.0300	-0.0295	
112	Friday, January 11, 2013	**0.1189**	**0.0991**	Erratic	**0.1135**	**0.0991**	-0.0350	**0.1065**	**0.0991**	-0.0350	-0.0350	
224	Friday, May 03, 2013	**0.1183**	**0.0990**	Erratic	**0.1129**	**0.0990**	-0.0400	**0.1059**	**0.0990**	-0.0400	-0.0400	
448	Friday, December 13, 2013	**0.1179**	**0.0986**	Erratic	**0.1123**	**0.0986**	-0.0420	**0.1055**	**0.0986**	-0.0400	-0.0410	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 11

Mix Date Thursday, September 20, 2012 Mix Time: 11:49 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8140	11.63350	1.6295	10.0040
B	10.0000	0.8150	0.8145	11.64100	1.6295	10.0115
C	10.0000	0.8140	0.8145	11.63400	1.6285	10.0055

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Friday, September 28, 2012	**0.1167**	**0.1002**	0.0165	**0.1137**	**0.1001**	0.0136	**0.1114**	**0.1002**	0.0112	0.0138	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 28, 2012	**0.1167**	**0.1002**	0.0000	**0.1137**	**0.1001**	0.0000	**0.1114**	**0.1002**	0.0000	0.0000	
4	Tuesday, October 02, 2012	**0.1156**	**0.1001**	-0.0100	**0.1128**	**0.1000**	-0.0080	**0.1106**	**0.1000**	-0.0060	-0.0080	Shrinkage Room
7	Friday, October 05, 2012	**0.1151**	**0.0998**	-0.0120	**0.1123**	**0.0998**	-0.0110	**0.1101**	**0.0998**	-0.0090	-0.0107	
14	Friday, October 12, 2012	**0.1145**	**0.0996**	-0.0160	**0.1118**	**0.0996**	-0.0140	**0.1095**	**0.0996**	-0.0130	-0.0143	
28	Friday, October 26, 2012	**0.1137**	**0.0995**	-0.0230	**0.1111**	**0.0995**	-0.0200	**0.1087**	**0.0995**	-0.0200	-0.0210	
56	Friday, November 23, 2012	**0.1130**	**0.0994**	-0.0290	**0.1104**	**0.0994**	-0.0260	**0.1080**	**0.0994**	-0.0260	-0.0270	
112	Friday, January 18, 2013	**0.1119**	**0.0991**	-0.0370	**0.1094**	**0.0991**	-0.0330	**0.1069**	**0.0991**	-0.0340	-0.0347	
224	Friday, May 10, 2013	**0.1115**	**0.0990**	-0.0400	**0.1089**	**0.0990**	-0.0370	**0.1065**	**0.0990**	-0.0370	-0.0380	
448	Friday, December 20, 2013	**0.1110**	**0.0985**	-0.0400	**0.1083**	**0.0985**	-0.0380	**0.1058**	**0.0985**	-0.0390	-0.0390	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 11

Mix Date Thursday, September 20, 2012 Mix Time: 11:49 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8130	11.63250	1.6275	10.0050
B	10.0000	0.8155	0.8135	11.63400	1.6290	10.0050
C	10.0000	0.8135	0.8160	11.61950	1.6295	9.9900

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Friday, October 05, 2012	**0.1042**	**0.0998**	0.0044	**0.1088**	**0.0997**	0.0091	**0.0927**	**0.0997**	-0.0070	0.0022	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 05, 2012	**0.1042**	**0.0998**	0.0000	**0.1088**	**0.0997**	0.0000	**0.0927**	**0.0997**	0.0000	0.0000	
4	Tuesday, October 09, 2012	**0.1035**	**0.0998**	-0.0070	**0.1082**	**0.0999**	-0.0080	**0.0920**	**0.0998**	-0.0080	-0.0077	Shrinkage Room
7	Friday, October 12, 2012	**0.1032**	**0.0996**	-0.0080	**0.1079**	**0.0996**	-0.0080	**0.0918**	**0.0996**	-0.0080	-0.0080	
14	Friday, October 19, 2012	**0.1028**	**0.0996**	-0.0120	**0.1075**	**0.0996**	-0.0120	**0.0913**	**0.0995**	-0.0120	-0.0120	
28	Friday, November 02, 2012	**0.1022**	**0.0994**	-0.0160	**0.1069**	**0.0994**	-0.0160	**0.0906**	**0.0994**	-0.0180	-0.0167	
56	Friday, November 30, 2012	**0.1015**	**0.0995**	-0.0240	**0.1063**	**0.0995**	-0.0230	**0.0901**	**0.0995**	-0.0240	-0.0237	
112	Friday, January 25, 2013	**0.1007**	**0.0992**	-0.0290	**0.1057**	**0.0992**	-0.0260	**0.0893**	**0.0992**	-0.0290	-0.0280	
224	Friday, May 17, 2013	**0.1000**	**0.0990**	-0.0340	**0.1051**	**0.0990**	-0.0300	**0.0887**	**0.0990**	-0.0330	-0.0323	
448	Friday, December 27, 2013	**0.0994**	**0.0985**	-0.0350	**0.1045**	**0.0985**	-0.0310	**0.0881**	**0.0986**	-0.0350	-0.0337	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 11

Mix Date Thursday, September 20, 2012 Mix Time: 11:49 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8160	0.8160	11.62400	1.6320	9.9920
B	10.0000	0.8130	0.8150	11.64800	1.6280	10.0200
C	10.0000	0.8175	0.8150	11.63850	1.6325	10.0060

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Friday, October 19, 2012	**0.1004**	**0.0995**	0.0009	**0.1225**	**0.0995**	0.0230	**0.1095**	**0.0995**	0.0100	0.0113	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 19, 2012	**0.1004**	**0.0995**	0.0000	**0.1225**	**0.0995**	0.0000	**0.1095**	**0.0995**	0.0000	0.0000	Soak
4	Tuesday, October 23, 2012	**0.0999**	**0.0995**	-0.0050	**0.1220**	**0.0995**	-0.0050	**0.1089**	**0.0995**	-0.0060	-0.0053	Shrinkage Room
7	Friday, October 26, 2012	**0.0996**	**0.0994**	-0.0070	**0.1216**	**0.0994**	-0.0080	**0.1087**	**0.0994**	-0.0070	-0.0073	
14	Friday, November 02, 2012	**0.0991**	**0.0994**	-0.0120	**0.1214**	**0.0994**	-0.0100	**0.1083**	**0.0994**	-0.0110	-0.0110	
28	Friday, November 16, 2012	**0.0986**	**0.0993**	-0.0160	**0.1206**	**0.0993**	-0.0170	**0.1077**	**0.0993**	-0.0160	-0.0163	
56	Friday, December 14, 2012	**0.0982**	**0.0994**	-0.0210	**0.1200**	**0.0994**	-0.0240	**0.1071**	**0.0994**	-0.0230	-0.0227	
112	Friday, February 08, 2013	**0.0972**	**0.0991**	-0.0280	**0.1192**	**0.0991**	-0.0290	**0.1063**	**0.0991**	-0.0280	-0.0283	
224	Friday, May 31, 2013	**0.0965**	**0.0989**	-0.0330	**0.1185**	**0.0989**	-0.0340	**0.1056**	**0.0989**	-0.0330	-0.0333	
448	Friday, January 10, 2014	**0.0960**	**0.0985**	-0.0340	**0.1179**	**0.0985**	-0.0360	**0.1053**	**0.0985**	-0.0320	-0.0340	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer: **MDOT** | Project: **110375** | MIX **12** | Set #:

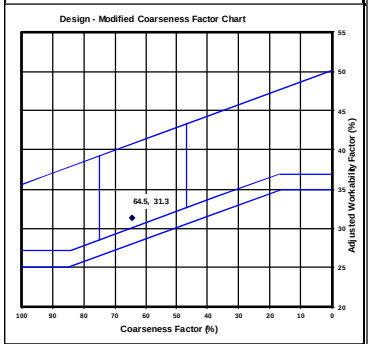
MIX NUMBER Mix 12 | Notes:

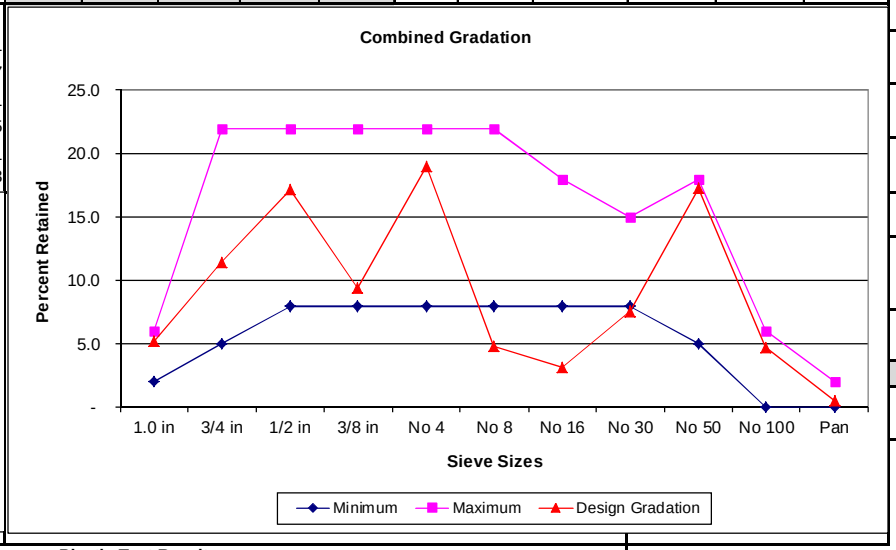
MIX DESIGN INFO | Date: 9/24/2012 | f'c: 4,000 psi | Size(c.f.): 2.25 | Factor: 0.0833

