BURNS COOLEY DENNIS, INC.
GEOTECHNICAL AND MATERIALS ENGINEERING CONSULTANTS

SHRINKAGE AND DURABILITY STUDY OF BRIDGE DECK CONCRETE

State Study 216

Project No. SPR-1(54)/105366 139000

Prepared for
Mississippi Department of Transportation

Prepared by
Robert L. Varner, P.E.

December, 2010

Technical Report Documentation Page

1. Report No. FHWA/MS-DOT-RD-09-216	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Shrinkage and Durability Study of Bridge Deck Concrete		5. Report Date December 2010 6. Performing Organization Code BCD No. 080739
7. Author Robert L. Varner, P.E.		8. Performing Organization Report No. MS-DOT-RD-09-216
9. Performing Organization Name and Address Burns Cooley Dennis, Inc. Post Office Box 12828 Jackson, Mississippi 39236		10. Work Unit No. (TRAIS) 11. Contract or Grant No. CS 00002386
12. Sponsoring Agency Name and Address Mississippi Department of Transportation P.O. Box 1850 Jackson, MS 39215-1850		13. Type Report and Period Covered **Final Report** (March 2009 to December 2010) 14. Sponsoring Agency Code
15. Supplementary Notes MDOT State Study 216 Project No. SPR-1(54)/105366 139000		

16. Abstract: The Mississippi Department of Transportation is incorporating changes to material specifications and construction procedures for bridge decks in an effort to reduce shrinkage cracking. These changes are currently being implemented into a limited number of projects to evaluate MDOT's new Class BD concrete. This class of concrete was modeled after Kansas Department of Transportation's special provision for low cracking, high performance concrete which was based on studies conducted by the University of Kansas. While Class BD concrete is based on recommendations of the research performed at the University of Kansas, there was limited data available for MDOT engineers to evaluate shrinkage characteristics of concrete made with gravel and cementitious materials available in Mississippi. This research generates shrinkage and permeability data for thirty mixtures developed with readily available materials in Mississippi.

17. Key Words Aggregate Gradation Optimization, Bridge Deck, Cementitious Material, Coarseness Factor Chart, Concrete, Concrete Mixture, Durability, Length Change, Penetrability, Permeability, Shrinkage, Shrinkage Cracks	18. Distribution Statement Unclassified		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 181	22. Price

Reproduction of completed page authorized

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Mississippi Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government and the State of Mississippi assume no liability for its contents or use thereof.

The United States Government and the State of Mississippi do not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

Acknowledgements

This work was performed under the supervision of the MDOT TAC Committee:

Research Division: Bill Barstis, P.E.
Materials Division: James Williams, P.E.
Mike O'Brien, P.E.
Jeremy Robinson, P.E.
Adam Browne, P.E

This work was accomplished with the support of Burns Cooley Dennis' staff and management and the technical knowledge and experience of the following:

R.C. Ahlrich, Ph.D., P.E.
L. Allen Cooley, Jr., Ph.D.

Abstract

Shrinkage induced cracks have been a long term occurrence in Mississippi bridge decks, but have received little attention due to the apparent lack of severity relative to the longevity and serviceability of the bridges. 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. The Mississippi Department of Transportation (MDOT) is incorporating changes to material specifications and construction procedures for bridge decks in an effort to reduce shrinkage cracking. These changes are currently being implemented into a limited number of projects to evaluate MDOT's new Class BD concrete. This class of concrete was modeled after Kansas Department of Transportation's special provision for low cracking, high performance concrete which was based on studies conducted by the University of Kansas. A significant aspect of this special provision is an effort to reduce the cementitious paste content of concrete mixtures used on bridge decks because as the paste content increases, the potential for shrinkage and cracking increases. While Class BD concrete is based on recommendations of the research performed at the University of Kansas, there was limited data available for MDOT engineers to evaluate shrinkage characteristics of concrete made with gravel and cementitious materials available in Mississippi. This research generates shrinkage and permeability data for thirty mixtures developed with readily available materials in Mississippi. It focuses on the use of cementitious material to reduce shrinkage and permeability. Cementitious materials used in this study include Type I and Type GU cement, Class C fly ash, Class F fly ash, and ground granulated blast furnace slag.

Table of Contents

Table of Tables

Table of Figures

Chapter 1 - Introduction

Reinforced concrete is commonly used in the design and construction of highway bridges. Durable concrete is critical for bridges to provide long service life and low maintenance costs. It is essential for contractors to use high quality materials in concrete to meet these demands. Each ingredient must meet requirements established in construction material standards provided by the American Association of State Highway and Transportation Officials (AASHTO) or the American Society for Testing and Materials (ASTM) to achieve high quality concrete. These materials must be proportioned to produce strong and durable concrete. Low shrinkage and low permeability are important characteristics that enhance durability of concrete structures. The cementitious paste and each cementitious material must receive careful consideration when considering ways to reduce shrinkage and permeability. The purpose of this study was to generate laboratory data documenting cementitious material's influence on shrinkage and permeability. Cementitious materials used in this study include Type I and Type GU cement, Class C fly ash, Class F fly ash, and ground granulated blast furnace slag (GGBFS).

Concrete is a composite material consisting of aggregates, cementitious materials, water, air, and admixtures. Concrete can be divided into two major components including aggregates and cementitious paste. Fine and coarse aggregates make up the aggregate portion. Fine aggregates generally range in size from the smallest grain up to 3/8 in. Fine aggregates occur naturally or may be manufactured during the production of crushed coarse aggregate. Coarse aggregates contain particles retained on the No. 16 sieve and up to 1 in. size or larger. Coarse aggregates can be gravel or crushed stone. Round gravel with sizes up to 1 in. are abundant in Mississippi and require minimal processing before they are ready for use in concrete. Natural sands are also abundant making gravel aggregate concrete with natural sand common in

Mississippi. Aggregates make up 60% to 75% of the total volume of concrete (1). The remaining 25% to 40% of the volume of concrete is void space developed by the irregular shape of individual particles of aggregates. This void space must be filled with cementitious paste.

Cementitious paste is composed of cementitious materials, water, air, and chemical admixtures. Portland cement is the primary cementing ingredient in the cementitious paste. Portland cement is a hydraulic cement which means it sets and hardens by reacting chemically with water (1). This chemical reaction is called hydration. Portland cement is made of many compounds, and four of these compounds include tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite (1). The calcium silicates react with water to form calcium hydroxide and calcium silicate hydrate. The calcium silicate hydrate is the most important cementing component in concrete because it causes concrete to set and gain strength. Portland cement is often complemented with other cementitious materials that can contribute to the fresh and hardened properties of concrete through hydraulic or pozzolanic activity (1).

A pozzolan is a siliceous or aluminosiliceous material that chemically reacts with calcium hydroxide produced during the hydration of portland cement. This reaction produces additional calcium silicate hydrate and other cementitious compounds (2). Fly ash and GGBFS may have both hydraulic and pozzolanic qualities and are generally categorized as supplementary cementitious materials (SCMs) (1).

Concrete experiences volume changes while in a plastic or hardened state. These volumetric changes are relatively small compared to the entire volume of concrete and primarily occur in the paste portion of the mixture as shrinkage. Volume change can be either in the form of swelling (expansion) or shrinkage (contraction). Volume change in plastic and early age concrete is commonly due to 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.

Autogenous shrinkage occurs as water in the pores of the 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 (1). It is more prominent in concrete with high cementitious contents and low water contents. Autogenous shrinkage is most prominent in concrete having a water to cement ratio less than 0.42 (2). This additional consumption of water by hydration causes less volume and shrinkage in the cementitious paste.

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 volume of concrete. This reduction of water causes shrinkage in the overall volume of concrete. Settlement shrinkage was not considered in this study because initial shrinkage comparator readings were performed after settlement had occurred.

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 is addressed in specification with curing methods to reduce rapid evaporation. Plastic shrinkage was not considered in this study because rapid evaporation was prevented by using a moist room and water curing tank.

Hardened concrete also experiences volume changes and may be in the form of expansion and shrinkage with changes in moisture and temperature. When external water is available to replace water that is consumed by chemical shrinkage, expansion occurs. Additionally, expansion will occur when hardened concrete gets wet. While concrete expands and contracts with changes in temperature and moisture, the overall tendency of concrete is to shrink. As hardened concrete dries due to the relative humidity of air being lower than the relative humidity of the concrete, drying shrinkage occurs.

When shrinkage of concrete is restrained, shrinkage cracks can occur. Concrete shrinkage is restrained by supporting subbase/base materials or from reinforcing steel and other structural elements. A combination of shrinkage of concrete materials and restraint is the mechanism that produces cracking. This restraint of shrinkage causes cracks to form as restrained shrinkage stresses exceed the strength of the concrete. Reinforcing steel is designed to resist tensile stresses in the concrete that are induced by imposed loads. It is also designed to hold faces of shrinkage cracks tight together. These shrinkage cracks are expected and included in the design of reinforcing steel. Even though shrinkage cracks are considered in reinforced concrete design, every effort should be made to minimize these cracks. These cracks provide channels for water and chloride ions to get to and corrode the reinforcing steel. They also provide an opening for concrete to be attacked by sulfates and other chemicals that can cause deterioration of the concrete.

While effort should be made to reduce shrinkage characteristics of concrete, the concrete should be proportioned to have low permeability. Permeability of concrete refers to the amount of water that migrates through concrete when the water is under pressure or the ability of concrete to resist penetration of other substances (2). The overall permeability of concrete is a function of the permeability of the cementitious paste (1). Permeability of the cementitious paste is important because cementitious paste provides a medium for penetration of chemicals that can attack and deteriorate concrete. Permeability of the cementitious paste is a function of the porosity of the paste (1). As porosity of the paste increases, the permeability of the concrete increases.

Low shrinkage and low permeability characteristics are critical for durable bridge decks. Bride decks form an integral structural component critical to the stability of a bridge. Bridge decks that exhibit low cracking and have low permeability potentially will produce bridge decks with the longest service life and lowest maintenance costs. Specifications for concrete materials used in bridge decks must incorporate strategies to provide durability. MDOT has recently developed a new Class BD concrete for concrete bridge decks with a focus on durability.

Class BD concrete addresses both concrete materials and construction procedures critical for durable concrete. Durability is achieved in this class of concrete by reducing shrinkage and reducing permeability. The maximum amount of cementitious materials that can be used in Class BD concrete is 564 pounds per cubic yard. Setting a maximum amount of cementitious materials will control the amount of cementitious materials available to consume water during hydration thereby reducing shrinkage. A nominal slump of 3 in. is specified to limit the amount of free water in the mixture to reduce drying shrinkage. Aggregate gradation optimization is also incorporated in an effort to replace cementitious paste that shrinks with aggregates that are volumetrically stable relative to cementitious paste. Low permeability is incorporated with a maximum water cementitious ratio ranging from 0.43 to 0.45. MDOT's Class BD concrete at the time of this research allows two cementitious materials including portland cement and GGBFS, but does not allow fly ash to be used.

MDOT Class BD concrete reflects the experience and research of the Kansas Department of Transportation (KDOT). KDOT has implemented a special provision for low cracking, high performance concrete for bridge decks. This special provision was based on studies conducted by the University of Kansas (KU). It incorporated strategies to reduce cementitious paste content which has the highest potential for shrinkage. This reduction in cementitious paste is partly accomplished by increasing aggregate content. Therefore, aggregate gradation optimization is an integral part of the KU model. The KU model uses a minimum cementitious content of 500 pounds per cubic yard and a maximum of 540 pounds per cubic yard to limit the amount of cementitious materials that will shrink during hydration. Low permeability is incorporated by specifying a maximum water cementitious ratio ranging from 0.44 to 0.45. Both portland cement and GGBFS can be used in mixtures designed according to the KU model.

Aggregate gradation optimization is embraced in both the MDOT Class BD concrete and the KU model. Reported benefits associated with aggregate gradation optimization include less cementitious paste, less shrinkage, greater strengths, better pumpability, and enhanced finishability (3). A goal of aggregate gradation optimization is to fill voids in concrete with aggregate particles in lieu of cementitious paste. This provides more cementitious paste for workability if it is not used for filling voids. Aggregate gradation optimization may be found in other documents including the American Concrete Institute's (ACI) 302 guide entitled "Guide for Concrete Floor and Slab Construction" used by designers for slab on ground construction.

Common aggregate optimization methods use general guidelines for controlling total percentage of fine and coarse aggregate particles retained on any one sieve. These limits vary based on locally available aggregates and experience of the designer. Table 1 shows the combined percent materials retained on individual sieves used by ACI, KDOT, and MDOT for maximum size material up to 1 in. There are also other design aids available for optimization including a "Coarseness Factor Chart" to evaluate the workability of a mixture based on the combined aggregate gradation. Figure 1 presents an example of a Coarseness Factor Chart presented in ACI 302 modified to include MDOT's limits indicated by an ellipse.

Table 1: Combined Percent Retained on Individual Sieves - ACI, KDOT, MDOT

	Combined Percent Retained on Individual Sieves											
	1-1/2 in.	1 in.	¾ in.	½ in.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Pan
ACI	NA	0-4	8-22	8-22	8-22	8-22	8-22	8-22	8-15	8-15	1.5-5	NA	NA
KDOT	0	2-6	5-18	8-18	8-18	8-18	8-18	8-18	8-15	5-15	0-5	NA	0-2.5
MDOT	0	1-6	5-22	8-22	8-22	8-22	8-22	8-18	8-15	5-18	0-6	0-5	0-2

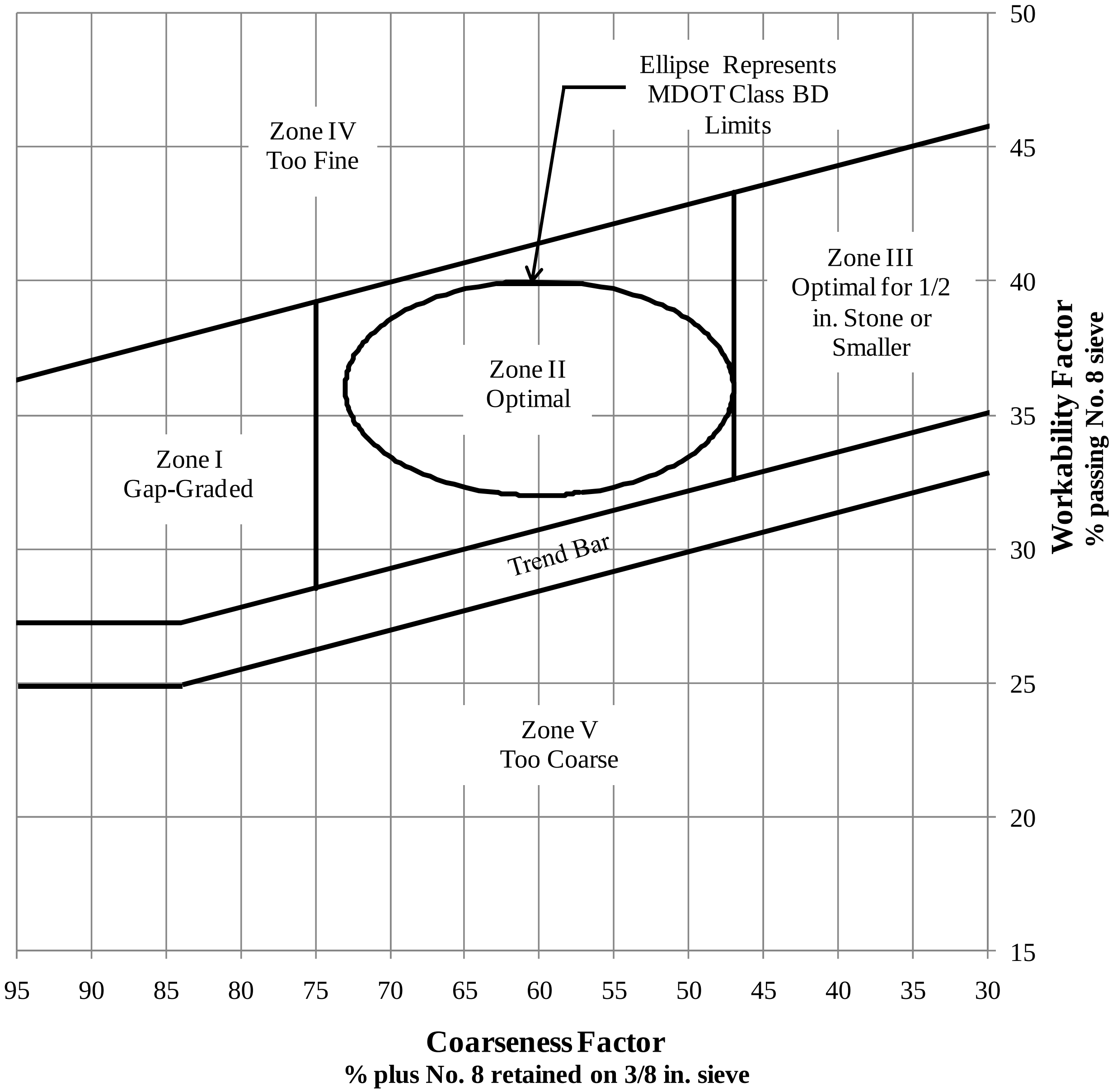

Figure 1: Coarseness Factor Chart

Concrete used in bridge deck construction must be durable. Durability of concrete can be measured by the amount of shrinkage and permeability associated with specific concrete mixtures. Designers can implement strategies to reduce shrinkage cracking and reduce permeability. Model specifications for low cracking, durable concrete available for MDOT engineers are based on studies formulated without the use of Mississippi materials. The model used by MDOT for the Class BD concrete was based on studies performed by the University of Kansas and it places a great deal of emphasis on aggregate gradation optimization that may or may not be applicable for Mississippi aggregates. State Study 216 “Shrinkage and Durability Study of Bridge Deck Concrete” documents shrinkage and permeability characteristics of concrete made with various combinations of cementitious materials and Mississippi aggregates.

Objective

The objective of this research was to determine the usefulness of supplemental cementitious materials in decreasing shrinkage and permeability of concrete. Concrete with low shrinkage potential and low permeability is critical to provide long-term durability for bridge decks.

Approach

The approach used to determine the influence of SCMs on shrinkage and permeability was to measure these characteristics on mixtures that contain SCMs and mixtures that did not contain SCMs and compare the results. Additional mixtures representing model specification for low cracking, high performance concrete bridge decks and current MDOT specifications were also included in the study to evaluate shrinkage and permeability characteristics associated with these common practices. Test methods used to measure shrinkage and permeability include

AASHTO T 160 / ASTM C 157 "Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete" and AASHTO T 277 / ASTM C 1202 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration." These tests were conducted on each of the thirty mixtures.

Shrinkage of each mixture was determined according to AASHTO T 160 / ASTM C 157. This test method 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 prisms compared to a standard reference steel bar. Length change measurements extended over a 476 day period including both expansion and shrinkage calculations for each specimen. Expansion occurred while specimens remained in a water bath for the first 28 days. The specimens were placed in a temperature and humidity controlled room after the first 28 days where shrinkage began. Specimens remained in this room until testing was completed. Length change resulting from chemical shrinkage, autogenous shrinkage, and/or drying shrinkage was calculated for each mixture. Chapter 4 "Laboratory Testing" provides a detailed description of test procedures and length change calculations.

AASHTO T 277 / ASTM C 1202 was used to indicate the permeability of each concrete mixture. These tests were conducted over a six hour period with a constant 60 ± 0.1 volt DC current placed across the specimens. Automatic data processing equipment was used to determine the area under a current (in amperes) verses time (in seconds) graph representing the total charge passed during the test period. This total charge is a measure of the electrical conductance of the concrete during the test period and is expressed in coulombs. Coulombs are correlated to the resistance of the specimen to chloride ion penetration, also known as penetrability. Chapter 4 "Laboratory Testing" provides a detailed description of test procedures for permeability.

A total of thirty mixtures were tested to provide data for this study. These thirty mixtures can be divided into five mixture categories including KU, MDOT Class AA, research, blended aggregates, and MDOT Class BD. Table 2 provides a general description of each mixture category. Two of these categories were selected to serve as benchmarks (i.e., controls) to compare the performance of the other mixtures to typical performance. These control mixture categories are KU and MDOT Class AA. Each mixture in each category was repeated with a second aggregate source. Repeating these mixtures with a second aggregate source provided additional shrinkage and permeability data and provided data to evaluate the influence of aggregate properties on shrinkage and permeability.

Table 2: Experimental Mixtures

Mixture Category	Mix Numbers	Aggregate Type	Aggregate Source	Cement Type	Supplemental Cementitious Materials			
					No SCM	25% Class C Fly Ash	25% Class F Fly Ash	50% GGBFS
KU	1	Limestone	1	I	X	---	---	---
	16	Limestone	2	I	X	---	---	---
MDOT Class AA	2.1,3	Gravel	1	I	X	X	---	---
	17,18	Gravel	2	I	X	X	---	---
Research	4,5,6,7	Gravel	1	I	X	X	X	X
	8,9,10,11	Gravel	1	GU	X	X	X	X
	19,20.1,21,22	Gravel	2	I	X	X	X	X
	23.1,24,25,26	Gravel	2	GU	X	X	X	X
Blended Aggregates	12,13	Gravel	1	I	---	X	X	---
	27.1,28	Gravel	2	I	---	X	X	---
MDOT Class BD	14,15.1	Gravel	1	I	X	---	---	X
	29,30	Gravel & Limestone	2	I	X	---	---	X

The KU category incorporated strategies to reduce shrinkage and permeability that are similar to those in KDOT's special provision. This model used recommendations from research performed at the University of Kansas. Mixtures associated with this model are referred to herein as KU mixes. Mixtures proportioned for this category have 100% Type I portland cement and aggregate gradation optimization. This optimization includes concepts of coarseness factor (CF), workability factor (WF), and adjusted workability factor (AWF) to utilize a wellgraded aggregate blend which imparts workability to the mixture while maintaining a low paste content and low cracking potential. The adjusted workability factor accounts for any excess or deficiency of fines contributed by the cementitious materials in the mixture. MDOT's "Concrete Field Manual contains Equation 1 for CF, Equation 2 for WF, and Equation 3 for AWF (9). The KU model also places limits of combined percent retained on individual sieve sizes and these limits are given in Table 1. Computer software developed at the University of Kansas was used in proportioning the KU mixes.

$$CF = \frac{Cumulative\ \%\ retained\ on\ 3/8\,in.\ sieve}{Cumulative\ \%\ retained\ on\ No.8\ sieve} * 100 \quad (1)$$

$$WF = \frac{Cumulative\ \%\ passing\ No.8\ sieve}{Cumulative\ \%\ retained\ on\ all\ sieves} * 100 \quad (2)$$

$$AWF = WF + \frac{2.5}{sack} * \left[\frac{Total\ weight\ of\ cementitious\ materials}{94 \frac{lb}{sack}} - 6\ sack \right] \quad (3)$$

For development of mixtures in the MDOT Class AA category, MDOT engineers reviewed records of mixtures submitted to the Department for use on bridge decks. These previously submitted mixtures were summarized and evaluated for common industry practices for mixtures proportioned for bridge decks in Mississippi. Mixtures developed from these submitted mixtures are referred herein to as MDOT Class AA. The MDOT Class AA category incorporated mixtures with 100% Type I portland cement and mixtures using 75% Type I portland cement with 25% Class C fly ash. Aggregate grading optimization was not utilized in mixtures developed for the MDOT Class AA category.

To determine the impact of cementitious materials on shrinkage and permeability, a category of research mixtures was developed. This category contains four variations in cementitious materials including 100% Type I portland cement, 75% Type I portland cement with 25% Class C fly ash, 75% Type I portland cement with 25% Class F fly ash, and 50% Type I portland cement with 50% GGBFS. These four variations of cementitious materials were repeated using Type GU cement to replace the Type I portland cement. These eight mixtures were then repeated using a second gravel aggregate source. A total of sixteen mixtures are included in the research category. Aggregate gradation optimization was not used in developing any mixtures in the research category. A No. 57 gravel was used for the coarse aggregate and concrete sand was used for the fine aggregate and the gradation of each reflected the gradation as sampled from the supplier.

The blended aggregates category was developed to determine if increased workability can be achieved by blending aggregates that are typically stockpiled at concrete plants in Mississippi. These aggregates included No. 57 gravel, No. 8 gravel, and concrete sand. Cementitious materials used included 75% Type I portland cement with 25% Class C fly ash and 75% Type I portland cement with 25% Class F fly ash. These blended aggregate mixtures were similar to mixtures in the research mixture category that had 75% Type I portland cement with 25% Class C fly ash and 75% Type I portland cement with 25% Class F fly ash. Water and cementitious content were adjusted for blended mixtures based on slump test results from non-blended mixtures to take advantage of increased workability associated with blended aggregates. A 0.48 water cementitious ratio was held in the blended aggregates mixtures and the research mixtures. The KU software was used to assist with aggregate gradation optimization. In addition, these blended aggregates mixtures were proportioned to meet limits established by MDOT for CF and AWF. See equations 4 through 7 for MDOT limits for CF and AWF.

$$AWF_{upper\ limit} = 36 + \sqrt{16 - \left(\frac{4}{13}\right)^2 \ X\ (CF - 61)^2} \tag{4}$$

$$AWF_{lower\ limit} = 36 - \sqrt{16 - \left(\frac{4}{13}\right)^2 \ X\ (CF - 61)^2} \tag{5}$$

$$CF_{upper\ limit} = 61 + \sqrt{169 - \left(\frac{13}{4}\right)^2 \ X\ (AWF - 36)^2} \tag{6}$$

$$CF_{lower\ limit} = 61 - \sqrt{169 - \left(\frac{13}{4}\right)^2 \ X\ (AWF - 36)^2} \tag{7}$$

The MDOT Class BD category was developed to determine shrinkage and permeability performance of MDOT's Class BD concrete. Cementitious materials used included 100% Type I portland cement and 50% Type I portland cement with 50% GGBFS. All of the MDOT Class BD category mixtures used aggregate gradation optimization. This optimization produced combined aggregate gradations within the limits established by MDOT for CF and AWF. These mixtures did not meet MDOT's limits for combined percent retained on individual sieve sizes listed in Table 1. The gravel aggregate sources selected for this study could not be combined to meet the lower limits required by the MDOT Class BD specifications for the No. 8 and No. 16 sieves.

Chapter 2 - Materials

Hydraulic Cement

Both an ordinary portland cement (OPC) and blended cement were used in this study. These are hydraulic cements and provide the primary cementing material in the mixtures. Type I portland cement meeting requirements of ASTM C 150 / AASHTO M 85 and a Type GU cement meeting requirements of ASTM C 1157 were used. 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 to create more cementing compounds.

Type I

Type I portland cement meeting requirements of ASTM C 150 / AASHTO M 85 is hydraulic cement made to conform to specific chemical and physical property limits according to these specifications. These specifications provide for ten types of portland cement. Type I LA (low alkali) was used in this study and is referred to herein as Type I. Only one source of Type I cement was used in this study. Chemical and physical properties of the Type I portland cement used in this study were provided by the supplier and are presented in Table 3.

Type GU

Type GU cement meeting requirements of ASTM C 1157 was also used in this study. It is also hydraulic cement and usually performs similarly to Type I portland cement. This cement may contain other blended or interground materials including pozzolans, slag, limestone, or other related materials. It is produced to conform to performance limits essentially without specific chemical requirements. There are six types of cements established in ASTM C 1157 and the type used is selected according to application. Type GU used in this study is ordinary portland cement except that the interground limestone content was approximately 10%. This amount of interground limestone exceeds the limestone content allowed by ASTM C 150 / AASHTO M 85 which is a maximum of 5%. While MDOT does not currently recognize ASTM 1157, it is important to note that there is now a proposed change to ASTM C 595 / AASHTO M 240 for a category of "blended" cement that would contain higher amounts (up to 15%) of interground limestone such that this Type GU cement would meet that proposed new specification. Only one source of Type GU cement was used in this study and this source is a different source than the source of the Type I portland cement. Physical properties of the Type GU cement used in this study were provided by the supplier and are presented in Table 4.

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 some plastic or hardened property of the concrete. SCMs included in this research are Class C fly ash, Class F fly ash, and GGBFS, commonly referred to as 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. However, some fly ash is enhanced by separation of particle sizes and chemical treatment of carbon residue in the ash. 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%, but MDOT projects require a CaO content of Class C fly ash greater than or equal to 6%. MDOT projects require a CaO content of less than 6% 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% of the portland cement for all classes of concrete except for Class BD. At the time of this research, MDOT Class BD concrete specifications did not allow either Class C or Class F fly ash. 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 Table 5 and 6, respectively.

Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) 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. GGBFS 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 GGBFS cement. MDOT concrete specifications allow up to 50% replacement of portland cement with GGBFS cement for all classes of concrete. Chemical and physical properties of the GGBFS used in this study were provided by the supplier and are presented in Table 7.

Table 3: Type I Portland Cement - Chemical and Physical Properties

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	19.6
Aluminum Oxide (Al_2O_3), %	5.6
Ferric Oxide (Fe_2O_3), %	3.6
Calcium Oxide (CaO), %	64.2
Magnesium Oxide (MgO), %	0.9
Sulfur Trioxide (SO_3), %	3.6
Loss of Ignition (LOI), %	2.3
Insoluble Residue, %	0.24
Free Lime, %	1.10
Alkalies (Na_2O equivalent), %	0.54
Carbon Dioxide (CO2), %	0.9
Limestone, %	2.1
CaCO3 in limestone, %	93
Tricalcium Silicate (C_3S), %	55
Dicalcium Silicate (C_2S), %	15
Tricalcium Aluminate (C_3A), %	9
Tetracalcium Aluminoferrite (C_4AF), %	11
Physical Properties	**Results**
Blaine Fineness, m^2/kg	378
325 Mesh (% passing)	92.9
Time of setting (Vicat) Initial Set, minutes	90
Time of setting (Vicat) Final Set, minutes	190
Time of Setting (Gillmore) Initial Set, minutes	140
Time of Setting (Gillmore) Final Set, minutes	240
Air Content, %	6.6
False Set, %	83
Normal Consistency, %	25.1
Autoclave Expansion, %	0.04
Expansion in Water, %	0.007
Compressive Strength, 1 day (psi)	2550
Compressive Strength, 3 day (psi)	4100
Compressive Strength, 7 day (psi)	4950

Table 4: Type GU Cement - Physical Properties

Physical Properties	Results
Air Content, %	6
Blaine Fineness (m^2/kg)	525
Autoclave Expansion, %	0.03
Compressive Strength, 3 day (psi)	4980
Compressive Strength, 7 day (psi)	5810
Compressive Strength, 28 day (psi)	7180
Initial Vicat (minutes)	105
Mortar Bar Expansion, %	0.015

Table 5: Class C Fly Ash - Chemical and Physical Properties

Chemical Properties	Results
Silicon Dioxide (SiO_2), %	36.05
Aluminum Oxide (Al_2O_3), %	19.43
Iron Oxide (Fe_2O_3), %	6.91
Sum of Constituents, %	62.39
Sulfur Trioxide (SO_3), %	1.89
Calcium Oxide (CaO), %	24.34
Moisture Content, %	0.08
Loss on Ignition, %	0.36
Available Alkalies, as Na_2O, %	1.47
Physical Properties	**Results**
Fineness, % retained on No. 325	19.60
Strength Activity Index 7 day, % of control	86
Strength Activity Index 28 day, % of control	79
Water Requirement, % control	95
Autoclave Soundness, %	0.06
True Particle Density	2.64

Table 6: Class F Fly Ash - Chemical and Physical Properties

Chemical Properties	Results
Total Silica, Aluminum, Iron, %	89.7
Silicon Dioxide (SiO_2), %	56.3
Aluminum Oxide (Al_2O_3), %	27.7
Iron Oxide (Fe_2O_3), %	5.7
Sulfur Trioxide (SO_3), %	0.0
Calcium Oxide (CaO), %	1.0
Moisture Content, %	0.2
Loss on Ignition, %	3.2
Available Alkalies, as Na_2O, %	0.6
Sodium Oxide, %	0.10
Potassium Oxide, %	0.70
Physical Properties	**Results**
Fineness, % retained on No. 325	20.0
Strength Activity Index 7 day, % of control	76.3
Strength Activity Index 28 day, % of control	77.6
Water Requirement, % control	95.0
Autoclave Soundness	-0.04
Drying Shrinkage, Increase at 28 day, %	0.00
Density Mg/m^3	2.24

Table 7: GGBFS - Chemical and Physical Properties

Chemical Properties	Results
Sulfide S, %	0.8
Sulfate Ion (SO_3), %	1.79
Physical Properties	**Results**
+45 µm (No. 325) Sieve, %	0.54
Blaine Fineness (m^2/kg)	591
Air Content, %	4.45
Slag Activity 7 Day Index, %	90
Slag Activity 28 Day Index, %	130
Compressive Strength Slag-Ref, 7 day (psi)	3920
Compressive Strength Slag-Ref, 28 day (psi)	6820

Aggregates

Two sources for aggregate were selected and used in this research for all categories of mixtures. Two sources of crushed limestone were used in developing mixtures for the KU category and two sources of gravel were used to develop mixtures in all other categories. Two aggregate sources were included in order to determine if a change in aggregate mineralogy would produce significantly different length change and permeability results. Aggregate sources used in the study were from MDOT approved sources. Coarse and fine aggregates from source number one were used in mixes 1 through 15.1. Coarse and fine aggregates from source number two were used in mixes 16 through 30. See Table 2 for a general description of mixtures and aggregate sources used in this study.

Crushed Limestone

Four sizes of coarse crushed limestone aggregate were used in mixes 1 and 16 to meet strict combined individual percent retained limits of the KU mix design method. Crushed limestone coarse aggregate sizes in these mixtures include No. 4, No. 57, No. 89, and No. 11. Two sources of crushed limestone were used for all sizes except for the No. 4. No. 11 crushed limestone was also used in mixes 29 and 30 in an effort to meet combined individual percent retained limits of MDOT's Class BD concrete. Crushed limestone aggregate properties are presented in Tables 8 and 9.

Gravel

Gravel aggregates were used in mixes 2.1 through 15.1 and 17 through 30 except for the addition on No. 11 crushed limestone that was used in mixes 29 and 30. No. 57 gravel and concrete sand was used in mixes 2.1 through 11 and 17 through 26. Three aggregates including

No. 57, No. 8 and concrete sand were used in mixes 12 through 15.1 and 27.1 through 28. No. 57, No. 11, and concrete sand are used in mixes 29 and 30. Properties for gravel aggregates used in this study are presented in Tables 10 and 11.

Table 8: Crushed Limestone - Source Number 1

	No.4		No. 57		No. 89		No. 11	
Sieve Size	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing
1”	63.4	37	1.1	99	0.0	100	0.0	100
¾”	29.6	7	16.4	82	0.0	100	0.0	100
½”	5.7	1	43.5	39	0.1	100	0.0	100
3/8”	0.1	1	19.1	20	10.9	89	0.0	100
No. 4	0.1	1	14.0	6	62.9	26	7.8	92
No. 8	0.0	1	3.4	2	13.0	13	26.7	65
No. 16	0.0	1	0.7	2	5.7	7	20.5	45
No. 30	0.0	1	0.4	1	2.3	5	13.7	31
No. 50	0.0	1	0.3	1	1.1	4	8.4	23
No. 100	0.0	1	0.3	1	0.8	3	5.6	17
No. 200	0.6	0.4	0.3	0.4	1.8	1.5	3.2	14.1
FM	7.86		6.84		5.52		3.26	
Bulk Gravity (SSD)	2.651		2.690		2.673		2.604	
Absorption (%)	1.33		0.97		1.37		2.43	

Table 9: Crushed Limestone - Source Number 2

	No.4		No. 57		No. 89		No. 11	
Sieve Size	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing
1”	63.4	37	0.9	99	0.0	100	0.0	100
¾”	29.6	7	18.4	81	0.0	100	0.0	100
½”	5.7	1	38.2	43	0.0	100	0.0	100
3/8”	0.1	1	22.3	20	0.8	99	0.0	100
No. 4	0.1	1	18.5	2	59.5	40	0.2	100
No. 8	0.0	1	0.8	1	29.7	10	14.2	86
No. 16	0.0	1	0.0	1	5.9	4	30.5	55
No. 30	0.0	1	0.0	1	1.7	3	22.5	33
No. 50	0.0	1	0.1	1	0.5	2	14.8	18
No. 100	0.0	1	0.1	1	0.3	2	9.7	8
No. 200	0.6	0.4	0.1	0.6	0.2	1.6	3.5	4.7
FM	7.86		6.93		5.41		3.00	
Bulk Gravity (SSD)	2.651		2.739		2.746		2.727	
Absorption (%)	1.33		0.63		0.39		0.62	

Table 10: Gravel Aggregate - Source Number 1

	No.57		No. 8		Sand	
Sieve Size	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing
1”	13.5	86	0.0	100	0.0	100
¾”	21.1	65	0.0	100	0.0	100
½”	32.6	33	0.0	100	0.0	100
3/8”	14.7	18	10.7	89	0.0	100
No. 4	16.4	2	81.4	8	2.1	98
No. 8	1.2	0	7.3	1	15.0	83
No. 16	0.1	0	0.4	0	13.3	70
No. 30	0.1	0	0.1	0	23.9	46
No. 50	0.0	0	0.0	0	38.1	7
No. 100	0.0	0	0.0	0	7.1	0
No. 200	0.0	0.1	0.0	0	0.1	0.3
FM	7.14		6.02		2.96	
Bulk Gravity (SSD)	2.529		2.522		2.632	
Absorption %	2.29		2.88		0.31	

Table 11: Gravel Aggregate - Source Number 2

	No.57		No. 8		Sand	
Sieve Size	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing	Individual % Retained	Total % Passing
1”	3.5	96	0.0	100	0.0	100
¾”	8.6	88	0.0	100	0.0	100
½”	27.7	60	0.0	100	0.0	100
3/8”	25.3	35	2.5	98	0.0	100
No. 4	32.6	2	94.6	3	5.7	94
No. 8	1.2	1	2.6	0	8.7	86
No. 16	0.3	1	0.1	0	8.4	77
No. 30	0.2	1	0.0	0	16.6	61
No. 50	0.1	0	0.0	0	48.1	12
No. 100	0.1	0	0.0	0	10.7	2
No. 200	0.0	0	0.0	0	1.0	0.8
FM	6.72		5.99		2.68	
Bulk Gravity (SSD)	2.523		2.523		2.644	
Absorption %	2.22		2.57		0.38	

Admixtures

Water Reducer

All mixtures in this study included a single Type A water reducing admixture meeting requirements of AASHTO M 194 / ASTM C 494 “Standard Specifications for Chemical Admixtures for Concrete.” Water reducers can be used to provide a higher slump without increasing the water cementitious ratio or lower water cement ratio without reducing slump. In addition, higher strengths can be achieved due to increased dispersion of the cementitious particles leading to increased hydration. Dosage rates in this study are given in ounces per 100 pounds of cementitious materials in the mixture. The dosage rate for the KU mixes was 5 ounces. Dosage rate ranged from 2 to 4.5 ounces for MDOT Class AA mixes 2.1, 3, 17, and 18. A common dosage rate of 4 ounces was used for all other mixtures. Actual dosage rates for each mix are provided in Appendix A. MDOT requires either a type A, D, F, G, or mid-range chemical admixture to be used in all classes of concrete except for drill shaft concrete. Water reducing admixtures can influence length change of concrete (1).

Air Entraining

Entrained air is chemically induced in concrete to reduce surface delamination caused by freeze thaw cycles on moist concrete. Moisture expands when it freezes and this expansion can cause cracking and scaling of the concrete surface. Entrained air provides microscopic air voids in the cementitious paste that provide relief from stresses caused by expansion of water. A common air entraining admixture was used in all mixtures except for the KU mixes. This admixture meets requirements of ASTM C 260 / AASHTO M 154 "Standard Specifications for Air-Entraining Admixture." The air entraining admixture used in KU mixes had to be vinsol resin or tall oil based to comply with KDOT's specifications. A separate air entraining admixture was used for the KU mixtures to meet this requirement. The dosage rate was selected to provide the proper amount of air required for each mixture. The dosage rate is given in ounces per 100 pounds of cementitious materials in the mixture. Dosage rates ranged from 0.4 ounces to 1.5 ounces. Actual dosage rates for each mixture are provided in Appendix A.

Chapter 3 - Mixes

The influence of Mississippi gravel aggregates and SCMs on shrinkage and durability is described herein based on laboratory test results and experience gained during production of thirty concrete mixtures. The thirty mixes were derived from fifteen unique mixtures repeated using a different aggregate source. Mixture design parameters used in developing mixtures for this study are presented in Table 13. Mixtures were divided into five categories covering (1) KU mixes - mixes incorporating key elements of the KDOT's model, (2) MDOT Class AA - mixes representing typical MDOT bridge deck concrete, (3) Research mixes - mixes with various combinations of SCMs and cement type, (4) Blended Aggregates - mixes optimized by aggregate blending, and (5) MDOT Class BD mixes.

KU Mix

Key elements of the University of Kansas Mix Method (KU Mix) were employed for mixes 1 and 16. It is important to note that this study did not incorporate every detail associated with KU's requirements for concrete and aggregates. For example, KU requires that coarse aggregates have a maximum absorption of 0.7%. Neither source of limestone used in the study meets this requirement for absorption. In addition, testing protocols used in this study were not the same protocols as those used by KU; therefore, this study may generate results that differ from those generated by the University of Kansas.

KU's computer software was used to develop these mixtures. This is a Microsoft Excel Workbook, utilizing visual basic for applications, that performs the aggregate gradation optimization process. Available from www.iri.ku.edu, this application determines an optimized aggregate gradation based on combined coarse and fine aggregate individual percent retained and a coarseness factor chart. Figure 4 shows the combined individual percent retained for aggregates used in KU mixes. A KU mix consists of user-selected aggregates combined in proportions suggested by the KU application to produce an "*ideal gradation*." This study employed No.4, No. 57, No. 89, and No. 11 maximum nominal size crushed limestone and combined these with a local sand source in the increments suggested by the KU application. Source number one sand and limestone was used in mix 1. Source number two sand and limestone was used in mix 16. 540 pounds per cubic yard of Type I portland cement was used in the KU mixes with a 0.45 water-cement ratio (w/c).

Figure 2: Sampling Gravel Aggregate Source No. 1

Figure 3: KU Mix Laboratory Samples

MDOT Class AA

Typical MDOT Class AA concrete mixes are represented by four mixtures including mixes 2.1, 3, 17, and 18. See Table 12 for key properties for MDOT Class AA mixes. No. 57 gravel aggregate representing 70% of the bulk volume per unit volume of concrete was used in each mixture. 100% Type I portland cement was used in mixes 2.1 and 17 while mixes 3 and 18 utilized 75% Type I portland cement with 25% Class C fly ash. Each MDOT Class AA mixture contained 588 pounds of cementitious material proportioned with a water-cementitious ratio (w/cm) of 0.40. Source number one sand and gravel was used in mixes 2.1 and 3. Source number two sand and gravel was used in mixes 17 and 18. No. 57 gravel and concrete sand was combined and aggregate gradation optimization was not incorporated into these mixtures. Figures 5 and 6 illustrate the combined fine and coarse aggregate individual percent retained used in the MDOT Class AA mixes.

Research Mixes

Combinations of SCMs along with Type I and Type GU cements were used in sixteen of the mixtures, including mixes 4 through 11 and 19 through 26. These mixtures had similar design parameters and were the primary focus for this study. Each of the two aggregate sources were proportioned with Type I portland cement, 25% C fly ash, 25% F fly ash, and 50% GGBFS. These mixtures were then repeated with Type GU cement replacing the Type I portland cement. A w/cm ratio of 0.48 was held for all research mixtures and cementitious content and water content was adjusted to produce the same cement paste volume of 24.47% for each mixture. Total cementitious material content ranged from 495 to 517 pounds per cubic yard. No. 57 gravel and concrete sand was combined and no aggregate optimization was incorporated. Figure 7 illustrates the combined individual percent retained for aggregates used in research mixes.

Blended Aggregates

Mixes 12, 13, 27.1, and 28 used a blend of No. 57 and No. 8 gravel aggregates for the coarse aggregate portion. Blended aggregate mixtures were optimized by the KU mix design software and were within limits of MDOT’s CF and AWF. These mixtures used either 75% Type I portland cement with 25% Class C fly ash or 75% portland cement with 25% Class F fly ash. Mixes 12, 13, 27.1, and 28 are similar to their companion mixes, 5, 6, 20.1, and 21, respectively. The difference being that water was reduced in the blended aggregate mixtures due to a slight increase in slump that resulted from the blended aggregate gradation. In order to maintain a slump comparable to their companion mixes and a 0.48 w/cm ratio, cementitious content was reduced. Cementitious content ranged from 470 to 490 pounds per cubic yard which is lower than all other mixtures. Source number one aggregates were used for mixes 12 and 13 and source number two aggregates were used for mixes 27.1 and 28. Figures 8 and 9 illustrate combined individual percent retained for aggregates used in the blended aggregate mixtures.

MDOT Class BD

The final part of the research was used to generate shrinkage and permeability data on MDOT's Class BD concrete. Mixes 14, 15.1, 29, and 30 were proportioned according to MDOT Class BD concrete and key properties can be found in Table 12. 100% Type I portland cement was used for mixes 14 and 29. 50% Type I portland cement with 50% GGBFS was used in mixes 15.1 and 30. Cementitious content in pounds per cubic yard varied from 525 in mix 14, 509 in mix 15.1, to 564 in mixes 29 and 30. These cementitious contents represent the highest and most likely the lowest cementitious contents that will be used in typical field applications. No. 57 and No. 8 gravel and concrete sand from gravel source number one was used in mixes 14 and 15.1. No. 57 gravel and concrete sand from gravel aggregate source two and No. 11 crushed limestone from crushed limestone source two was used in mixes 29 and 30. All of MDOT's Class BD concrete criteria were met in these mixtures except for the combined percent retained on individual sieves No. 8 and No. 16. Figures 10 and 11 illustrate the combined individual percent retained for aggregates used in MDOT Class BD mixtures. When compared to MDOT's requirements, the graphs indicate a deficiency in material retained on the No. 8 and No. 16 sieve. MDOT Class BD's limits for combined individual percent retained could not be met with the gravel aggregate sources used in this study. A 0.45 w/cm ratio was held for these mixtures.