Material	% Retained MDOT Min	% Retained MDOT Max	% Retained MDOT Design	DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						2.0185	396.7550	33.0630	33.06	33.06	Paste
SCM 1				2.410						0.6596	99.1887	8.2660	8.27	8.27	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	Sand
Total Grad%			100.0						-3.84	26.9984	3866.4404	322.2030	326.06	326.06	

75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.2	31.9	31.3





Plastic Test Results

Batch Time	10:00 AM	% Air	1.75	Unit Wt w/o Air	146.88	Design w/c	0.478
Sample Time	10:09 AM	Bucket Weight	7.70	Unit Wt (pcf)	146.20	Actual w/c	0.478
Air Temp.	71.9	Bucket Full	44.25	Theorectial Air	0.46	Design Unit Wt	143.21
Mix Temp.	69.6	Bucket Volume	0.250	Yield	2.23	Fine/Coarse	0.65
Slump, in.	6.00	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.28

Comments / Notes / Observations

F Ash Source 2

80/20

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/25/12	1	1420	1410
	1	1400	
10/01/12	7	3180	3370
	7	3560	
10/08/12	14	4080	4010
	14	3940	
10/22/12	28	4010	3990
	28	3790	
	28	4170	
11/19/12	56	5080	5050
	56	5020	

Technician who conducted tests:

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375
Mix Number Mix 12
Mix Date Monday, September 24, 2012 Mix Time: 10:00 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8110	0.8150	11.62400	1.6260	9.9980
B	10.0000	0.8150	0.8135	11.62800	1.6285	9.9995
C	10.0000	0.8145	0.8155	11.61850	1.6300	9.9885

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Tuesday, September 25, 2012	**0.0944**	**0.1001**	-0.0057	**0.0884**	**0.1002**	-0.0118	**0.0896**	**0.1002**	-0.0106	-0.0094	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, September 25, 2012	**0.0944**	**0.1001**	Erratic	**0.0884**	**0.1002**	0.0000	**0.0896**	**0.1002**	0.0000	0.0000	Soak
3	Friday, September 28, 2012	**0.0937**	**0.1002**	Erratic	**0.0877**	**0.1002**	-0.0070	**0.0895**	**0.1002**	-0.0010	-0.0040	
7	Tuesday, October 02, 2012	**0.0930**	**0.1000**	Erratic	**0.0871**	**0.1000**	-0.0110	**0.0890**	**0.1000**	-0.0040	-0.0075	
14	Tuesday, October 09, 2012	**0.0920**	**0.0998**	Erratic	**0.0863**	**0.0997**	-0.0160	**0.0879**	**0.0997**	-0.0120	-0.0140	
28	Tuesday, October 23, 2012	**0.0909**	**0.0995**	Erratic	**0.0854**	**0.0995**	-0.0230	**0.0867**	**0.0995**	-0.0220	-0.0225	
56	Tuesday, November 20, 2012	**0.0899**	**0.0993**	Erratic	**0.0845**	**0.0993**	-0.0300	**0.0857**	**0.0993**	-0.0300	-0.0300	
112	Tuesday, January 15, 2013	**0.0890**	**0.0992**	Erratic	**0.0837**	**0.0992**	-0.0370	**0.0850**	**0.0992**	-0.0360	-0.0365	
224	Tuesday, May 07, 2013	**0.0885**	**0.0990**	Erratic	**0.0832**	**0.0990**	-0.0400	**0.0846**	**0.0990**	-0.0380	-0.0390	
448	Tuesday, December 17, 2013	**0.0878**	**0.0986**	Erratic	**0.0827**	**0.0986**	-0.0410	**0.0839**	**0.0986**	-0.0410	-0.0410	Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 12

Mix Date Monday, September 24, 2012 Mix Time: 10:00 AM

Curing Method:
7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8130	0.8130	11.60900	1.6260	9.9830
B	10.0000	0.8135	0.8145	11.62450	1.6280	9.9965
C	10.0000	0.8155	0.8120	11.63850	1.6275	10.0110

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Tuesday, October 02, 2012	**0.0852**	**0.1000**	-0.0148	**0.0992**	**0.1001**	-0.0009	**0.1122**	**0.1000**	0.0122	-0.0012	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 02, 2012	**0.0852**	**0.1000**	0.0000	**0.0992**	**0.1001**	0.0000	**0.1122**	**0.1000**	0.0000	0.0000	
3	Friday, October 05, 2012	**0.0843**	**0.0999**	-0.0080	**0.0983**	**0.0999**	-0.0070	**0.1113**	**0.0998**	-0.0070	-0.0073	Shrinkage Room
7	Tuesday, October 09, 2012	**0.0838**	**0.0970**	0.0160	**0.0979**	**0.0997**	-0.0090	**0.1109**	**0.0997**	-0.0100	-0.0010	
14	Tuesday, October 16, 2012	**0.0831**	**0.0995**	-0.0160	**0.0973**	**0.0995**	-0.0130	**0.1106**	**0.0995**	-0.0110	-0.0133	
28	Tuesday, October 30, 2012	**0.0824**	**0.0994**	-0.0220	**0.0966**	**0.0994**	-0.0190	**0.1095**	**0.0994**	-0.0210	-0.0207	
56	Tuesday, November 27, 2012	**0.0815**	**0.0992**	-0.0290	**0.0959**	**0.0992**	-0.0240	**0.1086**	**0.0992**	-0.0280	-0.0270	
112	Tuesday, January 22, 2013	**0.0808**	**0.0992**	-0.0360	**0.0951**	**0.0992**	-0.0320	**0.1079**	**0.0992**	-0.0350	-0.0343	
224	Tuesday, May 14, 2013	**0.0801**	**0.0991**	-0.0420	**0.0945**	**0.0991**	-0.0370	**0.1073**	**0.0991**	-0.0400	-0.0397	
448	Tuesday, December 24, 2013	**0.0796**	**0.0986**	-0.0420	**0.0939**	**0.0986**	-0.0380	**0.1068**	**0.0985**	-0.0390	-0.0397	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 12

Mix Date Monday, September 24, 2012 Mix Time: 10:00 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8120	0.8125	11.66400	1.6245	10.0395
B	10.0000	0.8120	0.8150	11.63800	1.6270	10.0110
C	10.0000	0.8105	0.8120	11.64950	1.6225	10.0270

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Tuesday, October 09, 2012	**0.1321**	**0.0997**	0.0324	**0.1107**	**0.0996**	0.0111	**0.1148**	**0.0996**	0.0152	0.0196	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 09, 2012	**0.1321**	**0.0997**	0.0000	**0.1107**	**0.0996**	0.0000	**0.1148**	**0.0996**	0.0000	0.0000	
3	Friday, October 12, 2012	**0.1316**	**0.0997**	-0.0050	**0.1103**	**0.0996**	-0.0040	**0.1144**	**0.0996**	-0.0040	-0.0043	Shrinkage Room
7	Tuesday, October 16, 2012	**0.1312**	**0.0996**	-0.0080	**0.1098**	**0.0995**	-0.0080	**0.1140**	**0.0995**	-0.0070	-0.0077	
14	Tuesday, October 23, 2012	**0.1309**	**0.0995**	-0.0100	**0.1094**	**0.0995**	-0.0120	**0.1136**	**0.0995**	-0.0110	-0.0110	
28	Tuesday, November 06, 2012	**0.1303**	**0.0994**	-0.0150	**0.1087**	**0.0994**	-0.0180	**0.1130**	**0.0994**	-0.0160	-0.0163	
56	Tuesday, December 04, 2012	**0.1297**	**0.0994**	-0.0210	**0.1081**	**0.0994**	-0.0240	**0.1124**	**0.0994**	-0.0220	-0.0223	
112	Tuesday, January 29, 2013	**0.1287**	**0.0991**	-0.0280	**0.1072**	**0.0991**	-0.0300	**0.1116**	**0.0991**	-0.0270	-0.0283	
224	Tuesday, May 21, 2013	**0.1281**	**0.0991**	-0.0340	**0.1065**	**0.0991**	-0.0370	**0.1111**	**0.0990**	-0.0310	-0.0340	
448	Tuesday, December 31, 2013	**0.1274**	**0.0984**	-0.0340	**0.1058**	**0.0984**	-0.0370	**0.1104**	**0.0984**	-0.0320	-0.0343	

Note: Initial reading of specimen "C" was changed from 0.1131 to 0.1147.

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 12

Mix Date Monday, September 24, 2012 Mix Time: 10:00 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8135	0.8120	11.62050	1.6255	9.9950
B	10.0000	0.8140	0.8150	11.64350	1.6290	10.0145
C	10.0000	0.8135	0.8150	11.64100	1.6285	10.0125

SHRINKAGE TESTING - ASTM C157

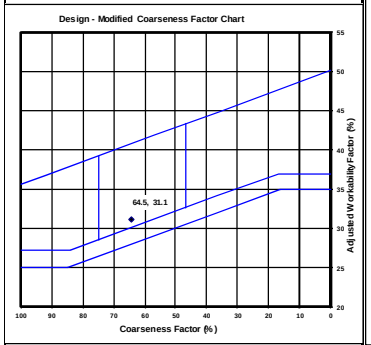
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Tuesday, October 23, 2012	**0.0960**	**0.0995**	-0.0035	**0.1192**	**0.0995**	0.0197	**0.1119**	**0.0995**	0.0124	0.0095	**M/Rm**
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 23, 2012	**0.0960**	**0.0995**	0.0000	**0.1192**	**0.0995**	0.0000	**0.1119**	**0.0995**	0.0000	0.0000	
3	Friday, October 26, 2012	**0.0955**	**0.0994**	-0.0040	**0.1188**	**0.0995**	-0.0040	**0.1113**	**0.0995**	-0.0060	-0.0047	Shrinkage Room
7	Tuesday, October 30, 2012	**0.0951**	**0.0994**	-0.0080	**0.1184**	**0.0994**	-0.0070	**0.1110**	**0.0994**	-0.0080	-0.0077	
14	Tuesday, November 06, 2012	**0.0947**	**0.0994**	-0.0120	**0.1180**	**0.0994**	-0.0110	**0.1105**	**0.0994**	-0.0130	-0.0120	
28	Tuesday, November 20, 2012	**0.0942**	**0.0993**	-0.0160	**0.1176**	**0.0993**	-0.0140	**0.1100**	**0.0993**	-0.0170	-0.0157	
56	Tuesday, December 18, 2012	**0.0936**	**0.0995**	-0.0240	**0.1171**	**0.0995**	-0.0210	**0.1095**	**0.0995**	-0.0240	-0.0230	
112	Tuesday, February 12, 2013	**0.0928**	**0.0991**	-0.0280	**0.1163**	**0.0991**	-0.0250	**0.1087**	**0.0991**	-0.0280	-0.0270	
224	Tuesday, June 04, 2013	**0.0921**	**0.0989**	-0.0330	**0.1156**	**0.0989**	-0.0300	**0.1079**	**0.0989**	-0.0340	-0.0323	
448	Tuesday, January 14, 2014	**0.0915**	**0.0984**	-0.0340	**0.1151**	**0.0984**	-0.0300	**0.1073**	**0.0984**	-0.0350	-0.0330	

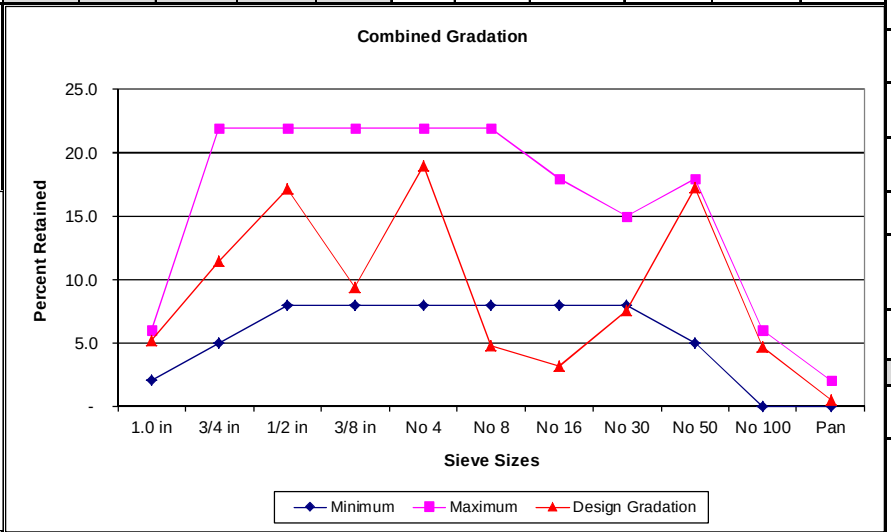
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375								MIX	13	Comments / Notes / Observations	
MIX NUMBER	Mix 13		Notes:									Set #:		F Ash Source 2	
MIX DESIGN INFO	Date:	9/25/2012	f'c:	4,000 psi						Size(c.f.):	2.25	Factor:	0.0833	75/25	
	% Retained MDOT			DRY	AGG		AGG	Free	Batch		DRY Mix	DRY Mix	Adjusted	Actual	Note: Only 10 Strength Specimens cast. Broke 1 (not 2) at 1 day age.
Material	Min	Max	Design	Specific Gravity	Absorp-tion		Moisture Content	H20 Content	Free H2O	Volume (c.f.)	1 cu yd Wt. (lbs.)	lab batch Wt. (lbs.)	lab batch Wt. (lbs.)	lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.8654	366.6543	30.5550	30.56	30.56	Paste
SCM 1				2.410						0.8127	122.2181	10.1850	10.19	10.19	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)
Total Grad%			100.0						-3.84	26.9984	3859.3691	321.6140	325.48	325.48	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.0	31.7	31.1





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/26/12	1	1270	1270
10/02/12	7	3170	3030
	7	2890	
10/09/12	14	3110	3220
	14	3330	
10/23/12	28	3720	3850
	28	3820	
	28	4010	
11/20/12	56	5050	5010
	56	4970	

Technician who conducted tests:

Plastic Test Results

Batch Time	1:43 PM	% Air	1.25	Unit Wt w/o Air	146.61	Design w/c	0.485
Sample Time	1:52 PM	Bucket Weight	7.70	Unit Wt (pcf)	146.00	Actual w/c	0.484
Air Temp.	90.7	Bucket Full	44.20	Theorectial Air	0.42	Design Unit Wt	142.95
Mix Temp.	79.1	Bucket Volume	0.250	Yield	2.23	Fine/Coarse	0.65
Slump, in.	8.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	0.99	Bag Factor	5.20

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 13

Mix Date Tuesday, September 25, 2012 Mix Time: 1:43 PM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8155	11.62150	1.6300	9.9915
B	10.0000	0.8145	0.8155	11.62000	1.6300	9.9900
C	10.0000	0.8150	0.8130	11.59600	1.6280	9.9680

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Wednesday, September 26, 2012	**0.0936**	**0.1000**	-0.0064	**0.0931**	**0.1000**	-0.0069	**0.0715**	**0.1000**	-0.0285	-0.0139	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, September 26, 2012	**0.0936**	**0.1000**	0.0000	**0.0931**	**0.1000**	Erratic	**0.0715**	**0.1000**	0.0000	0.0000	Soak
5	Monday, October 01, 2012	**0.0928**	**0.1001**	-0.0090	**0.0922**	**0.1001**	Erratic	**0.0704**	**0.1001**	-0.0120	-0.0105	
7	Wednesday, October 03, 2012	**0.0925**	**0.0999**	-0.0100	**0.0913**	**0.0999**	Erratic	**0.0700**	**0.0999**	-0.0140	-0.0120	
14	Wednesday, October 10, 2012	**0.0919**	**0.0996**	-0.0130	**0.0905**	**0.0996**	Erratic	**0.0692**	**0.0996**	-0.0190	-0.0160	
28	Wednesday, October 24, 2012	**0.0910**	**0.0994**	-0.0200	**0.0894**	**0.0994**	Erratic	**0.0682**	**0.0994**	-0.0270	-0.0235	
56	Wednesday, November 21, 2012	**0.0903**	**0.0995**	-0.0280	**0.0886**	**0.0995**	Erratic	**0.0676**	**0.0995**	-0.0340	-0.0310	
112	Wednesday, January 16, 2013	**0.0894**	**0.0991**	-0.0330	**0.0875**	**0.0991**	Erratic	**0.0665**	**0.0991**	-0.0410	-0.0370	
224	Wednesday, May 08, 2013	**0.0891**	**0.0990**	-0.0350	**0.0867**	**0.0990**	Erratic	**0.0662**	**0.0990**	-0.0430	-0.0390	
448	Wednesday, December 18, 2013	**0.0887**	**0.0986**	-0.0350	**0.0861**	**0.0986**	Erratic	**0.0657**	**0.0986**	-0.0440	-0.0395	Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

Curing Method:
7 Day Soak

BCD JOB NO. 110375
Mix Number Mix 13
Mix Date Tuesday, September 25, 2012 Mix Time: 1:43 PM

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8135	0.8145	11.59450	1.6280	9.9665
B	10.0000	0.8160	0.8145	11.60750	1.6305	9.9770
C	10.0000	0.8165	0.8150	11.61100	1.6315	9.9795

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Wednesday, October 03, 2012	**0.0761**	**0.0998**	-0.0237	**0.0867**	**0.0998**	-0.0131	**0.0851**	**0.0998**	-0.0147	-0.0172	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 03, 2012	**0.0761**	**0.0998**	0.0000	**0.0867**	**0.0998**	0.0000	**0.0851**	**0.0998**	0.0000	0.0000	
5	Monday, October 08, 2012	**0.0751**	**0.0997**	-0.0090	**0.0858**	**0.0997**	-0.0080	**0.0841**	**0.0997**	-0.0090	-0.0087	Shrinkage Room
7	Wednesday, October 10, 2012	**0.0749**	**0.0996**	-0.0100	**0.0855**	**0.0996**	-0.0100	**0.0838**	**0.0996**	-0.0110	-0.0103	
14	Wednesday, October 17, 2012	**0.0743**	**0.0996**	-0.0160	**0.0848**	**0.0996**	-0.0170	**0.0832**	**0.0996**	-0.0170	-0.0167	
28	Wednesday, October 31, 2012	**0.0735**	**0.0994**	-0.0220	**0.0841**	**0.0994**	-0.0220	**0.0823**	**0.0994**	-0.0240	-0.0227	
56	Wednesday, November 28, 2012	**0.0727**	**0.0994**	-0.0300	**0.0834**	**0.0994**	-0.0290	**0.0816**	**0.0994**	-0.0310	-0.0300	
112	Wednesday, January 23, 2013	**0.0719**	**0.0991**	-0.0350	**0.0827**	**0.0991**	-0.0330	**0.0807**	**0.0991**	-0.0370	-0.0350	
224	Wednesday, May 15, 2013	**0.0712**	**0.0990**	-0.0410	**0.0820**	**0.0990**	-0.0390	**0.0802**	**0.0990**	-0.0410	-0.0403	
448	Wednesday, December 25, 2013	**0.0706**	**0.0986**	-0.0430	**0.0815**	**0.0986**	-0.0400	**0.0795**	**0.0985**	-0.0430	-0.0420	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

Curing Method:
14 Day Soak

BCD JOB NO. 110375
Mix Number Mix 13
Mix Date Tuesday, September 25, 2012 Mix Time: 1:43 PM