Table 12: Key Mix Properties - KU, MDOT Class BD, and MDOT Class AA

Properties	KU		MDOT BD		MDOT Class AA	
	Min	Max	Min	Max	Min	Max
Lbs of Cement or Cementitious per Cubic Yard	500	540		564	NA	
w/c or w/cm	0.44	0.45	0.43	0.45	0.45	0.45
Designated Air Content Percent by Volume	7.0	9.0	6.0	8.0	3.0	6.0
Specified 28 Day Compressive Strength (psi)	3,500	5,500	4,000		4,000	
Max. CA Size No.	NA		57		67 or 57	
Set Retarding Admixes	Not Permitted		As Required		As Required	
Accelerating Admixes	Not Permitted		As Required		As Required	
Air-Entraining Admixes	Only vinsol resin or tall oil based		As Required		As Required	
Water-reducing Admixes	Type A or dual Rated Type A-F		Type A		As Required	
Designated Slump (in.)	1.5	3.0	As Required	4.0	As Required	Up to 8 with approved water reducer

Table 13: Mixture Parameters

Mix Numbers		Description	w/cm	Cementitious: Total (lbs)	Type I (%)	Type GU (%)	Class C Fly Ash (%)	Class F Fly Ash (%)	GGBFS (%)	Aggregates: 57 Coarse Aggregate (Bulk Volume Per Unit Vol. of Concrete)	Second Coarse Aggregate (Percent Agg. Volume)	Fine Aggregate (Percent Agg. Volume)	Admixtures: Type A - Water Reducer (oz. per 100 lbs of cementitious)	Entrained Air	Slump (in.)
1	16	Type I -KU Mix	0.45	540	100	0	0	0	0	As Req'd By KU			5	7 to 9 %	1.5 to 3
2.1	17	Type I – MDOT Class AA	0.40	588	100	0	0	0	0	70	0	As Req'd	4 – 4.5	5.5 to 6.5 %	2.25 to 3.75
3	18	Type I – 25% C Ash – MDOT Class AA	0.40	588	75	0	25	0	0	70	0	As Req'd	2 – 3.6	5.5 to 6.5 %	2.25 to 3.75
4	19	Type I	0.48	Paste Volume To Be Same Approximately 25% Total Cementitious Range From 495 to 517	100	0	0	0	0	70	0	As Req'd	4	5.5 to 6.5 %	As Reported
5	20.1	Type I – 25% C Ash	0.48		75	0	25	0	0	70	0	As Req'd	4	5.5 to 6.5 %	
6	21	Type I – 25% F Ash	0.48		75	0	0	25	0	70	0	As Req'd	4	5.5 to 6.5 %	
7	22	Type I – 50% GGBFS	0.48		50	0	0	0	50	70	0	As Req'd	4	5.5 to 6.5 %	
8	23.1	Type GU	0.48		0	100	0	0	0	70	0	As Req'd	4	5.5 to 6.5 %	
9	24	Type GU – 25% C Ash	0.48		0	75	25	0	0	70	0	As Req'd	4	5.5 to 6.5 %	
10	25	Type GU – 25% F Ash	0.48		0	75	0	25	0	70	0	As Req'd	4	5.5 to 6.5 %	
11	26	Type GU – 50% GGBFS	0.48		0	50	0	0	50	70	0	As Req'd	4	5.5 to 6.5 %	
12	27.1	Type I – 25% C Ash - Blended Agg.	0.48	Optimized 483 to 490	75	0	25	0	0	Optimized By KU software and within limits of MDOT CF and AWF. Take water reduction for aggregate optimization.			4	5.5 to 6.5 %	6.25 – 7.25
13	28	Type I – 25% F Ash - Blended Agg.	0.48	Optimized 470 to 490	75	0	0	25	0				4	5.5 to 6.5 %	5 – 6
14	29	Type I – MDOT BD	0.45	Max. 564	100	0	0	0	0	Optimized By KU software and within limits of MDOT CF and AWF			4	6.5 – 7.5%	2.25 to 3.75
15.1	30	Type I – 50% GGBFS MDOT BD	0.45	Max. 564	50	0	0	0	50				4	6.5 – 6.5%	2.25 to 3.75

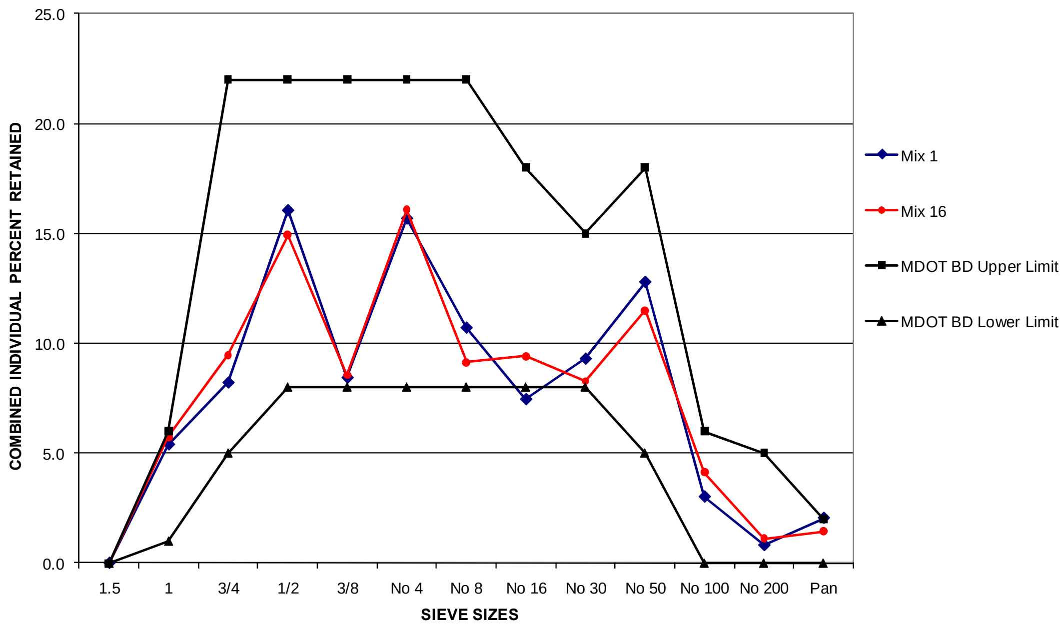

Figure 4: KU Mix - Combined Individual Percent

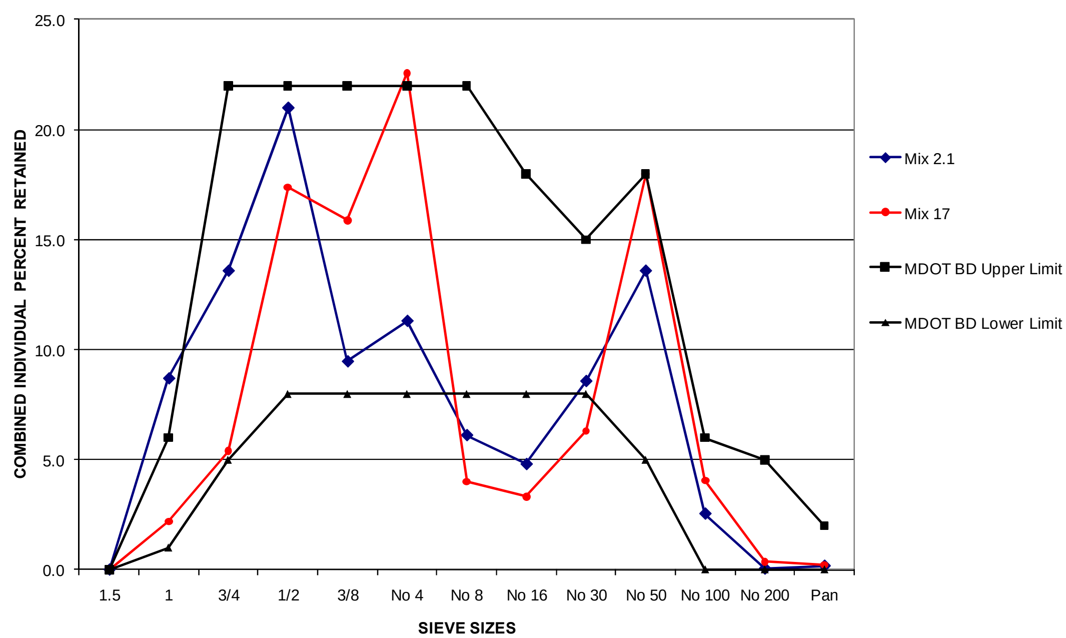

Figure 5: MDOT Class AA - Combined Individual Percent Retained

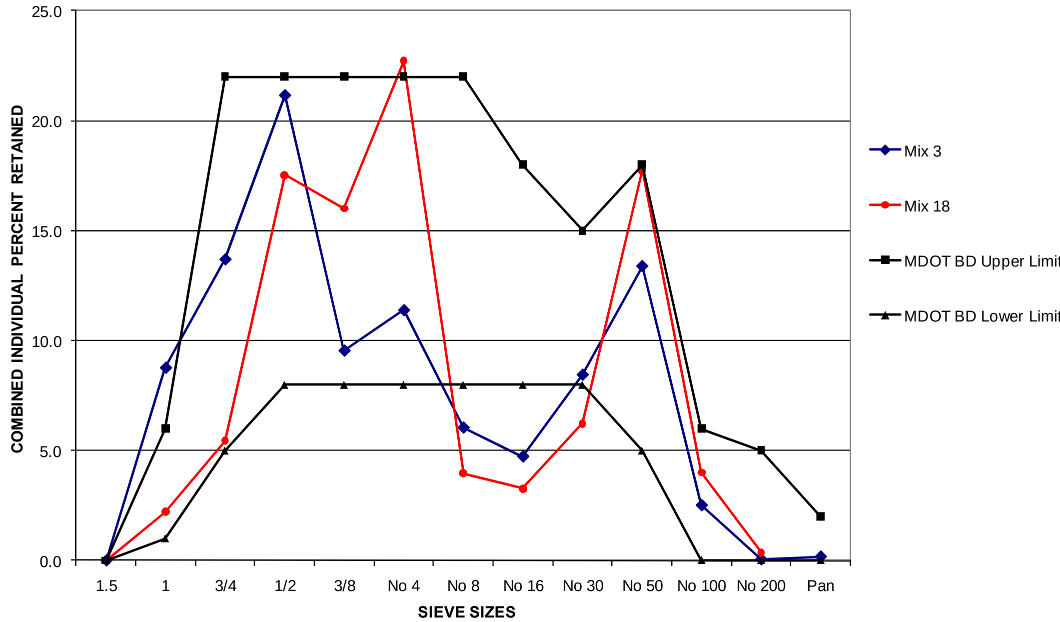

Figure 6: MDOT Class AA with 25% C Fly Ash - Combined Individual Percent Retained

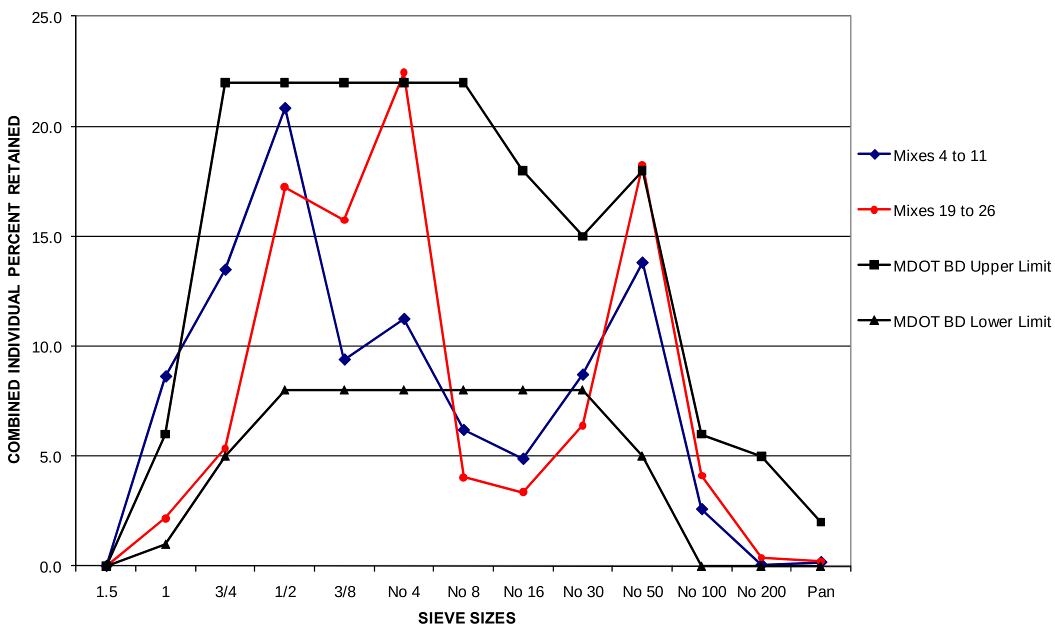

Figure 7: Research Mixes - Combined Individual Percent Retained

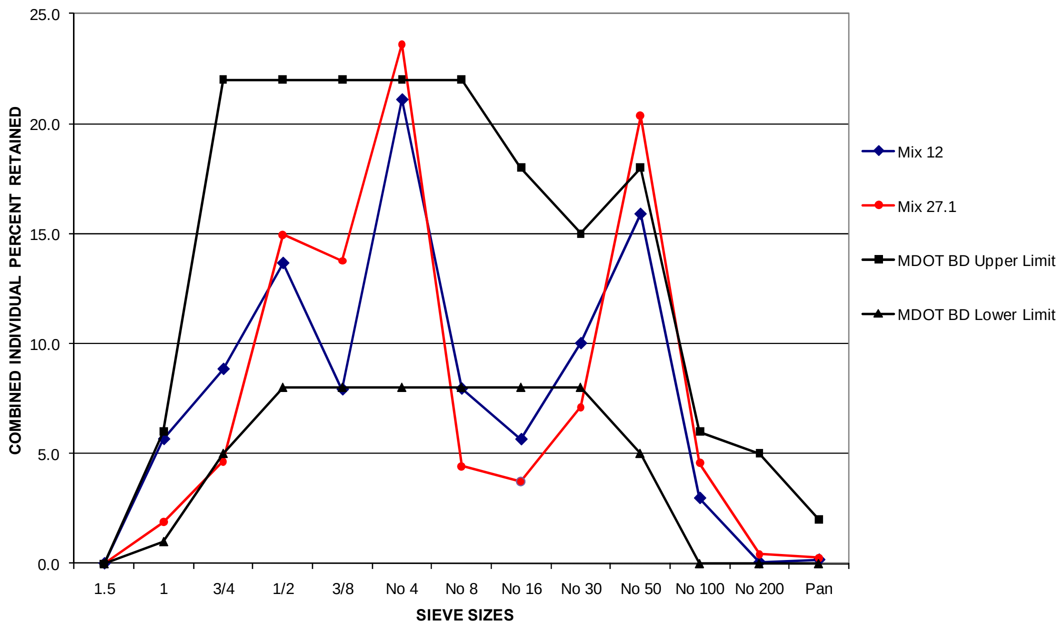

Figure 8: Blended Aggregates with 25% C Fly Ash-Combined Individual Percent Retained

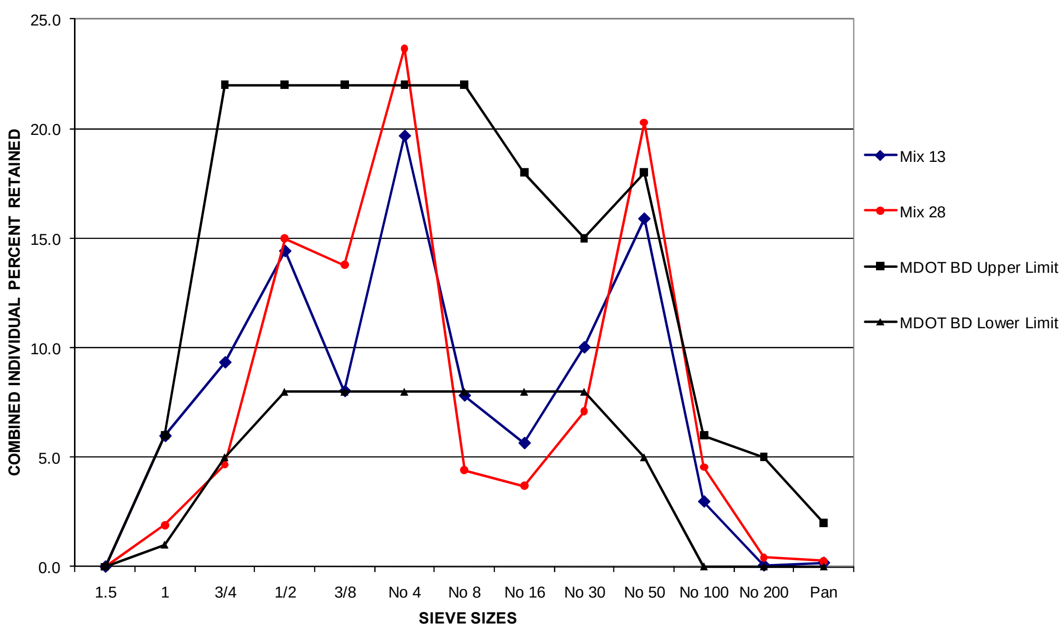

Figure 9: Blended Aggregates 25% F Fly Ash - Combined Individual Percent Retained

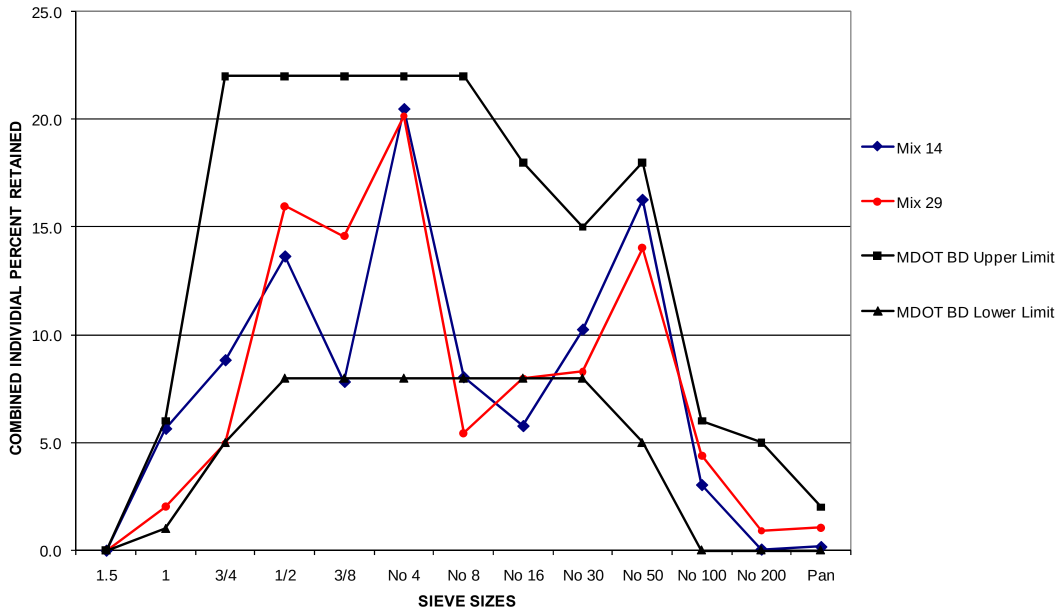

Figure 10: MDOT BD - Combined Individual Percent Retained

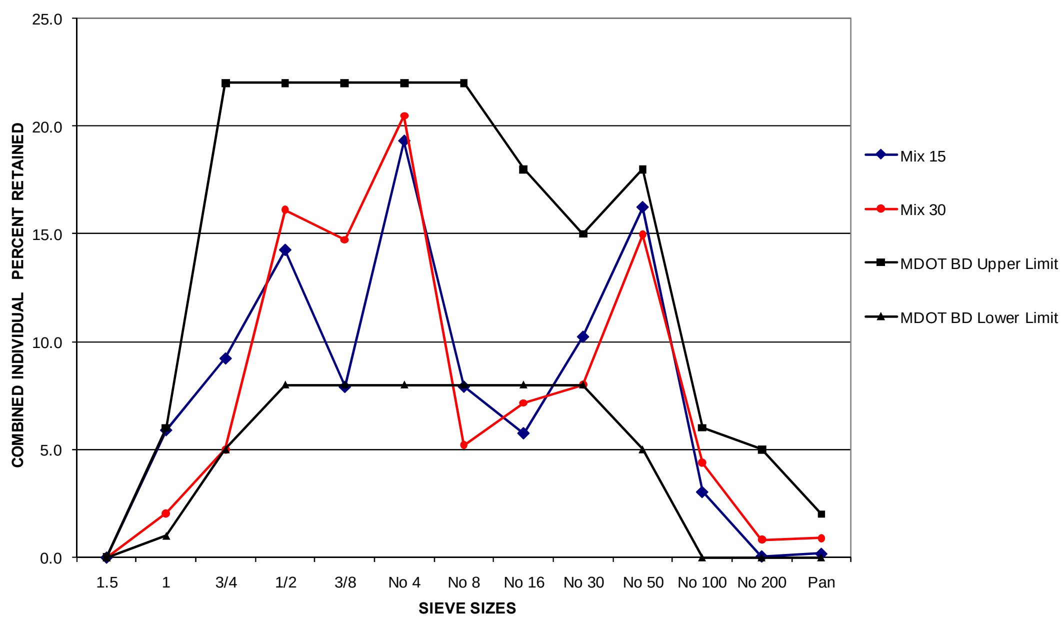

Figure 11: MDOT BD 50% GGBFS - Combined Individual Percent Retained

Chapter 4 - Laboratory Testing

Mixing

Laboratory mixing was conducted in 1.5 cubic feet batch quantities using a revolving drum mixer in accordance with AASHTO R 39 / ASTM C 192 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory." Coarse aggregates were soaked for 24 hours and allowed to drain for 24 hours prior to mixing to ensure uniform moisture content. Fine aggregates were placed on a canvas and mixed to ensure uniform moisture. Total evaporable moisture content was determined according to AASHTO T 255 / ASTM C 566 "Total Evaporable Moisture Content of Aggregates by Drying" prior to each day's mixing operations. Laboratory mixtures were adjusted based on aggregate moisture. All aggregates were batched with free moisture on the surface.

In accordance with AASHTO R 39 / ASTM C 192, the revolving-drum mixer was buttered to compensate for any loss of mortar from the test batch. The mixer was then charged with the coarse and fine aggregates along with admixtures dispersed in half of the mixing water. A minimal number of revolutions of the drum were used to mix the aggregates, water, and admixtures. Cementitious materials and the remaining mixing water were then added to a stopped mixer. A 3 minute mixing, 3 minute rest, 2 minute final mixing pattern was performed taking steps to guard against both loss of moisture during the rest period and segregation of the materials when discharging into 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 and these properties are presented in Tables 14 and 15. All testing was performed using ACI Certified Technicians according to the following applicable 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 12)
- **Slump –** AASHTO T 119 / ASTM C 143 “Standard Test Method for Slump of Hydraulic-Cement Concrete” (Figure 13)
- **Air Content –** AASHTO T 196 / ASTM C 173 “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method” (Figure 14)
- **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 15)
- **Temperature –** ASTM C 1064 “ Standard Test Method For Temperature of Freshly Mixed Hydraulic-Cement Concrete”

Table 14: Plastic Properties - Mixes 1 - 15

Mix No.	Mix Description	Slump (in.)	Air (%)	Temp (ºF)	Unit Wt (lbs/ft^3)
Mix 1	Type I - KU Mix	*3.25	7.00	74.0	144.2
Mix 2.1	Type I - MDOT Class AA	*5.75	*6.75	73.4	141.9
Mix 3	Type I - 25% C Ash - MDOT Class AA	2.25	6.50	75.6	142.5
Mix 4	Type I	5.50	6.25	74.7	142.8
Mix 5	Type I - 25% C Ash	6.75	6.25	73.8	141.4
Mix 6	Type I - 25% F Ash	5.50	6.00	73.4	140.6
Mix 7	Type I - 50% GGBFS	3.00	6.00	73.7	141.8
Mix 8	Type GU	4.00	*7.00	73.6	139.5
Mix 9	Type GU - 25% C Ash	7.25	5.75	73.0	142.7
Mix 10	Type GU - 25% F Ash	6.75	5.50	73.2	142.0
Mix 11	Type GU - 50% GGBFS	6.00	*7.00	71.8	140.8
Mix 12	TYPE I - 25% C Ash Blended Aggregates	6.50	6.00	75.3	142.0
Mix 13	Type I - 25% F Ash Blended Aggregates	5.00	5.50	75.5	142.0
Mix 14	Type I - MDOT BD	2.50	7.50	73.6	139.7
Mix 15.1	Type I - 50% GGBFS MDOT BD	*4.25	*7.50	72.5	140.1

*Denotes a value outside the parameters selected for the mixture.

Table 15: Plastic Properties - Mixes 16 - 30

Mix No.	Mix Description	Slump (in.)	Air (%)	Temp (ºF)	Unit Wt (lbs/ft^3)
Mix 16	Type I - KU Mix	2.25	8.15	74.5	145.2
Mix 17	Type I - MDOT Class AA	3.00	*6.75	75.1	141.0
Mix 18	Type I - 25% C Ash - MDOT Class AA	*4.25	6.00	74.5	139.3
Mix 19	Type I	3.25	6.50	74.8	140.8
Mix 20.1	Type I - 25% C Ash	4.75	5.25	73.3	140.8
Mix 21	Type I - 25% F Ash	3.25	6.00	73.9	141.8
Mix 22	Type I - 50% GGBFS	5.75	5.50	73.6	142.0
Mix 23.1	Type GU	4.25	6.00	73.7	142.0
Mix 24	Type GU - 25% C Ash	6.75	5.50	73.3	141.4
Mix 25	Type GU - 25% F Ash	8.00	5.50	73.9	140.7
Mix 26	Type GU - 50% GGBFS	6.75	6.00	72.3	142.1
Mix 27.1	Type I - 25% C Ash Blended Aggregates	5.00	6.25	72.8	140.4
Mix 28	Type I - 25% F Ash Blended Aggregates	2.75	6.00	72.4	141.2
Mix 29	Type I - MDOT BD	3.75	7.50	73.6	139.8
Mix 30	Type I - 50% GGBFS MDOT BD	3.50	6.50	73.5	141.3

*Denotes a value outside the parameters selected for the mixture.

Figure 12: Unit Weight Testing

Figure 13: Slump Testing

Figure 14: Air Content Testing

Figure 15: Curing Cylinders

Compressive Strength

Compressive strength specimens were cast immediately following collection of the plastic properties. Certified technicians made the 4 x 8 in. specimens and consolidation was accomplished using a vibrating table. Upon completion of consolidation and strike-off finishing of the top surfaces, strength specimens were moved to a temperature controlled moisture room for curing. 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, including expansion and shrinkage, was measured for each mixture according for 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. Three specimens were cast for each mixture and consolidated with a vibrating table. Results shown in this report are calculated as the average of the three specimens.

Length Change - Sample Preparation

Specimens were cast and compacted utilizing an external vibratory table. Specimens were immediately placed in a moist curing room for a 24 hour initial curing period. Specimens were demolded at an age of 23.5 ± 0.5 hours and were labeled with identifying information using a permanent marker. Specimens were then placed into a lime-saturated water curing bath maintained at 73 ± 1 degree Fahrenheit for 30 minutes before initial comparator reading.

Length Change - Initial Testing

Specimens were removed from the lime-saturated curing bath and towel dried, leaving only a small amount of free water. They 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 16). Specimens were removed from the comparator and returned to the lime-saturated curing bath until they reached an age of 28 days from the time they were cast. At the end of the 28 day curing period the specimens received a second comparator reading (Figure 17). This second comparator reading was used to calculate expansion or shrinkage as percent length change based on the initial comparator reading and a nominal gage length of 10 in.

Length Change - 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. Specimens were stacked on shelves with a clearance of at least 1 inch on all sides. Comparator readings were taken at 1, 28, 32, 35, 42, 56, 84, 140, 252, and 476 days after casting. Tables and figures in this report will indicate length change based on days in the temperature and humidity controlled room. These ages will be 4, 7, 14, 28, 56, 112, 224, and 448 days from the time the specimens were placed in the temperature and humidity controlled room, which is 28 days after casting.

Length Change - Calculations

Length change data was 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%. The equation for calculating length change of specimens at any age as a percent of the initial comparator reading is as follows:

$$L = \frac{L_x - L_i}{G} * 100 \tag{8}$$

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

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.

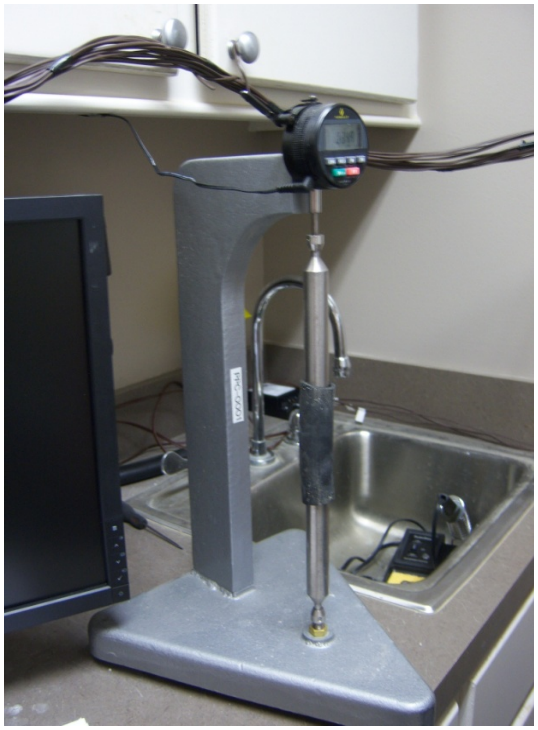

Figure 16: Comparator Reading of Standard Bar

Figure 17: Comparator Reading of Concrete Specimen

Resistance to Chloride Ion Penetrability

Resistance to chloride ion penetrability was determined according to AASHTO T 277 / ASTM 1202 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration." Specimens were cast utilizing 4 x 8 inch cylinder molds. Two specimens were cast for each mixture and the average coulomb reading of the two specimens was reported.

Penetrability - Sample Preparation

Specimens were cast and compacted utilizing an external vibratory table according to AASHTO 39 / ASTM C 192. Specimens were immediately placed into a moist curing room for a 24 hour initial curing period. After initial curing, specimens were labeled with identifying information using a permanent marker. Specimens were placed back into the moisture room and moist cured until the time of testing.

Penetrability - Specimen Preparation

Specimens were removed from the moisture curing room and the top 1/8 in. was removed utilizing a masonry wet saw. A second cut approximately 2 in. from the first cut produced a 2.0 ± 1/8 in. sample for testing. The unused portion of the sample was immediately returned to the moisture room for future penetrability testing. The 2 in. thick samples were placed in a sink and cleaned with tap water to remove excessive saw cutting residue. Once cleaned, the samples were towel dried and placed in front of a fan to remove excess surface moisture. Once dry, the sample was taped on the cut side and trimmed in preparation for a non-permeable paint to be applied on the perimeter of the specimens. Once the paint dried, the tape was removed to expose the unpainted sections. The specimens were then placed into containers and water was added to cover the specimens. Specimens were then placed back into the moisture room to keep the temperature constant for 18 ± 2 hours. Upon completion of the soak time the specimens were removed from the water and towel dried. Specimens were placed in the vacuum desiccators in a vacuum greater than 50 mm Hg. Once vacuum was achieved, they were left under vacuum for 3 hours and then water was introduced to the desiccators while maintaining the vacuum. The specimens remained under water and vacuum for one additional hour.

Penetrability - Testing Procedure

The specimens were removed from the desiccators and excess water was removed. Specimens were then placed in testing cells utilizing rubber gaskets and "C" clamps to prevent leaking (Figure 18). Testing cells had solutions of 3.0% sodium chloride (NaCl) in one cell and 0.3 normality (N) sodium hydroxide (NaOH) in an adjacent cell. A positive lead was attached to the cell containing the 0.3 N NaOH solution and a negative terminal attached to the cell with 3.0% NaCl. Ample solution was added to completely cover the entire ends of the specimens. An apparatus with a power supply and digital readout (Figure 19) was used to apply a constant 60 ± 0.1 volt DC current to the specimens and record coulombs. This apparatus was calibrated prior to each testing utilizing resistors and a volt meter. Once testing began the apparatus automatically took readings at 30 minute intervals and calculated the coulomb values. The testing intervals, cell number, milliamps, and coulombs were printed on a paper record. The coulomb value was calculated automatically by the digital voltage apparatus. The coulomb value was adjusted for specimen diameter according to AASHTO T 277 / ASTM C1202. This testing was conducted on two specimens cut from two cylinders and the average adjusted coulomb value was calculated and reported.

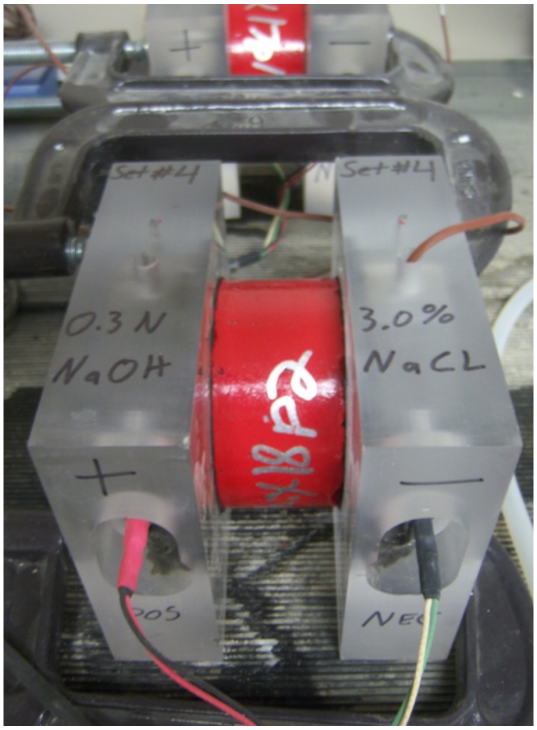

Figure 18: Penetrability Specimen in Test Cell

Figure 19: Chloride Ion Penetrability Apparatus

Chapter 5 - Results

Compressive Strength

Results from testing eleven compressive strength specimens per mixture are given 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

Compressive Strength: Mixes 1 – 15

Average 28 day compressive strengths for mixes 1 through 15 ranged from 4,333 psi to 6,187 psi. The mixture with the highest average 28 day compressive strength was mix 11 which had a w/cm ratio of 0.48 (highest w/cm ratio used in this study), used 50% Type GU cement with 50% GGBFS, and had a total cementitious content of 507 pounds per cubic yard. The mixture with the highest 56 day compressive strength was mix 15.1 which had a w/cm ratio of 0.45 and used 50% Type I portland cement with 50% GGBFS. The mixture with the lowest average 28 day compressive strength was mix 6 which has a w/cm ratio of 0.48, used 75% Type I portland cement with 25% Class F fly ash, and had 497 pounds of cementitious material per cubic yard. The mixture with the lowest 56 day compressive strength was mix 1 (KU mix) which had a w/cm ratio of 0.45, and used 540 pounds of 100% Type I portland cement. Table 16 presents the average compressive strengths and rankings for mixes 1 through 15. A ranking of 1 indicates the highest compressive strength and a ranking of 15 indicates the lowest compressive strength.

Table 16: Average Compressive Strength Ranking - Mixes 1 - 15

Mix No.	Mix Description	28 Day Avg. (psi)	28 Day Rank	56 Day Avg. (psi)	56 Day Rank
Mix 1	Type I - KU Mix	5,420	8	5,190	15
Mix 2.1	Type I - MDOT Class AA	5,757	4	6,355	3
Mix 3	Type I – 25% C Ash - MDOT Class AA	5,207	10	6,080	6
Mix 4	Type I	5,603	5	5,855	8
Mix 5	Type I - 25% C Ash	5,080	11	5,745	10
Mix 6	Type I - 25% F Ash	4,333	15	5,405	14
Mix 7	Type I - 50% GGBFS	5,847	3	6,165	5
Mix 8	Type GU	5,423	7	5,755	9
Mix 9	Type GU - 25% C Ash	5,420	8	6,340	4
Mix 10	Type GU - 25% F Ash	4,970	12	5,720	11
Mix 11	Type GU - 50% GGBFS	6,187	1	6,705	2
Mix 12	Type I - 25% C Ash Blended Aggregates	5,430	6	5,865	7
Mix 13	Type I - 25% F Ash Blended Aggregates	4,880	13	5,555	12
Mix 14	Type I - MDOT BD	4,713	14	5,450	13
Mix 15.1	Type I - 50% GGBFS MDOT BD	6,147	2	6,795	1

Compressive Strength: Mixes 16 - 30

Average 28 day compressive strengths for mix 16 through 30 ranged from 4,843 psi to 6,980 psi. The mixture with the highest average 28 day compressive strength was mix 30 which had a w/cm ratio of 0.45, used 50% Type I portland cement with 50% GGBFS, and had a total cementitious content of 564 pounds per cubic yard. The mixture with the highest 56 day compressive strength was mix 30 as well. The mix with the lowest average 28 day compressive strength was mix 16 (KU mix) which had a water cementitious ratio of 0.45, used 100% Type I portland cement, and had a total cement content of 540 pounds of cement per cubic yard. The mix with the lowest 56 day compressive strength was mix 16 as well. Table 17 presents the average compressive strengths and rankings for mixes 16 through 30. A ranking of 1 indicates the highest compressive strength and a ranking of 15 indicates the lowest.

Table 17: Average Compressive Strength Ranking Mixes 16-30

Mix No.	Mix Description	28 Day Avg. (psi)	28 Day Rank	56 Day Avg. (psi)	56 Day Rank
Mix 16	Type I - KU Mix	4,843	15	5,180	15
Mix 17	Type I - MDOT Class AA	5,793	8	5,955	12
Mix 18	Type I – 25% C Ash - MDOT Class AA	5,620	10	6,095	8
Mix 19	Type I	6,363	3	6,815	3
Mix 20.1	Type I - 25% C Ash	5,697	9	6,070	9
Mix 21	Type I - 25% F Ash	5,303	11	6,035	10
Mix 22	Type I - 50% GGBFS	5,917	7	5,970	11
Mix 23.1	Type GU	6,127	4	6,560	5
Mix 24	Type GU - 25% C Ash	6,093	5	6,590	4
Mix 25	Type GU - 25% F Ash	5,010	14	6,255	7
Mix 26	Type GU - 50% GGBFS	6,507	2	6,945	2
Mix 27.1	Type I - 25% C Ash Blended Aggregates	5,023	13	5,585	14
Mix 28	Type I - 25% F Ash Blended Aggregates	5,073	12	5,885	13
Mix 29	Type I - MDOT BD	6,017	6	6,315	6
Mix 30	Type I - 50% GGBFS MDOT BD	6,980	1	7,405	1

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 from the time specimens were placed in the temperature and humidity controlled room. Data indicates that ultimate shrinkage occurred at 224 days of storage in the temperature and humidity controlled room. Ultimate shrinkage ranges from a low of (-) 0.0170% (mix 22 – 50% Type I portland cement with 50% GGBFS) to a high of (-) 0.0503% (mix 1 – KU - 100% Type I portland cement).

Length Change – Mixes 1 – 15

Average percent length change and rankings for mixes 1 through 15 are shown in Table 18. A ranking of 1 represents the lowest average 224 day shrinkage and a ranking of 15 represents the highest 224 day shrinkage. The 224 day shrinkage results for mixes 1 through 15 ranged from a low of (-) 0.0230% (mix 15.1 – 50% Type I portland cement with 50% GGBFS) to a high of (-) 0.0503% (KU – 100% Type I portland cement).

Table 18: Average Percent Length Change and Ranking – Mixes 1 - 15

Mix No.	Mix Description	28 Day	56 Day	112 Day	224 Day	442 Day	Rank
Mix 1	Type I - KU Mix	-0.0223	-0.0307	-0.0457	-0.0503	-0.0477	**15**
Mix 2.1	Type I - MDOT Class AA	-0.0253	-0.0327	-0.0393	-0.0437	-0.0367	**11**
Mix 3	Type I - 25% C Ash - MDOT Class AA	-0.0120	-0.0180	-0.0323	-0.0390	-0.0363	**9**
Mix 4	Type I	-0.0143	-0.0193	-0.0340	-0.0337	-0.0333	**6**
Mix 5	Type I - 25% C Ash	-0.0143	-0.0210	-0.0347	-0.0393	-0.0353	**10**
Mix 6	Type I - 25% F Ash	-0.0023	-0.0057	-0.0193	-0.0240	-0.0203	**3**
Mix 7	Type I - 50% GGBFS	-0.0043	-0.0100	-0.0240	-0.0293	-0.0263	**4**
Mix 8	Type GU	-0.0193	-0.0257	-0.0403	-0.0440	-0.0393	**12**
Mix 9	Type GU - 25% C Ash	-0.0153	-0.0203	-0.0317	-0.0363	-0.0320	**8**
Mix 10	Type GU - 25% F Ash	-0.0057	-0.0123	-0.0240	-0.0297	-0.0270	**5**
Mix 11	Type GU - 50% GGBFS	0.0040	0.0003	-0.0153	-0.0233	-0.0227	**2**
Mix 12	TYPE I - 25% C Ash Blended Aggregates	-0.0137	-0.0237	-0.0400	-0.0440	-0.0440	**13**
Mix 13	Type I - 25% F Ash Blended Aggregates	-0.0110	-0.0163	-0.0300	-0.0340	-0.0330	**7**
Mix 14	Type I - MDOT BD	-0.0170	-0.0267	-0.0413	-0.0463	-0.0463	**14**
Mix 15.1	Type I - 50% GGBFS MDOT BD	-0.0110	-0.0167	-0.0237	-0.0230	-0.0243	**1**

Length Change – Mixes 16 – 30

Average percent shrinkage and rankings are presented in Table 19 for mixes 16 through 30. The 224 day shrinkage results for mixes 16 through 30 ranged from a low of (-) 0.0170%

(mix 22 – 50% Type I portland cement with 50% GGBFS) to a high of (-) 0.0487% (mix 29 – MDOT Class BD – 100% Type I portland cement).

Table 19: Average Percent Length Change and Ranking – Mixes 16 through 30

Mix No.	Mix Description	28 Day	56 Day	112 Day	224 Day	442 Day	Rank
Mix 16	Type I - KU Mix	-0.0067	-0.0213	-0.0290	-0.0337	-0.0307	**6**
Mix 17	Type I - MDOT Class AA	-0.0133	-0.0317	-0.0380	-0.0433	-0.0390	**11**
Mix 18	Type I - 25% C Ash - MDOT Class AA	-0.0053	-0.0207	-0.0277	-0.0327	-0.0280	**5**
Mix 19	Type I	-0.0207	-0.0383	-0.0440	-0.0473	-0.0460	**13**
Mix 20.1	Type I - 25% C Ash	-0.0193	-0.0363	-0.0433	-0.0450	-0.0437	**12**
Mix 21	Type I - 25% F Ash	-0.0093	-0.0250	-0.0300	-0.0307	-0.0273	**4**
Mix 22	Type I - 50% GGBFS	0.0087	-0.0070	-0.0140	-0.0170	-0.0140	**1**
Mix 23.1	Type GU	-0.0250	-0.0320	-0.0390	-0.0420	-0.0353	**8**
Mix 24	Type GU - 25% C Ash	-0.0187	-0.0353	-0.0407	-0.0423	-0.0413	**9**
Mix 25	Type GU - 25% F Ash	-0.0223	-0.0283	-0.0333	-0.0403	-0.0337	**7**
Mix 26	Type GU - 50% GGBFS	-0.0107	-0.0153	-0.0217	-0.0293	-0.0277	**3**
Mix 27.1	TYPE I - 25% C Ash Blended Agg	-0.0303	-0.0360	-0.0463	-0.0477	-0.0433	**14**
Mix 28	Type I - 25% F Ash Blended Agg.	-0.0270	-0.0337	-0.0413	-0.0430	-0.0387	**10**
Mix 29	Type I - MDOT BD	-0.0277	-0.0367	-0.0443	-0.0487	-0.0437	**15**
Mix 30	Type I - 50% GGBFS MDOT BD	-0.0037	-0.0090	-0.0183	-0.0273	-0.0263	**2**

Penetrability

A summary of chloride ion penetrability data is presented in Table 20 for mixes 1 through 15 and Table 21 for mixes 16 through 30. These data are ranked by 365 day results. A ranking of 1 indicates the mixture with the lowest average coulombs and a ranking of 15 indicates the mixture with the highest average coulombs.

Table 20: Chloride Ion Penetrability - Mixes 1 - 15.1

Mix No.	Mix Description	28 Day (Coulombs)	91 Day (Coulombs)	365 Day (Coulombs)	Rank
Mix 1	Type I - KU Mix	2,151	1,675	1,191	**14**
Mix 2.1	Type I - MDOT Class AA	1,505	1,327	1,004	**11**
Mix 3	Type I – 25% C Ash - MDOT Class AA	1,668	789	492	**8**
Mix 4	Type I	1,749	1,475	1,328	**15**
Mix 5	Type I - 25% C Ash	2,638	1,343	871	**10**
Mix 6	Type I - 25% F Ash	2,149	708	246	**3**
Mix 7	Type I - 50% GGBFS	790	368	318	**5**
Mix 8	Type GU	2,112	1,312	1,134	**12**
Mix 9	Type GU - 25% C Ash	1,828	1,089	321	**6**
Mix 10	Type GU - 25% F Ash	2,196	805	189	**1**
Mix 11	Type GU - 50% GGBFS	415	251	204	**2**
Mix 12	Type I - 25% C Ash Blended Agg	2,526	1,302	675	**9**
Mix 13	Type I - 25% F Ash Blended Agg.	2,465	816	273	**4**
Mix 14	Type I - MDOT BD	1,717	1,377	1,191	**13**
Mix 15.1	Type I - 50% GGBFS MDOT BD	714	444	328	**7**

Table 21: Chloride Ion Penetrability - Mixes 16 - 30

Mix No.	Mix Description	28 Day (Coulombs)	91 Day (Coulombs)	365 Day (Coulombs)	Rank
Mix 16	Type I - KU Mix	1,474	1,144	1,053	**10**
Mix 17	Type I - MDOT Class AA	1,628	1,354	1,245	**13**
Mix 18	Type I – 25% C Ash - MDOT Class AA	2,778	1,222	638	**8**
Mix 19	Type I	2,109	1,866	1,615	**14**
Mix 20.1	Type I - 25% C Ash	4,088	1,780	489	**7**
Mix 21	Type I - 25% F Ash	2,093	735	275	**4**
Mix 22	Type I - 50% GGBFS	799	468	339	**6**
Mix 23.1	Type GU	1,972	1,750	1,677	**15**
Mix 24	Type GU - 25% C Ash	1,944	1,001	1,018	**9**
Mix 25	Type GU - 25% F Ash	1,930	613	200	**2**
Mix 26	Type GU - 50% GGBFS	424	290	193	**1**
Mix 27.1	Type I - 25% C Ash Blended Agg	2,883	1,703	1,189	**11**
Mix 28	Type I - 25% F Ash Blended Agg.	2,723	1,078	324	**5**
Mix 29	Type I - MDOT BD	1,865	1,598	1,194	**12**
Mix 30	Type I - 50% GGBFS MDOT BD	464	337	251	**3**

Chapter 6 – Discussion of Results

Mixture parameters, plastic properties and test results are presented in Tables 23 for mixes 1 through 15.1 and in Table 24 for mixes 16 through 30. Raw data for each mixture are presented in Appendix A. Raw data for shrinkage and permeability are presented in Appendix B.

Compressive Strength

Compressive Strength: Research Mixes 4 – 11

Mixes 4 through 11 are similar mixtures having the same gravel aggregate source (source number one), same w/cm ratio, and same volume of cementitious paste (cementitious material plus water). The w/cm ratio for these mixtures was 0.48 and the total cementitious paste volume was 24.47 percent. The difference in these mixes was in the cementitious materials. Type I portland cement was used in mixes 4 through 7 and Type GU cement was used in mixes 8 through 11. Combinations of 25 % Class C fly ash, 25% Class F fly ash, and 50% GGBFS are included with each type of cement. Figure 20 illustrates strength gain versus time for mixes 4 through 7 and Figure 21 illustrates strength gain versus time for mixes 8 through 11.

The highest 28 day and 56 day compressive strengths in mixes 4 through 7 were mixtures that included 50% Type I portland cement with 50% GGBFS (Figure 20). 100% Type I portland cement provided the next highest compressive strengths followed by mixtures with 25% Class C fly ash then 25% Class F fly ash. Compressive strengths in mixtures with 100% Type I (mix 4) and 100% Type GU (mix 8) cement were similar. However, when SCMs were used in combination with Type GU cement, higher compressive strengths are achieved. This higher strength was more notable when Type GU cement was combined with Class C fly ash. Similar to mixtures with Type I portland cement, Type GU cement mixtures achieved the highest 28 day and 56 day compressive strengths when combined with 50% GGBFS.

Early strength is an important consideration with mixture proportioning because of construction scheduling. The faster concrete sets the faster the contractor can finish a project. In all cases for mixes 4 through 11, 100% Type I portland cement or 100% Type GU cement mixes achieved the highest one day compressive strengths. Mixtures with 25% Class C and Class F fly ash produced similar compressive strengths at one day and these strengths were 70 percent of the strength of similar mixes with 100% Type I portland cement or 100% Type GU cement. Mixes using 50% GGBFS had roughly 25 percent of the one day compressive strengths of similar mixes with 100% Type I portland cement or Type GU cement.

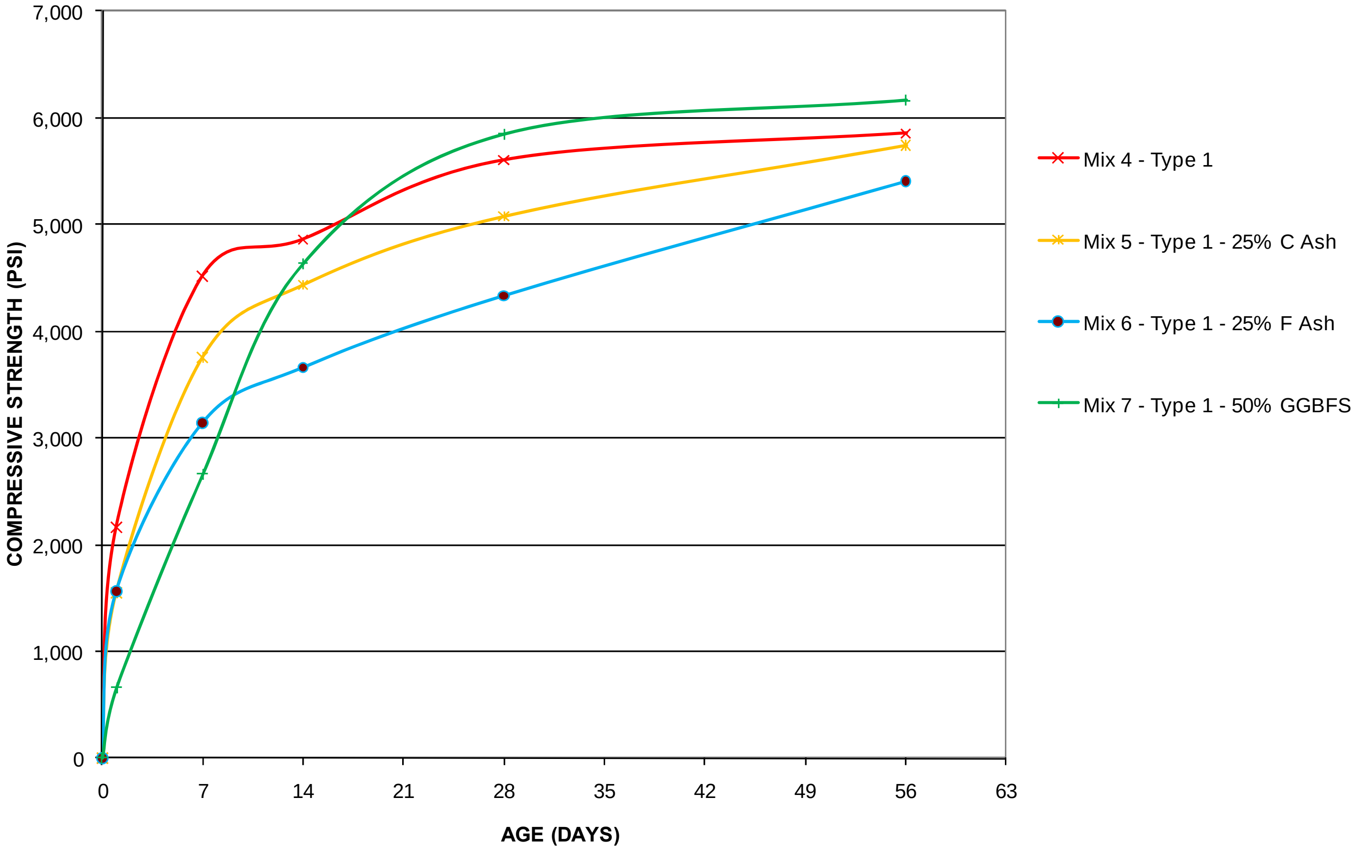

Figure 20: Average Compressive Strength VS Age Mixes 4-7

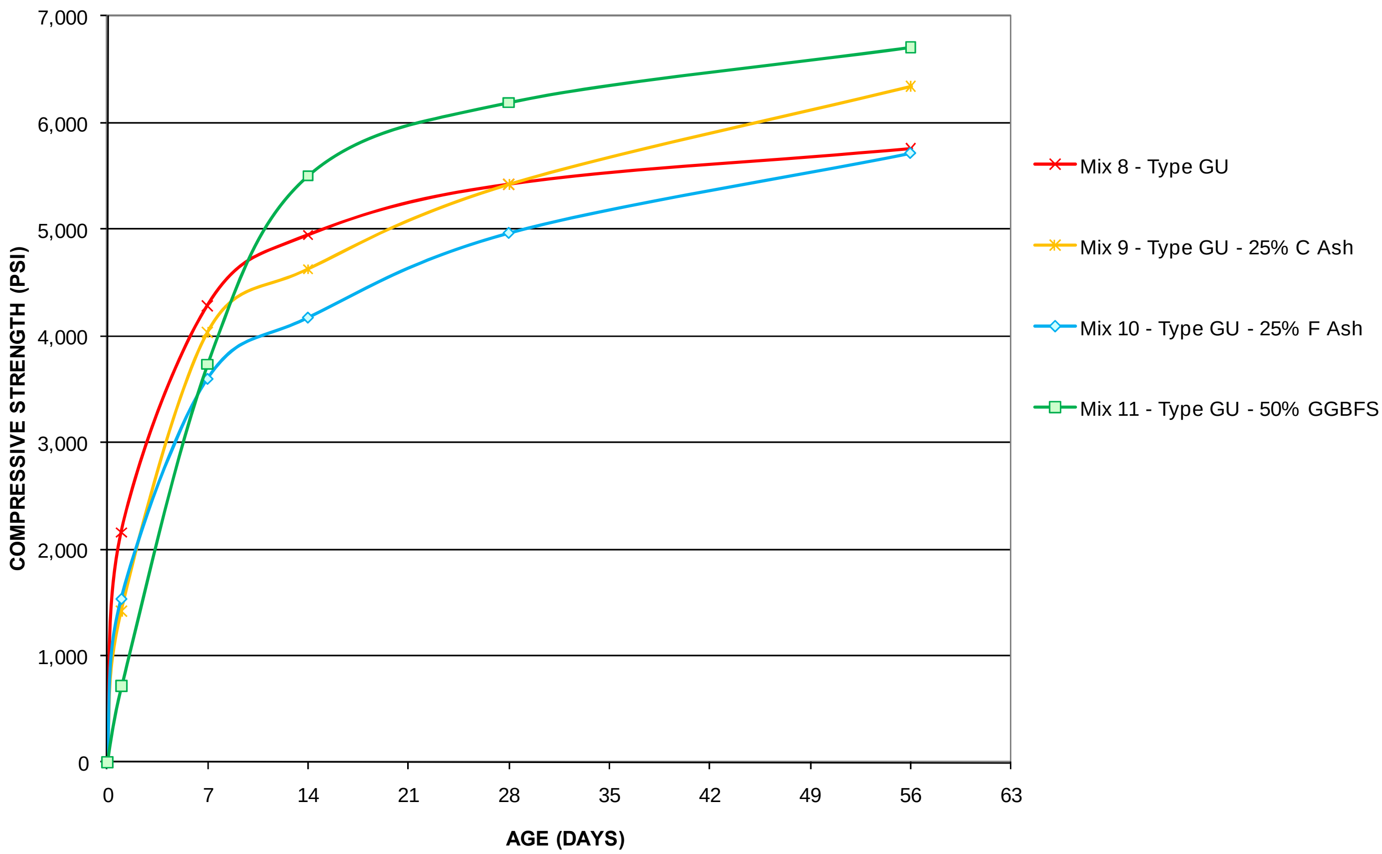

Figure 21: Average Compressive Strength VS Age Mixes 8-11

Compressive Strength: Research Mixes 19 – 26

Mixes 19 through 26 were similar mixtures having the same gravel aggregate source (source number two), same w/cm ratio, and same volume of cementitious paste. The w/cm ratio for these mixtures was 0.48 and the total cementitious paste volume was 24.47 percent. The difference in these mixes was in the cementitious materials. Type I portland cement was used in mixes 19 through 22 and Type GU cement was used in mixes 23.1 through 26. Combinations of 25 % Class C fly ash, 25% Class F fly ash, and 50% GGBFS were included with each type of cement. Figure 22 illustrates strength gain versus time for mixes 19 through 22 and Figure 23 illustrates strength gain versus time for mixes 23.1 through 26.

The mixture with the highest 28 day and 56 day compressive strengths of mixtures 19 through 22 was mix 19 using 100% Type I portland cement. This higher compressive strength was not expected and may indicate an outlier in the data. The highest compressive strengths in similar research mixtures all had 50% GGBFS. The mixture using 50% Type I cement with 50% GGBFS provided the next highest 28 day compressive strength followed by mixtures with 25% Class C fly ash and then 25% Class F fly ash. Interestingly, all mixtures with SCMs had similar 56 day compressive strengths.

The mixture with the highest 28 day and 56 day compressive strengths of mixes 23 through 26 was mix 26 using 50% Type GU cement with 50% GGBFS. 100% Type GU cement and 25% Class C fly ash mixtures had the next highest compressive strengths followed by the 25% Class F fly ash mixture.

In all cases for mixes 19 through 26, 100% Type I portland cement and 100% Type GU cement mixtures achieved the highest one day compressive strengths. Mixtures with 25% Class C fly ash and Class F fly ash produced roughly the same compressive strengths at one day and these strengths were 58 percent of the strength of similar mixtures with 100% Type I portland cement or 100% Type GU cement. Mixes 22 and 26, using 50% GGBFS, had 31 percent of the one day compressive strengths of similar mixes with 100% Type I portland cement or Type GU cement.

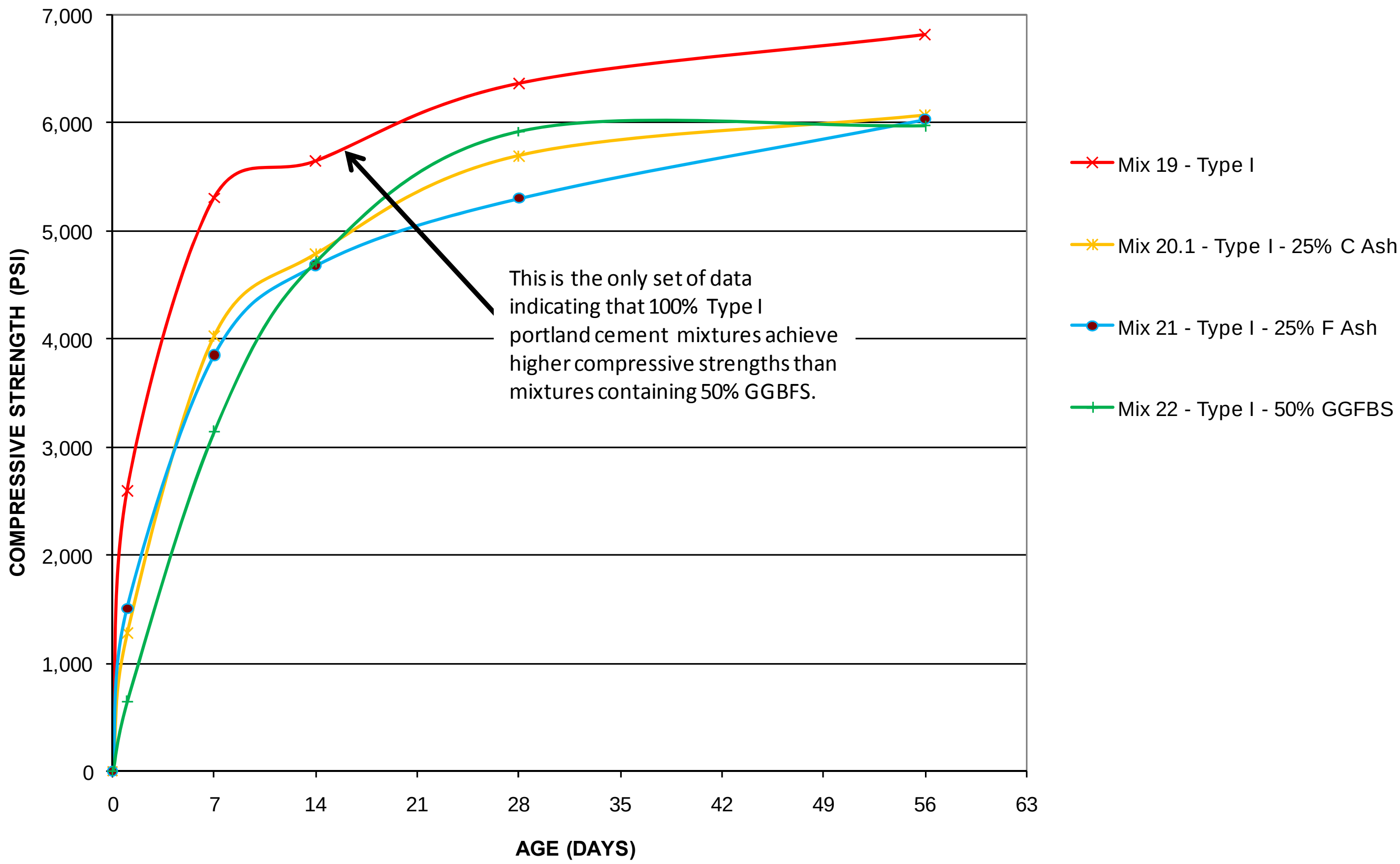

Figure 22: Average Compressive Strength VS Age - Mixes 19-22

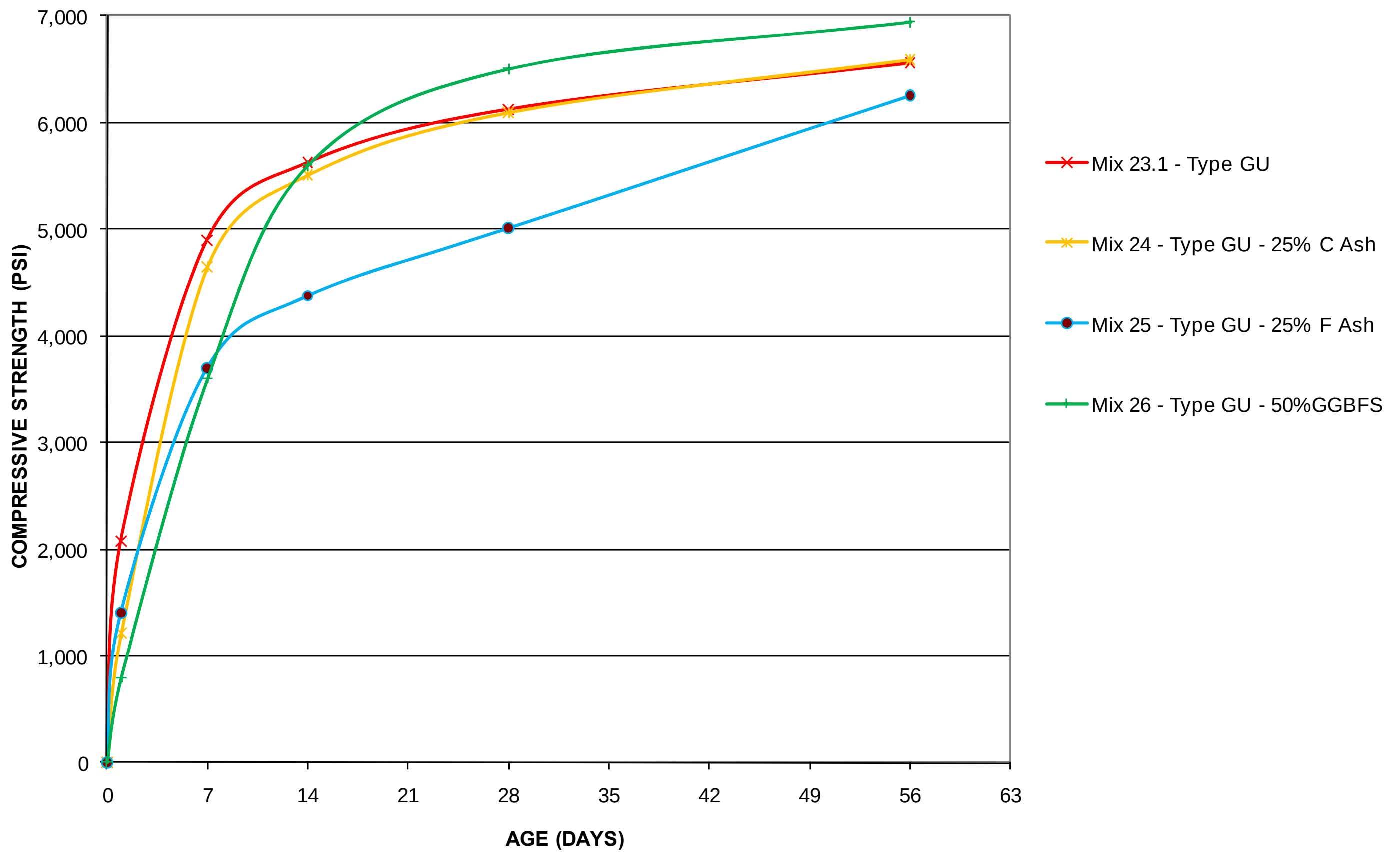

Figure 23: Average Compressive Strength VS Age Mixes 23.1 – 26

Compressive Strength: Mixes 1, 14, and 15.1

Mixes 1, 14, and 15.1 all had a w/cm ratio of 0.45 and used aggregate gradation optimization. Total cementitious contents were 540, 525, and 509 pounds per cubic yard, respectively. Average compressive strengths versus age for these mixes are illustrated in Figure 24. Mix 1 and 14 included 100% Type I portland cement and mix 15.1 included 50% Type I portland cement with 50% GGBFS. Crushed limestone coarse aggregates were used for mix 1. Mixes 14 and 15.1 utilized gravel aggregates. Mix 15.1 using 50% Type I portland cement with 50% GGBFS (lowest total cementitious) provided higher 28 day and 56 compressive strengths than the 100% Type I cement mixtures.

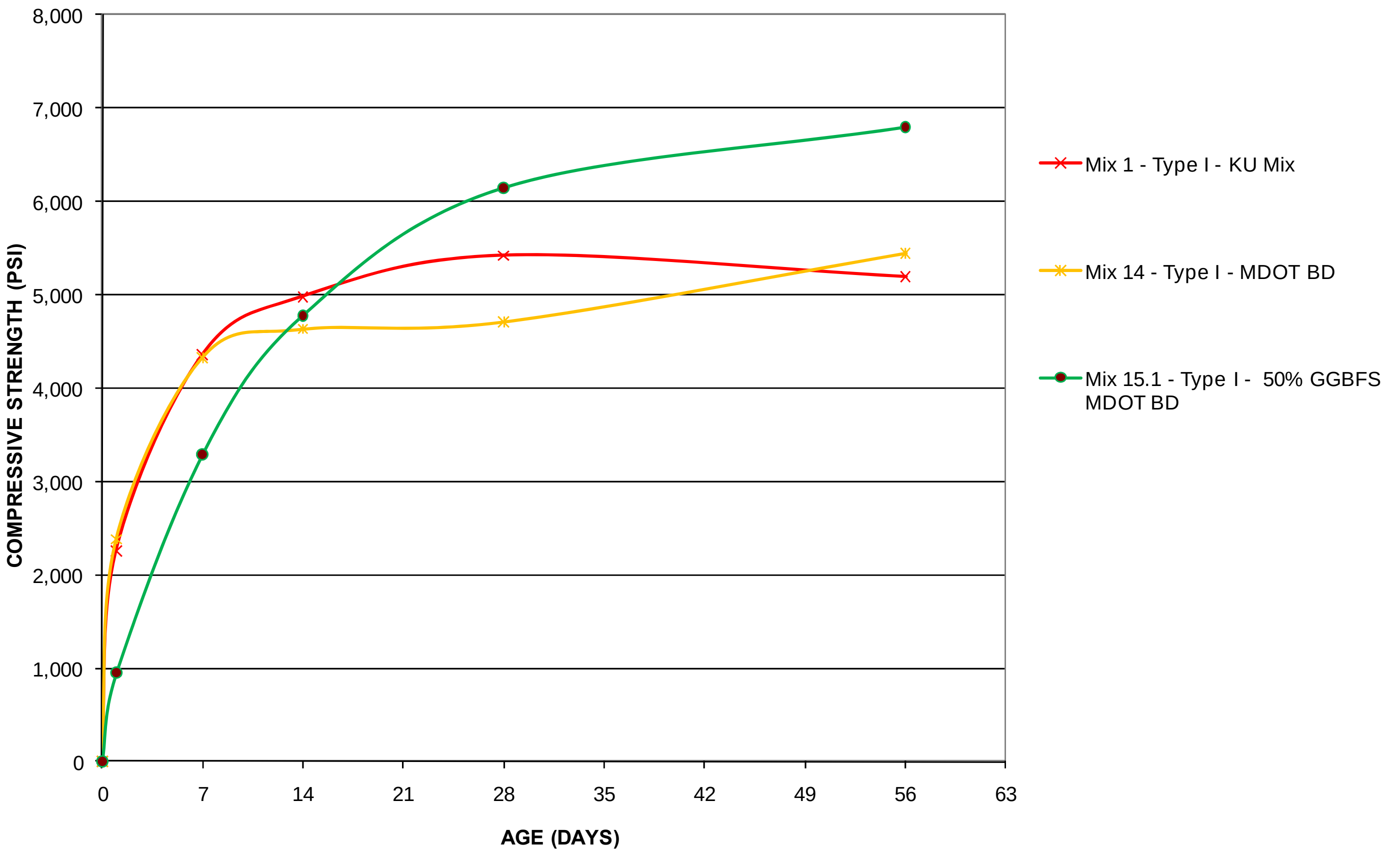

Figure 24: Average Compressive Strength VS Age Mixes 1, 14 and 15.1

Compressive Strength: Mixes 16, 29, and 30

Mixes 16, 29, and 30 all had a w/cm ratio of 0.45 and all utilized aggregate gradation optimization. Total cementitious contents were 540, 564, and 564 pounds per cubic yard, respectively. Average compressive strengths versus age are illustrated in Figure 25. Mix 16 had 540 pounds per cubic yard of 100% Type I portland cement. Mixes 29 and 30 had 564 pounds of cementitious materials per cubic yard. Mix 29 included 100% Type I cement and mix 30 had

50% Type I portland cement with 50% GGBFS. Mix number 16 utilized crushed limestone coarse aggregates and mixes 29 and 30 utilized gravel aggregates. Mix 30, using 50% Type I portland cement with 50% GGBFS, provided higher 28 day and 56 compressive strengths than 100% Type I portland cement mixtures. Mix 29 (MDOT BD) had lower 28 day and 56 day compressive strengths than mix 30 followed by mix number 16 (KU).

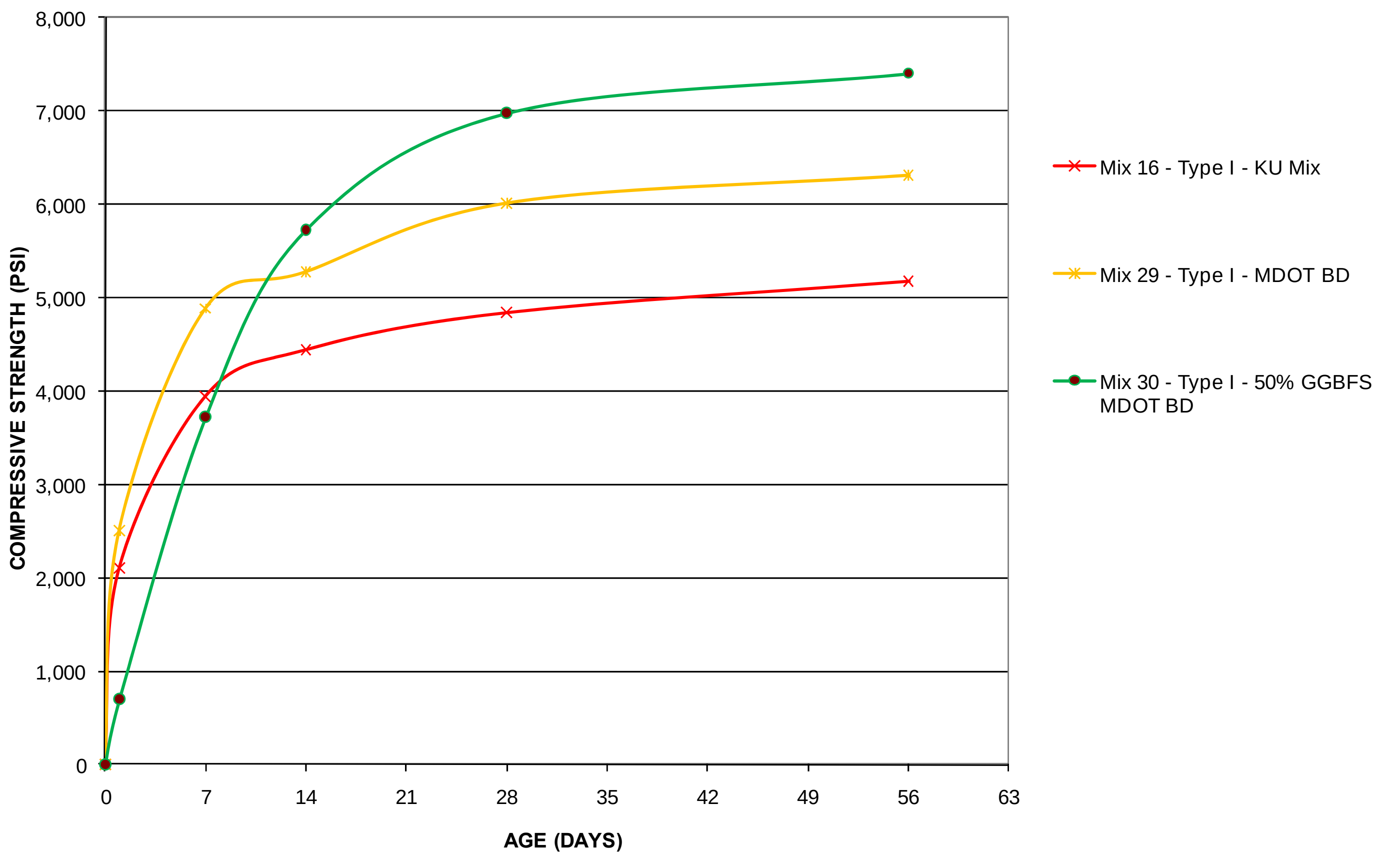

Figure 25: Average Compressive Strength VS Age Mixes 16, 29, and 30

Compressive Strength: MDOT Class AA Mixes 2.1, 3, 17, and 18

Mixes 2.1, 3, 17, and 18 provide examples of typical MDOT Class AA bridge deck mixtures. Figures 26 and 27 illustrate average compressive strength versus age. All had a w/cm ratio of 0.40 and a total cementitious content of 588 pounds per cubic yard. Mixes 2.1 and 17 used 100% Type I portland cement while mixes 3 and 18 had 75% Type I portland cement with 25% Class C fly ash. The primary difference in the mixes being that mixes 2.1 and 3 utilized gravel aggregate source number one and mixes 17 and 18 utilized aggregate source number two.

These mixtures produced similar 28 and 56 day compressive strengths.

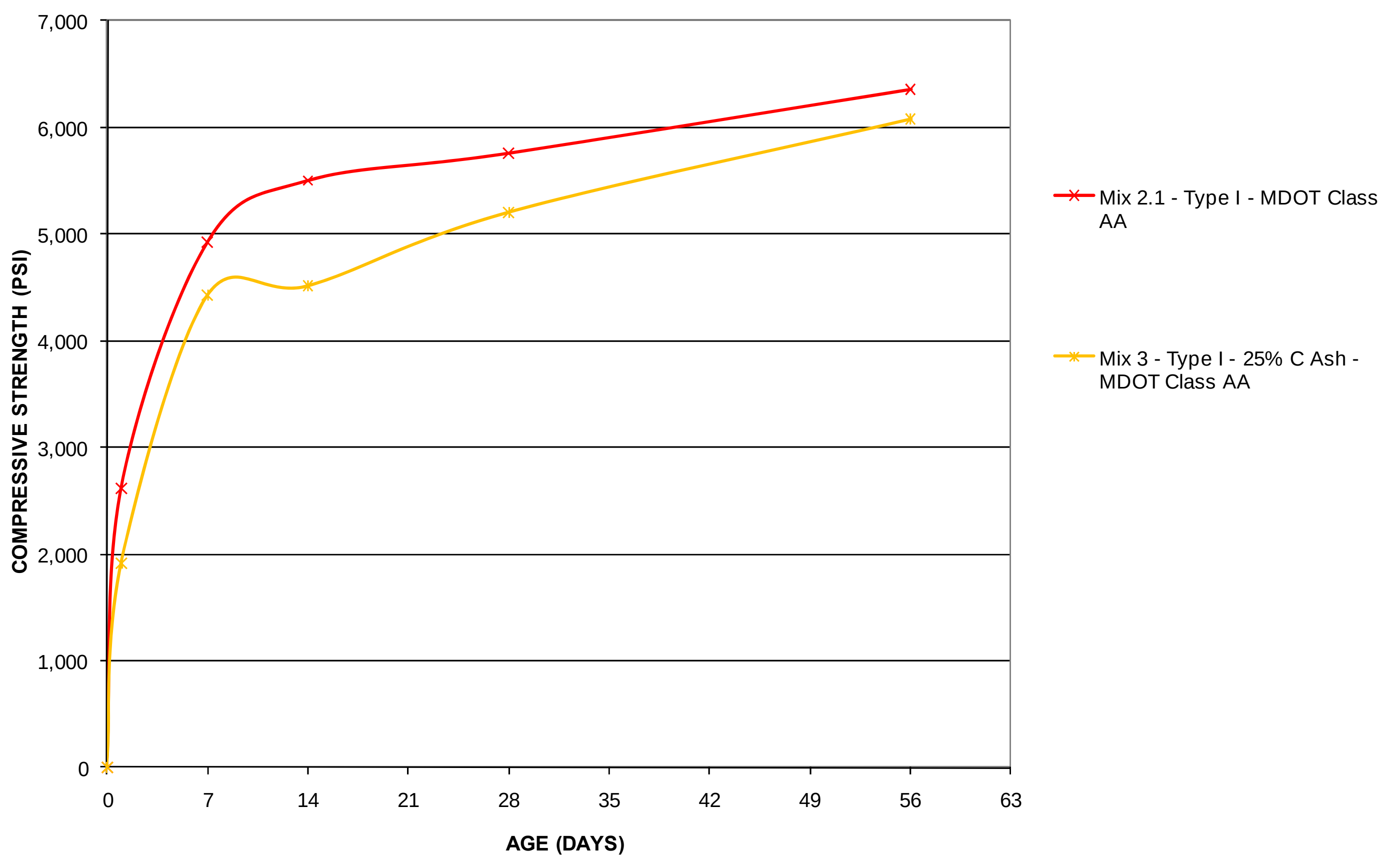

Figure 26: Average Compressive Strength VS Age Mixes 2.1 and 3

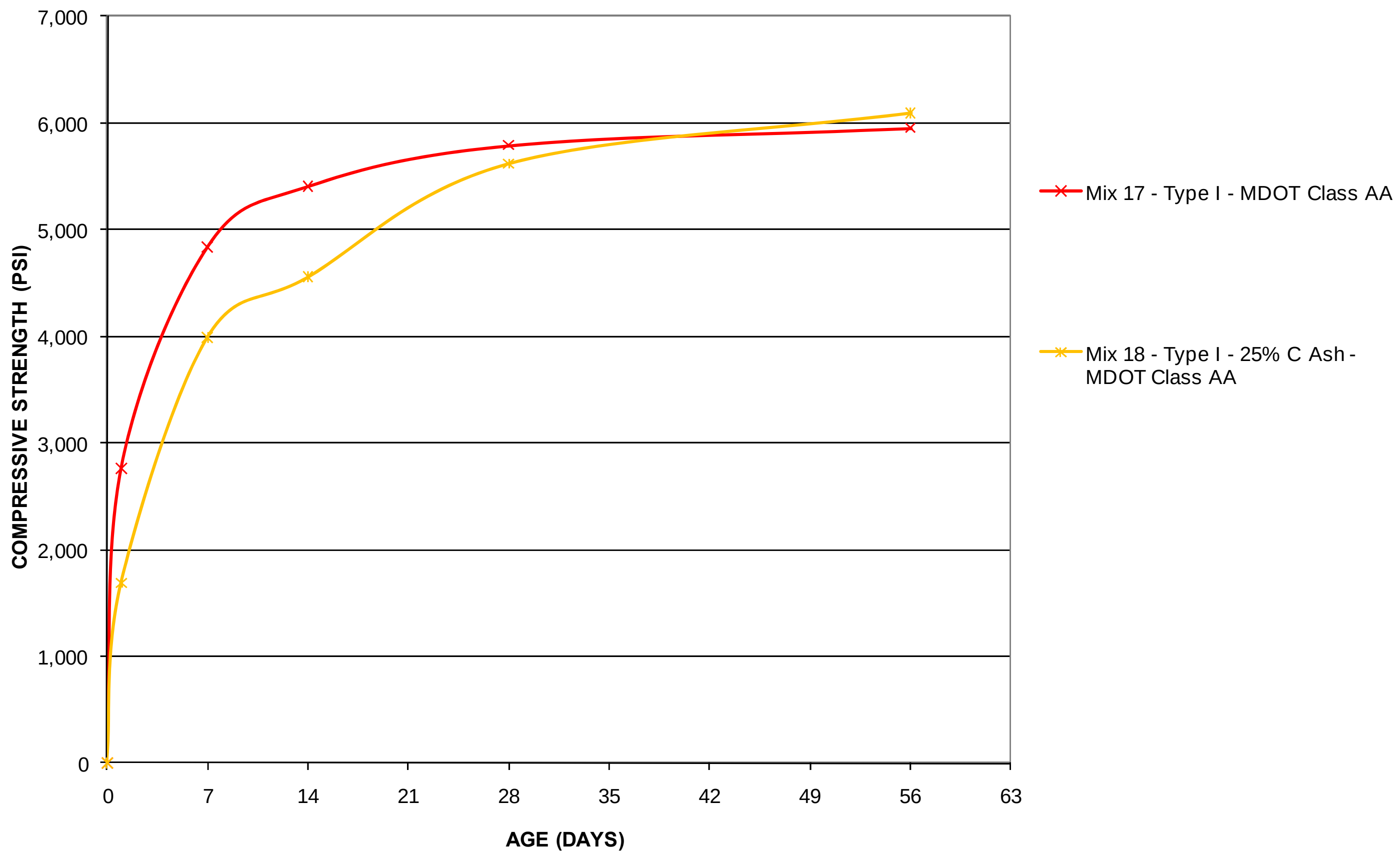

Figure 27: Average Compressive Strength VS Age Mixes 17 and 18

Compressive Strength: Blended Aggregate Mixes 12 and 13

Mixes 12 and 13 incorporate aggregate gradation optimization by blending No. 57 and No. 8 from gravel source one to decrease cementitious content by increased workability achieved through blending these aggregates. The main difference in these two mixes was the class of fly ash used. Water and cementitious materials were adjusted for mixes 12 and 13 to produce similar slumps to their companion mixtures 5 and 6, respectively. Figure 28 illustrates average compressive strength versus age and the strengths are similar for all mixtures. Mixtures with

Class F fly ash had lower 28 day and 56 day compressive strengths than mixtures with Class C fly ash.

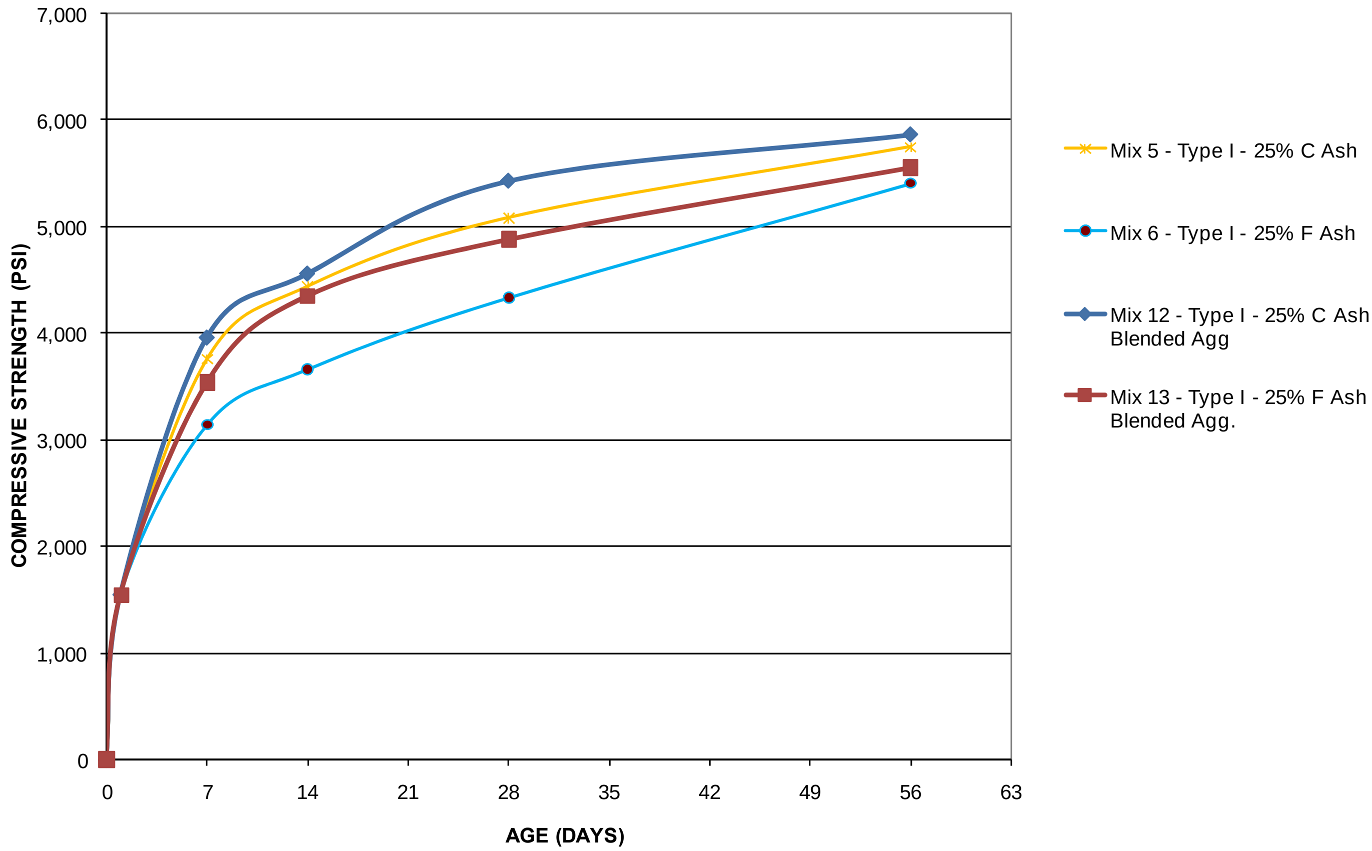

Figure 28: Average Compressive Strength VS Age Mixes 5, 6, 12, 13

Compressive Strength: Blended Aggregate Mixes 27.1 and 28

Aggregate gradation optimization was incorporated in mixes 27.1 and 28 by blending No. 57 and No. 8 gravel from gravel source two in order to decrease cementitious content by increased workability achieved through blending these aggregates. Water and cementitious materials were adjusted for mixes 27.1 and 28 to produce slump test results similar to their companion mixtures 20.1 and 21, respectively. Figure 29 illustrates average compressive strength versus age for these mixtures. Compressive strengths were similar when comparing these four mixtures.

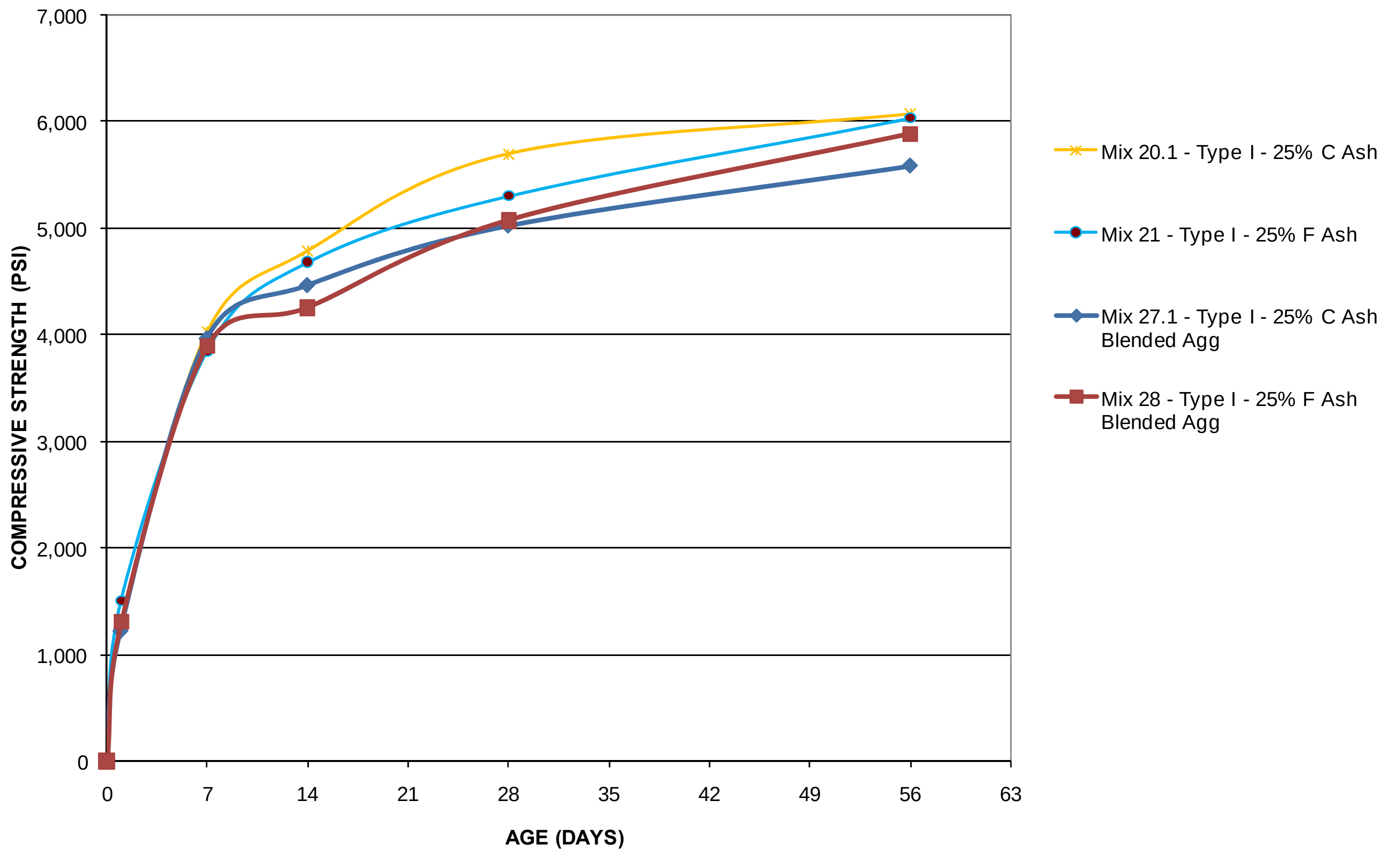

Figure 29: Average Compressive Strength VS Age Mixes 20.1, 21, 27.1, 28

Length Change

Length Change – KU Mixes 1 and 16

Mixes 1 and 16 incorporated aggregate gradation optimization to fill voids with aggregates in order to reduce cement paste shrinkage. Figure 30 illustrates percent length change versus age for mixes 1 and 16. The KU software was used to optimize these mixtures and each mixture has combined aggregate gradations that are within KDOT's limits for individual percent retained with one exception. Mix 1 had a combined individual percent retained on the No. 16 sieve of 7.5% which is 0.5% under the limit. CF and AWF for these mixtures are within Zone II (optimal) of the Coarseness Factor Chart. Mix 1 produced a length change of (-) 0.0503 percent at 224 days and this was the highest shrinkage of all mixtures included in this study. Mix 16 produced a length change of (-) 0.0337 percent which was the lowest 224 day shrinkage when compared to all other mixtures using 100% Type I or 100% Type GU cement. An interesting observation when comparing these two mixes, mix 1 had limestone aggregates (Source 1, Table 8) with slightly more water absorption than the limestone aggregates (Source 2, Table 9) utilized within mix 16. The overall water absorption for mix 1 was 1.02 percent which is above the 0.7 percent required for coarse aggregates used in the KU method, while the overall water absorption for mix 16 was less than 0.7 percent at 0.61 percent.