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8130	0.8150	11.65750	1.6280	10.0295
B	10.0000	0.8145	0.8140	11.64200	1.6285	10.0135
C	10.0000	0.8135	0.8155	11.64300	1.6290	10.0140

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Wednesday, October 10, 2012	**0.1330**	**0.0996**	0.0334	**0.1136**	**0.0996**	0.0140	**0.1205**	**0.0996**	0.0209	0.0228	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 10, 2012	**0.1330**	**0.0996**	0.0000	**0.1136**	**0.0996**	0.0000	**0.1205**	**0.0996**	0.0000	0.0000	
5	Monday, October 15, 2012	**0.1323**	**0.0996**	-0.0070	**0.1128**	**0.0996**	-0.0080	**0.1198**	**0.0996**	-0.0070	-0.0073	Shrinkage Room
7	Wednesday, October 17, 2012	**0.1321**	**0.0996**	-0.0090	**0.1127**	**0.0996**	-0.0090	**0.1197**	**0.0996**	-0.0080	-0.0087	
14	Wednesday, October 24, 2012	**0.1315**	**0.0994**	-0.0130	**0.1123**	**0.0994**	-0.0110	**0.1192**	**0.0994**	-0.0110	-0.0117	
28	Wednesday, November 07, 2012	**0.1309**	**0.0994**	-0.0190	**0.1117**	**0.0994**	-0.0170	**0.1186**	**0.0994**	-0.0170	-0.0177	
56	Wednesday, December 05, 2012	**0.1303**	**0.0994**	-0.0250	**0.1110**	**0.0993**	-0.0230	**0.1181**	**0.0994**	-0.0220	-0.0233	
112	Wednesday, January 30, 2013	**0.1294**	**0.0991**	-0.0310	**0.1101**	**0.0991**	-0.0300	**0.1173**	**0.0991**	-0.0270	-0.0293	
224	Wednesday, May 22, 2013	**0.1287**	**0.0989**	-0.0360	**0.1095**	**0.0988**	-0.0330	**0.1168**	**0.0988**	-0.0290	-0.0327	
448	Wednesday, January 01, 2014	**0.1280**	**0.0984**	-0.0380	**0.1090**	**0.0984**	-0.0340	**0.1162**	**0.0984**	-0.0310	-0.0343	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

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State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 13

Mix Date Tuesday, September 25, 2012 Mix Time: 1:43 PM

Curing Method: 28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8145	11.63950	1.6270	10.0125
B	10.0000	0.8165	0.8150	11.65200	1.6315	10.0205
C	10.0000	0.8135	0.8160	11.61350	1.6295	9.9840

SHRINKAGE TESTING - ASTM C157

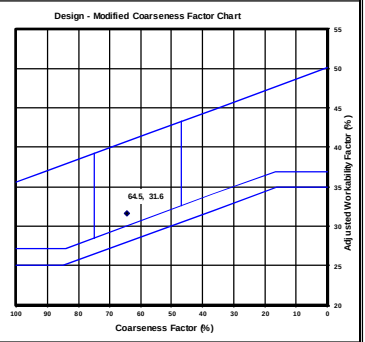
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Wednesday, October 24, 2012	**0.1140**	**0.0994**	0.0146	**0.1257**	**0.0994**	0.0263	**0.0922**	**0.0994**	-0.0072	0.0112	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 24, 2012	**0.1140**	**0.0994**	0.0000	**0.1257**	**0.0994**	0.0000	**0.0922**	**0.0994**	0.0000	0.0000	
5	Monday, October 29, 2012	**0.1135**	**0.0995**	-0.0060	**0.1251**	**0.0995**	-0.0070	**0.0916**	**0.0995**	-0.0070	-0.0067	Shrinkage Room
7	Wednesday, October 31, 2012	**0.1131**	**0.0993**	-0.0080	**0.1248**	**0.0993**	-0.0080	**0.0913**	**0.0993**	-0.0080	-0.0080	
14	Wednesday, November 07, 2012	**0.1128**	**0.0994**	-0.0120	**0.1245**	**0.0994**	-0.0120	**0.0911**	**0.0994**	-0.0110	-0.0117	
28	Wednesday, November 21, 2012	**0.1124**	**0.0995**	-0.0170	**0.1240**	**0.0995**	-0.0180	**0.0906**	**0.0995**	-0.0170	-0.0173	
56	Wednesday, December 19, 2012	**0.1117**	**0.0995**	-0.0240	**0.1232**	**0.0994**	-0.0250	**0.0899**	**0.0994**	-0.0230	-0.0240	
112	Wednesday, February 13, 2013	**0.1110**	**0.0991**	-0.0270	**0.1224**	**0.0991**	-0.0300	**0.0892**	**0.0991**	-0.0270	-0.0280	
224	Wednesday, June 05, 2013	**0.1102**	**0.0989**	-0.0330	**0.1216**	**0.0989**	-0.0360	**0.0885**	**0.0988**	-0.0310	-0.0333	
448	Wednesday, January 15, 2014	**0.1097**	**0.0984**	-0.0330	**0.1210**	**0.0984**	-0.0370	**0.0880**	**0.0984**	-0.0320	-0.0340	

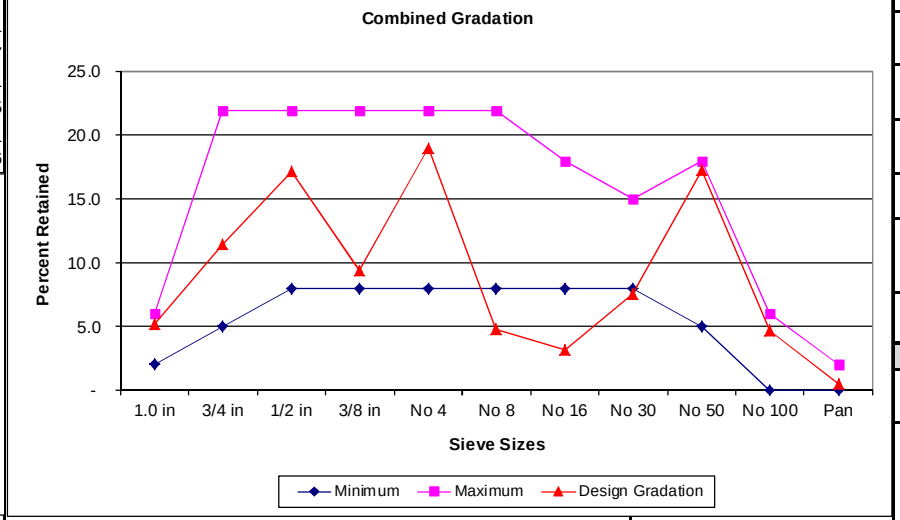
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375						MIX	14		Comments / Notes / Observations		
MIX NUMBER	Mix 14		Notes:							Set #:			Slag Source 1		
MIX DESIGN INFO	Date: 9/27/2012			f'c: 4,000 psi						Size(c.f.): 2.25			Factor: 0.0833		60/40
	% Retained MDOT			DRY Specific	AGG Absorp-		AGG Moisture	Free H20	Batch Free	Volume	DRY Mix 1 cu yd	DRY Mix lab batch	Adjusted lab batch	Actual lab batch	
Material	Min	Max	Design	Gravity	tion		Content	Content	H2O	(c.f.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.5510	304.8689	25.4060	25.41	25.41	Paste
SCM 1				2.890						1.1270	203.2460	16.9370	16.94	16.94	Paste
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	Gravel
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	Gravel
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	Gravel
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	Sand
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	Sand
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	Sand
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	
Total Grad%			100.0						-3.84	26.9983	3878.6116	323.2170	327.08	327.08	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.5	32.2	31.6





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
09/28/12	1	950	890
	1	830	
10/04/12	7	3160	3205
	7	3250	
10/11/12	14	4020	4225
	14	4430	
10/25/12	28	4190	4630
	28	4780	
	28	4920	
11/22/12	56	5770	5600
	56	5430	

Technician who conducted tests:

Plastic Test Results

Batch Time	10:57 AM	% Air	3.00	Unit Wt w/o Air	147.35	Design w/c	0.466
Sample Time	11:06 AM	Bucket Weight	7.70	Unit Wt (pcf)	145.20	Actual w/c	0.466
Air Temp.	89.2	Bucket Full	44.00	Theorectial Air	1.46	Design Unit Wt	143.66
Mix Temp.	74.8	Bucket Volume	0.250	Yield	2.25	Fine/Coarse	0.65
Slump, in.	3.50	Cmt+Wtr Vol(%)	23.98	Relative Yield	1.00	Bag Factor	5.41

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 14

Mix Date Thursday, September 27, 2012 Mix Time: 10:57 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	**Length of Standard Bar Distance Betw. Studs (0.0001 in.)**	**Length Stud 1 (0.0001 inches)**	**Length Stud 2 (0.0001 inches)**	**Measured Length of Specimen**	**Combined Stud Length**	**Net Distance betw Studs**
A	10.0000	0.8140	0.8155	11.62550	1.6295	9.9960
B	10.0000	0.8140	0.8125	11.61850	1.6265	9.9920
C	10.0000	0.8125	0.8125	11.61600	1.6250	9.9910

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	**Specimen A**	**Reference Bar A**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Friday, September 28, 2012	**0.0974**	**0.1002**	-0.0028	**0.0876**	**0.1002**	-0.0126	**0.0967**	**0.1002**	-0.0035	-0.0063	**M/Rm**
Curing Compound		**LENGTH CHANGE CALCULATIONS**										**Soak**
		Specimen A	**Reference Bar 1**	**Δ Length A**	**Specimen B**	**Reference Bar 2**	**Δ Length B**	**Specimen C**	**Reference Bar 3**	**Δ Length C**	**Average**	
Drying Days	**Comparator Reading Date**	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, September 28, 2012	**0.0974**	**0.1002**	0.0000	**0.0876**	**0.1002**	Erratic	**0.0967**	**0.1002**	0.0000	0.0000	
4	Tuesday, October 02, 2012	**0.0980**	**0.1000**	0.0080	**0.0872**	**0.1000**	Erratic	**0.0961**	**0.1000**	-0.0040	0.0020	**Shrinkage Room**
7	Friday, October 05, 2012	**0.0970**	**0.0998**	0.0000	**0.0856**	**0.0998**	Erratic	**0.0954**	**0.0998**	-0.0090	-0.0045	
14	Friday, October 12, 2012	**0.0963**	**0.0997**	-0.0060	**0.0851**	**0.0997**	Erratic	**0.0950**	**0.0997**	-0.0120	-0.0090	
28	Friday, October 26, 2012	**0.0957**	**0.0995**	-0.0100	**0.0843**	**0.0995**	Erratic	**0.0943**	**0.0995**	-0.0170	-0.0135	
56	Friday, November 23, 2012	**0.0951**	**0.0994**	-0.0150	**0.0837**	**0.0994**	Erratic	**0.0938**	**0.0994**	-0.0210	-0.0180	
112	Friday, January 18, 2013	**0.0942**	**0.0991**	-0.0210	**0.0828**	**0.0991**	Erratic	**0.0928**	**0.0991**	-0.0280	-0.0245	
224	Friday, May 10, 2013	**0.0936**	**0.0990**	-0.0260	**0.0822**	**0.0990**	Erratic	**0.0924**	**0.0990**	-0.0310	-0.0285	
448	Friday, December 20, 2013	**0.0930**	**0.0985**	-0.0270	**0.0816**	**0.0985**	Erratic	**0.0917**	**0.0985**	-0.0330	-0.0300	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

Curing Method:
7 Day Soak

BCD JOB NO. 110375
Mix Number Mix 14
Mix Date Thursday, September 27, 2012 Mix Time: 10:57 AM

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8135	11.64200	1.6280	10.0140
B	10.0000	0.8150	0.8125	11.63700	1.6275	10.0095
C	10.0000	0.8130	0.8165	11.59850	1.6295	9.9690

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Friday, October 05, 2012	**0.1172**	**0.0998**	0.0174	**0.1202**	**0.0998**	0.0204	**0.0664**	**0.0998**	-0.0334	0.0015	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 05, 2012	**0.1172**	**0.0998**	0.0000	**0.1202**	**0.0998**	0.0000	**0.0664**	**0.0998**	0.0000	0.0000	
4	Tuesday, October 09, 2012	**0.1165**	**0.0997**	-0.0060	**0.1195**	**0.0997**	-0.0060	**0.0659**	**0.0997**	-0.0040	-0.0053	Shrinkage Room
7	Friday, October 12, 2012	**0.1163**	**0.0997**	-0.0080	**0.1194**	**0.0997**	-0.0070	**0.0658**	**0.0997**	-0.0050	-0.0067	
14	Friday, October 19, 2012	**0.1160**	**0.0995**	-0.0090	**0.1191**	**0.0995**	-0.0080	**0.0655**	**0.0995**	-0.0060	-0.0077	
28	Friday, November 02, 2012	**0.1154**	**0.0994**	-0.0140	**0.1187**	**0.0994**	-0.0110	**0.0651**	**0.0994**	-0.0090	-0.0113	
56	Friday, November 30, 2012	**0.1151**	**0.0995**	-0.0180	**0.1184**	**0.0995**	-0.0150	**0.0647**	**0.0995**	-0.0140	-0.0157	
112	Friday, January 25, 2013	**0.1143**	**0.0992**	-0.0230	**0.1176**	**0.0992**	-0.0200	**0.0639**	**0.0992**	-0.0190	-0.0207	
224	Friday, May 17, 2013	**0.1135**	**0.0990**	-0.0290	**0.1169**	**0.0990**	-0.0250	**0.0632**	**0.0990**	-0.0240	-0.0260	
448	Friday, December 27, 2013	**0.1127**	**0.0986**	-0.0330	**0.1160**	**0.0986**	-0.0300	**0.0623**	**0.0985**	-0.0280	-0.0303	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 14

Mix Date Thursday, September 27, 2012 Mix Time: 10:57 AM

Curing Method:
14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8115	0.8130	11.64000	1.6245	10.0155
B	10.0000	0.8155	0.8145	11.62000	1.6300	9.9900
C	10.0000	0.8150	0.8120	11.62650	1.6270	9.9995

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Friday, October 12, 2012	**0.1311**	**0.0997**	0.0314	**0.0888**	**0.0997**	-0.0109	**0.0835**	**0.0997**	-0.0162	0.0014	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 12, 2012	**0.1311**	**0.0997**	0.0000	**0.0888**	**0.0997**	0.0000	**0.0835**	**0.0997**	0.0000	0.0000	
4	Tuesday, October 16, 2012	**0.1308**	**0.0995**	-0.0010	**0.0886**	**0.0995**	0.0000	**0.0831**	**0.0995**	-0.0020	-0.0010	
7	Friday, October 19, 2012	**0.1307**	**0.0995**	-0.0020	**0.0886**	**0.0995**	0.0000	**0.0831**	**0.0995**	-0.0020	-0.0013	
14	Friday, October 26, 2012	**0.1305**	**0.0995**	-0.0040	**0.0883**	**0.0995**	-0.0030	**0.0828**	**0.0995**	-0.0050	-0.0040	
28	Friday, November 09, 2012	**0.1303**	**0.0994**	-0.0050	**0.0879**	**0.0994**	-0.0060	**0.0825**	**0.0994**	-0.0070	-0.0060	
56	Friday, December 07, 2012	**0.1299**	**0.0994**	-0.0090	**0.0876**	**0.0994**	-0.0090	**0.0822**	**0.0994**	-0.0100	-0.0093	
112	Friday, February 01, 2013	**0.1290**	**0.0991**	-0.0150	**0.0868**	**0.0991**	-0.0140	**0.0814**	**0.0991**	-0.0150	-0.0147	
224	Friday, May 24, 2013	**0.1285**	**0.0990**	-0.0190	**0.0863**	**0.0989**	-0.0170	**0.0807**	**0.0988**	-0.0190	-0.0183	
448	Friday, January 03, 2014	**0.1276**	**0.0984**	-0.0220	**0.0853**	**0.0984**	-0.0220	**0.0795**	**0.0984**	-0.0270	-0.0237	Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 14

Mix Date Thursday, September 27, 2012 Mix Time: 10:57 AM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8155	0.8140	11.64500	1.6295	10.0155
B	10.0000	0.8130	0.8150	11.65350	1.6280	10.0255
C	10.0000	0.8140	0.8160	11.65950	1.6300	10.0295

SHRINKAGE TESTING - ASTM C157

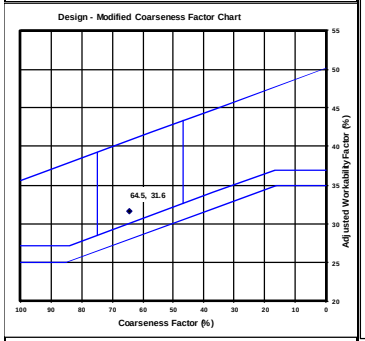
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Friday, October 26, 2012	**0.1130**	**0.0995**	0.0135	**0.1252**	**0.0995**	0.0257	**0.1311**	**0.0995**	0.0316	0.0236	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Friday, October 26, 2012	**0.1130**	**0.0995**	0.0000	**0.1252**	**0.0995**	0.0000	**0.1311**	**0.0995**	0.0000	0.0000	
4	Tuesday, October 30, 2012	**0.1127**	**0.0994**	-0.0020	**0.1250**	**0.0994**	-0.0010	**0.1308**	**0.0994**	-0.0020	-0.0017	Shrinkage Room
7	Friday, November 02, 2012	**0.1127**	**0.0994**	-0.0020	**0.1248**	**0.0994**	-0.0030	**0.1308**	**0.0994**	-0.0020	-0.0023	
14	Friday, November 09, 2012	**0.1124**	**0.0994**	-0.0050	**0.1247**	**0.0994**	-0.0040	**0.1306**	**0.0994**	-0.0040	-0.0043	
28	Friday, November 23, 2012	**0.1123**	**0.0994**	-0.0060	**0.1244**	**0.0994**	-0.0070	**0.1304**	**0.0994**	-0.0060	-0.0063	
56	Friday, December 21, 2012	**0.1118**	**0.0994**	-0.0110	**0.1239**	**0.0994**	-0.0120	**0.1300**	**0.0994**	-0.0100	-0.0110	
112	Friday, February 15, 2013	**0.1110**	**0.0991**	-0.0160	**0.1230**	**0.0991**	-0.0180	**0.1293**	**0.0991**	-0.0140	-0.0160	
224	Friday, June 07, 2013	**0.1102**	**0.0988**	-0.0210	**0.1222**	**0.0988**	-0.0230	**0.1286**	**0.0988**	-0.0180	-0.0207	
448	Friday, January 17, 2014	**0.1092**	**0.0984**	-0.0270	**0.1215**	**0.0984**	-0.0260	**0.1278**	**0.0984**	-0.0220	-0.0250	