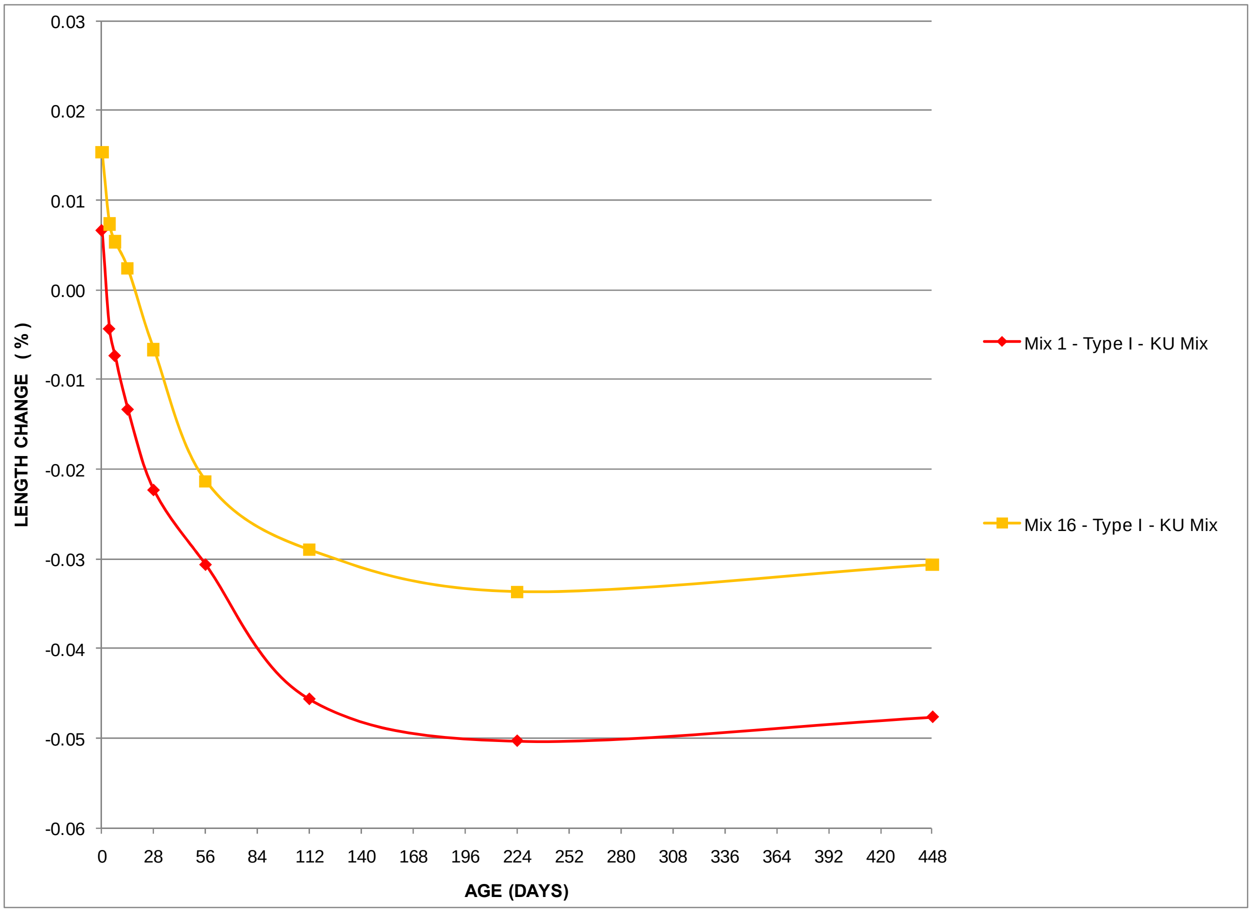

Figure 30: Average Length Change VS Age - Mixes 1 and 16

Length Change – MDOT Class AA Mixes 2.1, 3, 17, and 18

Mixes 2.1, 3, 17, and 18 represent typical mixtures used by MDOT for bridge decks before Class BD concrete was incorporated in project specifications. Results from shrinkage testing of these mixtures are illustrated in Figure 31. 224 day shrinkage results ranged from (-) 0.0327 percent for mix 18 to (-) 0.0437 percent for mix 2.1. The average 224 day shrinkage of mixes 2.1 and 17 (100% Type I portland cement) was (-) 0.0435 percent. Mixes 3 and 18 used 75% Type I portland cement with 25% Class C fly ash and the data indicates less volume change than mixes 2.1 and 17. The average 224 day shrinkage of mixes 3 and 18 was (-) 0.0359 percent. The average percent 224 day shrinkage for all MDOT Class AA mixes was (-) 0.0397 percent.

MDOT Class AA mixtures using 75% Type I portland cement with 25% Class C fly ash on average had 82 percent of the shrinkage of similar MDOT Class AA mixtures that use 100% Type I portland cement.

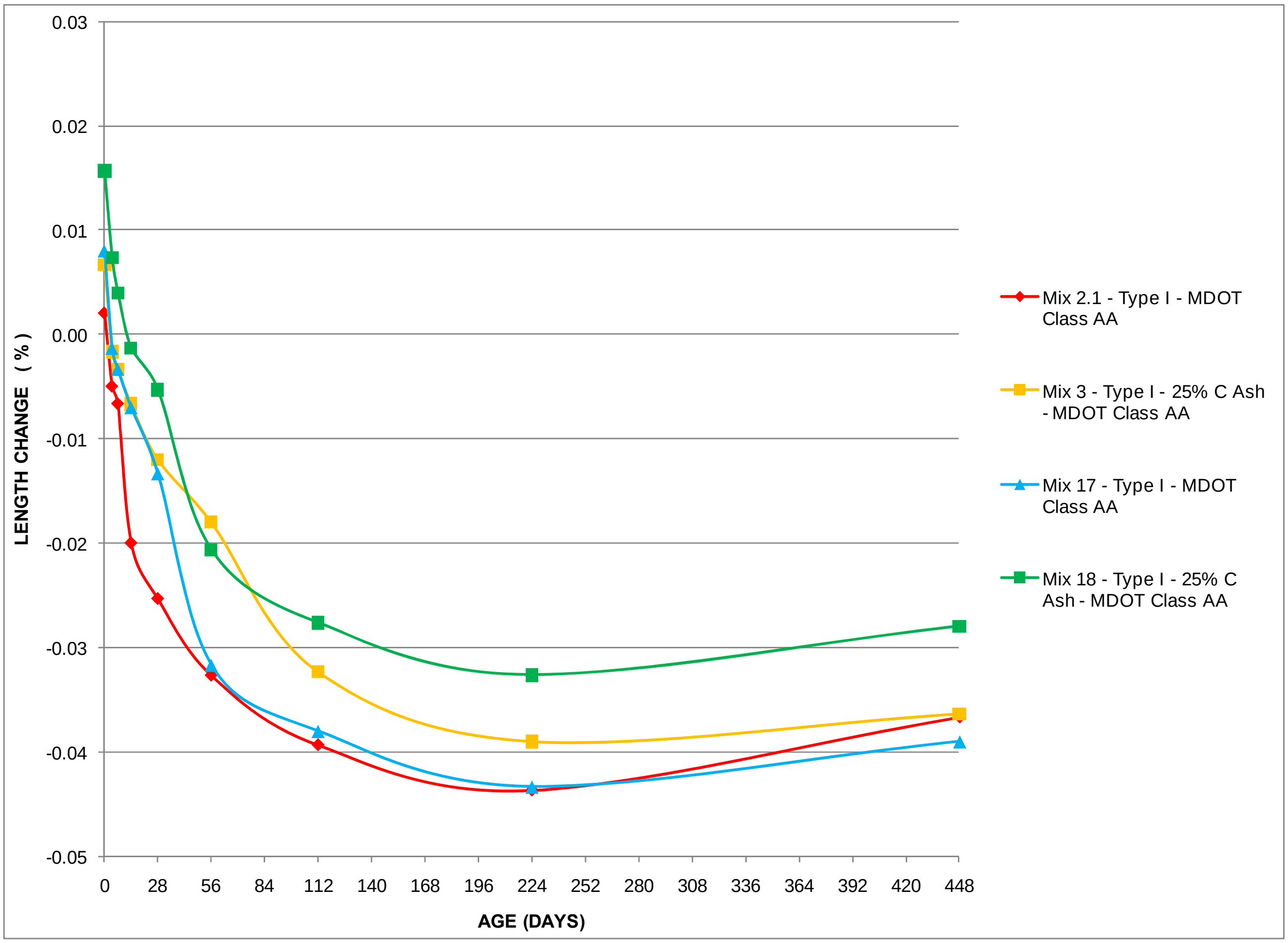

Figure 31: Average Length Change VS Age - MDOT Class AA Mixes 2.1, 3, 17, and 18

Length Change: Research Mixes 4 – 11 and 19 - 26

Average percent length change versus age data for mixes 4 through 11 and 19 through 26 are illustrated in Figures 32 through 35. These mixtures were all similar with two exceptions. Mixes 4 through 11used gravel aggregate source one and mixes 19 through 26 used gravel aggregate source number two. In addition, the type of cement and SCMs vary between mixtures.

The data indicates that SCMs have a significant influence on the amount of length change experienced with each of these mixtures. While mixtures with SCMs did not provide the same results in all cases, the majority of the data shows that SCMs reduced the amount of length change compared to mixtures with no SCMs. Mixtures with 100% Type I or 100% Type GU cement produced the greatest amount of length change. Mixtures with 25% Class C fly ash performed similar to mixtures with 100% Type I or 100% Type GU cement. Mixtures with 25% Class F fly ash performed better than mixtures with 100% Type I or 100% Type GU cement and better than mixtures with 25% Class C fly ash. Mixtures with 50% GGBFS performed best relative to length change when compared to similar mixtures using 25% Class C fly ash, 25% Class F fly ash or mixtures with 100% Type I or 100% Type GU cement.

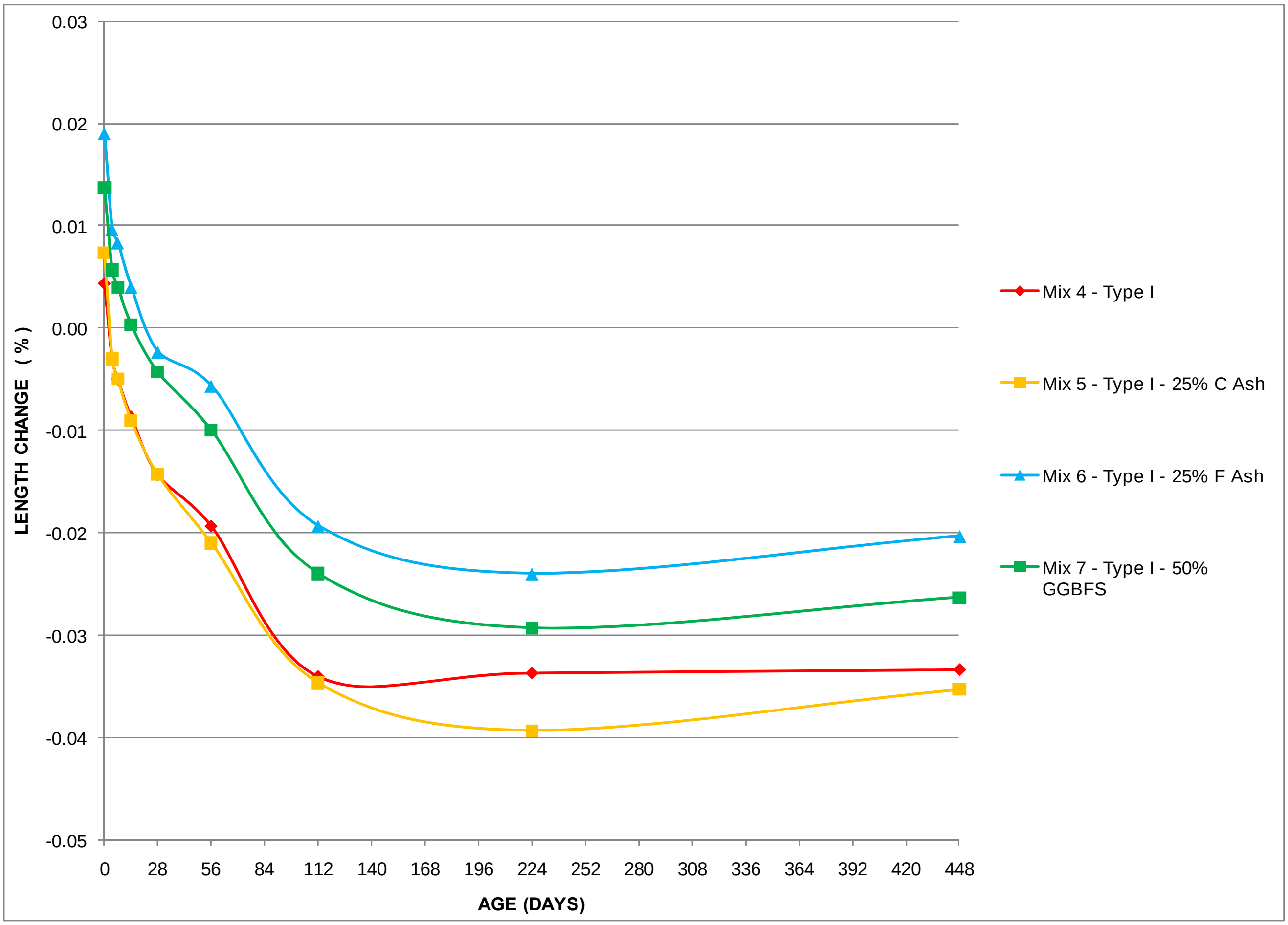

Figure 32: Average Length Change VS Age - Mixes 4 - 7

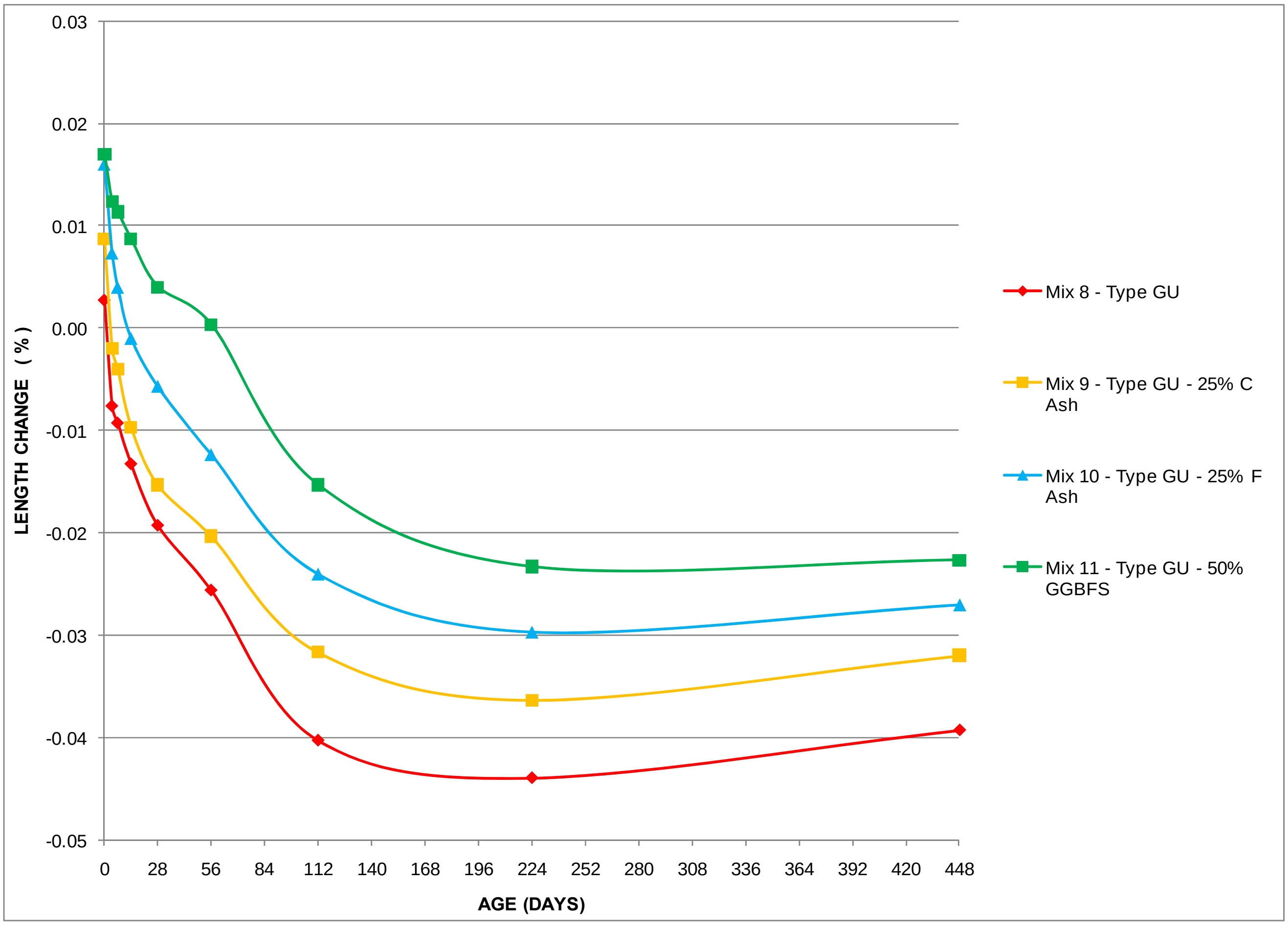

Figure 33: Average Length Change VS Age – Mixes 8 - 11

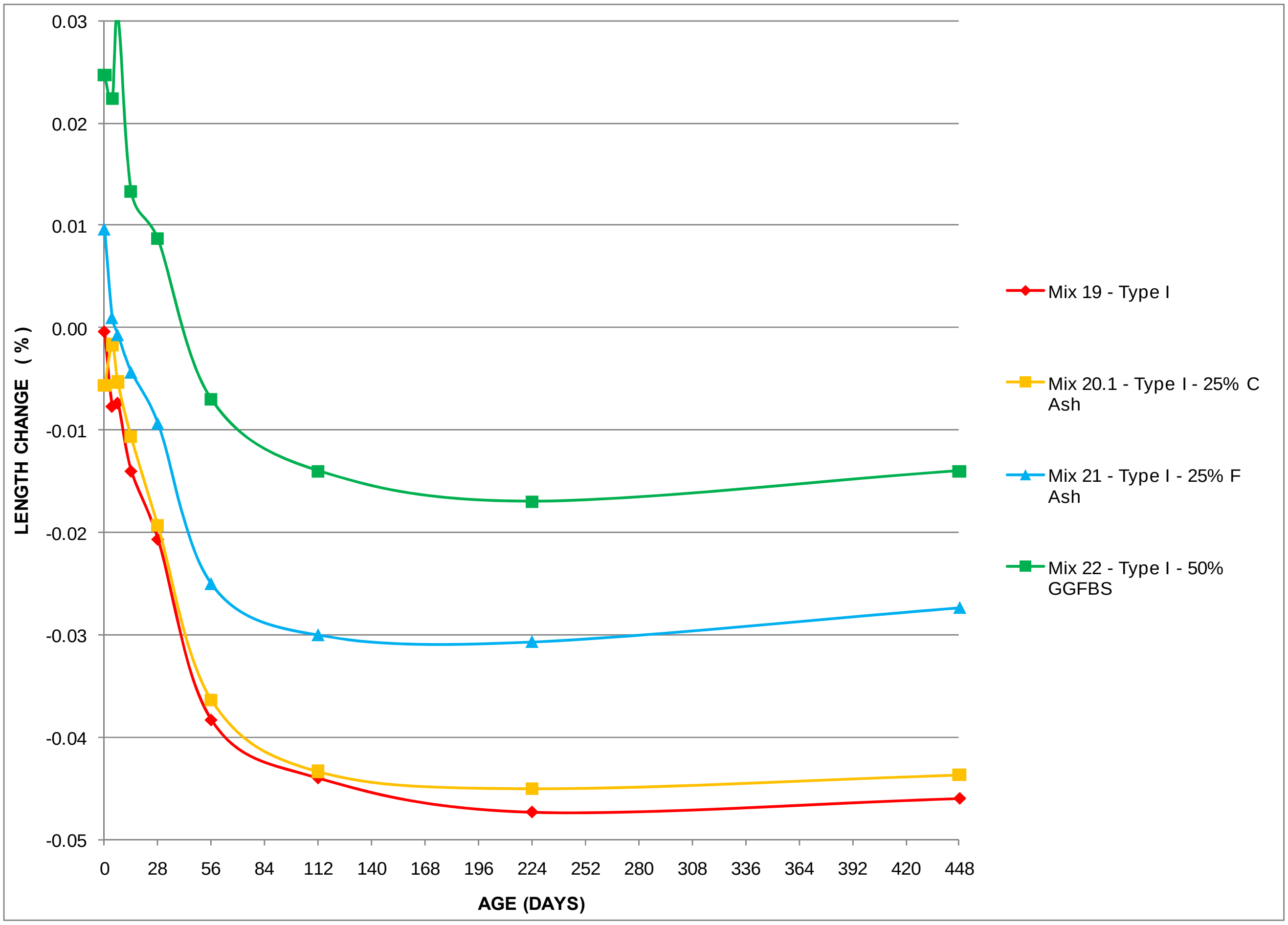

Figure 34: Average Length Change VS Age - Mixes 19 - 22

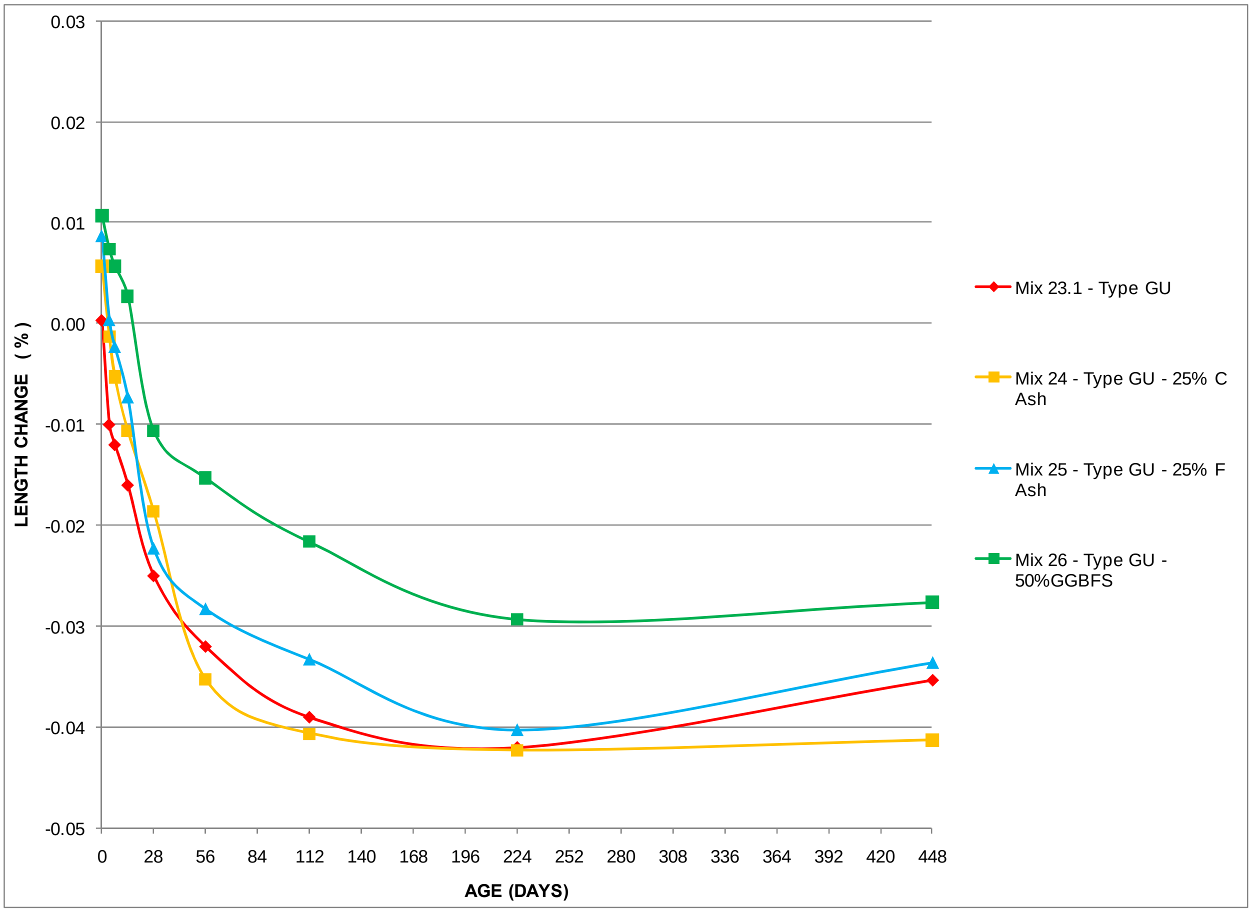

Figure 35: Average Length Change VS Age - Mixes 23.1 - 26

Length Change – Blended Aggregate Mixes 12, 13, 27.1, and 28

Blended aggregate mixtures and companion mixtures are as follows: Mix 12 and 5, Mix 13 and 6, Mix 27.1 and 20.1, Mix 28 and 21. Mixes 5, 6, 20.1, and 21 were produced before the blended aggregate mixtures in order to optimize water required to produce similar slump test results. The w/cm ratio of all of these mixtures was 0.48. The addition of the No. 8 gravel on average allowed a reduction in water of approximately one gallon per cubic yard. Figures 36 and 37 provide an illustration of shrinkage data for the blended aggregate mixtures along with their companion mixtures. In all cases, the addition of the No. 8 gravel to optimize aggregate gradation increases 224 day shrinkage even though water and cement are reduced relative to companion mixtures. The shrinkage of mixtures that use 75% Type I portland cement with 25% Class F fly ash were impacted most by aggregate blending with an average increase in shrinkage of 41 percent relative to their companion mixtures. The blended aggregate mixtures using 75% Type I portland cement with 25% Class C fly ash had an average increase in shrinkage of 9 percent relative to their companion mixtures. Mixtures using 75% Type I portland cement with 25% Class F fly ash had less shrinkage than mixtures using 75% Type I portland cement with 25% Class C fly ash.

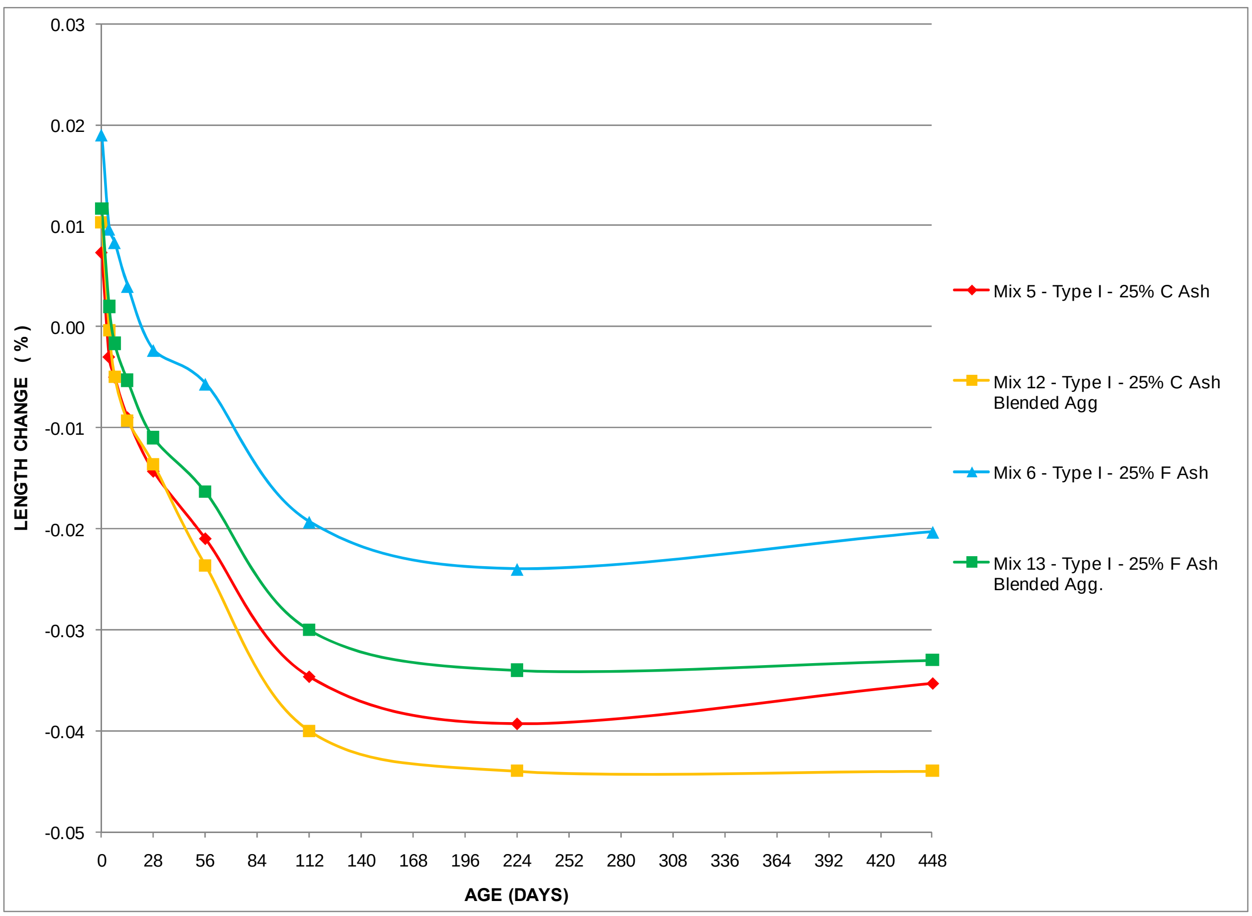

Figure 36: Average Length Change VS Age - Blended Aggregate Mixes 12 and 13

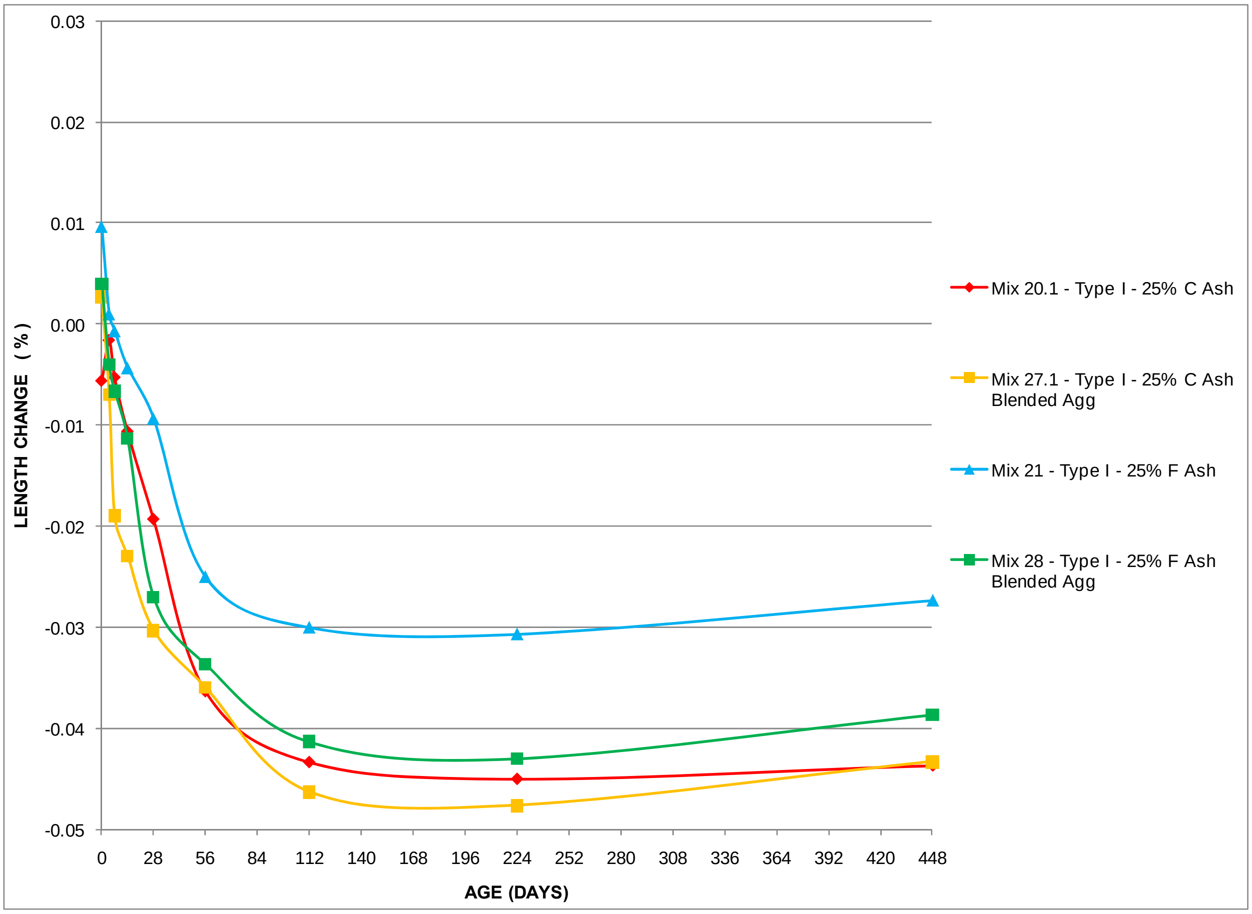

Figure 37: Average Length Change VS Age - Blended Aggregates Mixes 27.1 and 28

Length Change – MDOT BD Mixes 14, 15.1, 29, and 30

Mixes 14, 15.1, 29, and 30 incorporated MDOT's Class BD specifications for bridge deck concrete. Mixes 14 and 15.1 used 100% Type I portland cement. Mixes 15.1 and 30 used 50% Type I portland cement with 50% GGBFS. Shrinkage data for these mixtures are illustrated in Figure 38. The average 224 day shrinkage of mixes 14 and 29 was (-) 0.0475 percent. The average 224 day shrinkage of mixes 15.1 and 30 was (-) 0.0252 percent. MDOT Class BD mixtures that include 50% GGBFS on average have 53 percent of the 224 day shrinkage of similar MDOT Class BD mixtures with 100% Type I portland cement.

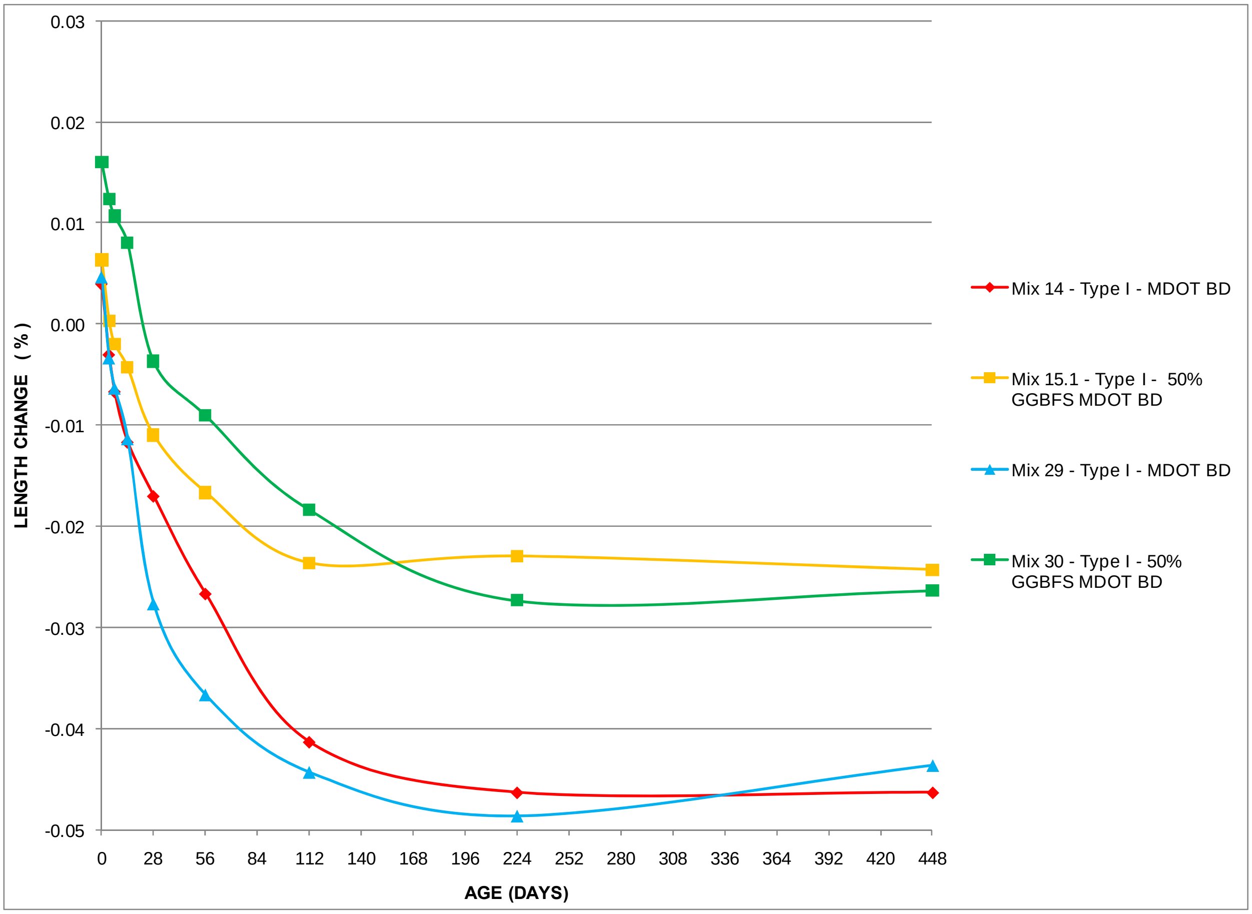

Figure 38: Average Length Change VS Age - MDOT BD Mixes 14, 15.1, 29, and 30

Shrinkage VS Cementitious Material and Total Cementitious Content

The influence of cementitious materials and total cementitious content on shrinkage is illustrated for all mixtures in Figures 39 and 40. These data indicate that high shrinkage mixtures can be produced with mixtures having high or low total cementitious content. High and low shrinkage mixtures can also be produced with the same total cementitious contents.

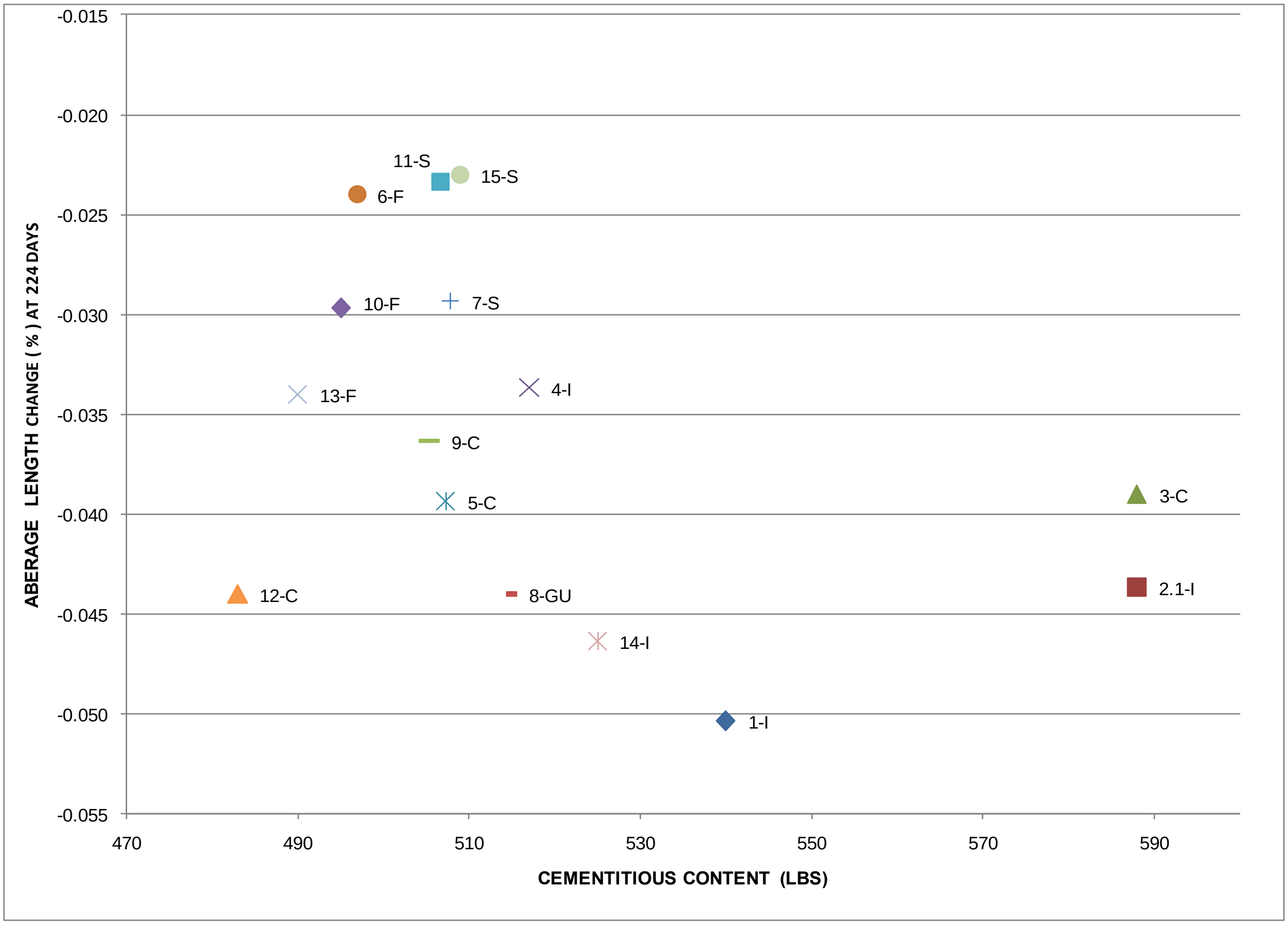

Figure 39: Average Length Change VS Cementitious Content - Mixes 1 -15

Notes for Figure 39: The number indicates mix number. I denotes 100% Type I portland cement, GU denotes 100% Type GU cement, C denotes mixes with 25% C ash, F denotes mixes with 25% F ash, and S denotes mixes with 50% GGBFS.

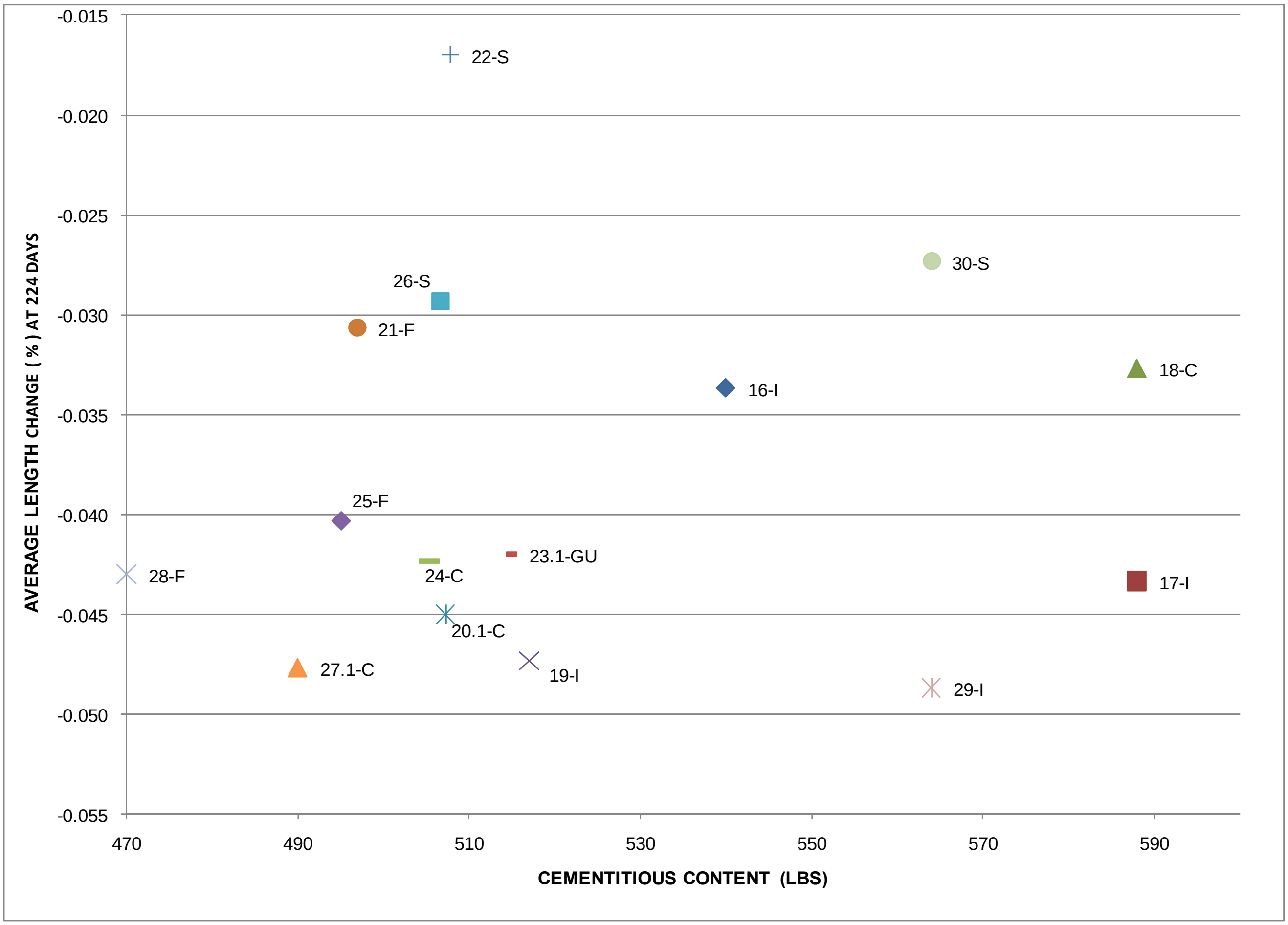

Figure 40: Average Length Change VS Cementitious Content - Mixes 16 – 30

Notes for Figure 40: The number indicates mix number. I denotes 100% Type I portland cement, GU denotes 100% Type GU cement, C denotes mixes with 25% C ash, F denotes mixes with 25% F ash, and S denotes mixes with 50% GGBFS.

Chloride Ion Penetrability

Average penetrability of concrete expressed in coulombs was determined at specimen ages of 28, 91, and 365 days for each mixture. A table indicating electrical charge passed in coulombs and concrete performance related to chloride ion penetration is presented in AASHTO T 277 and ASTM C 1202 standards. This table sets ranges for coulombs passed correlated with a rating for the concrete from negligible to high. Table 22 contains table “Chloride ion Penetrability based on Charge Passed” from AASHTO T 277 / ASTM C1202.

Table 22: Chloride Ion Penetrability based on Charge Passed

Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000 – 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very Low
<100	Negligible

Chloride Ion Penetrability Data

Chloride ion penetrability test results performed at 28 days are presented in Figure 41. Mix 20.1, using 75% Type I portland cement with 25% Class C ash, was the only mixture that had high chloride ion penetrability according to Table 22. All other 28 day results indicate moderate to very low chloride ion penetrability. Mixes 7, 11, 15.1, 22, 26, and 30 had very low chloride ion penetrability at 28 days and were the best performers. All of these best performing mixtures contained 50% GGBFS.

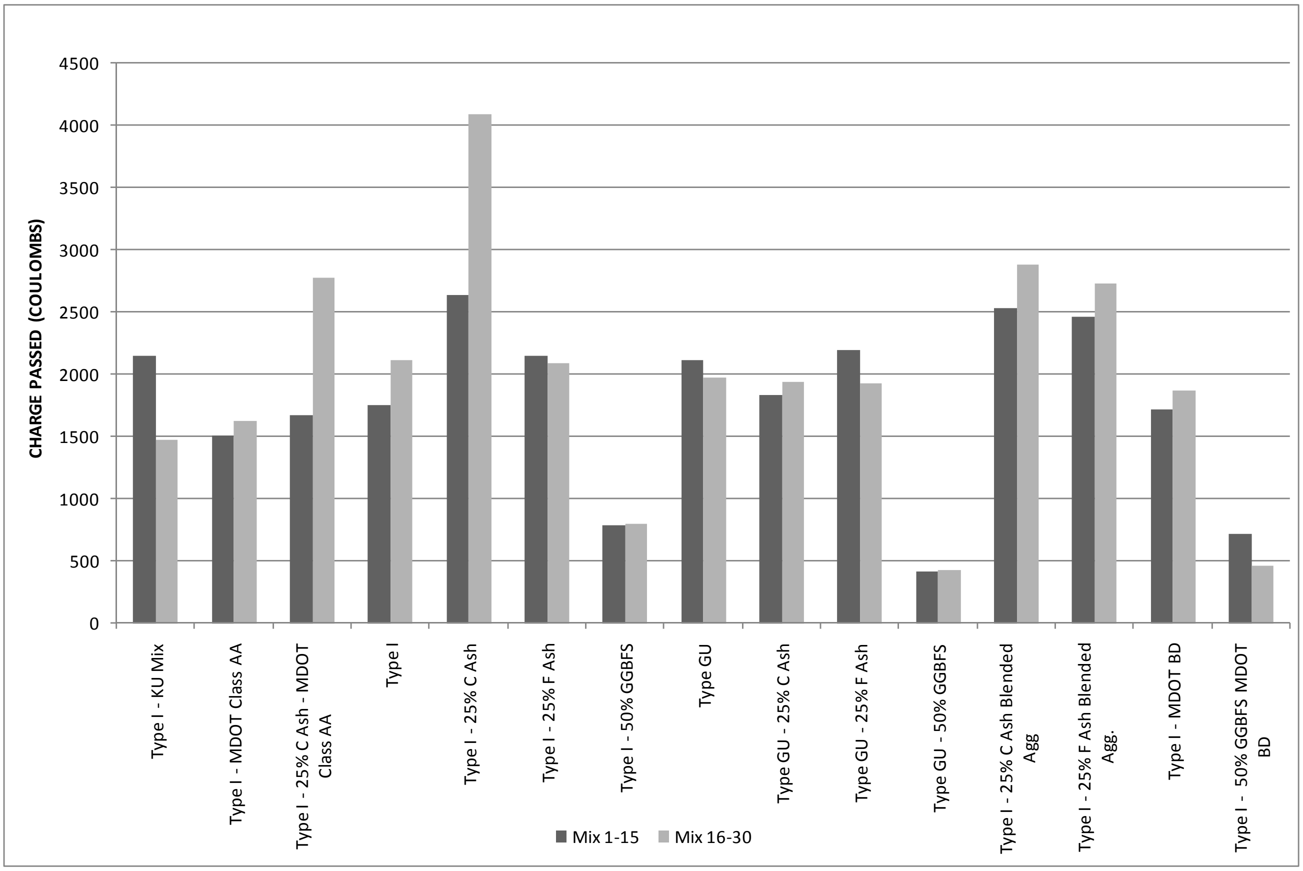

Figure 41: 28 Day Chloride Ion Penetrability - All Mixes

Chloride ion penetrability test results performed at 91 days are presented in Figure 42. All mixtures had low chloride ion penetrability at 91 days. Several mixtures had very low chloride ion penetrability including mixes 3, 6, 7, 10, 11, 13, 15.1, 21, 22, 24, 25, 26, and 30. All of these best performers contained SCMs. All mixtures with 50% GGBFS and all but one of the mixtures with 25% Class F fly ash had very low chloride ion penetrability. This one mixture was mix 28.

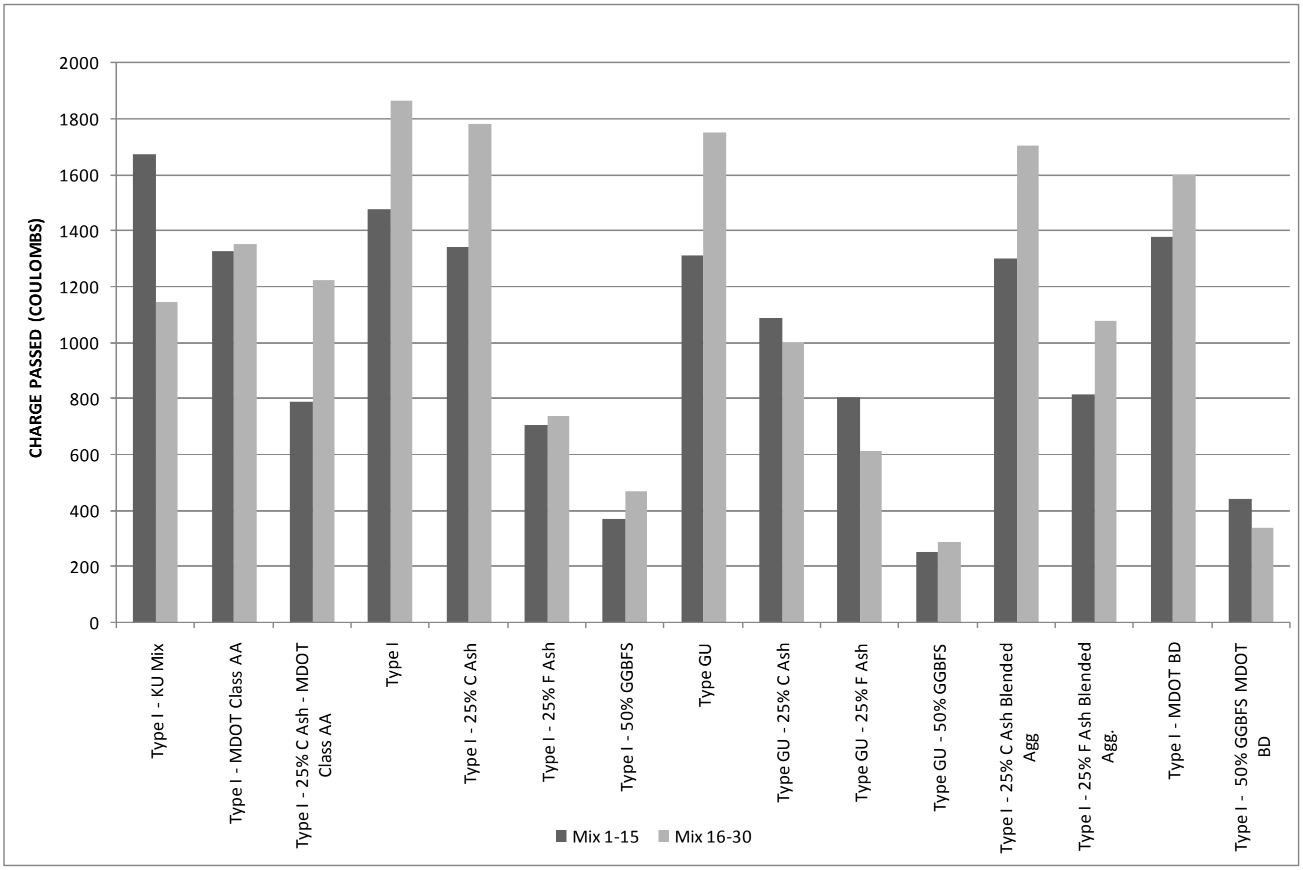

Figure 42: 91 Day Chloride Ion Penetrability - All Mixes

Chloride ion penetrability test results performed at 365 days are presented in Figure 43. Over half of the mixtures had very low chloride ion penetrability including mixes 3, 5, 6, 7, 9, 10, 11, 12, 13, 15.1, 18, 20.1, 21, 22, 25, 26, 28, and 30. All of these best performers contained SCMs. None of the mixtures in this study with 100% Type I or 100% Type GU cement achieved very low chloride ion penetrability. This included mixes 2.1 and 17 using MDOT Class AA criteria with a w/c ratio of 0.40.

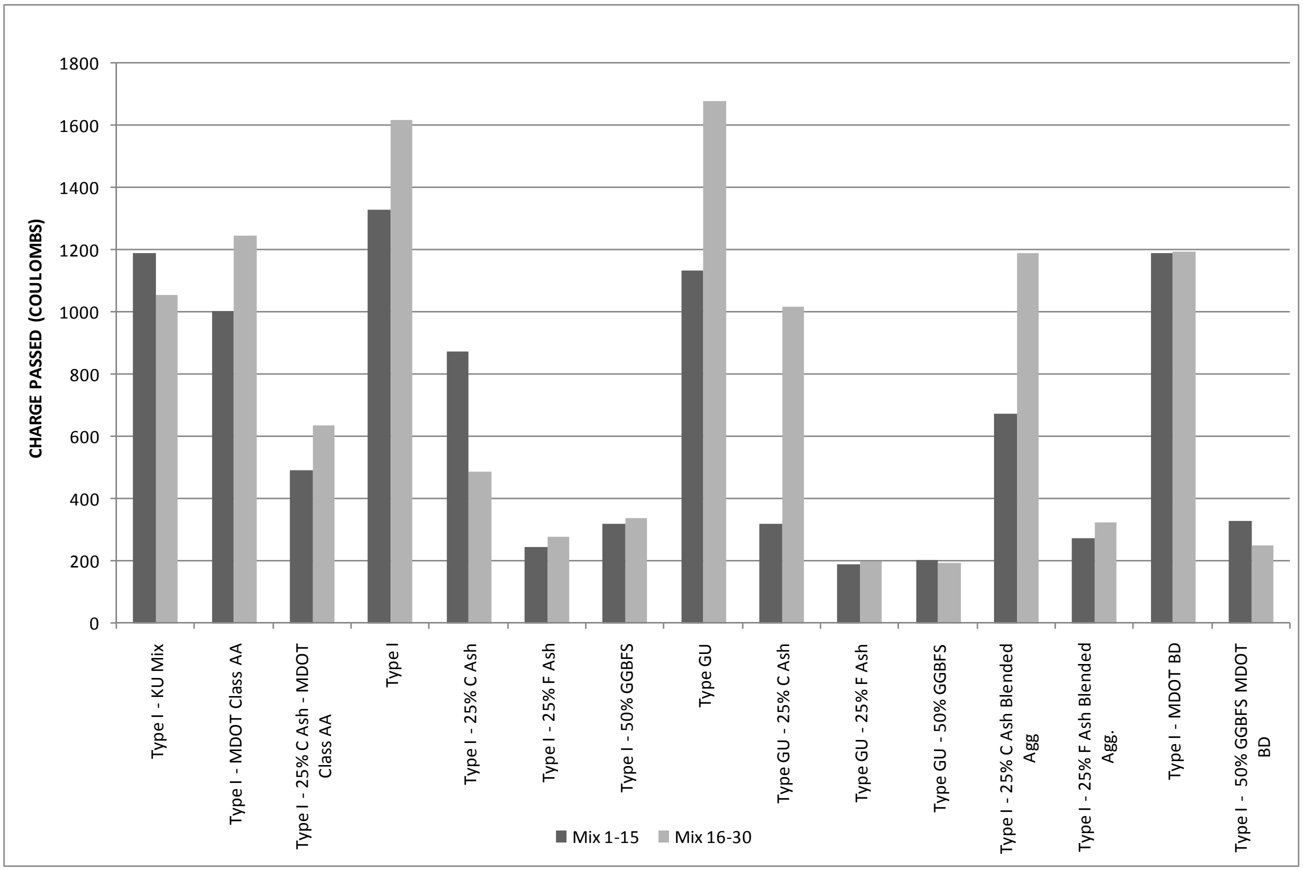

Figure 43: 365 Day Chloride Ion Penetrability - All Mixes

Table 23: Mixture Parameters, Plastic Properties, Test Results - Mixes 1-15.1 (Aggregate Source 1)

Mix Identifiers			Design Parameters			Plastic Properties				Test Results		
Mix No	Mixture Description	Aggregate Type	w/cm Ratio	Water Content lbs/yd³	Cementitious Content lbs/yd³	Paste Volume %	Slump In.	Air %	Unit Weight lbs/ft³	28 Day Compressive psi	28 Day Permeability Coulombs	224 Day Shrinkage %
1	Type I - KU Mix	Limestone	0.45	243.00	540.00	24.60%	3.25	7.00	144.2	5,420	2,151	-0.0503
2.1	Type I - MDOT Class AA	Gravel	0.40	235.20	588.00	25.04%	5.75	6.75	141.9	5,757	1,505	-0.0437
3	Type I - 25% C Ash - MDOT Class AA	Gravel	0.40	235.20	588.00	25.57%	2.25	6.50	142.5	5,207	1,668	-0.0390
4	Type I	Gravel	0.48	248.16	517.00	24.47%	5.50	6.25	142.8	5,603	1,749	-0.0337
5	Type I - 25% C Ash	Gravel	0.48	243.48	507.25	24.47%	6.75	6.25	141.4	5,080	2,638	-0.0393
6	Type I - 25% F Ash	Gravel	0.48	238.52	496.91	24.47%	5.50	6.00	140.6	4,333	2,149	-0.0240
7	Type I - 50% GGBFS	Gravel	0.48	243.79	507.90	24.47%	3.00	6.00	141.8	5,847	790	-0.0293
8	Type GU	Gravel	0.48	246.90	514.37	24.47%	4.00	7.00	139.5	5,423	2,112	-0.0440
9	Type GU - 25% C Ash	Gravel	0.48	242.57	505.35	24.47%	7.25	5.75	142.7	5,420	1,828	-0.0363
10	Type GU - 25% F Ash	Gravel	0.48	237.64	495.08	24.47%	6.75	5.50	142.0	4,970	2,196	-0.0297
11	Type GU - 50% GGBFS	Gravel	0.48	243.18	506.64	24.47%	6.00	7.00	140.8	6,187	415	-0.0233
12	Type I - 25% C Ash Blended Agg	Gravel	0.48	232.00	483.00	23.31%	6.50	6.00	142.0	5,430	2,526	-0.0440
13	Type I - 25% F Ash Blended Agg.	Gravel	0.48	235.00	490.00	24.12%	5.00	5.50	142.0	4,880	2,465	-0.0340
14	Type I - MDOT BD	Gravel	0.45	236.00	525.00	23.90%	2.50	7.50	139.7	4,713	1,717	-0.0463
15.1	Type I - 50% GGBFS MDOT BD	Gravel	0.45	229.00	509.00	23.61%	4.25	7.50	140.1	6,147	714	-0.0230

Table 24: Mixture Parameters, Plastic Properties, Test Results - Mixes 16-30 (Aggregate Source 2)

Mix Identifiers			**Design Parameters**			**Plastic Properties**				**Test Results**		
Mix No	**Mixture Description**	**Aggregate Type**	**w/cm Ratio**	**Water Content lbs/yd³**	**Cementitious Content lbs/yd³**	**Paste Volume %**	**Slump In.**	**Air %**	**Unit Weight lbs/ft³**	**28 Day Compressive psi**	**28 Day Permeability Coulombs**	**224 Day Shrinkage %**
16	Type I - KU Mix	Limestone	0.45	243.00	540.00	24.60%	2.25	8.15	145.2	4,843	1,474	-0.0337
17	Type I - MDOT Class AA	Gravel	0.40	235.20	588.00	25.04%	3.00	6.75	141.0	5,793	1,628	-0.0433
18	Type I - 25% C Ash - MDOT Class AA	Gravel	0.40	235.20	588.00	25.57%	4.25	6.00	139.3	5,620	2,778	-0.0327
19	Type I	Gravel	0.48	248.16	517.00	24.47%	3.25	6.50	140.8	6,363	2,109	-0.0473
20.1	Type I - 25% C Ash	Gravel	0.48	243.48	507.25	24.47%	4.75	5.25	140.8	5,697	4,088	-0.0450
21	Type I - 25% F Ash	Gravel	0.48	238.52	496.91	24.47%	3.25	6.00	141.8	5,303	2,093	-0.0307
22	Type I - 50% GGBFS	Gravel	0.48	243.79	507.90	24.47%	5.75	5.50	142.0	5,917	799	-0.0170
23	Type GU	Gravel	0.48	246.90	514.37	24.47%	4.25	6.00	142.0	6,127	1,972	-0.0420
24	Type GU - 25% C Ash	Gravel	0.48	242.57	505.35	24.47%	6.75	5.50	141.4	6,093	1,944	-0.0423
25	Type GU - 25% F Ash	Gravel	0.48	237.64	495.08	24.47%	8.00	5.50	140.7	5,010	1,930	-0.0403
26	Type GU - 50% GGBFS	Gravel	0.48	243.18	506.64	24.47%	6.75	6.00	142.1	6,507	424	-0.0293
27	Type I - 25% C Ash Blended Agg.	Gravel	0.48	235.00	490.00	23.63%	5.00	6.25	140.4	5,023	2,883	-0.0477
28	Type I - 25% F Ash Blended Agg.	Gravel	0.48	225.50	470.00	23.14%	2.75	6.00	141.2	5,073	2,723	-0.0430
29	Type I - MDOT BD	Gravel & Limestone	0.45	254.00	564.00	25.70%	3.75	7.50	139.8	6,017	1,865	-0.0487
30	Type I - 50% GGBFS MDOT BD	Gravel & Limestone	0.45	254.00	564.00	26.18%	3.50	6.50	141.3	6,980	464	-0.0273

Chapter 7 – Analysis of Shrinkage Data

Influence of SCMs on Shrinkage

SCMs appear to have a significant impact on shrinkage of the mixtures developed for this study. This influence is illustrated in Figure 44. A comparison can also be made between 100% Type I or 100% Type GU cement mixtures and mixtures containing SCMs by simply calculating average 224 day length change percentage for all mixtures with 100% cement, all mixtures with 25% Class C fly ash, all mixtures with 25% Class F fly ash, and all mixtures with 50% GGBFS. Mixtures with 25% Class C fly ash have average 224 day shrinkage of 94 percent of the average shrinkage of 100% cement mixtures. The data indicates a significant reduction in length change when averages are used to compare 25% Class F fly ash mixtures and 50% GGBFS mixtures with 100% cement mixtures. Mixtures with 25% Class F fly ash have average 224 day shrinkage of 78 percent of mixtures with 100% cement. Mixtures with 50% GGBFS have an average 224 day shrinkage of 58 percent of mixtures with 100% cement.

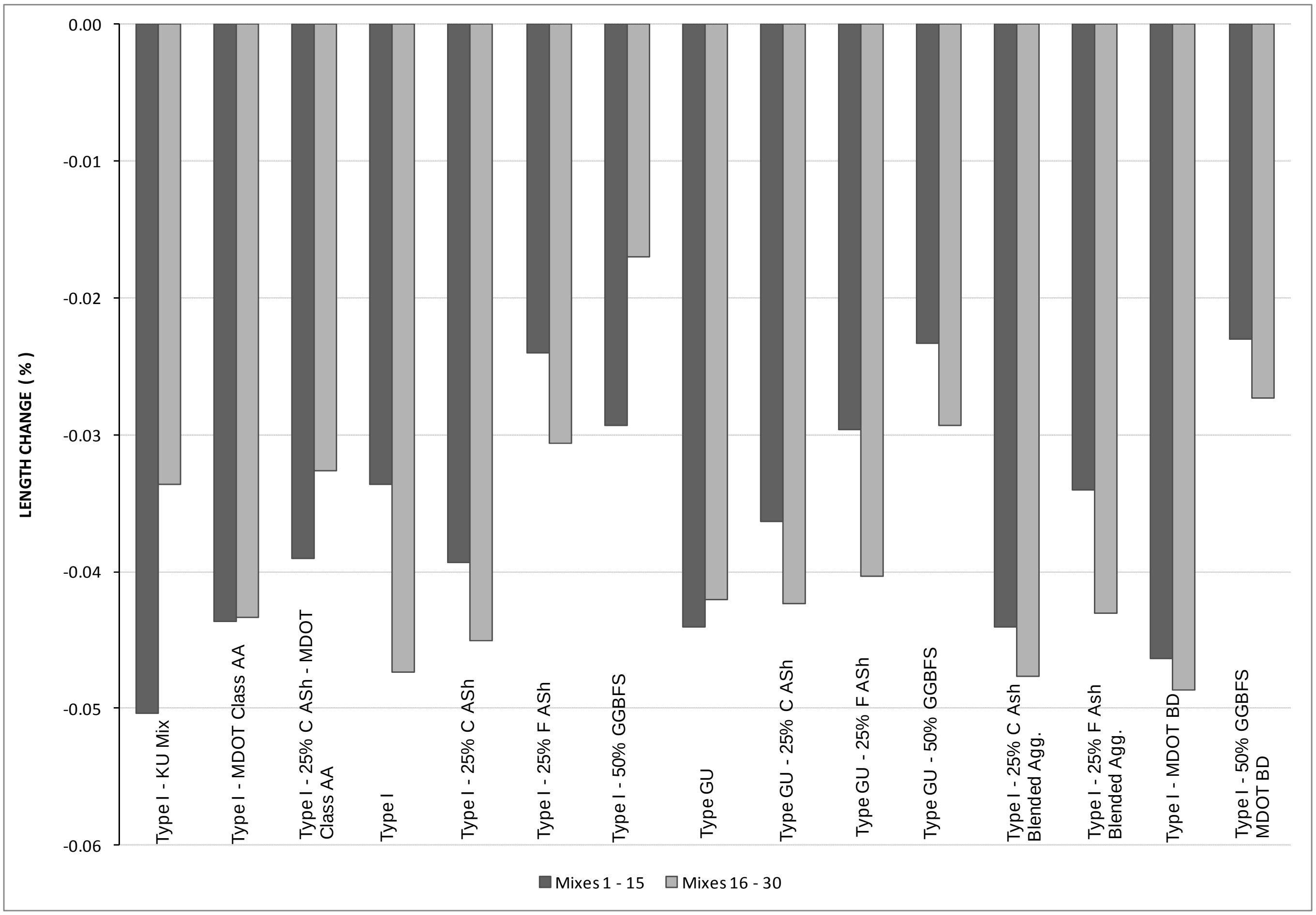

Figure 44: 224 Day Shrinkage For All Mixtures

Influence of Aggregate Gradation Optimization on Shrinkage

Aggregate gradation optimization was used in mix 1 and 16 (KU mixes) as a strategy to reduce cementitious paste and shrinkage. Aggregates for these mixtures comply with KDOT's specification for combined individual percent retained. CF and AWF of these mixtures are within Zone II (optimal) of the Coarseness Factor Chart. Mix 1 produced a length change of (-) 0.0503 percent at 224 days and this was the highest observed shrinkage when compared to all other mixtures. Mix 16 had a length change of (-) 0.0337 percent which was the lowest shrinkage observed when compared to all other mixtures using 100% Type I or 100% Type GU cement. The primary difference in mixes 1 and 16 was the absorption of the aggregates. Mix 1 had a combined aggregate absorption of 1.02 percent and mix 16 had a combined aggregate absorption of 0.61percent. This higher absorption may have influenced length change in these two mixes. Aggregates with high absorption may release more moisture during drying shrinkage compared to aggregates that have less absorption and this additional loss of moisture may result in higher length changes.

Aggregate gradation optimization was used in the MDOT Class BD concrete mixtures (mixes 14, 15.1, 29, 30), but was not used for MDOT Class AA mixtures (mixes 2.1, 3, 17, 18). A comparison can be made between these MDOT classes of concrete that utilized 100% Type I portland cement for influence on shrinkage. Figures 45 and 46 illustrate shrinkage associated with these mixtures. Mixes 14 and 29 were based on requirements of MDOT Class BD concrete and utilized the KU software to optimize these mixtures. CF and AWF were within MDOT's limits, but combined gradations do not meet MDOT's specification for combined individual percent retained because of the particle size distribution of Mississippi's natural gravel. Mixes 14 and 29 were similar mixes with different sources of gravel and different cement content. Mix 14 had 224 day shrinkage of (-) 0.0463 percent which was the second highest shrinkage when compared to all other 100% Type I or 100% Type GU cement mixtures using aggregate source number one. Mix number 29 had a 224 day shrinkage of (-) 0.0487 percent which was the highest shrinkage data when compared to all other 100% Type I or Type GU cement mixtures using aggregate source number two. MDOT Class BD mixtures using 100% Type I portland cement had an average 224 day shrinkage of (-) 0.0475 percent while MDOT Class AA mixtures with 100% Type I portland cement has an average 224 day shrinkage of (-) 0.0435. This slight increase in shrinkage of the MDOT Class BD over MDOT Class AA occurred even though MDOT Class BD mixtures had aggregate gradation optimization and lower cement contents. MDOT Class AA (w/cm = 0.40) has a lower w/c ratio than MDOT Class BD (w/cm = 0.45) and this lower w/cm appears to have influenced shrinkage as much as aggregate gradation optimization.

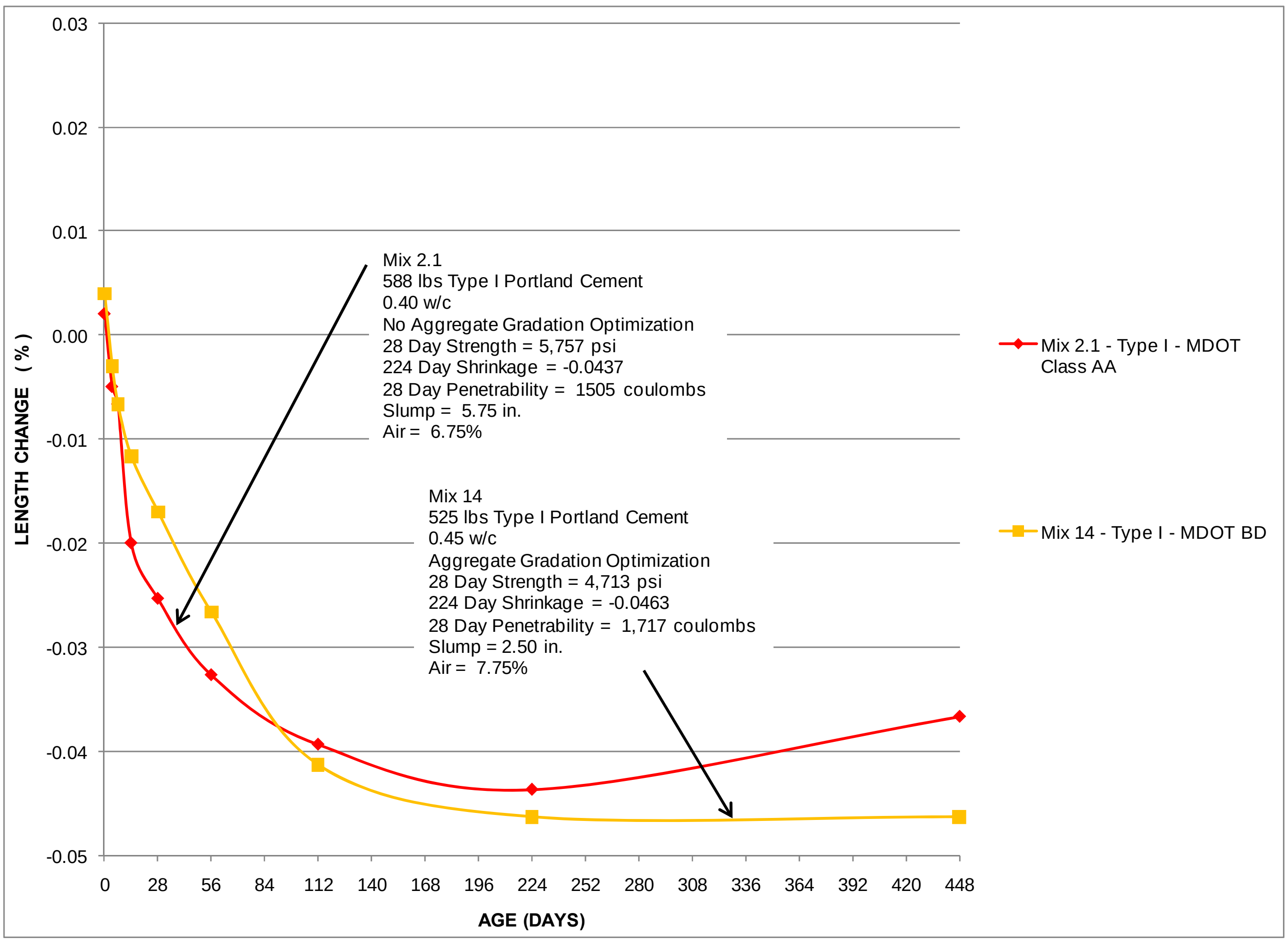

Figure 45: Average Length Change VS Age - Mixes 2.1 and 14

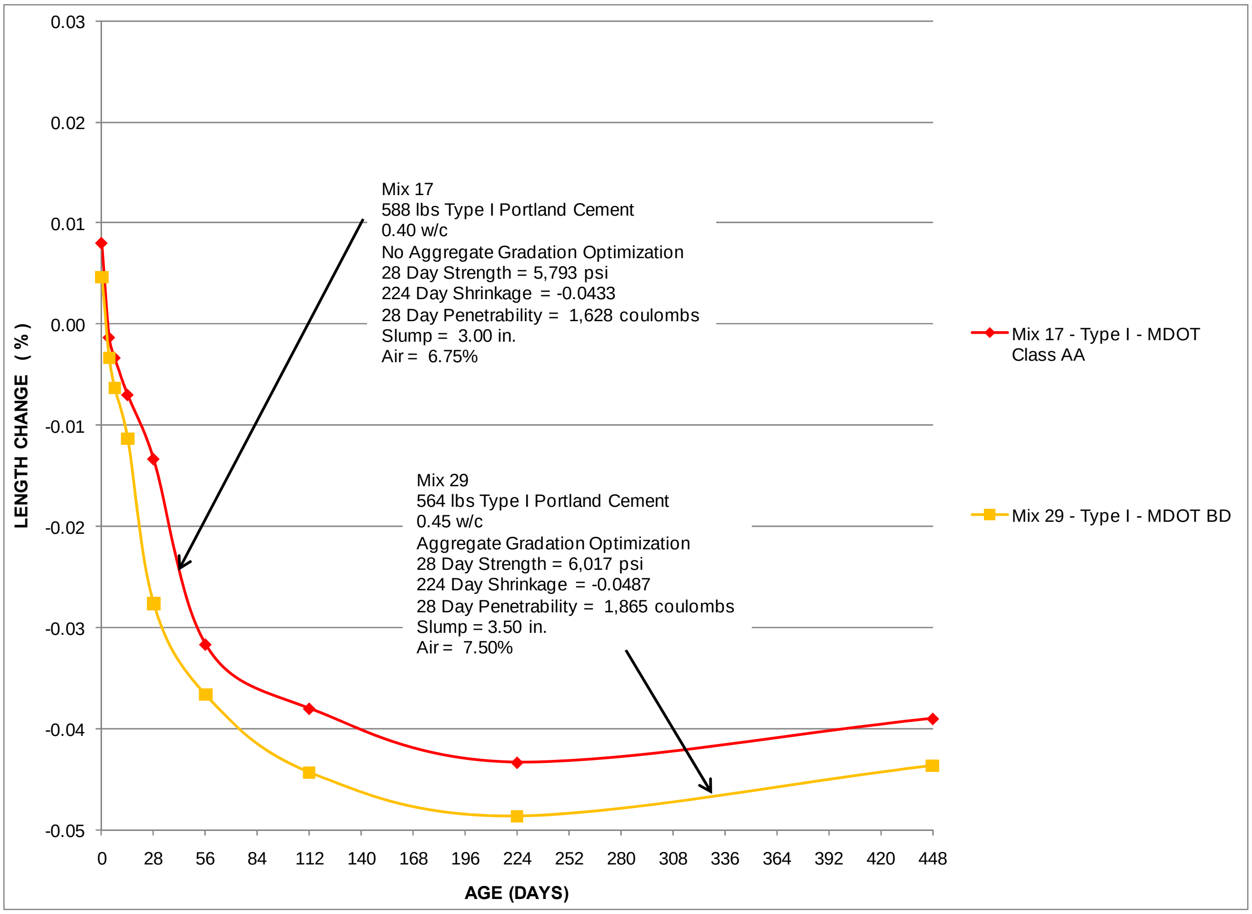

Figure 46: Average Length Change VS Age - Mixes 17 and 29

The blended aggregate mixtures, mixes 12, 13, 27.1 and 28, provided another example of increased shrinkage associated with aggregate gradation optimization. Figures 36 and 37 illustrate this increased shrinkage. This increase in shrinkage occurred by simply adding a No. 8 gravel to a No. 57 gravel. This increase in shrinkage occurred even after reducing water and cementitious content of the blended aggregate mixtures because of the increased workability achieved with the addition of the No. 8 gravel.

Data generated in this study also indicate that Mississippi gravel can produce low shrinkage mixes without the need for aggregate gradation optimization. This is illustrated in

Figure 47 by comparing shrinkage test results from mixes 4 and 16. The 224 day shrinkage was (-) 0.0337 percent for each of these mixtures even though mix 4 did not use aggregate gradation optimization and mix 16 used aggregate gradation optimization. Mix 16 was the best performing mixture for shrinkage of the two mixtures using the KU mix method. Four sizes of coarse limestone aggregate were used in this mixture in order to meet strict combined grading criteria. A 0.45 w/c ratio was used for mix 16 producing a 2.25 in. slump. On the other hand, mix 4 used Mississippi's typical concrete aggregates including a No. 57 gravel and concrete sand. Mix 4 provided the same shrinkage results as mix 16, a higher compressive strength than mix 16, and produced 3.25 inches more slump than mix 16.

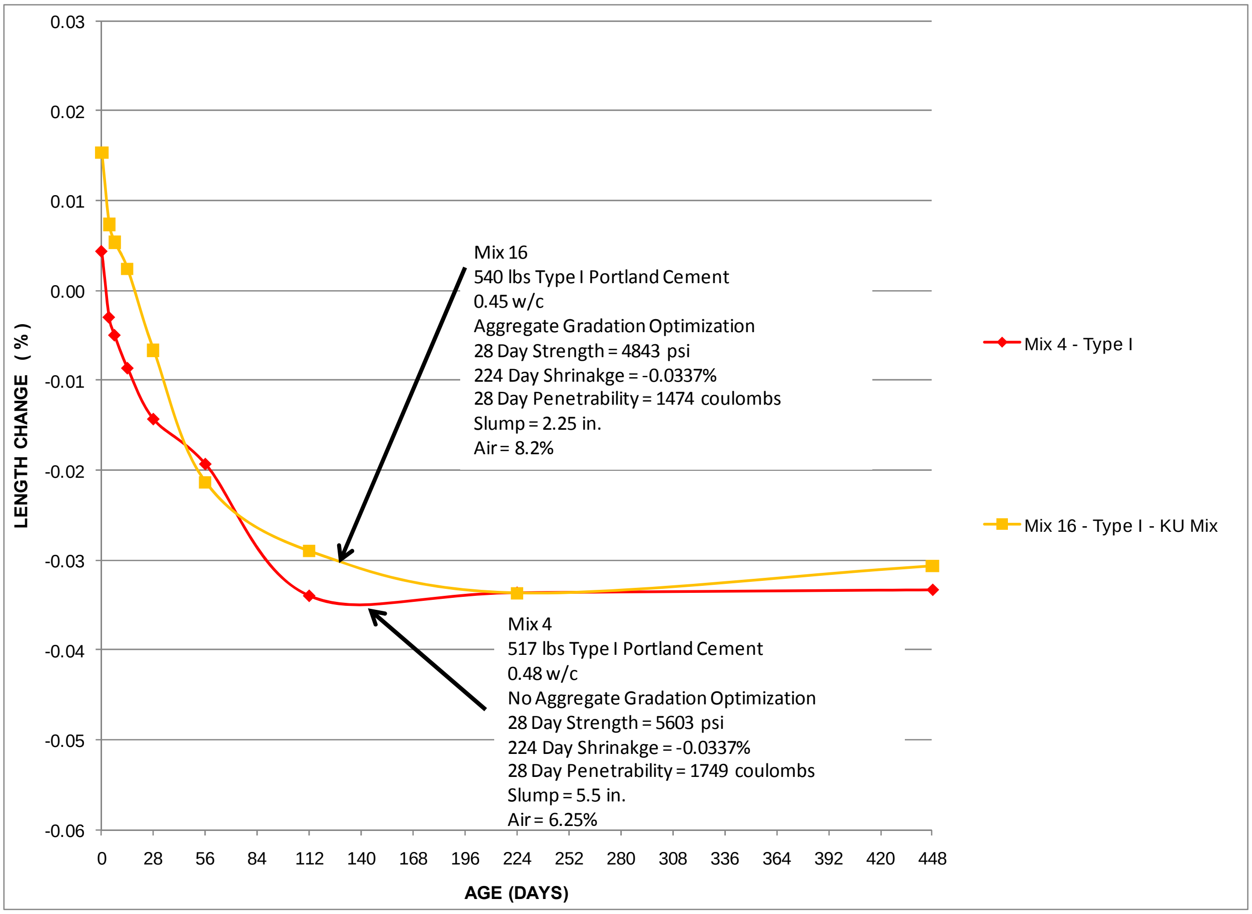

Figure 47: Shrinkage VS Age - Mixes 4 and 16

From the data obtained in this study, aggregate gradation optimization can produce both low shrinkage and high shrinkage test results. Aggregate gradation optimization may also increase shrinkage as seen in the blended aggregate mixtures (mixes 12, 13, 27.1, and 28). Mixtures made with Mississippi gravel without aggregate gradation optimization can provide shrinkage results that are as good as mixtures made with crushed limestone and aggregate gradation optimization.

Chapter 8 - Statistical Analysis

A portion of the mixtures tested provided a balanced factorial design that allowed a statistical evaluation of the ultimate penetrability results and the ultimate shrinkage results. The experimental design (Table 25) for these mixtures included three factors including: gravel source, cement type and SCM type. The gravel source factor included two levels: Source 1 and Source 2. The cement type factor also included two levels: Type I portland cement and Type GU cement. Four levels of the SCMs factor were included: 25% Class C ash, 25% Class F ash, 50% GGBFS and none.

Table 25: Experimental Design Including Factors and Levels

Mix ID	Gravel Source	Cement Type	SCM Type
4	Source 1	Type I	None
5		Type I	25% C Ash
6		Type I	25% F Ash
7		Type I	50% GGBFS
8		Type GU	None
9		Type GU	25% C Ash
10		Type GU	25% F Ash
11		Type GU	50% GGBFS
19	Source 2	Type I	None
20.1		Type I	25% C Ash
21		Type I	25% F Ash
22		Type I	50% GGBFS
23.1		Type GU	None
24		Type GU	25% C Ash
25		Type GU	25% F Ash
26		Type GU	50% GGBFS

An analysis of variance (ANOVA) was conducted to determine the effect of gravel source, cement type and SCM type on the measured response variables (ultimate penetrability and ultimate shrinkage). Table 26 presents the results of the ANOVA for the 365 day penetrability test results. Results of this ANOVA show that all of the factors had a significant effect on the ultimate penetrability test results as well as most interactions.

Table 26: Results of ANOVA for 365 Day Penetrability Test Results

Source	Degrees of Freedom	Mean Squares	F-Ratio	Probability Level	Significant Y/N*
A: Gravel Source	1	178,617	30.10	0.000	Y
B: Cement Type	1	31,186	6.27	0.024	Y
C: SCM Type	3	2,534,757	427.09	0.000	Y
AB	1	205,884	34.69	0.000	Y
AC	3	71,978	12.13	0.000	Y
BC	3	4,771	0.80	0.510	N
ABC	3	136,608	23.02	0.000	Y
Total	31				

* 0.05 level of significance

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 statistics. With regards to the three main factors within the experimental design, the SCM type had the most impact on the resulting ultimate penetrability (highest F-ratio). The factor having the next highest impact on the ultimate penetrability was gravel source. The cement type had the least impact on ultimate penetrability results; however, the effect of cement type was shown significant.

Once an ANOVA has shown that a factor significantly impacts a response variable, another useful statistical tool is a Duncan's Multiple Range Test (DMRT). The DMRT is useful by ranking the impact of the levels within a main factor and showing which levels are significantly different. Table 27 presents the results of the DMRT rankings for the ultimate penetrability test results. Within the rankings, means having different letter designations are significantly different. Likewise, means having the same letter are statistically similar.

Table 27: Results of DMRT Rankings for 365 Days Penetrability Test Results

Factor	Level	Mean Result (coulombs)	DMRT Ranking *
Gravel Source	Source 1	576.4	A
	Source 2	725.8	B
Cement Type	Type I	617.0	A
	Type GU	685.2	B
SCM	25% F Ash	227.5	A
	50% GGBFS	263.5	A
	25% C Ash	674.5	B
	None	1,438.7	C

* Rankings with the same letter are similar

For durability, lower penetrability values are desired. Because there were only two levels for the gravel source and cement type factors and the ANOVA showed that these two factors were significant, it is not surprising that the two levels within these two factors were ranked differently by the DMRT. Figure 48 graphically illustrates the results of the average ultimate penetrability tests for each level of gravel source and cement type factors. As shown by the DMRT rankings and Figure 48, mixes utilizing Gravel Source 1 had lower penetrability results than mixes with Gravel Source 2 suggesting that mixtures prepared with Gravel Source 1 were more durable. The DMRT rankings and Figure 48 also show that mixes prepared with the Type I portland cement had lower penetrability values than those mixtures prepared with Type GU cement.