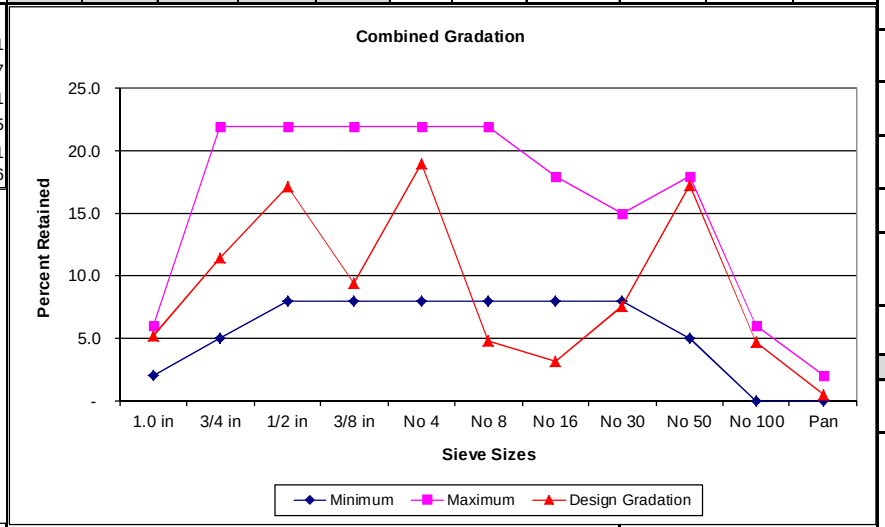
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375					MIX	15		Comments / Notes / Observations			
MIX NUMBER	Mix 15		Notes:						Set #:			Slag Source 1			
MIX DESIGN INFO	Date: 10/1/2012			f'c: 4,000 psi					Size(c.f.): 2.25			Factor: 0.0833	55/45		
	% Retained MDOT			DRY Specific Gravity	AGG Absorp-tion		AGG Moisture Content	Free H20 Content	Batch Free H2O	Volume (c.f.)	DRY Mix 1 cu yd Wt. (lbs.)	DRY Mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	
Material	Min	Max	Design												
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.4156	278.2550	23.1880	23.19	23.19	
SCM 1				2.890						1.2624	227.6632	18.9720	18.97	18.97	
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	Gravel
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	20.38	Sand
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)
Total Grad%			100.0						-3.84	26.9983	3876.4149	323.0340	326.89	326.89	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.5	32.2	31.6





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
10/02/12	1	950	885
	1	820	
10/08/12	7	2680	2745
	7	2810	
10/15/12	14	3840	3710
	14	3580	
10/29/12	28	4500	4710
	28	4930	
	28	4700	
11/26/12	56	5830	5915
	56	6000	

Technician who conducted tests:

Plastic Test Results

Batch Time	8:40 AM	% Air	3.00	Unit Wt w/o Air	147.26	Design w/c	0.468
Sample Time	8:50 AM	Bucket Weight	7.70	Unit Wt (pcf)	145.40	Actual w/c	0.468
Air Temp.	61.2	Bucket Full	44.05	Theorectial Air	1.26	Design Unit Wt	143.58
Mix Temp.	64.4	Bucket Volume	0.250	Yield	2.25	Fine/Coarse	0.65
Slump, in.	5.75	Cmt+Wtr Vol(%)	23.98	Relative Yield	1.00	Bag Factor	5.38

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 15

Mix Date Monday, October 01, 2012 Mix Time: 8:40 AM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8140	11.60650	1.6265	9.9800
B	10.0000	0.8145	0.8145	11.62450	1.6290	9.9955
C	10.0000	0.8135	0.8160	11.63300	1.6295	10.0035

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS									
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Tuesday, October 02, 2012	**0.0846**	**0.1000**	-0.0154	**0.0965**	**0.1001**	-0.0036	**0.1068**	**0.1001**	0.0067	-0.0041

M/Rm

Curing Compound		LENGTH CHANGE CALCULATIONS									
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)
0	Tuesday, October 02, 2012	**0.0846**	**0.1000**	Erratic	**0.0965**	**0.1001**	0.0000	**0.1068**	**0.1001**	0.0000	0.0000
3	Friday, October 05, 2012	**0.0787**	**0.0998**	Erratic	**0.0964**	**0.0998**	0.0020	**0.1069**	**0.0998**	0.0040	0.0030
7	Tuesday, October 09, 2012	**0.0782**	**0.0997**	Erratic	**0.0958**	**0.0997**	-0.0030	**0.1063**	**0.0997**	-0.0010	-0.0020
14	Tuesday, October 16, 2012	**0.0776**	**0.0995**	Erratic	**0.0951**	**0.0995**	-0.0080	**0.1055**	**0.0995**	-0.0070	-0.0075
28	Tuesday, October 30, 2012	**0.0771**	**0.0994**	Erratic	**0.0945**	**0.0994**	-0.0130	**0.1050**	**0.0994**	-0.0110	-0.0120
56	Tuesday, November 27, 2012	**0.0766**	**0.0992**	Erratic	**0.0939**	**0.0992**	-0.0170	**0.1044**	**0.0992**	-0.0150	-0.0160
112	Tuesday, January 22, 2013	**0.0759**	**0.0992**	Erratic	**0.0932**	**0.0992**	-0.0240	**0.1039**	**0.0992**	-0.0200	-0.0220
224	Tuesday, May 14, 2013	**0.0753**	**0.0991**	Erratic	**0.0924**	**0.0990**	-0.0300	**0.1032**	**0.0990**	-0.0250	-0.0275
448	Tuesday, December 24, 2013	**0.0745**	**0.0986**	Erratic	**0.0917**	**0.0986**	-0.0330	**0.1026**	**0.0986**	-0.0270	-0.0300

Soak

Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 15

Mix Date Monday, October 01, 2012 Mix Time: 8:40 AM

Curing Method: 7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8165	0.8160	11.63100	1.6325	9.9985
B	10.0000	0.8150	0.8165	11.59750	1.6315	9.9660
C	10.0000	0.8120	0.8155	11.62900	1.6275	10.0015

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Tuesday, October 09, 2012	**0.1051**	**0.0997**	0.0054	**0.0742**	**0.0997**	-0.0255	**0.1051**	**0.0997**	0.0054	-0.0049	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 09, 2012	**0.1051**	**0.0997**	0.0000	**0.0742**	**0.0997**	0.0000	**0.1051**	**0.0997**	0.0000	0.0000	
3	Friday, October 12, 2012	**0.1048**	**0.0997**	-0.0030	**0.0739**	**0.0997**	-0.0030	**0.1048**	**0.0997**	-0.0030	-0.0030	Shrinkage Room
7	Tuesday, October 16, 2012	**0.1044**	**0.0995**	-0.0050	**0.0736**	**0.0995**	-0.0040	**0.1045**	**0.0995**	-0.0040	-0.0043	
14	Tuesday, October 23, 2012	**0.1042**	**0.0995**	-0.0070	**0.0734**	**0.0995**	-0.0060	**0.1043**	**0.0995**	-0.0060	-0.0063	
28	Tuesday, November 06, 2012	**0.1038**	**0.0994**	-0.0100	**0.0729**	**0.0994**	-0.0100	**0.1039**	**0.0993**	-0.0080	-0.0093	
56	Tuesday, December 04, 2012	**0.1032**	**0.0993**	-0.0150	**0.0724**	**0.0993**	-0.0140	**0.1034**	**0.0993**	-0.0130	-0.0140	
112	Tuesday, January 29, 2013	**0.1024**	**0.0991**	-0.0210	**0.0717**	**0.0991**	-0.0190	**0.1026**	**0.0991**	-0.0190	-0.0197	
224	Tuesday, May 21, 2013	**0.1017**	**0.0989**	-0.0260	**0.0708**	**0.0989**	-0.0260	**0.1018**	**0.0989**	-0.0250	-0.0257	
448	Tuesday, December 31, 2013	**0.1009**	**0.0984**	-0.0290	**0.0700**	**0.0984**	-0.0290	**0.1010**	**0.0984**	-0.0280	-0.0287	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 15

Mix Date Monday, October 01, 2012 Mix Time: 8:40 AM

Curing Method: 14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8140	0.8150	11.65000	1.6290	10.0210
B	10.0000	0.8165	0.8160	11.60550	1.6325	9.9730
C	10.0000	0.8160	0.8145	11.62650	1.6305	9.9960

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Tuesday, October 16, 2012	**0.1276**	**0.0995**	0.0281	**0.0798**	**0.0995**	-0.0197	**0.1021**	**0.0995**	0.0026	0.0037	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 16, 2012	**0.1276**	**0.0995**	0.0000	**0.0798**	**0.0995**	0.0000	**0.1021**	**0.0995**	Erratic	0.0000	
3	Friday, October 19, 2012	**0.1275**	**0.0995**	-0.0010	**0.0798**	**0.0995**	0.0000	**0.1020**	**0.0995**	Erratic	-0.0005	Shrinkage Room
7	Tuesday, October 23, 2012	**0.1272**	**0.0995**	-0.0040	**0.0795**	**0.0995**	-0.0030	**0.1016**	**0.0995**	Erratic	-0.0035	
14	Tuesday, October 30, 2012	**0.1270**	**0.0994**	-0.0050	**0.0792**	**0.0994**	-0.0050	**0.1012**	**0.0994**	Erratic	-0.0050	
28	Tuesday, November 13, 2012	**0.1267**	**0.0994**	-0.0080	**0.0789**	**0.0994**	-0.0080	**0.1007**	**0.0994**	Erratic	-0.0080	
56	Tuesday, December 11, 2012	**0.1262**	**0.0994**	-0.0130	**0.0785**	**0.0994**	-0.0120	**0.1000**	**0.0994**	Erratic	-0.0125	
112	Tuesday, February 05, 2013	**0.1255**	**0.0991**	-0.0170	**0.0779**	**0.0991**	-0.0150	**0.0992**	**0.0991**	Erratic	-0.0160	
224	Tuesday, May 28, 2013	**0.1246**	**0.0988**	-0.0230	**0.0770**	**0.0988**	-0.0210	**0.0983**	**0.0988**	Erratic	-0.0220	
448	Tuesday, January 07, 2014	**0.1239**	**0.0986**	-0.0280	**0.0764**	**0.0986**	-0.0250	**0.0976**	**0.0986**	Erratic	-0.0265	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 15

Mix Date Monday, October 01, 2012 Mix Time: 8:40 AM

Curing Method: 28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8145	11.65100	1.6290	10.0220
B	10.0000	0.8150	0.8120	11.64950	1.6270	10.0225
C	10.0000	0.8150	0.8150	11.68450	1.6300	10.0545

SHRINKAGE TESTING - ASTM C157

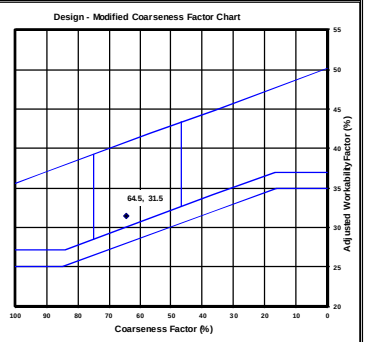
	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Tuesday, October 30, 2012	**0.1272**	**0.0994**	0.0278	**0.1239**	**0.0994**	0.0245	**0.1590**	**0.0994**	0.0596	0.0373	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Tuesday, October 30, 2012	**0.1272**	**0.0994**	0.0000	**0.1239**	**0.0994**	0.0000	**0.1590**	**0.0994**	0.0000	0.0000	
3	Friday, November 02, 2012	**0.1273**	**0.0994**	0.0010	**0.1240**	**0.0994**	0.0010	**0.1591**	**0.0994**	0.0010	0.0010	Shrinkage Room
7	Tuesday, November 06, 2012	**0.1271**	**0.0993**	0.0000	**0.1238**	**0.0993**	0.0000	**0.1588**	**0.0993**	-0.0010	-0.0003	
14	Tuesday, November 13, 2012	**0.1269**	**0.0994**	-0.0030	**0.1237**	**0.0994**	-0.0020	**0.1586**	**0.0994**	-0.0040	-0.0030	
28	Tuesday, November 27, 2012	**0.1266**	**0.0992**	-0.0040	**0.1233**	**0.0992**	-0.0040	**0.1581**	**0.0992**	-0.0070	-0.0050	
56	Tuesday, December 25, 2012	**0.1263**	**0.0995**	-0.0100	**0.1230**	**0.0995**	-0.0100	**0.1579**	**0.0995**	-0.0120	-0.0107	
112	Tuesday, February 19, 2013	**0.1255**	**0.0991**	-0.0140	**0.1222**	**0.0991**	-0.0140	**0.1571**	**0.0991**	-0.0160	-0.0147	
224	Tuesday, June 11, 2013	**0.1245**	**0.0989**	-0.0220	**0.1212**	**0.0989**	-0.0220	**0.1564**	**0.0989**	-0.0210	-0.0217	
448	Tuesday, January 21, 2014	**0.1238**	**0.0985**	-0.0250	**0.1205**	**0.0985**	-0.0250	**0.1557**	**0.0985**	-0.0240	-0.0247	

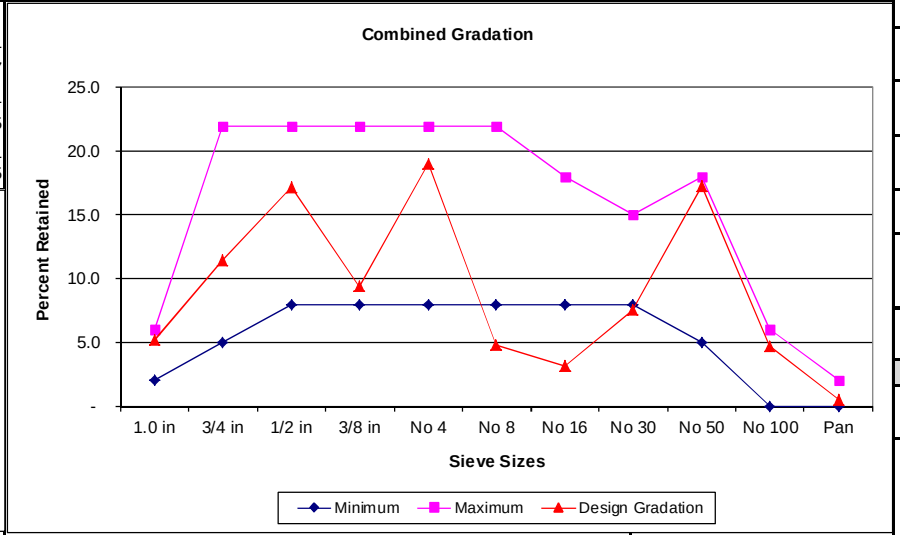
Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

Burns Cooley Dennis, Inc - State Study No. 247

Customer:	MDOT		Project:	110375								MIX	16	Comments / Notes / Observations	
MIX NUMBER	Mix 16		Notes:									Set #:		Slag Source 1	
MIX DESIGN INFO	Date: 10/2/2012			f'c: 4,000 psi						Size(c.f.): 2.25		Factor: 0.0833		50/50	
	% Retained MDOT			DRY	AGG		AGG	Free	Batch		DRY Mix	DRY Mix	Adjusted	Actual	
Material	Min	Max	Design	Specific Gravity	Absorp-tion		Moisture Content	H20 Content	Free H2O	Volume (c.f.)	1 cu yd Wt. (lbs.)	lab batch Wt. (lbs.)	lab batch Wt. (lbs.)	lab batch Wt. (lbs.)	
Entrapped Air			2.50%							0.6750					
Water				1.000						3.7962	236.8800	19.7400	23.58	23.58	Paste
Cementitious 1				3.150						1.2814	251.8702	20.9890	20.99	20.99	
SCM 1				2.890						1.3967	251.8702	20.9890	20.99	20.99	
1.0 in	2.0	6.0	5.20	2.473	2.23%		0	-2.230%	-0.30	1.0323	159.2922	13.2740	13.27	13.27	Gravel
3/4 in	5.0	22.0	11.43	2.473	2.23%		0	-2.230%	-0.65	2.2690	350.1365	29.1780	29.18	29.18	
1/2 in	8.0	22.0	17.14	2.473	2.23%		0	-2.230%	-0.98	3.4025	525.0515	43.7540	43.75	43.75	
3/8 in	8.0	22.0	9.37	2.473	2.23%		0	-2.230%	-0.53	1.8600	287.0322	23.9190	23.92	23.92	
No 4	8.0	22.0	18.95	2.473	2.23%		0	-2.230%	-1.08	3.7618	580.4974	48.3750	48.38	48.38	
No 8	8.0	22.0	4.77	2.625	0.28%		0	-0.280%	-0.04	0.9469	155.1010	12.9250	12.93	12.93	Sand
No 16	8.0	18.0	3.15	2.625	0.28%		0	-0.280%	-0.02	0.6253	102.4252	8.5350	8.54	8.54	
No 30	8.0	15.0	7.52	2.625	0.28%		0	-0.280%	-0.06	1.4928	244.5199	20.3770	20.38	2038	
No 50	5.0	18.0	17.29	2.625	0.28%		0	-0.280%	-0.13	3.4322	562.2006	46.8500	46.85	46.85	
No 100	-	6.0	4.65	2.625	0.28%		0	-0.280%	-0.04	0.9231	151.1991	12.6000	12.60	12.60	
Pan	-	2.0	0.52	2.509	1.75%		0	-1.750%	-0.02	0.1032	16.1611	1.3470	1.35	1.35	75.2% Gravel (1.02 lbs), 24.8% Sand (0.33 lbs)
Total Grad%			100.0						-3.84	26.9984	3874.2371	322.8520	326.71	2344.33	

Fineness Mod			0.77
Q	23.0	72.0	43.1
I	16.0	44.0	23.7
W	21.0	59.0	33.1
CF Actual	59.0	62.1	64.5
WF Actual	35.0	33.7	33.1
AWF	33.4	32.1	31.5





Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
10/03/12	1	540	590
	1	640	
10/09/12	7	2320	2280
	7	2240	
10/16/12	14	3790	3620
	14	3450	
10/30/12	28	4060	4117
	28	4330	
	28	3960	
11/27/12	56	5480	5290
	56	5100	

Technician who conducted tests:

Plastic Test Results

Batch Time	1:21 PM	% Air	3.00	Unit Wt w/o Air	147.18	Design w/c	0.470
Sample Time	1:31 PM	Bucket Weight	7.70	Unit Wt (pcf)	144.40	Actual w/c	0.470
Air Temp.	75.5	Bucket Full	43.80	Theorectial Air	1.89	Design Unit Wt	143.50
Mix Temp.	71.5	Bucket Volume	0.250	Yield	16.23	Fine/Coarse	0.65
Slump, in.	3.00	Cmt+Wtr Vol(%)	23.98	Relative Yield	7.22	Bag Factor	5.36

Reviewed by: Robert Varner, P.E.