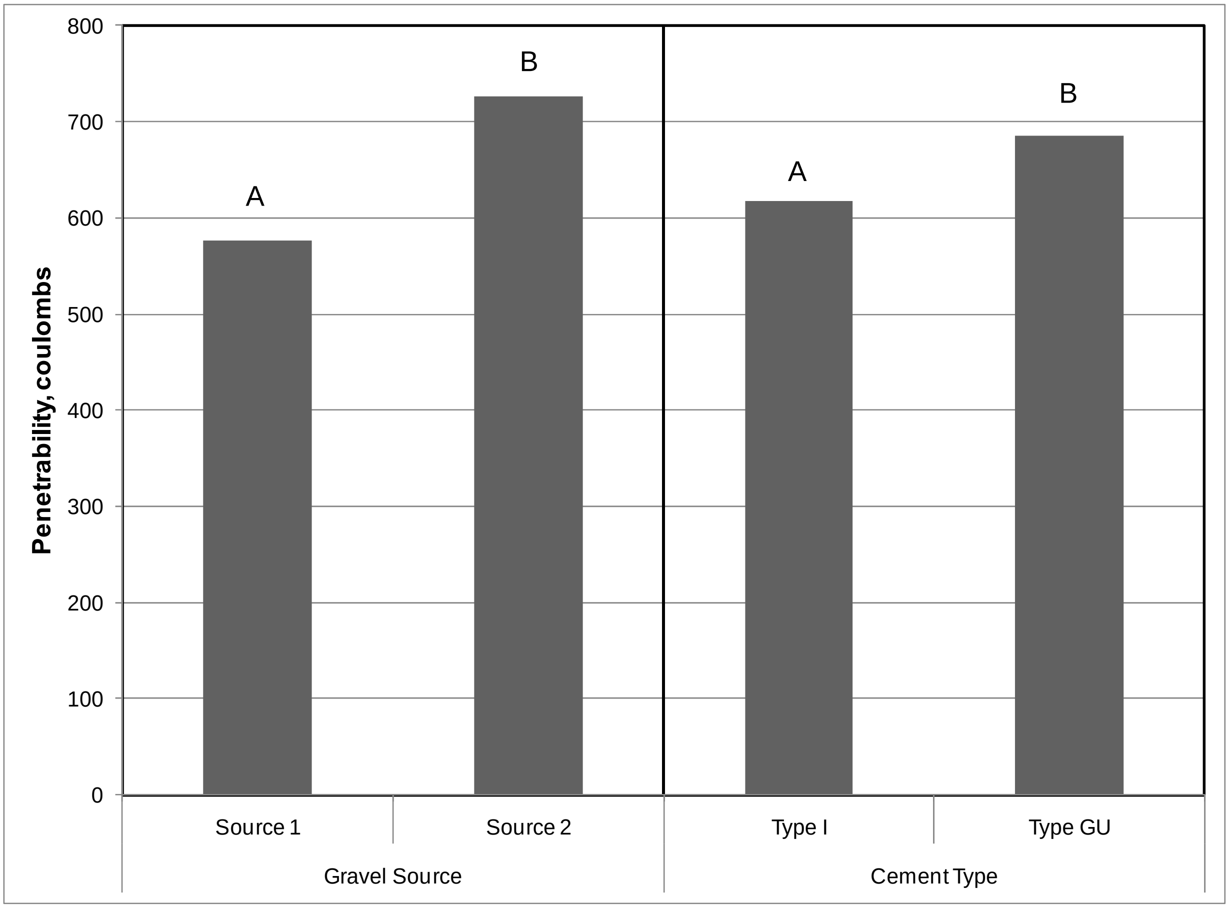

Figure 48: Means and DMRT Rankings for Gravel Source and Cement Type - Penetrability

Figure 49 shows that DMRT results graphically for the SCM factor. Based upon the DMRT rankings, the mixtures containing 25% F Ash and 50% GGBFS had similar penetrability values which were significantly lower than mixes with 25% C Ash and no SCM. The lower penetrability values suggest that mixture containing 25% F Ash and 50% GGBFS are more durable than mixes with Class C Fly Ash or no SCM. Another observation from Figure 49 is that the addition of 25% Class C Fly Ash did significantly lower penetrability compared to no SCM.

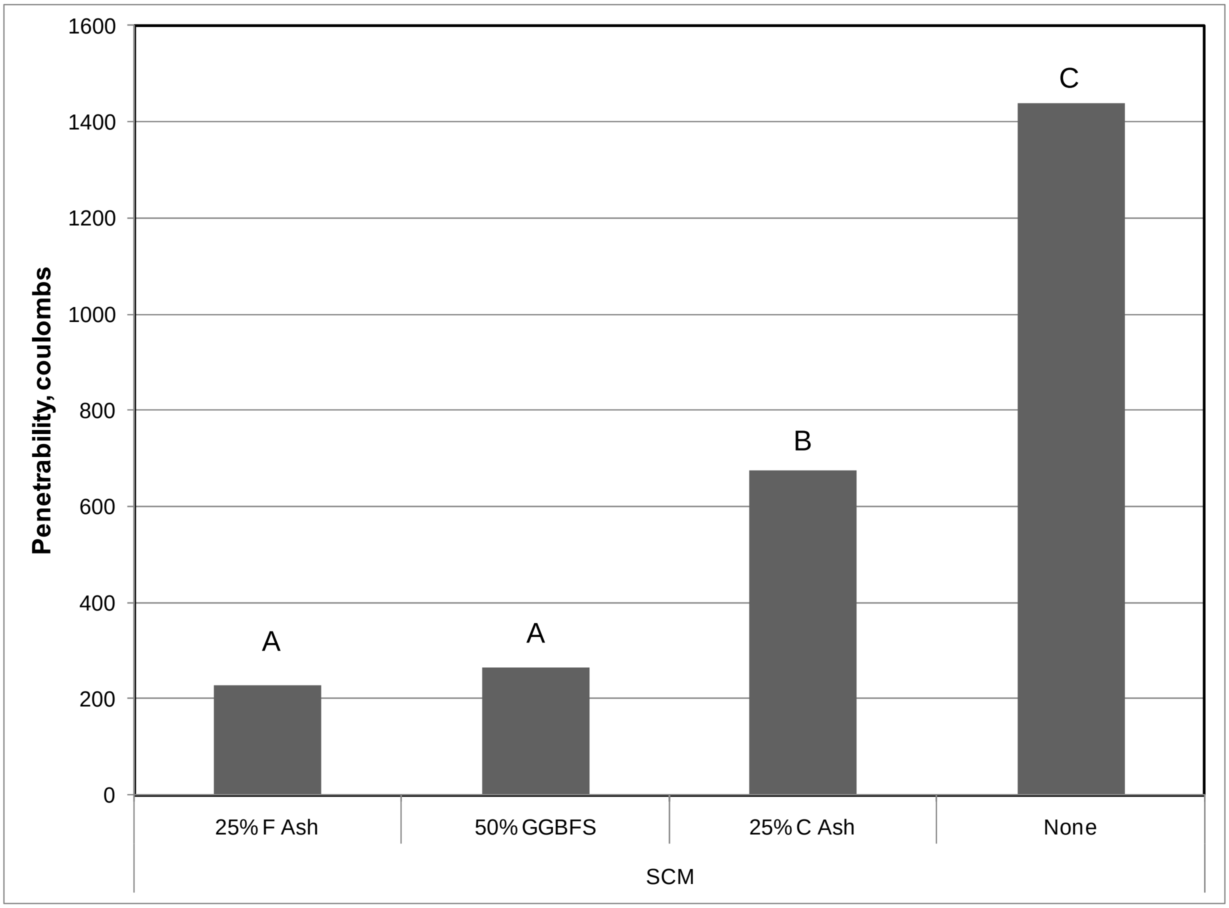

Figure 49: Means and DMRT Rankings for SCM Type - Penetrability

Table 28 presents the results of the ANOVA conducted on the ultimate shrinkage test results. Based upon Table 28, the gravel source and type SCM significantly affected ultimate shrinkage test results. Cement type did not significantly affect ultimate shrinkage. Based upon the F-ratios, the type of SCM had the most impact on ultimate shrinkage test results.

Table 28: Results ANOVA for 224 Day Shrinkage Test Results

Source	Degrees of Freedom	Mean Squares	F-Ratio	Probability Level	Significant Y/N*
A: Gravel Source	1	2.210 E-04	5.79	0.022	Y
B: Cement Type	1	8.268 E-05	2.17	0.151	N
C: SCM Type	3	7.910 E-04	20.73	0.000	Y
AB	1	9.188 E-06	0.24	0.627	N
AC	3	7.952 E-05	2.08	0.122	N
BC	3	5.552 E-05	1.45	0.245	N
ABC	3	1.463 E-04	3.83	0.019	Y
Total	47				

* 0.05 level of significance

Similar to the analysis for the penetrability results, a DMRT was conducted for the factors found significant (gravel source and SCM type). Results of the DMRT rankings are presented in Table 29 and illustrated in Figure 50. Based upon the test method, higher percentages of shrinkage (i.e., less negative values) are considered to be better with respect to durability. Based upon Table 29 and Figure 50, mixtures containing Gravel Source 1 had lower percentages of shrinkage than mixtures containing Gravel Source 2. Also, mixtures containing 50% GGBFS performed better than mixtures containing the other three SCM types. Mixtures containing 25% Class F fly ash performed better than mixtures with Class C fly ash and mixtures with no SCM's. The addition of 25% percent Class C ash did not affect the shrinkage results when compared to no SCM.

Table 29: Results of DMRT Rankings for 224 Day Shrinkage Test Results

Factor	Level	Mean Result (%)	DMRT Ranking *
Gravel Source	Source 1	-0.0325	A
	Source 2	-0.0368	B
SCM Material	50% GGBFS	-0.0248	A
	25% F Ash	-0.0312	B
	25 % C Ash	-0.0408	C
	None	-0.0418	C

* Rankings with the same letter are similar

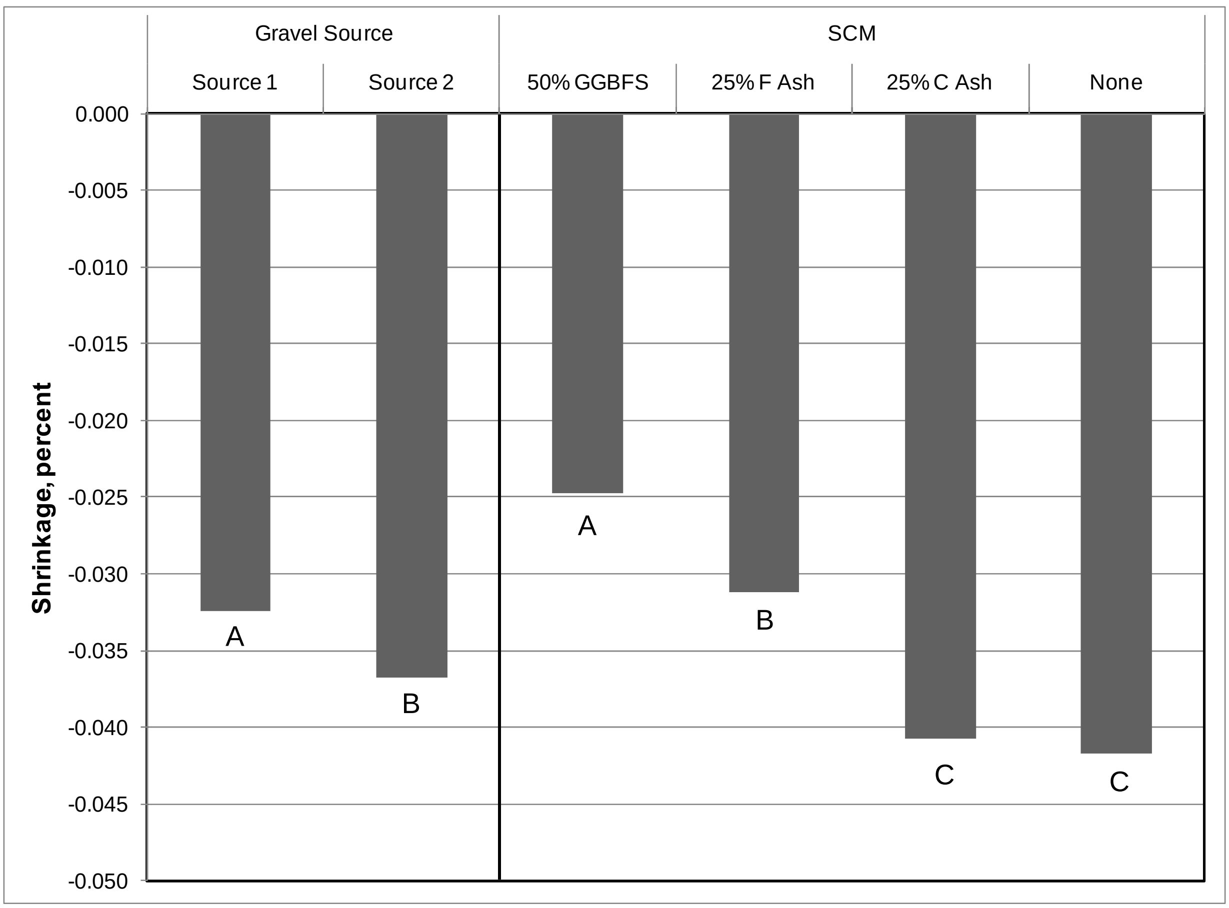

Figure 50: Means and DMRT Rankings for Gravel Source and SCM Type - Ultimate Shrinkage

Chapter 9 - Conclusions and Recommendations

Conclusions and recommendations are based on data sets generated from mixture proportions and materials used in this research. These data represent results from mixtures that use cementitious materials from one source including: one source of Type I portland cement, one source of Type GU cement (from a different supplier than the Type I portland cement), one source of Class C fly ash, one source of Class F fly ash and one source of GGBFS. Conclusions and recommendations may not be applicable for mixtures made with any other sources of materials or other mixture proportions than those in this study. Cementitious source-specific trends could be more critical than one class of materials verses another and this has not been investigated in this study.

Conclusions

The study showed that including SCMs in mixtures increases concrete's ability to resist chloride ion penetration and reduce the length change (shrinkage) of concrete materials.

Replacing cement with 25% Class C fly ash produces on average 94 percent of the shrinkage of mixtures with 100% Type I or 100% Type GU cement. Replacing cement with 25% Class F fly ash produces, on average, 78 percent of the shrinkage of mixtures with 100% Type I or 100% Type GU cement. Replacing cement with 50% GGBFS produces, on average, 58 percent of the shrinkage of mixtures with 100% Type I or Type GU cement.

Permeability / penetrability was significantly reduced in mixtures containing 25% Class C fly ash, 25% Class F fly ash, or 50% GGBFS compared to mixtures with 100% Type I or 100% Type GU cement. Chloride ion penetrability test results performed at 365 days indicate that all but one mixture (mix 27.1) containing these SCMs achieved very low chloride ion penetrability and none of the mixtures with 100% Type I or 100% Type GU cement achieved very low chloride ion penetrability. Mixtures with 25% Class F fly ash or 50% GGBFS provided the lowest penetrability test results providing the most durable mixtures.

Mixtures incorporating aggregate gradation optimization to maximize aggregate content and reduce cement paste content were also evaluated in this study. Results varied from best performers to worst performers when evaluating its influence on shrinkage. Aggregate gradation optimization did not have as much influence on length change as the use of SCMs. Mixtures using common Mississippi concrete aggregates including No. 57 gravel and concrete sand performed as good as or better than mixtures with aggregate gradation optimization with respect to shrinkage. Aggregate gradation optimization may increase shrinkage as indicated with the blended aggregates category of mixtures.

Recommendations

MDOT Class BD concrete specifications at the time of this study allow for either 100% portland cement mixtures or mixtures with up to 50% GGBFS to a replace portland cement. MDOT BD specifications at the time of this study do not currently allow the use of either Class C or Class F fly ash. We recommend that MDOT re-evaluate the usefulness of fly ash in reducing shrinkage and reducing permeability of concrete for bridge decks.

MDOT Class BD specifications require aggregate gradation optimization to increase workability and reduce shrinkage. We recommend that MDOT consider that the natural grading of Mississippi gravel aggregates can produce mixtures with good workability and low shrinkage characteristics without aggregate gradation optimization.

Research Opportunities

1. Shrinkage data for mix 1 and 16 indicate that aggregate absorption may have a significant influence on shrinkage. A research project should be conducted to determine if aggregate absorption has a significant impact on shrinkage.

2. This study provides data that indicate that supplementary cementitious materials have a significant influence in reducing shrinkage and permeability of concrete mixtures. A research project should be conducted to generate data to evaluate the influence of sources of cementitious materials on shrinkage and permeability.

3. Metakaolin, silica fume, and other pozzolans may also reduce shrinkage and permeability of concrete. These products are often available in bags that can be used in rural areas where concrete plants are limited to one silo for cementitious materials. A research project should be conducted to determine the usefulness of other supplemental cementitious materials in reducing shrinkage and permeability.

References

1. Steven H. Kosmatka, Beatrix Kerkhoff, and William C. Panarese. “Design and Control of Concrete Mixtures,” 14th Edition – Portland Cement Association.
2. Sidney Mindess and J. Francis Young. “Concrete.” Prentice-Hall, Inc., Englewood Cliffs, N.J. 1981
3. David N. Richardson. “Aggregate Gradation Optimization-Literature Search.” University of Missouri-Rolla. January 2005.
4. Abdol R. Chini, Larry C. Muszynski, and Jamie Hicks. “Determination of Acceptance Permeability Characteristics for Performance-Related Specifications for Portland Cement Concrete.” M.E. Rinker, Sr. School of Building Construction University of Florida. July 2003
5. Kansas Department of Transportation Special Provision to the Standard Specifications 1990 Edition: Section 402: Low Cracking High Performance Concrete.
6. KU Mix 2.1 BETA 1 Software. University of Kansas CEAE Department. Available at www.iri.ku.edu.
7. Mississippi Department of Transportation Special Provision No. 907-804-9. Project BR-0022-02(049) / 104632301 – Neshoba County
8. Mississippi Department of Transportation. 804 Specifications “Concrete Bridges and Structures.”
9. Mississippi Department of Transportation. “Concrete Field Manual.” August 2008.
10. ACI Committee 302, “Guide for Concrete Floor and Slab Construction. (ACI 302.1R-04).” American Concrete Institute, Farmington Hills, MI. pp 30-34.

11. ACI Committee 209. “Factors Affecting Shrinkage and Creep of Hardened Concrete. (ACI 209.1R-3).” American Concrete Institute, Farmington Hills, MI. pp 5-7.

12. ACI Committee 201. “Guide to Durable Concrete. (ACI 201.2R-08.” American Concrete Institute, Farmington Hills, MI. pp 17 – 22.

13. W. Calvin McCall, Michael E. King, and Michael Whisonant. Concrete International “Effects of Aggregate Grading on Drying Shrinkage of Florida Concretes.” March 2005

14. Karthik H. Obla and Haejin Kim. Concrete International “On Aggregate Grading – Is good concrete performance dependent on meeting grading limits?” March 2008.

Appendix A

Raw Data of Concrete Mixtures

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT** | Project: **BCD 080739** | Lab #: **BCD**

MIX NUMBER: Mix 1 | Notes: **Type I - KU Mix** | Set #: Mix 1

Date: **3/17/2009** | Mix Code: | f'c: **4,000 psi** | Size(c.f.): **1.50** | Factor: **0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.75	540.00	30.00	30.00	30.00	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	5.58	915.90	50.88	52.49	52.49	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	1.44	238.00	13.22	13.23	13.23	No 4 Limestone Source 1	2.651	1.33%	7.86
Coarse Aggregate 2:	6.44	1081.00	60.06	60.64	60.64	No 57 Limestone Source 1	2.690	0.97%	6.84
Coarse Aggregate 3:	2.63	438.00	24.33	24.66	24.66		2.673	1.37%	5.52
Coarse Aggregate 4:	2.12	344.00	19.11	20.45	20.45	No 11 Limestone Source 1	2.604	2.43%	3.26
Air: 8.00%	2.16	0.00	0.00	0.00	0.00				
Water:	3.89	243.00	13.50	9.63	9.63		1.00		
"+-Air: 1.00%									
Total:	27.00	3799.90	211.11	211.11					
UW w/o Air:		152.98	152.98	152.98					

Comments / Notes / Observations

Slump 1 1/2 to 3". 13 ml max for air. 44 ml max for water reducer. Water 64.5. Sensor 1.

Strength Test Results

Date	AGE (4x8 CYLINDERS)	psi	Avg. psi
03/18/09	1 days	2260	2260
	1 days		
03/24/09	7 days	4370	4355
	7 days	4340	
03/31/09	14 days	4970	4980
	14 days	4990	
04/14/09	28 days	5710	5420
	28 days	5300	
	28 days	5250	
05/12/09	56 days	4570	5190
	56 days	5810	

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	1.18	6.4	188.4	10.5	10.5	
WR Type A	4.96	26.8	792.1	44.0	44.0	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.16%	1.60
CA 1	0.09%	0.01
CA 2	0.99%	0.59
CA 3	1.37%	0.33
CA 4	7.16%	1.34

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	11:56 AM	% Air	7.00
Sample Time	12:11 PM	Unit Weight (pcf)	144.24
Slump, in.	3.25	Yield	1.46
Mix Temp.	74.0	Initial set, min.	NA
Air Temp.	76.0	Relative Yield	0.976

OTHER INFO

Des. w/c	0.450
Act. w/c	0.450
Des.Un.Wt.	140.74
Fine/Coarse	0.72
Bag Factor	5.7

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	30.00	1	30.00	24.598%
Cementitious 2:	0.00	1	0.00	
Sand #1:	52.49	2	26.24	30.359%
Coarse Aggregate 1:	13.23	1	13.23	7.889%
Coarse Aggregate 2:	60.64	2	30.32	35.831%
Coarse Aggregate 3:	24.66	1	24.66	14.518%
Coarse Aggregate 4:	20.45	1	20.45	11.402%

	Air	Un. Wt.	Bucket Full
Low Range	7.00%	142.16	43.30
Design Un. Wt	8.00%	140.74	42.94
High Range	9.00%	139.34	42.60
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.82		
Theoretical Air	5.71		

Workability / Coarseness

CF Actual	59.1	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	34.8	Within MDOT Limits
CF upper limit	73.4	Positive
CF lower limit	48.6	Positive
WF Actual	35.5	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 2.1	Notes:	Type I - MDOT Class AA	Set #:	Mix 2.1
Date:	5/28/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.99	588.00	32.67	32.67	32.67	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.46	1060.82	58.93	61.13	61.13	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	107.31	107.31	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Air: 6.00%	1.62	0.00	0.00	0.00	0.00				
Water:	3.77	235.20	13.07	10.17	10.17		1.00		
"+-Air: 0.50%									
Total:	27.00	3803.02	211.28	211.28					
UW w/o Air:		149.84	149.84	149.84					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	3.1	90.4	5.0	5.0	
WR Type A	4.00	23.5	695.6	38.6	38.6	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.74%	2.20
CA 1	0.67%	0.70
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	1:41 PM	% Air	6.75
Sample Time	1:49 PM	Unit Weight (pcf)	141.88
Slump, in.	5.75	Yield	1.49
Mix Temp.	73.4	Initial set, min.	NA
Air Temp.	72.4	Relative Yield	0.993

OTHER INFO

Des. w/c	0.400
Act. w/c	0.400
Des.Un.Wt.	140.85
Fine/Coarse	0.55
Bag Factor	6.3

Comments / Notes / Observations

Slump 2 1/4 to 3 3/4. Air 5 1/2% to 6 1/2%. Water 67. Slump 5.75. Slump after 7 minutes 4.0. Sensor 3.

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
05/29/09	1 days	2720	2615
	1 days	2510	
06/04/09	7 days	4840	4920
	7 days	5000	
06/11/09	14 days	5660	5500
	14 days	5340	
06/25/09	28 days	5460	5757
	28 days	6060	
	28 days	5750	
07/23/09	56 days	6390	6355
	56 days	6320	

Technician who conducted tests:

Material	Design	Buckets	Weight	Paste Vol
Cementitious 1:	32.67	1	32.67	25.040%
Cementitious 2:	0.00	1	0.00	
Sand #1:	61.13	2	30.57	35.600%
Coarse Aggregate 1:	107.31	2	53.65	64.400%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	141.56	43.15
Design Un. Wt	6.00%	140.85	42.97
High Range	6.50%	140.15	42.80
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.23		
Theoretical Air	5.31		

Workability / Coarseness

CF Actual	75.2	#NUM!
AWF $_{upper\ limit}$	#NUM!	Negative Under Radical
AWF $_{lower\ limit}$	#NUM!	Negative Under Radical
AWF	30.4	#NUM!
CF $_{upper\ limit}$	#NUM!	Negative Under Radical
CF $_{lower\ limit}$	#NUM!	Negative Under Radical
WF Actual	29.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT** Project: **BCD 080739** Lab #: **BCD**

MIX NUMBER Mix 3 | Notes: **Type I - 25% C Ash - MDOT Class AA** | Set #: Mix 3

Date: **3/24/2008** | Mix Code: | f'c: **4,000 psi** | Size(c.f.): **1.50** | Factor: **0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.24	441.00	24.50	24.50	24.50	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.89	147.00	8.17	8.17	8.17	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.31	1037.09	57.62	59.47	59.47	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	108.38	108.38	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Air: 6.00%	1.62	0.00	0.00	0.00	0.00				
Water:	3.77	235.20	13.07	9.44	9.44		1.00		
"+-Air: 0.50%									
Total:	27.00	3779.29	209.96	209.96					
UW w/o Air:		148.91	148.91	148.91					

Comments / Notes / Observations

Slump 2 1/4 to 3 3/4. 48 ml max for water reducer. Water 65.5. Sensor 1.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	1.04	6.1	180.9	10.0	10.0	
WR Type A	3.62	21.3	629.5	35.0	35.0	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.23%	1.86
CA 1	1.70%	1.77
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
03/25/09	1 days	1890	1910
	1 days	1930	
03/31/09	7 days	4240	4425
	7 days	4610	
04/07/09	14 days	3940	4515
	14 days	5090	
04/21/09	28 days	4770	5207
	28 days	5480	
	28 days	5370	
05/19/09	56 days	6270	6080
	56 days	5890	

PLASTIC TEST RESULTS

Batch Time	12:59 PM	% Air	6.50
Sample Time	1:07 PM	Unit Weight (pcf)	142.48
Slump, in.	2.25	Yield	1.47
Mix Temp.	75.6	Initial set, min.	NA
Air Temp.	75.7	Relative Yield	0.982

OTHER INFO

Des. w/c	0.400
Act. w/c	0.400
Des.Un.Wt.	139.97
Fine/Coarse	0.54
Bag Factor	6.3

Technician who conducted tests:

Material	Design	Buckets	Weight	Paste Vol
Cementitious 1:	24.50	1	24.50	25.575%
Cementitious 2:	8.17	1	8.17	
Sand #1:	59.47	2	29.74	35.083%
Coarse Aggregate 1:	108.38	2	54.19	64.917%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.68	42.93
Design Un. Wt	6.00%	139.97	42.75
High Range	6.50%	139.28	42.58
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.38		
Theoretical Air	4.32		

Workability / Coarseness

CF Actual	75.3	#NUM!
$AWF_{upper\ limit}$	#NUM!	Negative Under Radical
$AWF_{lower\ limit}$	#NUM!	Negative Under Radical
AWF	30.0	#NUM!
$CF_{upper\ limit}$	#NUM!	Negative Under Radical
$CF_{lower\ limit}$	#NUM!	Negative Under Radical
WF Actual	29.3	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 4	Notes:	Type I	Set #:	Mix 4
Date:	3/19/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.63	517.00	28.72	28.72	28.72	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.61	1086.03	60.34	62.28	62.28	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	107.48	107.48	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Air: 6.00%	1.62	0.00	0.00	0.00	0.00				
Water:	3.98	248.16	13.79	10.97	10.97		1.00		
"+-Air: 0.50%									
Total:	27.00	3770.19	209.46	209.46					
UW w/o Air:		148.55	148.55	148.55					

Comments / Notes / Observations

Water 65.9. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	2.7	79.5	4.4	4.4	
WR Type A	4.00	20.7	611.6	34.0	34.0	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.24%	1.95
CA 1	0.83%	0.87
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
03/30/09	1 days	2300	2160
	1 days	2020	
03/26/09	7 days	4530	4515
	7 days	4500	
04/02/09	14 days	4870	4860
	14 days	4850	
04/16/09	28 days	5690	5603
	28 days	5590	
	28 days	5530	
05/14/09	56 days	5850	5855
	56 days	5860	

PLASTIC TEST RESULTS

Batch Time	1:34 PM	% Air	6.25
Sample Time	1:42 PM	Unit Weight (pcf)	142.76
Slump, in.	5.50	Yield	1.47
Mix Temp.	74.7	Initial set, min.	NA
Air Temp.	73.6	Relative Yield	0.978

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.64
Fine/Coarse	0.57
Bag Factor	5.5

Technician who conducted tests:

Material	Design	Buckets	Weight	Paste Vol
Cementitious 1:	28.72	1	28.72	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	62.28	1	62.28	36.140%
Coarse Aggregate 1:	107.48	2	53.74	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.34	42.84
Design Un. Wt	6.00%	139.64	42.67
High Range	6.50%	138.94	42.50
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.45		
Theoretical Air	3.90		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF $_{upper\ limit}$	#NUM!	Negative Under Radical
AWF $_{lower\ limit}$	#NUM!	Negative Under Radical
AWF	29.0	#NUM!
CF $_{upper\ limit}$	#NUM!	Negative Under Radical
CF $_{lower\ limit}$	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 5	Notes:	Type I - 25% C Ash	Set #:	Mix 5
Date:	3/24/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.94	380.44	21.14	21.14	21.14	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.77	126.81	7.04	7.04	7.04	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.61	1086.03	60.33	62.28	62.28	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	108.38	108.38	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Air: 6.00%	1.62	0.00	0.00	0.00	0.00				
Water:	3.90	243.48	13.53	9.81	9.81		1.00		
"+-Air: 0.50%									
Total:	27.00	3755.76	208.65	208.65					
UW w/o Air:		147.98	147.98	147.98					

Comments / Notes / Observations

Report Slump. 41.5 ml max for water reducer. Water 64.0. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
03/25/09	1 days	1590	1550
	1 days	1510	
03/31/09	7 days	3860	3755
	7 days	3650	
04/07/09	14 days	4500	4435
	14 days	4370	
04/21/09	28 days	4920	5080
	28 days	5440	
	28 days	4880	
05/19/09	56 days	5850	5745
	56 days	5640	

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.53	2.7	79.5	4.4	4.4	
WR Type A	4.00	20.3	600.1	33.3	33.3	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.23%	1.94
CA 1	1.70%	1.77
CA 2	1.00%	0.00
CA 3	1.00%	0.00
CA 4	1.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	8:51 AM	% Air	6.25
Sample Time	8:59 AM	Unit Weight (pcf)	141.40
Slump, in.	6.75	Yield	1.48
Mix Temp.	73.8	Initial set, min.	NA
Air Temp.	73.3	Relative Yield	0.984

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.10
Fine/Coarse	0.57
Bag Factor	5.4

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	21.14	1	21.14	24.471%
Cementitious 2:	7.04	1	7.04	
Sand #1:	62.28	2	31.14	36.140%
Coarse Aggregate 1:	108.38	2	54.19	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.80	42.71
Design Un. Wt	6.00%	139.10	42.54
High Range	6.50%	138.41	42.36
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.11		
Theoretical Air	4.45		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF $_{upper\ limit}$	#NUM!	Negative Under Radical
AWF $_{lower\ limit}$	#NUM!	Negative Under Radical
AWF	28.7	#NUM!
CF $_{upper\ limit}$	#NUM!	Negative Under Radical
CF $_{lower\ limit}$	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	**MDOT**	Project:	**BCD 080739**	Lab #:	**BCD**
MIX NUMBER	**Mix 6**	Notes:	**Type I - 25% F Ash**	Set #:	Mix 6
Date:	**3/26/2009**	Mix Code:	f'c: **4,000 psi** Size(c.f.): **1.50**	Factor:	**0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.90	372.68	**20.70**	**20.70**	20.70	**Cement Type I**	3.15		
Cement 2:	0.00		**0.00**	**0.00**					
Fly Ash:	0.89	124.23	**6.90**	**6.90**	6.90	**Type F Fly Ash**	2.24		
GGBFS:	0.00		**0.00**	**0.00**					
Sand 1:	6.61	1086.02	**60.33**	**62.55**	62.55	**Sand Source 1**	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	**106.61**	**108.11**	108.11	**No 57 Gravel Source 1**	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	**0.00**	**0.00**	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	**0.00**	**0.00**	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	**0.00**	**0.00**	0.00		1.000	1.00%	1.00
Air: **6.00%**	1.62	0.00	**0.00**	**0.00**	0.00				
Water:	3.82	238.52	**13.25**	**9.54**	9.54		1.00		
"+-Air: **0.50%**									
Total:	27.00	3740.45	207.80	207.80					
UW w/o Air:		147.38	147.38	147.38					

Comments / Notes / Observations

Report Slump. 41.5 ml max for water reducer. Water 63.9. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	1.00	5.0	147.0	8.2	8.2	
WR Type A	4.00	19.9	587.8	32.7	32.7	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.68%	2.21
CA 1	1.44%	1.50
CA 2	1.00%	0.00
CA 3	1.00%	0.00
CA 4	1.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
03/27/09	1 days	1490	1560
	1 days	1630	
04/02/09	7 days	3130	3140
	7 days	3150	
04/09/09	14 days	3610	3660
	14 days	3710	
04/23/09	28 days	4260	4333
	28 days	4290	
	28 days	4450	
05/21/09	56 days	5540	5405
	56 days	5270	

PLASTIC TEST RESULTS / OTHER INFO

PLASTIC TEST RESULTS				OTHER INFO	
Batch Time	10:15 AM	% Air	6.00	Des. w/c	0.480
Sample Time	10:36 AM	Unit Weight (pcf)	140.60	Act. w/c	0.480
Slump, in.	5.50	Yield	1.48	Des.Un.Wt.	138.54
Mix Temp.	73.4	Initial set, min.	NA	Fine/Coarse	0.57
Air Temp.	73.2	Relative Yield	0.985	Bag Factor	5.3

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.70	1	20.70	24.471%
Cementitious 2:	6.90	1	6.90	
Sand #1:	62.55	2	31.27	36.140%
Coarse Aggregate 1:	108.11	2	54.06	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.23	42.58
Design Un. Wt	6.00%	138.54	42.40
High Range	6.50%	137.85	42.23
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	42.92		
Theoretical Air	4.60		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF upper limit	#NUM!	Negative Under Radical
AWF lower limit	#NUM!	Negative Under Radical
AWF	28.4	#NUM!
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT**	Project: **BCD 080739**	Lab #:	**BCD**
MIX NUMBER Mix 7	Notes: **Type I - 50% GGBFS**	Set #:	Mix 7
Date: 3/26/2009	Mix Code: f'c: **4,000 psi** Size(c.f.): **1.50**	Factor:	**0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.29	253.95	14.11	14.11	14.11	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.41	253.95	14.11	14.11	14.11	GGBFS	2.89		
Sand 1:	6.61	1086.05	60.34	62.55	62.55	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	108.11	108.11	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	0.00	0.00	0.00		1.000	1.00%	1.00
Air: 6.00%	1.62	0.00	0.00	0.00	0.00				
Water:	3.91	243.79	13.54	9.83	9.83		1.00		
"+-Air: 0.50%									
Total:	27.00	3756.74	208.71	208.71					
UW w/o Air:		148.02	148.02	148.02					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	2.6	78.1	4.3	4.3	
WR Type A	4.00	20.3	600.8	33.4	33.4	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.68%	2.21
CA 1	1.44%	1.50
CA 2	1.00%	0.00
CA 3	1.00%	0.00
CA 4	1.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	1:21 PM	% Air	6.00
Sample Time	1:29 PM	Unit Weight (pcf)	141.80
Slump, in.	3.00	Yield	1.47
Mix Temp.	73.7	Initial set, min.	NA
Air Temp.	75.7	Relative Yield	0.981

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.14
Fine/Coarse	0.57
Bag Factor	5.4

Comments / Notes / Observations

Report Slump. 41.5 ml max for water reducer. Water 63.5. Sensor 4.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
03/27/09	1 days	690	660
	1 days	630	
04/02/09	7 days	2600	2660
	7 days	2720	
04/09/09	14 days	4710	4635
	14 days	4560	
04/23/09	28 days	5960	5847
	28 days	5650	
	28 days	5930	
05/21/09	56 days	6340	6165
	56 days	5990	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	14.11	1	14.11	24.471%
Cementitious 2:	14.11	1	14.11	
Sand #1:	62.55	2	31.27	36.141%
Coarse Aggregate 1:	108.11	2	54.06	63.859%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.84	42.73
Design Un. Wt	6.00%	139.14	42.55
High Range	6.50%	138.45	42.38
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	43.22		
Theoretical Air	4.20		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF upper limit	#NUM!	Negative Under Radical
AWF lower limit	#NUM!	Negative Under Radical
AWF	28.7	#NUM!
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT** | Project: **BCD 080739** | Lab #: **BCD**

MIX NUMBER: **Mix 8** | Notes: **Type GU** | Set #: Mix 8

Date: **3/31/2009** | Mix Code: | f'c: **4,000 psi** | Size(c.f.): **1.50** | Factor: **0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.65	514.37	28.58	28.58	28.58	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.61	1086.02	60.33	62.08	62.08	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	108.80	108.80	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00			2.690	0.97%	6.84
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.96	246.90	13.72	9.78	9.78		1.00		
"+-Air: 0.50%									
Total:	27.00	3766.29	209.24	209.24					
UW w/o Air:		148.40	148.40	148.40					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.60	3.1	91.3	5.1	5.1	
WR Type A	4.00	20.6	608.5	33.8	33.8	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	2.90%	1.74
CA 1	2.10%	2.19
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/01/09	1 days	2250	2155
	1 days	2060	
04/07/09	7 days	4060	4285
	7 days	4510	
04/14/09	14 days	5060	4945
	14 days	4830	
04/28/09	28 days	5580	5423
	28 days	5280	
	28 days	5410	
05/26/09	56 days	5820	5755
	56 days	5690	

PLASTIC TEST RESULTS

Batch Time	4:03 PM	% Air	7.00
Sample Time	4:11 PM	Unit Weight (pcf)	139.52
Slump, in.	4.00	Yield	1.50
Mix Temp.	73.6	Initial set, min.	NA
Air Temp.	73.6	Relative Yield	1.000

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.49
Fine/Coarse	0.57
Bag Factor	5.5

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	28.58	1	28.58	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	62.08	2	31.04	36.140%
Coarse Aggregate 1:	108.80	1	108.80	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.19	42.82
Design Un. Wt	6.00%	139.49	42.64
High Range	6.50%	138.80	42.47
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	42.65		
Theoretical Air	5.98		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF upper limit	#NUM!	Negative Under Radical
AWF lower limit	#NUM!	Negative Under Radical
AWF	28.9	#NUM!
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 9	Notes:	Type GU - 25% C Ash	Set #:	Mix 9
Date:	4/2/2009	Mix Code:	f'c: 4,000 psi; Size(c.f.): 1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.95	379.01	21.06	21.06	21.06	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.77	126.34	7.02	7.02	7.02	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.61	1086.02	60.33	62.11	62.11	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	107.82	107.82	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00			2.690	0.97%	6.84
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.89	242.57	13.48	10.49	10.49		1.00		
"+-Air: 0.50%									
Total:	27.00	3752.94	208.50	208.50					
UW w/o Air:		147.87	147.87	147.87					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %. 66 water. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	2.6	77.7	4.3	4.3	
WR Type A	4.00	20.2	597.8	33.2	33.2	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	2.95%	1.77
CA 1	1.16%	1.21
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/03/09	1 days	1480	1415
	1 days	1350	
04/09/09	7 days	4020	4030
	7 days	4040	
04/16/09	14 days	4710	4625
	14 days	4540	
04/30/09	28 days	5630	5420
	28 days	4930	
	28 days	5700	
05/28/09	56 days	6360	6340
	56 days	6320	

PLASTIC TEST RESULTS

Batch Time	8:42 AM	% Air	5.75
Sample Time	8:50 AM	Unit Weight (pcf)	142.68
Slump, in.	7.25	Yield	1.46
Mix Temp.	73.0	Initial set, min.	NA
Air Temp.	73.6	Relative Yield	0.974

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.00
Fine/Coarse	0.57
Bag Factor	5.4

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	21.06	1	21.06	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	62.11	2	31.05	36.140%
Coarse Aggregate 1:	107.82	2	53.91	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.70	42.69
Design Un. Wt	6.00%	139.00	42.52
High Range	6.50%	138.31	42.35
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	43.44		
Theoretical Air	3.51		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF $_{upper\ limit}$	#NUM!	Negative Under Radical
AWF $_{lower\ limit}$	#NUM!	Negative Under Radical
AWF	28.6	#NUM!
CF $_{upper\ limit}$	#NUM!	Negative Under Radical
CF $_{lower\ limit}$	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT** | Project: **BCD 080739** | Lab #: **BCD**

MIX NUMBER	Mix 10	Notes:	Type GU - 25% F Ash			Set #:	Mix 10
Date:	4/2/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.):	1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.91	371.31	20.63	20.63	20.63	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.89	123.77	6.88	6.88	6.88	Type F Fly Ash	2.24		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.61	1086.04	60.34	62.11	62.11	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	107.82	107.82	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00			2.690	0.97%	6.84
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.81	237.64	13.20	10.22	10.22		1.00		
"+-Air: 0.50%									
Total:	27.00	3737.76	207.65	207.65					
UW w/o Air:		147.27	147.27	147.27					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %. 67 water. Sensor 4.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.80	4.0	117.1	6.5	6.5	
WR Type A	4.00	19.8	585.7	32.5	32.5	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	2.95%	1.77
CA 1	1.16%	1.21
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/03/09	1 days	1490	1535
	1 days	1580	
04/09/09	7 days	3610	3600
	7 days	3590	
04/16/09	14 days	4230	4175
	14 days	4120	
04/30/09	28 days	5000	4970
	28 days	4920	
	28 days	4990	
05/28/09	56 days	6030	5720
	56 days	5410	

PLASTIC TEST RESULTS

Batch Time	10:43 AM	% Air	5.50
Sample Time	11:00 AM	Unit Weight (pcf)	142.04
Slump, in.	6.75	Yield	1.46
Mix Temp.	73.2	Initial set, min.	NA
Air Temp.	73.8	Relative Yield	0.975

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	138.44
Fine/Coarse	0.57
Bag Factor	5.3

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.63	1	20.63	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	62.11	2	31.05	36.141%
Coarse Aggregate 1:	107.82	2	53.91	63.859%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.13	42.55
Design Un. Wt	6.00%	138.44	42.38
High Range	6.50%	137.75	42.21
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	43.28		
Theoretical Air	3.55		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF upper limit	#NUM!	Negative Under Radical
AWF lower limit	#NUM!	Negative Under Radical
AWF	28.4	#NUM!
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 11	Notes:	Type GU - 50% GGBFS	Set #:	Mix 11
Date:	4/7/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.31	253.32	14.07	14.07	14.07	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.40	253.32	14.07	14.07	14.07	GGBFS	2.89		
Sand 1:	6.61	1086.03	60.34	62.09	62.09	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	12.16	1919.00	106.61	107.55	107.55	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	0.00	0.00	0.00	0.00			2.690	0.97%	6.84
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.90	243.18	13.51	10.82	10.82		1.00		
"+-Air: 0.50%									
Total:	27.00	3754.85	208.60	208.60					
UW w/o Air:		147.95	147.95	147.95					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %. Water 72. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.48	2.4	71.9	4.0	4.0	
WR Type A	4.00	20.3	599.3	33.3	33.3	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	2.91%	1.75
CA 1	0.90%	0.94
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/08/09	1 days	740	715
	1 days	690	
04/14/09	7 days	3810	3735
	7 days	3660	
04/21/09	14 days	5330	5500
	14 days	5670	
05/05/09	28 days	5870	6187
	28 days	6340	
	28 days	6350	
06/02/09	56 days	6730	6705
	56 days	6680	

PLASTIC TEST RESULTS

Batch Time	12:13 PM	% Air	7.00
Sample Time	12:22 PM	Unit Weight (pcf)	140.80
Slump, in.	6.00	Yield	1.48
Mix Temp.	71.8	Initial set, min.	NA
Air Temp.	74.3	Relative Yield	0.988

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.07
Fine/Coarse	0.57
Bag Factor	5.4

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	14.07	1	14.07	24.471%
Cementitious 2:	14.07	1	14.07	
Sand #1:	62.09	2	31.04	36.140%
Coarse Aggregate 1:	107.55	2	53.77	63.860%
Coarse Aggregate 2:	0.00	2	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.77	42.72
Design Un. Wt	6.00%	139.07	42.55
High Range	6.50%	138.38	42.37
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	42.98		
Theoretical Air	4.83		

Workability / Coarseness

CF Actual	75.0	#NUM!
AWF upper limit	#NUM!	Negative Under Radical
AWF lower limit	#NUM!	Negative Under Radical
AWF	28.7	#NUM!
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	30.2	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 12	Notes:	TYPE I - 25% C Ash Blended Agg	Set #:	Mix 12
Date:	4/9/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.85	363.00	20.17	20.17	20.17	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.73	120.00	6.67	6.67	6.67	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	7.77	1275.61	70.87	73.07	73.07	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	8.13	1283.00	71.28	71.71	71.71	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	3.19	502.00	27.89	28.60	28.60	No 8 Gravel Source 1	2.522	2.88%	6.02
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.72	232.00	12.89	9.54	9.54		1.00		
"+-Air: 0.50%									
Total:	27.00	3775.61	209.76	209.76					
UW w/o Air:		148.76	148.76	148.76					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.35	1.7	50.0	2.8	2.8	
WR Type A	4.00	19.3	571.4	31.7	31.7	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.12%	2.20
CA 1	0.62%	0.43
CA 2	2.64%	0.72
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	10:19 AM	% Air	6.00
Sample Time	10:27 AM	Unit Weight (pcf)	141.96
Slump, in.	6.50	Yield	1.48
Mix Temp.	75.3	Initial set, min.	NA
Air Temp.	75.2	Relative Yield	0.985

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.84
Fine/Coarse	0.71
Bag Factor	5.1

Comments / Notes / Observations

Slump 6 1/4 to 7 1/4". Air 5.5 to 6.5 %. Sensor 3. Water 72.8.

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/10/09	1 days	1570	1550
	1 days	1530	
04/16/09	7 days	3930	3960
	7 days	3990	
04/23/09	14 days	4560	4560
	14 days	4560	
05/07/09	28 days	5270	5430
	28 days	5400	
	28 days	5620	
06/04/09	56 days	5860	5865
	56 days	5870	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.17	1	20.17	23.308%
Cementitious 2:	6.67	1	6.67	
Sand #1:	73.07	2	36.54	41.678%
Coarse Aggregate 1:	71.71	2	35.85	41.920%
Coarse Aggregate 2:	28.60	2	14.30	16.402%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.54	42.92
Design Un. Wt	6.00%	139.84	42.74
High Range	6.50%	139.14	42.57
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	43.27		
Theoretical Air	4.57		

Workability / Coarseness

CF Actual	55.4	Within MDOT Limits
AWF $_{upper\ limit}$	39.6	Positive
AWF $_{lower\ limit}$	32.4	Positive
AWF	32.6	Within MDOT Limits
CF $_{upper\ limit}$	68.1	Positive
CF $_{lower\ limit}$	53.9	Positive
WF Actual	34.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 13	Notes:	Type I - 25% F Ash Blended Agg.	Set #:	Mix 13
Date:	4/9/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.87	368.00	20.44	20.44	20.44	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.87	122.00	6.78	6.78	6.78	Type F Fly Ash	2.24		
GGBFS:	0.00		0.00	0.00					
Sand 1:	7.67	1259.81	69.99	72.17	72.17	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	8.47	1337.00	74.28	74.73	74.73	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	2.73	429.00	23.83	24.32	24.32	No 8 Gravel Source 1	2.522	2.88%	6.02
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.77	235.00	13.06	9.94	9.94		1.00		
"+-Air: 0.50%									
Total:	27.00	3750.81	208.38	208.38					
UW w/o Air:		147.79	147.79	147.79					

Comments / Notes / Observations

Slump 5 to 6. Air 5.5 to 6.5 %.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.75	3.7	108.7	6.0	6.0	
WR Type A	4.00	19.6	579.7	32.2	32.2	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	3.12%	2.18
CA 1	0.62%	0.45
CA 2	2.09%	0.48
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results (4x8 CYLINDERS)

Date	AGE	psi	Avg. psi
04/10/09	1 days	1530	1545
	1 days	1560	
04/16/09	7 days	3430	3535
	7 days	3640	
04/23/09	14 days	4360	4350
	14 days	4340	
05/07/09	28 days	4730	4880
	28 days	4790	
	28 days	5120	
06/04/09	56 days	5470	5555
	56 days	5640	

PLASTIC TEST RESULTS

Batch Time	1:40 PM	% Air	5.50
Sample Time	1:49 PM	Unit Weight (pcf)	141.96
Slump, in.	5.00	Yield	1.47
Mix Temp.	75.5	Initial set, min.	NA
Air Temp.	74.9	Relative Yield	0.979

OTHER INFO

Des. w/c	0.480
Act. w/c	0.479
Des.Un.Wt.	138.92
Fine/Coarse	0.71
Bag Factor	5.2

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.44	1	20.44	24.115%
Cementitious 2:	0.00	1	0.00	
Sand #1:	72.17	2	36.08	41.635%
Coarse Aggregate 1:	74.73	1	74.73	44.186%
Coarse Aggregate 2:	24.32	2	12.16	14.178%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.62	42.68
Design Un. Wt	6.00%	138.92	42.51
High Range	6.50%	138.23	42.34
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	43.27		
Theoretical Air	3.94		

Workability / Coarseness

CF Actual	57.9	Within MDOT Limits
AWF upper limit	39.9	Positive
AWF lower limit	32.1	Positive
AWF	32.8	Within MDOT Limits
CF upper limit	68.8	Positive
CF lower limit	53.2	Positive
WF Actual	34.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer: **MDOT** | Project: **BCD 080739** | Lab #: **BCD**

MIX NUMBER	Mix 14	Notes:	Type I - MDOT BD	Set #:	Mix 14
Date:	4/14/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	2.67	525.00	29.17	29.17	29.17	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	7.76	1274.85	70.82	72.55	72.55	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	7.93	1251.00	69.50	70.38	70.38	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	2.97	467.00	25.94	26.60	26.60	No 8 Gravel Source 1	2.522	2.88%	6.02
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 7.00%	1.89	0.00	0.00	0.00					
Water:	3.78	236.00	13.11	9.86	9.86		1.00		
"+-Air: 0.50%									
Total:	27.00	3753.85	208.55	208.55					
UW w/o Air:		149.50	149.50	149.50					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.78	4.1	121.1	6.7	6.7	
WR Type A	4.00	21.0	621.1	34.5	34.5	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	2.44%	1.72
CA 1	1.29%	0.88
CA 2	2.58%	0.65
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS / OTHER INFO

Batch Time	1:16 PM	% Air	7.50	Des. w/c	0.450
Sample Time	1:30 PM	Unit Weight (pcf)	139.72	Act. w/c	0.449
Slump, in.	2.50	Yield	1.49	Des.Un.Wt.	139.03
Mix Temp.	73.6	Initial set, min.	NA	Fine/Coarse	0.74
Air Temp.	73.8	Relative Yield	0.995	Bag Factor	5.6

Comments / Notes / Observations

Slump 2 1/4 - 3 3/4". Air 6 1/2 - 7 1/2%. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
04/15/09	1 days	2340	2380
	1 days	2420	
04/21/09	7 days	4570	4330
	7 days	4090	
04/28/09	14 days	4870	4635
	14 days	4400	
05/12/09	28 days	4180	4713
	28 days	4850	
	28 days	5110	
06/09/09	56 days	5470	5450
	56 days	5430	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	29.17	1	29.17	23.900%
Cementitious 2:	0.00	1	0.00	
Sand #1:	72.55	2	36.27	42.596%
Coarse Aggregate 1:	70.38	2	35.19	41.800%
Coarse Aggregate 2:	26.60	1	26.60	15.604%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	6.50%	139.73	42.71
Design Un. Wt	7.00%	139.03	42.54
High Range	7.50%	138.34	42.36
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	42.71		
Theoretical Air	6.54		

Workability / Coarseness

CF Actual	55.8	Within MDOT Limits
$AWF_{upper\ limit}$	39.7	Positive
$AWF_{lower\ limit}$	32.3	Positive
AWF	34.5	Within MDOT Limits
$CF_{upper\ limit}$	73.1	Positive
$CF_{lower\ limit}$	48.9	Positive
WF Actual	35.6	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 15.1	Notes:	Type I - 50% GGBFS MDOT BD	Set #:	Mix 15.1
Date:	8/11/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.29	254.50	14.14	14.14	14.14	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.41	254.50	14.14	14.14	14.14	GGBFS	2.89		
Sand 1:	7.99	1311.62	72.87	73.59	73.59	Sand Source 1	2.632	0.31%	2.96
Coarse Aggregate 1:	8.16	1288.00	71.56	72.45	72.45	No 57 Gravel Source 1	2.529	2.29%	7.14
Coarse Aggregate 2:	2.59	407.00	22.61	23.00	23.00	No 8 Gravel Source I	2.522	2.88%	6.02
Coarse Aggregate 3:	0.00	0.00	0.00	0.00			2.673	1.37%	5.52
Coarse Aggregate 4:	0.00	0.00	0.00	0.00			2.604	2.43%	3.26
Air: 7.00%	1.89	0.00	0.00	0.00					
Water:	3.67	229.00	12.72	10.72	10.72		1.00		
"+-Air: 0.50%									
Total:	27.00	3744.62	208.03	208.03					
UW w/o Air:		149.13	149.13	149.13					

Comments / Notes / Observations

Slump 2 1/4 - 3 3/4". Air 6 1/2 - 7 1/2%. Sensor 7. Water 64.8

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	2.6	78.3	4.3	4.3	
WR Type A	4.00	20.4	602.1	33.5	33.5	

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	0.99%	0.72
CA 1	1.28%	0.90
CA 2	1.78%	0.39
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
08/12/09	1 days	950	950
	1 days	950	
08/18/09	7 days	3240	3290
	7 days	3340	
08/25/09	14 days	4680	4780
	14 days	4880	
09/08/09	28 days	6250	6147
	28 days	6160	
	28 days	6030	
10/06/09	56 days	6660	6795
	56 days	6930	

PLASTIC TEST RESULTS

Batch Time	9:29 AM	% Air	7.50
Sample Time	9:36 AM	Unit Weight (pcf)	140.08
Slump, in.	4.25	Yield	1.49
Mix Temp.	72.5	Initial set, min.	NA
Air Temp.	72.7	Relative Yield	0.990

OTHER INFO

Des. w/c	0.450
Act. w/c	0.450
Des.Un.Wt.	138.69
Fine/Coarse	0.77
Bag Factor	5.4

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	14.14	1	14.14	23.614%
Cementitious 2:	14.14	1	14.14	
Sand #1:	73.59	2	36.79	43.624%
Coarse Aggregate 1:	72.45	2	36.23	42.839%
Coarse Aggregate 2:	23.00	1	23.00	13.537%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	6.50%	139.39	42.62
Design Un. Wt	7.00%	138.69	42.44
High Range	7.50%	138.00	42.27
Bucket Weight	7.77		
Bucket Volume	0.250		
Bucket Full	42.79		
Theoretical Air	6.07		

Workability / Coarseness

CF Actual	57.8	Within MDOT Limits
AWF upper limit	39.9	Positive
AWF lower limit	32.1	Positive
AWF	34.0	Within MDOT Limits
CF upper limit	72.3	Positive
CF lower limit	49.7	Positive
WF Actual	35.5	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 16	Notes:	Type I - KU Mix	Set #:	Mix 16
Date:	4/23/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	Spec. absorption	Agg. FM
Cement 1:	2.75	540.00	30.00	30.00	30.00	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	3.06	504.40	28.02	29.56	29.56	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	1.58	262.00	14.56	14.59	14.59	No 4 Limestone Source 1	2.651	1.33%	7.86
Coarse Aggregate 2:	6.82	1165.00	64.72	64.92	64.92	No 57 Limestone Source 2	2.739	0.63%	6.93
Coarse Aggregate 3:	2.45	419.00	23.28	23.47	23.47		2.746	0.39%	5.41
Coarse Aggregate 4:	4.30	731.00	40.61	43.42	43.42	No 11 Limestone Source 2	2.727	0.62%	3.00
Air: 8.00%	2.16	0.00	0.00	0.00					
Water:	3.89	243.00	13.50	8.75	8.75		1.00		
"+-Air: 1.00%									
Total:	27.00	3864.40	214.69	214.69					
UW w/o Air:		155.57	155.57	155.57					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	1.46	7.9	233.2	13.0	13.0	
WR Type A	4.96	26.8	792.1	44.0	44.0	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	5.50%	1.54
CA 1	0.23%	0.03
CA 2	0.30%	0.19
CA 3	0.81%	0.19
CA 4	6.95%	2.81

Water Added/Withheld

+/- h2o	Added	W/held

Comments / Notes / Observations

Slump 1 1/2 to 3". 13 ml max for air. 44 ml max for water reducer. Water 66.5 . 4 pints 0.6 correction. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
04/24/09	1 days	2090	2100
	1 days	2110	
04/30/09	7 days	3970	3945
	7 days	3920	
05/07/09	14 days	4500	4445
	14 days	4390	
05/21/09	28 days	4830	4843
	28 days	4850	
	28 days	4850	
06/18/09	56 days	4970	5180
	56 days	5390	

Technician who conducted tests:

PLASTIC TEST RESULTS

Batch Time	8:44 AM	% Air	8.15
Sample Time	9:10 AM	Unit Weight (pcf)	145.16
Slump, in.	2.25	Yield	1.48
Mix Temp.	74.5	Initial set, min.	NA
Air Temp.	74.0	Relative Yield	0.986

OTHER INFO

Des. w/c	0.450
Act. w/c	0.450
Des.Un.Wt.	143.13
Fine/Coarse	0.67
Bag Factor	5.7

Material	Design	Buckets	Weight	Vol
Cementitious 1:	30.00	1	30.00	24.598%
Cementitious 2:	0.00	1	0.00	
Sand #1:	29.56	2	14.78	16.369%
Coarse Aggregate 1:	14.59	1	14.59	8.503%
Coarse Aggregate 2:	64.92	2	32.46	37.807%
Coarse Aggregate 3:	23.47	1	23.47	13.598%
Coarse Aggregate 4:	43.42	1	43.42	23.723%

	Air	Un. Wt.	Bucket Full
Low Range	7.00%	144.57	43.92
Design Un. Wt	8.00%	143.13	43.56
High Range	9.00%	141.71	43.21
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	44.07		
Theoretical Air	6.69		

Workability / Coarseness

CF Actual	60.5	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	35.3	Within MDOT Limits
CF upper limit	73.8	Positive
CF lower limit	48.2	Positive
WF Actual	36.0	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 17	Notes:	Type I - MDOT Class AA	Set #:	Mix 17
Date:	4/28/2009	Mix Code:	f'c: 4,000 psi; Size(c.f.): 1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	2.99	588.00	32.67	32.67	32.67	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.74	1111.19	61.73	64.25	64.25	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	104.72	104.72	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.77	235.20	13.07	9.78	9.78		1.00		
"+-Air: 0.50%									
Total:	27.00	3805.39	211.41	211.41					
UW w/o Air:		149.94	149.94	149.94					

Comments / Notes / Observations

Slump 2 1/4 to 3 3/4. 38 ml max for air. 48 ml max for water reducer. Water 73.5. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.52	3.1	90.4	5.0	5.0	
WR Type A	4.51	26.5	784.3	43.6	43.6	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	4.09%	2.52
CA 1	0.76%	0.77
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/29/09	1 days	2880	2765
	1 days	2650	
05/05/09	7 days	4830	4840
	7 days	4850	
05/12/09	14 days	5260	5410
	14 days	5560	
05/26/09	28 days	5770	5793
	28 days	5970	
	28 days	5640	
06/23/09	56 days	5930	5955
	56 days	5980	

PLASTIC TEST RESULTS / OTHER INFO

Batch Time	12:10 PM	% Air	6.75	Des. w/c	0.400
Sample Time	12:18 PM	Unit Weight (pcf)	141.00	Act. w/c	0.400
Slump, in.	3.00	Yield	1.50	Des.Un.Wt.	140.94
Mix Temp.	75.1	Initial set, min.	NA	Fine/Coarse	0.59
Air Temp.	72.9	Relative Yield	1.000	Bag Factor	6.3

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	32.67	1	32.67	25.040%
Cementitious 2:	0.00	1	0.00	
Sand #1:	64.25	2	32.12	37.261%
Coarse Aggregate 1:	104.72	2	52.36	62.739%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	141.65	43.19
Design Un. Wt	6.00%	140.94	43.02
High Range	6.50%	140.24	42.84
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	43.03		
Theoretical Air	5.96		

Workability / Coarseness

CF Actual	60.6	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	33.0	Within MDOT Limits
CF upper limit	69.6	Positive
CF lower limit	52.4	Positive
WF Actual	32.4	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT		Project:		BCD 080739			Lab #:	BCD	
MIX NUMBER	Mix 18		Notes:	Type I - 25% C Ash - MDOT Class AA				Set #:	Mix 18	
Date:	4/28/2009		Mix Code:		f'c:	4,000 psi	Size(c.f.):	1.50	Factor:	0.06

MIX DESIGN INFO Material		Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	SG absorp-tion	Agg. FM
Cement 1:		2.24	441.00	24.50	24.50	24.50	Cement Type I	3.15		
Cement 2:		0.00		0.00	0.00					
Fly Ash:		0.89	147.00	8.17	8.17	8.17	Type C Fly Ash	2.64		
GGBFS:		0.00		0.00	0.00					
Sand 1:		6.59	1087.35	60.41	62.87	62.87	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:		11.88	1871.00	103.94	104.72	104.72	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:		0.00		0.00	0.00					
Coarse Aggregate 3:		0.00		0.00	0.00					
Coarse Aggregate 4:		0.00		0.00	0.00					
Air:	6.00%	1.62	0.00	0.00	0.00					
Water:		3.77	235.20	13.07	9.83	9.83		1.00		
"+-Air:	0.50%									
Total:		27.00	3781.55	210.09	210.09					
UW w/o Air:			149.00	149.00	149.00					

Comments / Notes / Observations

Slump 2 1/4 to 3 3/4. 48 ml max for water reducer. Water 69.5. Sensor 4. Slump 7 - 4.25?

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.57	3.4	99.1	5.5	5.5	
WR Type A	2.00	11.8	347.8	19.3	19.3	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	4.09%	2.46
CA 1	0.76%	0.77
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
04/29/09	1 days	1690	1690
	1 days	1690	
05/05/09	7 days	3880	3990
	7 days	4100	
05/12/09	14 days	4270	4555
	14 days	4840	
05/26/09	28 days	5610	5620
	28 days	5670	
	28 days	5580	
06/23/09	56 days	6000	6095
	56 days	6190	

PLASTIC TEST RESULTS

Batch Time	3:07 PM	% Air	6.00
Sample Time	3:20 PM	Unit Weight (pcf)	139.28
Slump, in.	4.25	Yield	1.51
Mix Temp.	74.5	Initial set, min.	NA
Air Temp.	72.2	Relative Yield	1.006

OTHER INFO

Des. w/c	0.400
Act. w/c	0.400
Des.Un.Wt.	140.06
Fine/Coarse	0.58
Bag Factor	6.3

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	24.50	1	24.50	25.575%
Cementitious 2:	8.17	1	8.17	
Sand #1:	62.87	2	31.43	36.755%
Coarse Aggregate 1:	104.72	2	52.36	63.245%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.76	42.97
Design Un. Wt	6.00%	140.06	42.79
High Range	6.50%	139.36	42.62
Bucket Weight	7.78		
Bucket Volume	0.250		
Bucket Full	42.60		
Theoretical Air	6.52		

Workability / Coarseness

CF Actual	60.7	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	32.6	Within MDOT Limits
CF upper limit	67.7	Positive
CF lower limit	54.3	Positive
WF Actual	31.9	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 19	Notes:	Type I	Set #:	Mix 19
Date:	5/5/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	2.63	517.00	28.72	28.72	28.72	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.52	63.14	65.53	65.53	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	106.01	106.01	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.98	248.16	13.79	9.33	9.33		1.00		
"+-Air: 0.50%									
Total:	27.00	3772.68	209.59	209.59					
UW w/o Air:		148.65	148.65	148.65					

Comments / Notes / Observations

Air 5.5 - 6.5. Report slump. Water 71.0. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/06/09	1 days	2570	2590
	1 days	2610	
05/12/09	7 days	5190	5305
	7 days	5420	
05/19/09	14 days	5840	5645
	14 days	5450	
06/02/09	28 days	6450	6363
	28 days	6060	
	28 days	6580	
06/30/06	56 days	6560	6815
	56 days	7070	

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.35	1.8	53.5	3.0	3.0	
WR Type A	4.00	20.7	611.6	34.0	34.0	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.80%	2.39
CA 1	2.03%	2.06
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	10:46 AM	% Air	6.50
Sample Time	11:00 AM	Unit Weight (pcf)	140.80
Slump, in.	3.25	Yield	1.49
Mix Temp.	74.8	Initial set, min.	NA
Air Temp.	73.3	Relative Yield	0.992

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.73
Fine/Coarse	0.61
Bag Factor	5.5

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	28.72	1	28.72	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	65.53	2	32.77	37.789%
Coarse Aggregate 1:	106.01	2	53.00	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Fu
Low Range	5.50%	140.43	42.90
Design Un. Wt	6.00%	139.73	42.72
High Range	6.50%	139.03	42.55
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	42.99		
Theoretical Air	5.28		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.6	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 20.1	Notes:	Type I - 25% C Ash	Set #:	Mix 20.1
Date:	5/12/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	1.94	380.44	21.14	21.14	21.14	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.77	126.81	7.04	7.04	7.04	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.51	63.14	65.39	65.39	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	105.82	105.82	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.90	243.48	13.53	9.41	9.41		1.00		
"+-Air: 0.50%									
Total:	27.00	3758.24	208.79	208.79					
UW w/o Air:		148.08	148.08	148.08					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.36	1.8	54.0	3.0	3.0	
WR Type A	4.00	20.3	600.1	33.3	33.3	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.57%	2.25
CA 1	1.84%	1.87
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	9:44 AM	% Air	5.25
Sample Time	9:52 AM	Unit Weight (pcf)	140.80
Slump, in.	4.75	Yield	1.48
Mix Temp.	73.3	Initial set, min.	NA
Air Temp.	72.2	Relative Yield	0.989

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.19
Fine/Coarse	0.61
Bag Factor	5.4

Comments / Notes / Observations

Air 5.5 - 6.5. Report Slump should be between c3 and 4. Water 68. Rollermeter Twice.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/13/09	1 days	1240	1280
	1 days	1320	
05/19/09	7 days	3990	4030
	7 days	4070	
05/26/09	14 days	4880	4785
	14 days	4690	
06/09/09	28 days	5660	5697
	28 days	5820	
	28 days	5610	
07/07/09	56 days	6300	6070
	56 days	5840	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	21.14	1	21.14	24.471%
Cementitious 2:	7.04	1	7.04	
Sand #1:	65.39	2	32.69	37.789%
Coarse Aggregate 1:	105.82	2	52.91	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.89	42.76
Design Un. Wt	6.00%	139.19	42.59
High Range	6.50%	138.50	42.42
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	42.99		
Theoretical Air	4.92		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.3	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 21	Notes:	Type I - 25% F Ash	Set #:	Mix 21
Date:	5/5/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	1.90	372.68	20.70	20.70	20.70	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.89	124.23	6.90	6.90	6.90	Type F Fly Ash	2.24		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.51	63.14	65.53	65.53	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	106.01	106.01	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.82	238.52	13.25	8.80	8.80		1.00		
"+-Air: 0.50%									
Total:	27.00	3742.94	207.94	207.94					
UW w/o Air:		147.48	147.48	147.48					

Comments / Notes / Observations

Air 5.5 - 6.5. Report slump. Water 71.0
Sensor 4

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.91	4.5	133.7	7.4	7.4	
WR Type A	4.00	19.9	587.8	32.7	32.7	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.80%	2.39
CA 1	2.03%	2.06
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/06/09	1 days	1470	1505
	1 days	1540	
05/12/09	7 days	3750	3850
	7 days	3950	
05/19/09	14 days	4400	4680
	14 days	4960	
06/02/09	28 days	5270	5303
	28 days	5350	
	28 days	5290	
06/30/09	56 days	6130	6035
	56 days	5940	

PLASTIC TEST RESULTS

Batch Time	12:56 PM	% Air	6.00
Sample Time	1:11 PM	Unit Weight (pcf)	141.84
Slump, in.	3.25	Yield	1.47
Mix Temp.	73.9	Initial set, min.	NA
Air Temp.	73.4	Relative Yield	0.977

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	138.63
Fine/Coarse	0.61
Bag Factor	5.3

Technician who conducted tests:	GP &SK

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.70	1	20.70	24.471%
Cementitious 2:	6.90	1	6.90	
Sand #1:	65.53	2	32.76	37.789%
Coarse Aggregate 1:	106.01	2	53.00	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.32	42.62
Design Un. Wt	6.00%	138.63	42.45
High Range	6.50%	137.94	42.27
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	43.25		
Theoretical Air	3.82		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.0	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	**Mix 22**	Notes:	**Type I - 50% GGBFS**	Set #:	Mix 22
Date:	5/7/2009	Mix Code:	f'c: 4,000 psi; Size(c.f.): 1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	SSD absorp-tion	Agg. FM
Cement 1:	1.29	253.95	14.11	14.11	14.11	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.41	253.95	14.11	14.11	14.11	GGBFS	2.89		
Sand 1:	6.89	1136.53	63.14	65.58	65.58	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	105.21	105.21	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.91	243.79	13.54	9.84	9.84		1.00		
"+-Air: 0.50%									
Total:	27.00	3759.22	208.85	208.85					
UW w/o Air:		148.12	148.12	148.12					

Comments / Notes / Observations

Air 5.5% - 6.6%. Report Slump. Water 69. Sensor 3. Cylinder break changes - (1) 14-day & (1) 56 day.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.36	1.8	54.1	3.0	3.0	
WR Type A	4.00	20.3	600.8	33.4	33.4	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.88%	2.44
CA 1	1.24%	1.26
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/08/09	1 days	730	650
	1 days	570	
05/14/09	7 days	3200	3145
	7 days	3090	
05/21/09	14 days	4710	4710
	14 days		
06/04/09	28 days	5920	5917
	28 days	6160	
	28 days	5670	
07/02/09	56 days	5970	5970
	56 days		

Technician who conducted tests:

PLASTIC TEST RESULTS

Batch Time	9:04 AM	% Air	5.50
Sample Time	9:15 AM	Unit Weight (pcf)	141.96
Slump, in.	5.75	Yield	1.47
Mix Temp.	73.6	Initial set, min.	NA
Air Temp.	72.9	Relative Yield	0.981

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.23
Fine/Coarse	0.61
Bag Factor	5.4

Material	Design	Buckets	Weight	Vol
Cementitious 1:	14.11	1	14.11	24.471%
Cementitious 2:	14.11	1	14.11	
Sand #1:	65.58	2	32.79	37.790%
Coarse Aggregate 1:	105.21	2	52.60	62.210%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.93	42.77
Design Un. Wt	6.00%	139.23	42.60
High Range	6.50%	138.54	42.42
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	43.28		
Theoretical Air	4.16		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.3	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 23.1	Notes:	Type GU	Set #:	Mix 23.1
Date:	8/6/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	SSD absorption	Agg. FM
Cement 1:	2.65	514.37	28.58	28.58	28.58	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.50	63.14	64.64	64.64	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	105.50	105.50	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.96	246.90	13.72	10.66	10.66		1.00		
"+-Air: 0.50%									
Total:	27.00	3768.77	209.38	209.38					
UW w/o Air:		148.49	148.49	148.49					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.36	1.9	54.8	3.0	3.0	
WR Type A	4.00	20.6	608.5	33.8	33.8	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	2.39%	1.50
CA 1	1.53%	1.56
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	11:52 AM	% Air	6.00
Sample Time	12:00 PM	Unit Weight (pcf)	142.04
Slump, in.	4.25	Yield	1.47
Mix Temp.	73.7	Initial set, min.	NA
Air Temp.	74.9	Relative Yield	0.983

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.58
Fine/Coarse	0.61
Bag Factor	5.5

Comments / Notes / Observations

Air 5.5% - 6.6%. Report Slump. Water 65.0°F Sensor 6.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
08/07/09	1 days	2030	2080
	1 days	2130	
08/13/09	7 days	4870	4900
	7 days	4930	
08/20/09	14 days	5580	5625
	14 days	5670	
09/03/09	28 days	6310	6127
	28 days	5870	
	28 days	6200	
10/01/09	56 days	6470	6560
	56 days	6650	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	28.58	1	28.58	24.471%
Cementitious 2:	0.00	1	0.00	
Sand #1:	64.64	2	32.32	37.789%
Coarse Aggregate 1:	105.50	2	52.75	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.29	42.86
Design Un. Wt	6.00%	139.58	42.69
High Range	6.50%	138.89	42.51
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	43.30		
Theoretical Air	4.35		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.5	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 24	Notes:	Type GU - 25% C Ash	Set #:	Mix 24
Date:	5/12/2009	Mix Code:	f'c: 4,000 psi / Size(c.f.): 1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorption	Agg. FM
Cement 1:	1.95	379.01	21.06	21.06	21.06	Cement Type GU	3.11		
Cement 2:	0.00	0.00	0.00	0.00					
Fly Ash:	0.77	126.34	7.02	7.02	7.02	Type C Fly Ash	2.64		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.50	63.14	65.38	65.38	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	105.82	105.82	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.89	242.57	13.48	9.36	9.36		1.00		
"+-Air: 0.50%									
Total:	27.00	3755.42	208.63	208.63					
UW w/o Air:		147.97	147.97	147.97					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.36	1.8	53.8	3.0	3.0	
WR Type A	4.00	20.2	597.8	33.2	33.2	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.57%	2.25
CA 1	1.84%	1.87
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi (4x8 CYLINDERS)	Avg. psi
05/13/09	1 days	1190	1215
	1 days	1240	
05/19/09	7 days	4570	4645
	7 days	4720	
05/26/09	14 days	5530	5505
	14 days	5480	
06/09/09	28 days	6070	6093
	28 days	6110	
	28 days	6100	
07/07/09	56 days	6980	6590
	56 days	6200	

Technician who conducted tests:

PLASTIC TEST RESULTS

Batch Time	11:40 AM	% Air	5.50
Sample Time	11:49 AM	Unit Weight (pcf)	141.44
Slump, in.	6.75	Yield	1.48
Mix Temp.	73.3	Initial set, min.	NA
Air Temp.	72.0	Relative Yield	0.983

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.09
Fine/Coarse	0.61
Bag Factor	5.4

Material	Design	Buckets	Weight	Vol
Cementitious 1:	21.06	1	21.06	24.471%
Cementitious 2:	7.02	1	7.02	
Sand #1:	65.38	2	32.69	37.789%
Coarse Aggregate 1:	105.82	2	52.91	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Fu
Low Range	5.50%	139.79	42.74
Design Un. Wt	6.00%	139.09	42.56
High Range	6.50%	138.40	42.39
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	43.15		
Theoretical Air	4.41		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.3	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 25	Notes:	Type GU - 25% F Ash	Set #:	Mix 25
Date:	5/14/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	Agg. absorption	Agg. FM
Cement 1:	1.91	371.31	20.63	20.63	20.63	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.89	123.77	6.88	6.88	6.88	Type F Fly Ash	2.24		
GGBFS:	0.00		0.00	0.00					
Sand 1:	6.89	1136.52	63.14	65.44	65.44	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	104.87	104.87	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.81	237.64	13.20	9.97	9.97		1.00		
"+-Air: 0.50%									
Total:	27.00	3740.24	207.79	207.79					
UW w/o Air:		147.37	147.37	147.37					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.80	4.0	117.1	6.5	6.5	
WR Type A	4.00	19.8	585.7	32.5	32.5	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.66%	2.30
CA 1	0.91%	0.93
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	9:18 AM	% Air	5.50
Sample Time	9:27 AM	Unit Weight (pcf)	140.68
Slump, in.	8.00	Yield	1.48
Mix Temp.	73.9	Initial set, min.	NA
Air Temp.	72.7	Relative Yield	0.985

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	138.53
Fine/Coarse	0.61
Bag Factor	5.3

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/15/09	1 days	1390	1405
	1 days	1420	
05/21/09	7 days	3650	3700
	7 days	3750	
05/28/09	14 days	4340	4375
	14 days	4410	
06/11/09	28 days	5260	5010
	28 days	4570	
	28 days	5200	
07/09/09	56 days	6480	6255
	56 days	6030	

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.63	1	20.63	24.471%
Cementitious 2:	6.88	1	6.88	
Sand #1:	65.44	2	32.72	37.789%
Coarse Aggregate 1:	104.87	2	52.43	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Fu
Low Range	5.50%	139.22	42.60
Design Un. Wt	6.00%	138.53	42.42
High Range	6.50%	137.84	42.25
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	42.96		
Theoretical Air	4.54		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.0	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 26	Notes:	Type GU - 50% GGBFS	Set #:	Mix 26
Date:	5/14/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	agg absorp-tion	Agg. FM
Cement 1:	1.31	253.32	14.07	14.07	14.07	Cement Type GU	3.11		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.40	253.32	14.07	14.07	14.07	GGBFS	2.89		
Sand 1:	6.89	1136.52	63.14	65.44	65.44	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	11.88	1871.00	103.94	104.87	104.87	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.00		0.00	0.00					
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.90	243.18	13.51	10.28	10.28		1.00		
"+-Air: 0.50%									
Total:	27.00	3757.34	208.74	208.74					
UW w/o Air:		148.04	148.04	148.04					

Comments / Notes / Observations

Report Slump. Air 5.5 to 6.5 %.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.40	2.0	59.9	3.3	3.3	
WR Type A	4.00	20.3	599.3	33.3	33.3	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.66%	2.30
CA 1	0.91%	0.93
CA 2		0.00
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/15/09	1 days	810	800
	1 days	790	
05/21/09	7 days	3730	3600
	7 days	3470	
05/28/09	14 days	5630	5600
	14 days	5570	
06/11/09	28 days	6890	6507
	28 days	6320	
	28 days	6310	
07/09/09	56 days	6810	6945
	56 days	7080	

PLASTIC TEST RESULTS / **OTHER INFO**

Batch Time	10:30 AM	% Air	6.00	Des. w/c	0.480
Sample Time	10:38 AM	Unit Weight (pcf)	142.08	Act. w/c	0.480
Slump, in.	6.75	Yield	1.47	Des.Un.Wt.	139.16
Mix Temp.	72.3	Initial set, min.	NA	Fine/Coarse	0.61
Air Temp.	72.5	Relative Yield	0.979	Bag Factor	5.4

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	14.07	1	14.07	24.471%
Cementitious 2:	14.07	1	14.07	
Sand #1:	65.44	2	32.72	37.789%
Coarse Aggregate 1:	104.87	2	52.43	62.211%
Coarse Aggregate 2:	0.00	1	0.00	0.000%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	139.86	42.75
Design Un. Wt	6.00%	139.16	42.58
High Range	6.50%	138.47	42.41
Bucket Weight	7.79		
Bucket Volume	0.250		
Bucket Full	43.31		
Theoretical Air	4.03		

Workability / Coarseness

CF Actual	60.5	#NUM!
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	31.3	Out of MDOT Limits
CF upper limit	#NUM!	Negative Under Radical
CF lower limit	#NUM!	Negative Under Radical
WF Actual	32.8	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	**MDOT**	Project:	**BCD 080739**	Lab #:	**BCD**
MIX NUMBER	**Mix 27.1**	Notes:	**Type I - 25% C Ash Blended Agg.**	Set #:	Mix 27.1
Date:	**6/4/2009**	Mix Code:	f'c: **4,000 psi** Size(c.f.): **1.50**	Factor:	**0.06**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	1.87	367.50	**20.42**	**20.42**	20.42	**Cement Type I**	3.15		
Cement 2:	0.00		**0.00**	**0.00**					
Fly Ash:	0.74	122.50	**6.81**	**6.81**	6.81	**Type C Fly Ash**	2.64		
GGBFS:	0.00		**0.00**	**0.00**					
Sand 1:	7.80	1287.29	**71.52**	**74.54**	74.54	**Sand Source 2**	2.644	0.38%	2.68
Coarse Aggregate 1:	10.46	1647.00	**91.50**	**93.09**	93.09	**No 57 Gravel Source 2**	2.523	2.22%	6.72
Coarse Aggregate 2:	0.74	116.00	**6.44**	**6.58**	6.58	**No 8 Gravel Source 2**	2.523	2.57%	5.99
Coarse Aggregate 3:	0.00		**0.00**	**0.00**					
Coarse Aggregate 4:	0.00		**0.00**	**0.00**					
Air: **6.00%**	1.62	0.00	**0.00**	**0.00**					
Water:	3.77	235.00	**13.06**	**8.30**	8.30		1.00		
"+-Air: **0.50%**									
Total:	27.00	3775.29	209.74	209.74					
UW w/o Air:		148.75	148.75	148.75					

Comments / Notes / Observations

Slump 4 1/4 to 5 1/4". Air 5.5 to 6.5 %. Repeat of mix 20.1. with optimized aggregates. Water 68. Air 7.7% retested at 6.25%. Sensor 3.

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
06/05/09	1 days	1210	1225
	1 days	1240	
06/11/09	7 days	3980	3965
	7 days	3950	
06/18/09	14 days	4470	4465
	14 days	4460	
07/02/09	28 days	5040	5023
	28 days	5210	
	28 days	4820	
07/30/09	56 days	5450	5585
	56 days	5720	

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.37	1.8	53.6	3.0	3.0	
WR Type A	4.00	19.6	579.7	32.2	32.2	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	4.25%	3.03
CA 1	1.78%	1.59
CA 2	2.17%	0.14
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	**10:10 AM**	% Air	**6.25**
Sample Time	**10:18 AM**	Unit Weight (pcf)	**140.36**
Slump, in.	**5.00**	Yield	**1.49**
Mix Temp.	**72.8**	Initial set, min.	**NA**
Air Temp.	**71.6**	Relative Yield	**0.996**

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.83
Fine/Coarse	0.73
Bag Factor	5.2

Technician who conducted tests:	

Material	Design	Buckets	Weight	Vol
Cementitious 1:	20.42	1	20.42	23.627%
Cementitious 2:	6.81	1	6.81	
Sand #1:	74.54	2	37.27	42.202%
Coarse Aggregate 1:	93.09	2	46.55	53.995%
Coarse Aggregate 2:	6.58	1	6.58	3.803%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.53	42.89
Design Un. Wt	6.00%	139.83	42.72
High Range	6.50%	139.13	42.54
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	42.85		
Theoretical Air	5.64		

Workability / Coarseness

CF Actual	55.7	Within MDOT Limits
AWF upper limit	39.7	Positive
AWF lower limit	32.3	Positive
AWF	34.6	Within MDOT Limits
CF upper limit	73.1	Positive
CF lower limit	48.9	Positive
WF Actual	36.5	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 28	Notes:	Type I - 25% F Ash Blended Agg.	Set #:	Mix 28
Date:	5/19/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor: 0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	1.79	352.50	19.58	19.58	19.58	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.84	117.50	6.53	6.53	6.53	Fly Ash F- ST RDMorrow	2.24		
GGBFS:	0.00		0.00	0.00					
Sand 1:	7.83	1292.23	71.79	74.43	74.43	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	10.55	1661.00	92.28	93.48	93.48	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	0.75	118.00	6.56	6.74	6.74	No 8 Gravel Source 2	2.523	2.57%	5.99
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 6.00%	1.62	0.00	0.00	0.00					
Water:	3.61	225.50	12.53	8.51	8.51		1.00		
"+-Air: 0.50%									
Total:	27.00	3766.73	209.26	209.26					
UW w/o Air:		148.41	148.41	148.41					

Comments / Notes / Observations

Slump 5 to 6. Air 5.5 to 6.5 %.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.85	4.0	118.1	6.6	6.6	
WR Type A	4.00	18.8	556.0	30.9	30.9	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	3.69%	2.64
CA 1	1.33%	1.20
CA 2	2.85%	0.18
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/20/09	1 days	1310	1310
	1 days	1310	
05/26/09	7 days	3910	3895
	7 days	3880	
06/02/09	14 days	4470	4255
	14 days	4040	
06/16/09	28 days	5030	5073
	28 days	5180	
	28 days	5010	
07/14/09	56 days	5900	5885
	56 days	5870	

PLASTIC TEST RESULTS

Batch Time	11:07 AM	% Air	6.00
Sample Time	11:16 AM	Unit Weight (pcf)	141.16
Slump, in.	2.75	Yield	1.48
Mix Temp.	72.4	Initial set, min.	NA
Air Temp.	72.4	Relative Yield	0.988

OTHER INFO

Des. w/c	0.480
Act. w/c	0.480
Des.Un.Wt.	139.51
Fine/Coarse	0.73
Bag Factor	5.0

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	19.58	1	19.58	23.140%
Cementitious 2:	6.53	1	6.53	
Sand #1:	74.43	2	37.21	42.075%
Coarse Aggregate 1:	93.48	2	46.74	54.083%
Coarse Aggregate 2:	6.74	1	6.74	3.842%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	5.50%	140.21	42.81
Design Un. Wt	6.00%	139.51	42.64
High Range	6.50%	138.81	42.46
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.05		
Theoretical Air	4.89		

Workability / Coarseness

CF Actual	55.7	Within MDOT Limits
AWF upper limit	39.7	Positive
AWF lower limit	32.3	Positive
AWF	33.9	Within MDOT Limits
CF upper limit	72.1	Positive
CF lower limit	49.9	Positive
WF Actual	36.4	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739	Lab #:	BCD
MIX NUMBER	Mix 29	Notes:	Type I - MDOT BD	Set #:	Mix 29
Date:	5/26/2009	Mix Code:	f'c: 4,000 psi Size(c.f.): 1.50	Factor:	0.06

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	2.87	564.00	31.33	31.33	31.33	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	0.00		0.00	0.00					
Sand 1:	4.11	678.88	37.72	39.22	39.22	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	10.74	1691.00	93.94	95.47	95.47	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	3.31	564.00	31.33	33.54	33.54	No 11 Limestone Source 2	2.727	0.62%	3.00
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 7.00%	1.89	0.00	0.00	0.00					
Water:	4.07	254.00	14.11	8.88	8.88		1.00		
"+-Air: 0.50%									
Total:	27.00	3751.88	208.44	208.44					
UW w/o Air:		149.42	149.42	149.42					

Comments / Notes / Observations

Slump 2 1/4 - 3 3/4". Air 6 1/2 - 7 1/2%. Water Temp 68.0 F. Sensor 3.

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.49	2.8	81.7	4.5	4.5	
WR Type A	4.00	22.6	667.2	37.1	37.1	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	4.00%	1.50
CA 1	1.66%	1.53
CA 2	7.08%	2.20
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

Strength Test Results

Date	AGE	psi	Avg. psi
	4x8 CYLINDERS		
05/27/09	1 days	2460	2505
	1 days	2550	
06/02/09	7 days	4890	4885
	7 days	4880	
06/09/09	14 days	5170	5280
	14 days	5390	
06/23/09	28 days	5820	6017
	28 days	6180	
	28 days	6050	
07/21/09	56 days	6040	6315
	56 days	6590	

PLASTIC TEST RESULTS / **OTHER INFO**

Batch Time	10:28 AM	% Air	7.50	Des. w/c	0.450
Sample Time	10:36 AM	Unit Weight (pcf)	139.80	Act. w/c	0.450
Slump, in.	3.75	Yield	1.49	Des.Un.Wt.	138.96
Mix Temp.	73.6	Initial set, min.	NA	Fine/Coarse	0.73
Air Temp.	72.2	Relative Yield	0.994	Bag Factor	6.0

Technician who conducted tests:

Material	Design	Buckets	Weight	Vol
Cementitious 1:	31.33	1	31.33	25.703%
Cementitious 2:	0.00	1	0.00	
Sand #1:	39.22	2	19.61	23.139%
Coarse Aggregate 1:	95.47	2	47.74	57.637%
Coarse Aggregate 2:	33.54	1	33.54	19.224%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Full
Low Range	6.50%	139.66	42.67
Design Un. Wt	7.00%	138.96	42.50
High Range	7.50%	138.27	42.33
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	42.71		
Theoretical Air	6.44		

Workability / Coarseness

CF Actual	59.5	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	36.7	Within MDOT Limits
CF upper limit	73.8	Positive
CF lower limit	48.2	Positive
WF Actual	36.7	

MDOT Shrinkage and Durability - State Study No. 216

Customer:	MDOT	Project:	BCD 080739		Lab #:	BCD
MIX NUMBER	Mix 30	Notes:	Type I - 50% GGBFS MDOT BD		Set #:	Mix 30
Date:	5/26/2009	Mix Code:	f'c: 4,000 psi	Size(c.f.): 1.50	Factor:	0.06

Comments / Notes / Observations

Slump 2 1/4 - 3 3/4". Air 6 1/2 - 7 1/2%. Sensor 4.