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
State Study 247 - ASTM C 157 Shrinkage Testing

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 16

Mix Date Tuesday, October 02, 2012 Mix Time: 1:21 PM

Curing Method:
Curing Compound

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8140	11.60800	1.6265	9.9815
B	10.0000	0.8150	0.8125	11.62150	1.6275	9.9940
C	10.0000	0.8160	0.8160	11.60450	1.6320	9.9725

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar A	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
1	Wednesday, October 03, 2012	**0.0816**	**0.0998**	-0.0182	**0.0932**	**0.0998**	-0.0066	**0.0766**	**0.0998**	-0.0232	-0.0160	M/Rm
Curing Compound		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 03, 2012	**0.0816**	**0.0998**	Erratic	**0.0932**	**0.0998**	Erratic	**0.0766**	**0.0998**	0.0000	0.0000	
5	Monday, October 08, 2012	**0.0799**	**0.0997**	Erratic	**0.0948**	**0.0997**	Erratic	**0.0766**	**0.0997**	0.0010	0.0010	Shrinkage Room
7	Wednesday, October 10, 2012	**0.0796**	**0.0996**	Erratic	**0.0943**	**0.0996**	Erratic	**0.0763**	**0.0996**	-0.0010	-0.0010	
14	Wednesday, October 17, 2012	**0.0791**	**0.0996**	Erratic	**0.0935**	**0.0996**	Erratic	**0.0759**	**0.0996**	-0.0050	-0.0050	
28	Wednesday, October 31, 2012	**0.0783**	**0.0993**	Erratic	**0.0926**	**0.0993**	Erratic	**0.0751**	**0.0993**	-0.0100	-0.0100	
56	Wednesday, November 28, 2012	**0.0776**	**0.0994**	Erratic	**0.0919**	**0.0993**	Erratic	**0.0744**	**0.0993**	-0.0170	-0.0170	
112	Wednesday, January 23, 2013	**0.0769**	**0.0991**	Erratic	**0.0910**	**0.0991**	Erratic	**0.0736**	**0.0991**	-0.0230	-0.0230	
224	Wednesday, May 15, 2013	**0.0761**	**0.0990**	Erratic	**0.0905**	**0.0990**	Erratic	**0.0729**	**0.0990**	-0.0290	-0.0290	
448	Wednesday, December 25, 2013	**0.0755**	**0.0985**	Erratic	**0.0899**	**0.0985**	Erratic	**0.0722**	**0.0985**	-0.0310	-0.0310	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 16

Mix Date Tuesday, October 02, 2012 Mix Time: 1:21 PM

Curing Method: 7 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8125	0.8155	11.60500	1.6280	9.9770
B	10.0000	0.8145	0.8100	11.63200	1.6245	10.0075
C	10.0000	0.8150	0.8155	11.62950	1.6305	9.9990

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
7	Wednesday, October 10, 2012	**0.0786**	**0.0996**	-0.0210	**0.1056**	**0.0996**	0.0060	**0.1037**	**0.0996**	0.0041	-0.0036	M/Rm
7 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 10, 2012	**0.0786**	**0.0996**	0.0000	**0.1056**	**0.0996**	0.0000	**0.1037**	**0.0996**	0.0000	0.0000	
5	Monday, October 15, 2012	**0.0782**	**0.0996**	-0.0040	**0.1053**	**0.0996**	-0.0030	**0.1033**	**0.0996**	-0.0040	-0.0037	Shrinkage Room
7	Wednesday, October 17, 2012	**0.0780**	**0.0995**	-0.0050	**0.1052**	**0.0995**	-0.0030	**0.1032**	**0.0995**	-0.0040	-0.0040	
14	Wednesday, October 24, 2012	**0.0776**	**0.0994**	-0.0080	**0.1049**	**0.0994**	-0.0050	**0.1029**	**0.0994**	-0.0060	-0.0063	
28	Wednesday, November 07, 2012	**0.0774**	**0.0994**	-0.0100	**0.1045**	**0.0994**	-0.0090	**0.1025**	**0.0994**	-0.0100	-0.0097	
56	Wednesday, December 05, 2012	**0.0768**	**0.0994**	-0.0160	**0.1039**	**0.0994**	-0.0150	**0.1020**	**0.0994**	-0.0150	-0.0153	
112	Wednesday, January 30, 2013	**0.0760**	**0.0991**	-0.0210	**0.1031**	**0.0991**	-0.0200	**0.1012**	**0.0991**	-0.0200	-0.0203	
224	Wednesday, May 22, 2013	**0.0753**	**0.0988**	-0.0250	**0.1024**	**0.0988**	-0.0240	**0.1004**	**0.0988**	-0.0250	-0.0247	
448	Wednesday, January 01, 2014	**0.0746**	**0.0984**	-0.0280	**0.1016**	**0.0984**	-0.0280	**0.0998**	**0.0984**	-0.0270	-0.0277	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/12/2014

BURNS COOLEY DENNIS, INC.
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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 16

Mix Date Tuesday, October 02, 2012 Mix Time: 1:21 PM

Curing Method: 14 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8130	0.8120	11.64900	1.6250	10.0240
B	10.0000	0.8150	0.8170	11.63600	1.6320	10.0040
C	10.0000	0.8145	0.8150	11.63050	1.6295	10.0010

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
14	Wednesday, October 17, 2012	**0.1221**	**0.0995**	0.0226	**0.1092**	**0.0995**	0.0097	**0.1049**	**0.0995**	0.0054	0.0126	M/Rm
14 Day Soak		LENGTH CHANGE CALCULATIONS										Soak
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	
0	Wednesday, October 17, 2012	**0.1221**	**0.0995**	0.0000	**0.1092**	**0.0995**	0.0000	**0.1049**	**0.0995**	0.0000	0.0000	
5	Monday, October 22, 2012	**0.1218**	**0.0995**	-0.0030	**0.1088**	**0.0995**	-0.0040	**0.1046**	**0.0995**	-0.0030	-0.0033	Shrinkage Room
7	Wednesday, October 24, 2012	**0.1216**	**0.0994**	-0.0040	**0.1087**	**0.0994**	-0.0040	**0.1045**	**0.0994**	-0.0030	-0.0037	
14	Wednesday, October 31, 2012	**0.1214**	**0.0993**	-0.0050	**0.1083**	**0.0993**	-0.0070	**0.1041**	**0.0993**	-0.0060	-0.0060	
28	Wednesday, November 14, 2012	**0.1210**	**0.0994**	-0.0100	**0.1079**	**0.0993**	-0.0110	**0.1038**	**0.0993**	-0.0090	-0.0100	
56	Wednesday, December 12, 2012	**0.1206**	**0.0995**	-0.0150	**0.1077**	**0.0995**	-0.0150	**0.1034**	**0.0995**	-0.0150	-0.0150	
112	Wednesday, February 06, 2013	**0.1197**	**0.0991**	-0.0200	**0.1068**	**0.0991**	-0.0200	**0.1026**	**0.0991**	-0.0190	-0.0197	
224	Wednesday, May 29, 2013	**0.1186**	**0.0988**	-0.0280	**0.1061**	**0.0988**	-0.0240	**0.1016**	**0.0988**	-0.0260	-0.0260	
448	Wednesday, January 08, 2014	**0.1180**	**0.0986**	-0.0320	**0.1055**	**0.0985**	-0.0270	**0.1009**	**0.0985**	-0.0300	-0.0297	

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varmer, P.E. Date: 12/12/2014

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278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

BCD JOB NO. 110375

Mix Number Mix 16

Mix Date Tuesday, October 02, 2012 Mix Time: 1:21 PM

Curing Method:
28 Day Soak

Measurements Required Before Making Specimens						
Specimen	Length of Standard Bar Distance Betw. Studs (0.0001 in.)	Length Stud 1 (0.0001 inches)	Length Stud 2 (0.0001 inches)	Measured Length of Specimen	Combined Stud Length	Net Distance betw Studs
A	10.0000	0.8145	0.8120	11.71150	1.6265	10.0850
B	10.0000	0.8135	0.8150	11.62650	1.6285	9.9980
C	10.0000	0.8150	0.8160	11.63400	1.6310	10.0030

SHRINKAGE TESTING - ASTM C157

	Gage Length (in.)	INITIAL READINGS										
	10	Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches	
28	Wednesday, October 31, 2012	**0.1859**	**0.0993**	0.0866	**0.0962**	**0.0993**	-0.0031	**0.1090**	**0.0993**	0.0097	0.0311	M/Rm
28 Day Soak		LENGTH CHANGE CALCULATIONS										
		Specimen A	Reference Bar 1	Δ Length A	Specimen B	Reference Bar 2	Δ Length B	Specimen C	Reference Bar 3	Δ Length C	Average	
Drying Days	Comparator Reading Date	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001 in.)	(.0001 in.)	(0.0001%)	(.0001%)	Soak
0	Wednesday, October 31, 2012	**0.1859**	**0.0993**	0.0000	**0.0962**	**0.0993**	0.0000	**0.1090**	**0.0993**	0.0000	0.0000	
5	Monday, November 05, 2012	**0.1858**	**0.0993**	-0.0010	**0.0960**	**0.0993**	-0.0020	**0.1088**	**0.0993**	-0.0020	-0.0017	
7	Wednesday, November 07, 2012	**0.1859**	**0.0994**	-0.0010	**0.0961**	**0.0994**	-0.0020	**0.1089**	**0.0994**	-0.0020	-0.0017	
14	Wednesday, November 14, 2012	**0.1855**	**0.0994**	-0.0050	**0.0958**	**0.0993**	-0.0040	**0.1086**	**0.0993**	-0.0040	-0.0043	
28	Wednesday, November 28, 2012	**0.1852**	**0.0993**	-0.0070	**0.0953**	**0.0993**	-0.0090	**0.1082**	**0.0993**	-0.0080	-0.0080	
56	Wednesday, December 26, 2012	**0.1848**	**0.0995**	-0.0130	**0.0950**	**0.0995**	-0.0140	**0.1079**	**0.0995**	-0.0130	-0.0133	
112	Wednesday, February 20, 2013	**0.1839**	**0.0991**	-0.0180	**0.0940**	**0.0991**	-0.0200	**0.1070**	**0.0991**	-0.0180	-0.0187	
224	Wednesday, June 12, 2013	**0.1831**	**0.0989**	-0.0240	**0.0931**	**0.0989**	-0.0270	**0.1061**	**0.0989**	-0.0250	-0.0253	
448	Wednesday, January 22, 2014	**0.1823**	**0.0985**	-0.0280	**0.0925**	**0.0985**	-0.0290	**0.1055**	**0.0985**	-0.0270	-0.0280	Shrinkage Room

Note: Lowest Reading Value Recorded. Reviewed By: Robert Varner, P.E. Date: 12/29/2014