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd.	SSD mix lab batch	Adjusted lab batch	Actual lab batch	Material Source	Specific Gravity	absorp-tion	Agg. FM
Cement 1:	1.43	282.00	15.67	15.67	15.67	Cement Type I	3.15		
Cement 2:	0.00		0.00	0.00					
Fly Ash:	0.00		0.00	0.00					
GGBFS:	1.56	282.00	15.67	15.67	15.67	GGBFS	2.89		
Sand 1:	4.61	760.28	42.24	43.92	43.92	Sand Source 2	2.644	0.38%	2.68
Coarse Aggregate 1:	10.75	1692.00	94.00	95.53	95.53	No 57 Gravel Source 2	2.523	2.22%	6.72
Coarse Aggregate 2:	2.69	457.00	25.39	27.18	27.18	No 11 Limestone Source 2	2.727	0.62%	3.00
Coarse Aggregate 3:	0.00		0.00	0.00					
Coarse Aggregate 4:	0.00		0.00	0.00					
Air: 7.00%	1.89	0.00	0.00	0.00					
Water:	4.07	254.00	14.11	9.12	9.12		1.00		
"+-Air: 0.50%									
Total:	27.00	3727.28	207.07	207.07					
UW w/o Air:		148.44	148.44	148.44					

Strength Test Results

4x8 CYLINDERS

Date	AGE	psi	Avg. psi
05/27/09	1 days	700	700
	1 days	700	
06/02/09	7 days	3850	3720
	7 days	3590	
06/09/09	14 days	5720	5730
	14 days	5740	
06/23/09	28 days	6680	6980
	28 days	7020	
	28 days	7240	
07/21/09	56 days	7770	7405
	56 days	7040	

Technician who conducted tests:

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual ml	Brand / Name
Air	0.49	2.8	81.7	4.5	4.5	
WR Type A	4.00	22.6	667.2	37.1	37.1	

Aggregate Moistures

	Free H2O Content	Batch free H2O (lbs.)
Sand:	4.00%	1.68
CA 1	1.66%	1.53
CA 2	7.08%	1.79
CA 3		0.00
CA 4		0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	3:32 PM	% Air	6.50
Sample Time	3:40 PM	Unit Weight (pcf)	141.32
Slump, in.	3.50	Yield	1.47
Mix Temp.	73.5	Initial set, min.	NA
Air Temp.	73.8	Relative Yield	0.977

OTHER INFO

Des. w/c	0.450
Act. w/c	0.450
Des.Un.Wt.	138.05
Fine/Coarse	0.35
Bag Factor	6.0

Material	Design	Buckets	Weight	Vol
Cementitious 1:	15.67	1	15.67	26.181%
Cementitious 2:	15.67	1	15.67	
Sand #1:	43.92	1	43.92	26.133%
Coarse Aggregate 1:	95.53	2	47.76	58.159%
Coarse Aggregate 2:	27.18	1	27.18	15.708%
Coarse Aggregate 3:	0.00	1	0.00	0.000%
Coarse Aggregate 4:	0.00	1	0.00	0.000%

	Air	Un. Wt.	Bucket Fu
Low Range	6.50%	138.74	42.45
Design Un. Wt	7.00%	138.05	42.27
High Range	7.50%	137.36	42.10
Bucket Weight	7.76		
Bucket Volume	0.250		
Bucket Full	43.09		
Theoretical Air	4.80		

Workability / Coarseness

CF Actual	59.6	Within MDOT Limits
AWF upper limit	40.0	Positive
AWF lower limit	32.0	Positive
AWF	36.3	Within MDOT Limits
CF upper limit	74.0	Positive
CF lower limit	48.0	Positive
WF Actual	36.3	

Appendix B

Raw Data for Shrinkage and Permeability

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 1
Mix Date: Tuesday, March 17, 2009
Mix Time: 11:56 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, March 18, 2009	0.0401	0.0182	0.0219	0.0614	0.0182	0.0432	0.0501	0.0182	0.0319	0.0323
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, April 14, 2009	0.0626	0.0400	0.0070	0.0838	0.0400	0.0060	0.0718	0.0392	0.0070	0.0067
32	Saturday, April 18, 2009	0.0607	0.0392	-0.0040	0.0818	0.0392	-0.0060	0.0708	0.0392	-0.0030	-0.0043
35	Tuesday, April 21, 2009	0.0602	0.0391	-0.0080	0.0815	0.0391	-0.0080	0.0704	0.0391	-0.0060	-0.0073
42	Tuesday, April 28, 2009	0.0597	0.0392	-0.0140	0.0810	0.0392	-0.0140	0.0698	0.0391	-0.0120	-0.0133
56	Tuesday, May 12, 2009	0.0588	0.0392	-0.0230	0.0801	0.0392	-0.0230	0.0690	0.0392	-0.0210	-0.0223
84	Tuesday, June 09, 2009	0.0556	0.0369	-0.0320	0.0770	0.0369	-0.0310	0.0659	0.0369	-0.0290	-0.0307
140	Tuesday, August 04, 2009	0.0523	0.0351	-0.0470	0.0739	0.0351	-0.0440	0.0624	0.0351	-0.0460	-0.0457
252	Tuesday, November 24, 2009	0.0517	0.0350	-0.0520	0.0733	0.0350	-0.0490	0.0619	0.0350	-0.0500	-0.0503
476	Tuesday, July 06, 2010	0.1278	0.1108	-0.0490	0.1493	0.1108	-0.0470	0.1380	0.1108	-0.0470	-0.0477

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, April 14, 2009	4.021	4.016	2356	2052	4.030	4.022	2593	2250	2151
91	Tuesday, June 16, 2009	4.020	4.010	1983	1730	4.022	4.018	1861	1619	1675
365	Wednesday, March 17, 2010	4.020	4.009	1523	1329	4.017	4.021	1210	1053	1191

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number Mix 2.1
Mix Date Thursday, May 28, 2009
Mix Time 1:41 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, May 29, 2009	0.0475	0.0384	0.0091	0.0247	0.0384	-0.0137	0.0527	0.0384	0.0143	0.0032
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, June 25, 2009	0.0443	0.0351	0.0010	0.0216	0.0352	0.0010	0.0498	0.0351	0.0040	0.0020
32	Monday, June 29, 2009	0.0437	0.0352	-0.0060	0.0210	0.0352	-0.0050	0.0491	0.0352	-0.0040	-0.0050
35	Thursday, July 02, 2009	0.0435	0.0352	-0.0080	0.0208	0.0352	-0.0070	0.0490	0.0352	-0.0050	-0.0067
42	Thursday, July 09, 2009	0.0422	0.0352	-0.0210	0.0194	0.0352	-0.0210	0.0477	0.0352	-0.0180	-0.0200
56	Thursday, July 23, 2009	0.0415	0.0350	-0.0260	0.0187	0.0350	-0.0260	0.0469	0.0350	-0.0240	-0.0253
84	Thursday, August 20, 2009	0.0406	0.0348	-0.0330	0.0178	0.0348	-0.0330	0.0459	0.0348	-0.0320	-0.0327
140	Thursday, October 15, 2009	0.0401	0.0349	-0.0390	0.0171	0.0349	-0.0410	0.0454	0.0349	-0.0380	-0.0393
252	Thursday, February 04, 2010	0.0399	0.0351	-0.0430	0.0169	0.0351	-0.0450	0.0451	0.0351	-0.0430	-0.0437
476	Thursday, September 16, 2010	0.1052	0.0997	-0.0360	0.0822	0.0997	-0.0380	0.1104	0.0997	-0.0360	-0.0367

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
29	Friday, June 26, 2009	4.012	4.019	1660	1448	4.009	4.021	1790	1562	1505
92	Friday, August 28, 2009	3.994	4.002	1660	1460	4.000	4.001	1358	1193	1327
365	Friday, May 28, 2010	4.000	3.999	1185	1042	4.003	3.999	1100	966	1004

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 3
Mix Date: Tuesday, March 24, 2009
Mix Time: 12:59 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, March 25, 2009	0.1016	0.0188	0.0828	0.1088	0.0188	0.0900	0.0866	0.0188	0.0678	0.0802
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, April 21, 2009	0.1233	0.0392	0.0130	0.1295	0.0392	0.0030	0.1073	0.0391	0.0040	0.0067
32	Saturday, April 25, 2009	0.1226	0.0393	0.0050	0.1288	0.0393	-0.0050	0.1066	0.0393	-0.0050	-0.0017
35	Tuesday, April 28, 2009	0.1223	0.0392	0.0030	0.1285	0.0392	-0.0070	0.1064	0.0392	-0.0060	-0.0033
42	Tuesday, May 05, 2009	0.1219	0.0391	0.0000	0.1280	0.0391	-0.0110	0.1060	0.0391	-0.0090	-0.0067
56	Tuesday, May 19, 2009	0.1206	0.0383	-0.0050	0.1266	0.0383	-0.0170	0.1047	0.0383	-0.0140	-0.0120
84	Tuesday, June 16, 2009	0.1170	0.0352	-0.0100	0.1227	0.0352	-0.0250	0.1011	0.0352	-0.0190	-0.0180
140	Tuesday, August 11, 2009	0.1150	0.0349	-0.0270	0.1211	0.0349	-0.0380	0.0995	0.0349	-0.0320	-0.0323
252	Tuesday, December 01, 2009	0.1145	0.0350	-0.0330	0.1204	0.0350	-0.0460	0.0990	0.0350	-0.0380	-0.0390
476	Tuesday, July 13, 2010	0.1798	0.0999	-0.0290	0.1855	0.0999	-0.0440	0.1641	0.0999	-0.0360	-0.0363

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, April 21, 2009	4.020	4.011	1818	1586	4.011	4.034	2013	1750	1668
91	Tuesday, June 23, 2009	4.021	4.010	898	783	4.010	4.028	912	794	789
365	Wednesday, March 24, 2010	4.020	4.011	589	514	4.011	4.023	539	470	492

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 4
Mix Date: Thursday, March 19, 2009
Mix Time: 1:34 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, March 20, 2009	0.0955	0.0181	0.0774	0.1083	0.0181	0.0902	0.0879	0.0181	0.0698	0.0791
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, April 16, 2009	0.1171	0.0391	0.0060	0.1298	0.0391	0.0050	0.1091	0.0391	0.0020	0.0043
32	Monday, April 20, 2009	0.1164	0.0392	-0.0020	0.1292	0.0391	-0.0010	0.1083	0.0391	-0.0060	-0.0030
35	Thursday, April 23, 2009	0.1161	0.0390	-0.0030	0.1288	0.0390	-0.0040	0.1080	0.0390	-0.0080	-0.0050
42	Thursday, April 30, 2009	0.1159	0.0391	-0.0060	0.1285	0.0391	-0.0080	0.1077	0.0391	-0.0120	-0.0087
56	Thursday, May 14, 2009	0.1153	0.0391	-0.0120	0.1280	0.0391	-0.0130	0.1071	0.0391	-0.0180	-0.0143
84	Thursday, June 11, 2009	0.1108	0.0351	-0.0170	0.1235	0.0351	-0.0180	0.1026	0.0351	-0.0230	-0.0193
140	Thursday, August 06, 2009	0.1093	0.0351	-0.0320	0.1220	0.0351	-0.0330	0.1012	0.0351	-0.0370	-0.0340
252	Thursday, November 26, 2009	0.1089	0.0350	-0.0350	0.1217	0.0350	-0.0350	0.1017	0.0350	-0.0310	-0.0337
476	Thursday, July 08, 2010	0.1850	0.1108	-0.0320	0.1980	0.1108	-0.0300	0.1768	0.1108	-0.0380	-0.0333

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, April 16, 2009	4.022	4.021	2109	1834	4.018	4.019	1912	1665	1749
91	Thursday, June 18, 2009	4.021	4.019	1776	1545	4.018	4.020	1613	1404	1475
365	Friday, March 19, 2010	4.018	4.022	1532	1333	4.019	4.019	1520	1323	1328

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 5
Mix Date: Tuesday, March 24, 2009
Mix Time: 8:51 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, March 25, 2009	0.0881	0.0181	0.0700	0.0962	0.0181	0.0781	0.1145	0.0181	0.0964	0.0815
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, April 21, 2009	0.1096	0.0391	0.0050	0.1187	0.0391	0.0150	0.1357	0.0391	0.0020	0.0073
32	Saturday, April 25, 2009	0.1088	0.0393	-0.0050	0.1178	0.0393	0.0040	0.1349	0.0393	-0.0080	-0.0030
35	Tuesday, April 28, 2009	0.1085	0.0392	-0.0070	0.1175	0.0392	0.0020	0.1346	0.0392	-0.0100	-0.0050
42	Tuesday, May 05, 2009	0.1080	0.0391	-0.0110	0.1170	0.0391	-0.0020	0.1341	0.0391	-0.0140	-0.0090
56	Tuesday, May 19, 2009	0.1066	0.0383	-0.0170	0.1157	0.0383	-0.0070	0.1328	0.0383	-0.0190	-0.0143
84	Tuesday, June 16, 2009	0.1029	0.0352	-0.0230	0.1118	0.0352	-0.0150	0.1291	0.0352	-0.0250	-0.0210
140	Tuesday, August 11, 2009	0.1012	0.0349	-0.0370	0.1101	0.0349	-0.0290	0.1275	0.0349	-0.0380	-0.0347
252	Tuesday, December 01, 2009	0.1008	0.0350	-0.0420	0.1098	0.0350	-0.0330	0.1271	0.0350	-0.0430	-0.0393
476	Tuesday, July 13, 2010	0.1660	0.0999	-0.0390	0.1752	0.0999	-0.0280	0.1924	0.0999	-0.0390	-0.0353

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, April 21, 2009	4.020	4.015	3112	2711	3.999	4.022	2934	2565	2638
91	Tuesday, June 23, 2009	4.019	4.016	1517	1322	4.000	4.019	1560	1365	1343
365	Wednesday, March 24, 2010	4.019	4.014	944	823	4.000	4.018	1050	919	871

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 6
Mix Date: Thursday, March 26, 2009
Mix Time: 10:15 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, March 27, 2009	0.0952	0.0193	0.0759	0.0916	0.0193	0.0723	0.0831	0.0193	0.0638	0.0707
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, April 23, 2009	0.1161	0.0390	0.0120	0.1148	0.0391	0.0340	0.1040	0.0391	0.0110	0.0190
32	Monday, April 27, 2009	0.1154	0.0391	0.0040	0.1138	0.0391	0.0240	0.1030	0.0391	0.0010	0.0097
35	Thursday, April 30, 2009	0.1152	0.0391	0.0020	0.1137	0.0391	0.0230	0.1029	0.0391	0.0000	0.0083
42	Thursday, May 07, 2009	0.1147	0.0391	-0.0030	0.1133	0.0391	0.0190	0.1025	0.0391	-0.0040	0.0040
56	Thursday, May 21, 2009	0.1133	0.0383	-0.0090	0.1119	0.0383	0.0130	0.1010	0.0383	-0.0110	-0.0023
84	Thursday, June 18, 2009	0.1099	0.0351	-0.0110	0.1083	0.0351	0.0090	0.0974	0.0351	-0.0150	-0.0057
140	Thursday, August 13, 2009	0.1085	0.0349	-0.0230	0.1065	0.0349	-0.0070	0.0959	0.0349	-0.0280	-0.0193
252	Thursday, December 03, 2009	0.1082	0.0350	-0.0270	0.1061	0.0350	-0.0120	0.0955	0.0350	-0.0330	-0.0240
476	Thursday, July 15, 2010	0.1736	0.0999	-0.0220	0.1713	0.0999	-0.0090	0.1607	0.0999	-0.0300	-0.0203

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, April 23, 2009	4.021	4.015	2287	1992	4.016	4.020	2648	2307	2149
91	Thursday, June 25, 2009	4.018	4.012	872	761	4.017	4.022	754	656	708
365	Friday, March 26, 2010	4.017	4.013	276	241	4.013	4.019	288	251	246

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 7
Mix Date: Thursday, March 26, 2009
Mix Time: 1:21 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, March 27, 2009	0.1092	0.0191	0.0901	0.0859	0.0191	0.0668	0.0920	0.0191	0.0729	0.0766
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, April 23, 2009	0.1300	0.0391	0.0080	0.1083	0.0391	0.0240	0.1129	0.0391	0.0090	0.0137
32	Monday, April 27, 2009	0.1292	0.0391	0.0000	0.1075	0.0391	0.0160	0.1121	0.0391	0.0010	0.0057
35	Thursday, April 30, 2009	0.1290	0.0391	-0.0020	0.1074	0.0391	0.0150	0.1119	0.0391	-0.0010	0.0040
42	Thursday, May 07, 2009	0.1286	0.0391	-0.0060	0.1070	0.0391	0.0110	0.1116	0.0391	-0.0040	0.0003
56	Thursday, May 21, 2009	0.1274	0.0383	-0.0100	0.1057	0.0383	0.0060	0.1103	0.0383	-0.0090	-0.0043
84	Thursday, June 18, 2009	0.1237	0.0351	-0.0150	0.1018	0.0351	-0.0010	0.1066	0.0351	-0.0140	-0.0100
140	Thursday, August 13, 2009	0.1221	0.0349	-0.0290	0.1003	0.0349	-0.0140	0.1049	0.0349	-0.0290	-0.0240
252	Thursday, December 03, 2009	0.1217	0.0350	-0.0340	0.0999	0.0350	-0.0190	0.1044	0.0350	-0.0350	-0.0293
476	Thursday, July 15, 2010	0.1869	0.0999	-0.0310	0.1652	0.0999	-0.0150	0.1695	0.0999	-0.0330	-0.0263

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, April 23, 2009	4.015	4.015	957	835	4.011	4.015	853	745	790
91	Thursday, June 25, 2009	4.013	4.019	412	359	4.009	4.018	432	377	368
365	Friday, March 26, 2010	4.014	4.015	365	318	4.008	4.008	362	317	318

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 8
Mix Date: Tuesday, March 31, 2009
Mix Time: 4:03 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, April 01, 2009	0.0871	0.0369	0.0502	0.0789	0.0369	0.0420	0.1331	0.0369	0.0962	0.0628
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, April 28, 2009	0.0896	0.0391	0.0030	0.0813	0.0391	0.0020	0.1356	0.0391	0.0030	0.0027
32	Saturday, May 02, 2009	0.0887	0.0392	-0.0070	0.0803	0.0392	-0.0090	0.1347	0.0392	-0.0070	-0.0077
35	Tuesday, May 05, 2009	0.0884	0.0391	-0.0090	0.0801	0.0391	-0.0100	0.1344	0.0391	-0.0090	-0.0093
42	Tuesday, May 12, 2009	0.0880	0.0391	-0.0130	0.0797	0.0391	-0.0140	0.1340	0.0391	-0.0130	-0.0133
56	Tuesday, May 26, 2009	0.0865	0.0382	-0.0190	0.0781	0.0382	-0.0210	0.1326	0.0382	-0.0180	-0.0193
84	Tuesday, June 23, 2009	0.0828	0.0351	-0.0250	0.0744	0.0351	-0.0270	0.1288	0.0351	-0.0250	-0.0257
140	Tuesday, August 18, 2009	0.0812	0.0349	-0.0390	0.0726	0.0349	-0.0430	0.1272	0.0349	-0.0390	-0.0403
252	Tuesday, December 08, 2009	0.0811	0.0350	-0.0410	0.0723	0.0350	-0.0470	0.1268	0.0350	-0.0440	-0.0440
476	Tuesday, July 20, 2010	0.1468	0.1004	-0.0380	0.1380	0.1003	-0.0430	0.1928	0.1003	-0.0370	-0.0393

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, April 28, 2009	4.020	4.018	2240	1950	4.015	4.009	2603	2274	2112
91	Tuesday, June 30, 2009	4.020	4.019	1453	1265	4.018	4.012	1558	1359	1312
365	Wednesday, March 31, 2010	3.999	4.008	1269	1113	3.998	4.018	1320	1156	1134

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 9
Mix Date: Thursday, April 02, 2009
Mix Time: 8:42 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, April 03, 2009	0.0757	0.0370	0.0387	0.0945	0.0370	0.0575	0.1132	0.0370	0.0762	0.0575
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, April 30, 2009	0.0782	0.0391	0.0040	0.0983	0.0391	0.0170	0.1158	0.0391	0.0050	0.0087
32	Monday, May 04, 2009	0.0770	0.0391	-0.0080	0.0972	0.0391	0.0060	0.1149	0.0391	-0.0040	-0.0020
35	Thursday, May 07, 2009	0.0769	0.0391	-0.0090	0.0970	0.0391	0.0040	0.1146	0.0391	-0.0070	-0.0040
42	Thursday, May 14, 2009	0.0762	0.0391	-0.0160	0.0965	0.0391	-0.0010	0.1141	0.0391	-0.0120	-0.0097
56	Thursday, May 28, 2009	0.0746	0.0380	-0.0210	0.0947	0.0380	-0.0080	0.1126	0.0381	-0.0170	-0.0153
84	Thursday, June 25, 2009	0.0712	0.0352	-0.0270	0.0915	0.0352	-0.0120	0.1092	0.0352	-0.0220	-0.0203
140	Thursday, August 20, 2009	0.0699	0.0348	-0.0360	0.0899	0.0348	-0.0240	0.1075	0.0348	-0.0350	-0.0317
252	Thursday, December 10, 2009	0.0695	0.0350	-0.0420	0.0897	0.0350	-0.0280	0.1073	0.0350	-0.0390	-0.0363
476	Thursday, July 22, 2010	0.1355	0.1004	-0.0360	0.1554	0.1004	-0.0250	0.1731	0.1004	-0.0350	-0.0320

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, April 30, 2009	4.012	4.031	2011	1749	4.012	4.019	2187	1907	1828
91	Thursday, July 02, 2009	4.029	4.018	1257	1092	4.021	4.011	1246	1086	1089
365	Friday, April 02, 2010	4.007	4.012	359	314	4.017	4.009	375	327	321

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 10
Mix Date: Thursday, April 02, 2009
Mix Time: 10:43 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, April 03, 2009	0.0732	0.0370	0.0362	0.0763	0.0370	0.0393	0.0762	0.0370	0.0392	0.0382
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, April 30, 2009	0.0762	0.0391	0.0090	0.0806	0.0391	0.0220	0.0800	0.0391	0.0170	0.0160
32	Monday, May 04, 2009	0.0752	0.0391	-0.0010	0.0800	0.0391	0.0160	0.0790	0.0391	0.0070	0.0073
35	Thursday, May 07, 2009	0.0750	0.0391	-0.0030	0.0795	0.0392	0.0100	0.0788	0.0391	0.0050	0.0040
42	Thursday, May 14, 2009	0.0745	0.0391	-0.0080	0.0790	0.0391	0.0060	0.0782	0.0391	-0.0010	-0.0010
56	Thursday, May 28, 2009	0.0730	0.0380	-0.0120	0.0774	0.0380	0.0010	0.0766	0.0380	-0.0060	-0.0057
84	Thursday, June 25, 2009	0.0695	0.0352	-0.0190	0.0739	0.0352	-0.0060	0.0732	0.0352	-0.0120	-0.0123
140	Thursday, August 20, 2009	0.0679	0.0348	-0.0310	0.0725	0.0348	-0.0160	0.0715	0.0348	-0.0250	-0.0240
252	Thursday, December 10, 2009	0.0676	0.0350	-0.0360	0.0720	0.0350	-0.0230	0.0712	0.0350	-0.0300	-0.0297
476	Thursday, July 22, 2010	0.1332	0.1004	-0.0340	0.1376	0.1004	-0.0210	0.1370	0.1004	-0.0260	-0.0270

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, April 30, 2009	4.010	4.011	2187	1912	4.010	4.011	2836	2480	2196
91	Thursday, July 02, 2009	4.013	4.025	963	838	4.017	4.021	886	771	805
365	Friday, April 02, 2010	4.011	4.014	212	185	3.999	4.016	220	193	189

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 11
Mix Date: Tuesday, April 07, 2009
Mix Time: 12:13 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, April 08, 2009	0.0933	0.0373	0.0560	0.0760	0.0373	0.0387	0.0920	0.0373	0.0547	0.0498
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, May 05, 2009	0.0968	0.0391	0.0170	0.0792	0.0391	0.0140	0.0958	0.0391	0.0200	0.0170
32	Saturday, May 09, 2009	0.0963	0.0391	0.0120	0.0787	0.0391	0.0090	0.0954	0.0391	0.0160	0.0123
35	Tuesday, May 12, 2009	0.0962	0.0391	0.0110	0.0786	0.0391	0.0080	0.0953	0.0391	0.0150	0.0113
42	Tuesday, May 19, 2009	0.0951	0.0383	0.0080	0.0776	0.0383	0.0060	0.0942	0.0383	0.0120	0.0087
56	Tuesday, June 02, 2009	0.0943	0.0380	0.0030	0.0768	0.0380	0.0010	0.0935	0.0380	0.0080	0.0040
84	Tuesday, June 30, 2009	0.0912	0.0352	0.0000	0.0737	0.0352	-0.0020	0.0902	0.0352	0.0030	0.0003
140	Tuesday, August 25, 2009	0.0893	0.0349	-0.0160	0.0718	0.0349	-0.0180	0.0884	0.0349	-0.0120	-0.0153
252	Tuesday, December 15, 2009	0.0890	0.0353	-0.0230	0.0713	0.0353	-0.0270	0.0880	0.0353	-0.0200	-0.0233
476	Tuesday, July 27, 2010	0.1540	0.1003	-0.0230	0.1363	0.1003	-0.0270	0.1532	0.1003	-0.0180	-0.0227

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, May 05, 2009	4.024	4.010	488	425	4.003	4.002	462	406	415
91	Tuesday, July 07, 2009	4.022	4.012	291	254	4.005	4.004	284	249	251
375	Saturday, April 17, 2010	4.009	4.011	245	214	4.003	4.001	221	194	204

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 12
Mix Date: Thursday, April 09, 2009
Mix Time: 10:19 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, April 10, 2009	0.1202	0.0373	0.0829	0.0901	0.0373	0.0528	0.0895	0.0373	0.0522	0.0626
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, May 07, 2009	0.1223	0.0391	0.0030	0.0932	0.0391	0.0130	0.0928	0.0391	0.0150	0.0103
32	Monday, May 11, 2009	0.1212	0.0391	-0.0080	0.0922	0.0391	0.0030	0.0917	0.0391	0.0040	-0.0003
35	Thursday, May 14, 2009	0.1207	0.0391	-0.0130	0.0917	0.0391	-0.0020	0.0913	0.0391	0.0000	-0.0050
42	Thursday, May 21, 2009	0.1195	0.0383	-0.0170	0.0905	0.0383	-0.0060	0.0900	0.0383	-0.0050	-0.0093
56	Thursday, June 04, 2009	0.1187	0.0379	-0.0210	0.0898	0.0379	-0.0090	0.0890	0.0379	-0.0110	-0.0137
84	Thursday, July 02, 2009	0.1150	0.0352	-0.0310	0.0860	0.0352	-0.0200	0.0854	0.0352	-0.0200	-0.0237
140	Thursday, August 27, 2009	0.1131	0.0349	-0.0470	0.0840	0.0349	-0.0370	0.0835	0.0349	-0.0360	-0.0400
252	Thursday, December 17, 2009	0.1128	0.0351	-0.0520	0.0838	0.0351	-0.0410	0.0834	0.0351	-0.0390	-0.0440
476	Thursday, July 29, 2010	0.1781	0.1004	-0.0520	0.1492	0.1004	-0.0400	0.1486	0.1004	-0.0400	-0.0440

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, May 07, 2009	4.003	3.999	2586	2272	3.994	4.003	3161	2780	2526
91	Thursday, July 09, 2009	4.004	4.002	1501	1317	3.998	4.005	1466	1288	1302
375	Monday, April 19, 2010	4.001	4.006	754	662	3.999	4.001	783	688	675

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 13
Mix Date: Thursday, April 09, 2009
Mix Time: 1:40 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, April 10, 2009	0.0616	0.0373	0.0243	0.0980	0.0373	0.0607	0.1145	0.0373	0.0772	0.0541
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, May 07, 2009	0.0649	0.0391	0.0150	0.1012	0.0391	0.0140	0.1169	0.0391	0.0060	0.0117
32	Monday, May 11, 2009	0.0638	0.0391	0.0040	0.1003	0.0391	0.0050	0.1160	0.0391	-0.0030	0.0020
35	Thursday, May 14, 2009	0.0635	0.0391	0.0010	0.0999	0.0391	0.0010	0.1156	0.0391	-0.0070	-0.0017
42	Thursday, May 21, 2009	0.0623	0.0384	-0.0040	0.0987	0.0383	-0.0030	0.1146	0.0383	-0.0090	-0.0053
56	Thursday, June 04, 2009	0.0613	0.0379	-0.0090	0.0978	0.0379	-0.0080	0.1135	0.0379	-0.0160	-0.0110
84	Thursday, July 02, 2009	0.0581	0.0352	-0.0140	0.0944	0.0352	-0.0150	0.1104	0.0352	-0.0200	-0.0163
140	Thursday, August 27, 2009	0.0566	0.0349	-0.0260	0.0926	0.0349	-0.0300	0.1087	0.0349	-0.0340	-0.0300
252	Thursday, December 17, 2009	0.0564	0.0351	-0.0300	0.0924	0.0351	-0.0340	0.1085	0.0351	-0.0380	-0.0340
476	Thursday, July 29, 2010	0.1220	0.1004	-0.0270	0.1578	0.1004	-0.0330	0.1737	0.1004	-0.0390	-0.0330

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, May 07, 2009	4.002	3.992	3032	2669	3.999	3.994	2569	2262	2465
91	Thursday, July 09, 2009	4.001	3.995	910	801	4.002	3.998	947	832	816
376	Tuesday, April 20, 2010	4.000	4.001	314	276	4.003	3.999	307	270	273

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 14
Mix Date: Tuesday, April 14, 2009
Mix Time: 1:16 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, April 15, 2009	0.0565	0.0391	0.0174	0.1248	0.0391	0.0857	0.0864	0.0391	0.0473	0.0501
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, May 12, 2009	0.0570	0.0391	0.0050	0.1250	0.0391	0.0020	0.0869	0.0391	0.0050	0.0040
32	Saturday, May 16, 2009	0.0563	0.0391	-0.0020	0.1243	0.0391	-0.0050	0.0862	0.0391	-0.0020	-0.0030
35	Tuesday, May 19, 2009	0.0552	0.0383	-0.0050	0.1232	0.0383	-0.0080	0.0849	0.0383	-0.0070	-0.0067
42	Tuesday, May 26, 2009	0.0546	0.0382	-0.0100	0.1226	0.0382	-0.0130	0.0843	0.0382	-0.0120	-0.0117
56	Tuesday, June 09, 2009	0.0531	0.0374	-0.0170	0.1213	0.0374	-0.0180	0.0831	0.0374	-0.0160	-0.0170
84	Tuesday, July 07, 2009	0.0500	0.0352	-0.0260	0.1181	0.0352	-0.0280	0.0799	0.0352	-0.0260	-0.0267
140	Tuesday, September 01, 2009	0.0482	0.0348	-0.0400	0.1162	0.0348	-0.0430	0.0780	0.0348	-0.0410	-0.0413
252	Tuesday, December 22, 2009	0.0479	0.0350	-0.0450	0.1159	0.0350	-0.0480	0.0777	0.0350	-0.0460	-0.0463
476	Tuesday, August 03, 2010	0.1131	0.1003	-0.0460	0.1813	0.1003	-0.0470	0.1430	0.1003	-0.0460	-0.0463

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, May 12, 2009	4.020	4.019	1984	1727	4.026	3.998	1953	1706	1717
91	Tuesday, July 14, 2009	4.021	4.005	1586	1385	4.009	4.025	1571	1369	1377
371	Tuesday, April 20, 2010	4.019	4.002	1382	1208	4.003	4.007	1338	1173	1191

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 15.1
Mix Date: Tuesday, August 11, 2009
Mix Time: 9:29 AM

SHRINKAGE TESTING - ASTM C157

Reference Bar Length (in.): 10

INITIAL READINGS

Specimen Age	Test date	Specimen 1 (.0001 in.)	Reference Bar 1 (.0001 in.)	Δ Length 1 Inches	Specimen 2 (.0001 in.)	Reference Bar 2 (.0001 in.)	Δ Length 2 Inches	Specimen 3 (.0001 in.)	Reference Bar 3 (.0001 in.)	Δ Length 3 Inches	Average Inches
1	Wednesday, August 12, 2009	0.0415	0.0349	0.0066	0.0529	0.0349	0.0180	0.0528	0.0349	0.0179	0.0142

LENGTH CHANGE CALCULATIONS

Specimen Age	Test date	Specimen 1 (.0001 in.)	Reference Bar 1 (.0001 in.)	Δ Length 1 (0.001%)	Specimen 2 (.0001 in.)	Reference Bar 2 (.0001 in.)	Δ Length 2 (0.001%)	Specimen 3 (.0001 in.)	Reference Bar 3 (.0001 in.)	Δ Length 3 (0.001%)	Average (.01%)
28	Tuesday, September 08, 2009	0.0421	0.0349	0.0060	0.0534	0.0349	0.0050	0.0536	0.0349	0.0080	0.0063
32	Saturday, September 12, 2009	0.0415	0.0349	0.0000	0.0528	0.0349	-0.0010	0.0530	0.0349	0.0020	0.0003
35	Tuesday, September 15, 2009	0.0412	0.0348	-0.0020	0.0524	0.0348	-0.0040	0.0527	0.0348	0.0000	-0.0020
42	Tuesday, September 22, 2009	0.0410	0.0348	-0.0040	0.0522	0.0348	-0.0060	0.0524	0.0348	-0.0030	-0.0043
56	Tuesday, October 06, 2009	0.0404	0.0349	-0.0110	0.0517	0.0349	-0.0120	0.0518	0.0349	-0.0100	-0.0110
84	Tuesday, November 03, 2009	0.0399	0.0350	-0.0170	0.0512	0.0350	-0.0180	0.0514	0.0350	-0.0150	-0.0167
140	Tuesday, December 29, 2009	0.0394	0.0351	-0.0230	0.0506	0.0351	-0.0250	0.0507	0.0351	-0.0230	-0.0237
252	Tuesday, April 20, 2010	0.0393	0.0351	-0.0240	0.0507	0.0351	-0.0240	0.0509	0.0351	-0.0210	-0.0230
476	Tuesday, November 30, 2010	0.1053	0.1013	-0.0260	0.1167	0.1013	-0.0260	0.1171	0.1013	-0.0210	-0.0243

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, September 08, 2009	4.026	3.973	769	676	3.990	4.004	855	753	714
91	Tuesday, November 10, 2009	4.002	3.999	526	462	3.993	4.005	485	426	444
365	Wednesday, August 11, 2010	3.999	3.998	342	301	3.994	3.998	403	355	328

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 16
Mix Date: Thursday, April 23, 2009
Mix Time: 8:44 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, April 24, 2009	0.1323	0.0392	0.0931	0.1039	0.0392	0.0647	0.1138	0.0392	0.0746	0.0775
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, May 21, 2009	0.1330	0.0383	0.0160	0.1047	0.0383	0.0170	0.1142	0.0383	0.0130	0.0153
32	Monday, May 25, 2009	0.1322	0.0384	0.0070	0.1040	0.0384	0.0090	0.1135	0.0383	0.0060	0.0073
35	Thursday, May 28, 2009	0.1322	0.0386	0.0050	0.1039	0.0385	0.0070	0.1130	0.0380	0.0040	0.0053
42	Thursday, June 04, 2009	0.1312	0.0379	0.0020	0.1030	0.0379	0.0040	0.1126	0.0379	0.0010	0.0023
56	Thursday, June 18, 2009	0.1275	0.0351	-0.0070	0.0993	0.0351	-0.0050	0.1089	0.0351	-0.0080	-0.0067
84	Thursday, July 16, 2009	0.1258	0.0350	-0.0230	0.0978	0.0350	-0.0190	0.1074	0.0350	-0.0220	-0.0213
140	Thursday, September 10, 2009	0.1250	0.0349	-0.0300	0.0968	0.0349	-0.0280	0.1066	0.0349	-0.0290	-0.0290
252	Thursday, December 31, 2009	0.1248	0.0352	-0.0350	0.0966	0.0352	-0.0330	0.1065	0.0352	-0.0330	-0.0337
476	Thursday, August 12, 2010	0.1900	0.1002	-0.0330	0.1619	0.1002	-0.0300	0.1719	0.1002	-0.0290	-0.0307

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, May 21, 2009	4.014	4.016	1741	1519	4.004	4.033	1641	1429	1474
91	Thursday, July 23, 2009	4.018	4.015	1350	1177	4.008	4.027	1276	1112	1144
365	Friday, April 23, 2010	4.013	4.009	1143	999	4.009	4.012	1267	1108	1053

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 17
Mix Date: Tuesday, April 28, 2009
Mix Time: 12:10 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, April 29, 2009	0.0832	0.0392	0.0440	0.0945	0.0392	0.0553	0.0854	0.0392	0.0462	0.0485
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, May 26, 2009	0.0838	0.0382	0.0160	0.0940	0.0382	0.0050	0.0847	0.0382	0.0030	0.0080
32	Saturday, May 30, 2009	0.0832	0.0385	0.0070	0.0933	0.0385	-0.0050	0.0841	0.0385	-0.0060	-0.0013
35	Tuesday, June 02, 2009	0.0826	0.0380	0.0060	0.0925	0.0380	-0.0080	0.0834	0.0380	-0.0080	-0.0033
42	Tuesday, June 09, 2009	0.0819	0.0350	0.0290	0.0893	0.0377	-0.0370	0.0799	0.0350	-0.0130	-0.0070
56	Tuesday, June 23, 2009	0.0786	0.0351	-0.0050	0.0888	0.0351	-0.0160	0.0794	0.0351	-0.0190	-0.0133
84	Tuesday, July 21, 2009	0.0765	0.0351	-0.0260	0.0870	0.0351	-0.0340	0.0778	0.0351	-0.0350	-0.0317
140	Tuesday, September 15, 2009	0.0756	0.0348	-0.0320	0.0861	0.0348	-0.0400	0.0768	0.0348	-0.0420	-0.0380
252	Tuesday, January 05, 2010	0.0754	0.0351	-0.0370	0.0859	0.0351	-0.0450	0.0765	0.0351	-0.0480	-0.0433
476	Tuesday, August 17, 2010	0.1408	0.1000	-0.0320	0.1512	0.1000	-0.0410	0.1418	0.1000	-0.0440	-0.0390

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, May 26, 2009	4.011	4.015	1925	1681	3.993	4.031	1802	1574	1628
91	Tuesday, July 28, 2009	4.012	4.017	1461	1275	4.015	4.002	1637	1433	1354
365	Wednesday, April 28, 2010	4.001	4.012	1287	1127	4.012	4.004	1556	1362	1245

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 18
Mix Date: Tuesday, April 28, 2009
Mix Time: 3:07 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, April 29, 2009	0.0516	0.0392	0.0124	0.0615	0.0392	0.0223	0.0801	0.0392	0.0409	0.0252
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, May 26, 2009	0.0514	0.0382	0.0080	0.0626	0.0382	0.0210	0.0809	0.0382	0.0180	0.0157
32	Saturday, May 30, 2009	0.0507	0.0385	-0.0020	0.0616	0.0380	0.0130	0.0800	0.0380	0.0110	0.0073
35	Tuesday, June 02, 2009	0.0500	0.0381	-0.0050	0.0612	0.0380	0.0090	0.0797	0.0380	0.0080	0.0040
42	Tuesday, June 09, 2009	0.0487	0.0373	-0.0100	0.0603	0.0376	0.0040	0.0787	0.0376	0.0020	-0.0013
56	Tuesday, June 23, 2009	0.0462	0.0351	-0.0130	0.0573	0.0351	-0.0010	0.0758	0.0351	-0.0020	-0.0053
84	Tuesday, July 21, 2009	0.0446	0.0351	-0.0290	0.0558	0.0351	-0.0160	0.0743	0.0351	-0.0170	-0.0207
140	Tuesday, September 15, 2009	0.0436	0.0348	-0.0360	0.0548	0.0348	-0.0230	0.0733	0.0348	-0.0240	-0.0277
252	Tuesday, January 05, 2010	0.0433	0.0351	-0.0420	0.0547	0.0351	-0.0270	0.0731	0.0351	-0.0290	-0.0327
476	Tuesday, August 17, 2010	0.1087	0.1000	-0.0370	0.1201	0.1000	-0.0220	0.1384	0.1000	-0.0250	-0.0280

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
29	Wednesday, May 27, 2009	3.995	4.021	3409	2984	4.011	3.998	2932	2571	2778
91	Tuesday, July 28, 2009	3.999	4.015	1416	1240	4.012	4.008	1377	1204	1222
365	Wednesday, April 28, 2010	3.998	4.012	786	689	4.006	4.007	669	586	638

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 19
Mix Date: Tuesday, May 05, 2009
Mix Time: 10:46 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 06, 2009	0.0903	0.0391	0.0512	0.0562	0.0391	0.0171	0.0602	0.0391	0.0211	0.0298
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 02, 2009	0.0892	0.0379	0.0010	0.0550	0.0379	0.0000	0.0588	0.0379	-0.0020	-0.0003
32	Saturday, June 06, 2009	0.0887	0.0381	-0.0060	0.0544	0.0381	-0.0080	0.0583	0.0381	-0.0090	-0.0077
35	Tuesday, June 09, 2009	0.0883	0.0373	-0.0020	0.0539	0.0376	-0.0080	0.0575	0.0376	-0.0120	-0.0073
42	Tuesday, June 16, 2009	0.0853	0.0352	-0.0110	0.0509	0.0352	-0.0140	0.0546	0.0352	-0.0170	-0.0140
56	Tuesday, June 30, 2009	0.0846	0.0352	-0.0180	0.0503	0.0352	-0.0200	0.0539	0.0352	-0.0240	-0.0207
84	Tuesday, July 28, 2009	0.0826	0.0351	-0.0370	0.0483	0.0351	-0.0390	0.0523	0.0351	-0.0390	-0.0383
140	Tuesday, September 22, 2009	0.0817	0.0348	-0.0430	0.0475	0.0348	-0.0440	0.0514	0.0348	-0.0450	-0.0440
252	Tuesday, January 12, 2010	0.0814	0.0348	-0.0460	0.0472	0.0348	-0.0470	0.0510	0.0348	-0.0490	-0.0473
476	Tuesday, August 24, 2010	0.1469	0.1001	-0.0440	0.1124	0.1001	-0.0480	0.1166	0.1001	-0.0460	-0.0460

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, June 02, 2009	4.016	4.013	2328	2031	4.011	4.021	2508	2187	2109
91	Tuesday, August 04, 2009	4.015	4.016	2198	1917	4.012	4.017	2080	1815	1866
365	Wednesday, May 05, 2010	4.007	4.011	1964	1718	4.008	4.012	1729	1512	1615

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 20.1
Mix Date: Tuesday, May 12, 2009
Mix Time: 9:44 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	**INITIAL READINGS**									
	10	**Specimen 1**	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 13, 2009	0.0342	0.0392	-0.0050	0.0710	0.0392	0.0318	0.0737	0.0392	0.0345	0.0204
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 09, 2009	0.0326	0.0373	0.0030	0.0697	0.0374	0.0050	0.0698	0.0378	-0.0250	-0.0057
32	Saturday, June 13, 2009	0.0299	0.0352	-0.0030	0.0670	0.0352	0.0000	0.0695	0.0352	-0.0020	-0.0017
35	Tuesday, June 16, 2009	0.0295	0.0352	-0.0070	0.0667	0.0352	-0.0030	0.0691	0.0352	-0.0060	-0.0053
42	Tuesday, June 23, 2009	0.0288	0.0351	-0.0130	0.0661	0.0351	-0.0080	0.0685	0.0351	-0.0110	-0.0107
56	Tuesday, July 07, 2009	0.0280	0.0352	-0.0220	0.0653	0.0352	-0.0170	0.0678	0.0352	-0.0190	-0.0193
84	Tuesday, August 04, 2009	0.0262	0.0351	-0.0390	0.0636	0.0351	-0.0330	0.0659	0.0351	-0.0370	-0.0363
140	Tuesday, September 29, 2009	0.0253	0.0349	-0.0460	0.0627	0.0349	-0.0400	0.0650	0.0349	-0.0440	-0.0433
252	Tuesday, January 19, 2010	0.0252	0.0350	-0.0480	0.0627	0.0350	-0.0410	0.0649	0.0350	-0.0460	-0.0450
476	Tuesday, August 31, 2010	0.0906	0.1003	-0.0470	0.1282	0.1003	-0.0390	0.1303	0.1003	-0.0450	-0.0437

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	**Test date**	**Specimen P1 Diameter 1 (.001 in.)**	**Specimen P1 Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**	**Specimen P2 Diameter 1 (.001 in.)**	**Specimen P2 Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**	**Average Coulombs**
16	Thursday, May 28, 2009	4.005	4.022	4950	4321	3.999	4.024	4410	3854	4088
91	Tuesday, August 11, 2009	4.008	4.020	1967	1717	4.001	4.012	2104	1843	1780
365	Wednesday, May 12, 2010	4.003	4.017	553	484	3.998	4.003	562	494	489

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 21
Mix Date: Tuesday, May 05, 2009
Mix Time: 12:56 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 06, 2009	0.0830	0.0391	0.0439	0.0884	0.0391	0.0493	0.0620	0.0391	0.0229	0.0387
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 02, 2009	0.0821	0.0379	0.0030	0.0887	0.0379	0.0150	0.0619	0.0379	0.0110	0.0097
32	Saturday, June 06, 2009	0.0820	0.0386	-0.0050	0.0880	0.0381	0.0060	0.0613	0.0382	0.0020	0.0010
35	Tuesday, June 09, 2009	0.0809	0.0373	-0.0030	0.0867	0.0373	0.0010	0.0602	0.0373	0.0000	-0.0007
42	Tuesday, June 16, 2009	0.0783	0.0352	-0.0080	0.0844	0.0352	-0.0010	0.0577	0.0352	-0.0040	-0.0043
56	Tuesday, June 30, 2009	0.0777	0.0352	-0.0140	0.0840	0.0352	-0.0050	0.0572	0.0352	-0.0090	-0.0093
84	Tuesday, July 28, 2009	0.0759	0.0351	-0.0310	0.0824	0.0351	-0.0200	0.0556	0.0351	-0.0240	-0.0250
140	Tuesday, September 22, 2009	0.0751	0.0348	-0.0360	0.0816	0.0348	-0.0250	0.0548	0.0348	-0.0290	-0.0300
252	Tuesday, January 12, 2010	0.0750	0.0348	-0.0370	0.0815	0.0348	-0.0260	0.0548	0.0348	-0.0290	-0.0307
476	Tuesday, August 24, 2010	0.1407	0.1001	-0.0330	0.1471	0.1001	-0.0230	0.1204	0.1001	-0.0260	-0.0273

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, June 02, 2009	3.996	4.023	2328	2036	4.019	4.008	2462	2149	2093
91	Tuesday, August 04, 2009	4.000	4.018	893	781	4.012	4.170	820	689	735
365	Wednesday, May 05, 2010	3.999	4.003	292	257	4.003	4.012	336	294	275

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 22
Mix Date: Thursday, May 07, 2009
Mix Time: 9:04 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, May 08, 2009	0.1553	0.0392	0.1161	0.0603	0.0392	0.0211	0.0893	0.0392	0.0501	0.0624
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, June 04, 2009	0.1564	0.0383	0.0200	0.0614	0.0383	0.0200	0.0918	0.0383	0.0340	0.0247
32	Monday, June 08, 2009	0.1530	0.0359	0.0100	0.0588	0.0363	0.0140	0.0907	0.0363	0.0430	0.0223
35	Thursday, June 11, 2009	0.1525	0.0349	0.0150	0.0601	0.0350	0.0400	0.0888	0.0350	0.0370	0.0307
42	Thursday, June 18, 2009	0.1521	0.0351	0.0090	0.0571	0.0351	0.0090	0.0874	0.0351	0.0220	0.0133
56	Thursday, July 02, 2009	0.1517	0.0352	0.0040	0.0568	0.0352	0.0050	0.0870	0.0352	0.0170	0.0087
84	Thursday, July 30, 2009	0.1501	0.0352	-0.0120	0.0553	0.0352	-0.0100	0.0854	0.0352	0.0010	-0.0070
140	Thursday, September 24, 2009	0.1491	0.0349	-0.0190	0.0543	0.0349	-0.0170	0.0844	0.0349	-0.0060	-0.0140
252	Thursday, January 14, 2010	0.1489	0.0350	-0.0220	0.0540	0.0350	-0.0210	0.0843	0.0350	-0.0080	-0.0170
476	Thursday, August 26, 2010	0.2145	0.1001	-0.0170	0.1190	0.1001	-0.0220	0.1499	0.1001	-0.0030	-0.0140

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, June 04, 2009	4.015	4.030	968	841	4.020	4.012	868	757	799
91	Thursday, August 06, 2009	4.013	4.028	553	481	4.015	4.019	522	455	468
365	Friday, May 07, 2010	4.013	4.019	410	357	4.017	4.011	368	321	339

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 23.1
Mix Date: Thursday, August 06, 2009
Mix Time: 12:00 PM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, August 07, 2009	0.0312	0.0350	-0.0038	0.0385	0.0350	0.0035	0.0378	0.0350	0.0028	0.0008
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, September 03, 2009	0.0312	0.0348	0.0020	0.0384	0.0348	0.0010	0.0374	0.0348	-0.0020	0.0003
32	Monday, September 07, 2009	0.0302	0.0349	-0.0090	0.0375	0.0349	-0.0090	0.0365	0.0349	-0.0120	-0.0100
35	Thursday, September 10, 2009	0.0300	0.0349	-0.0110	0.0373	0.0349	-0.0110	0.0363	0.0349	-0.0140	-0.0120
42	Thursday, September 17, 2009	0.0296	0.0348	-0.0140	0.0367	0.0348	-0.0160	0.0358	0.0348	-0.0180	-0.0160
56	Thursday, October 01, 2009	0.0288	0.0350	-0.0240	0.0361	0.0350	-0.0240	0.0351	0.0350	-0.0270	-0.0250
84	Thursday, October 29, 2009	0.0280	0.0350	-0.0320	0.0353	0.0350	-0.0320	0.0346	0.0350	-0.0320	-0.0320
140	Thursday, December 24, 2009	0.0274	0.0350	-0.0380	0.0347	0.0350	-0.0380	0.0337	0.0350	-0.0410	-0.0390
252	Thursday, April 15, 2010	0.0269	0.0348	-0.0410	0.0342	0.0348	-0.0410	0.0332	0.0348	-0.0440	-0.0420
476	Thursday, November 25, 2010	0.0948	0.1022	-0.0360	0.1023	0.1022	-0.0340	0.1014	0.1022	-0.0360	-0.0353

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, September 03, 2009	3.990	4.009	2202	1936	3.995	4.001	2282	2008	1972
91	Thursday, November 05, 2009	3.998	4.003	2015	1771	3.997	4.003	1967	1729	1750
365	Friday, August 06, 2010	3.999	4.000	1703	1497	3.998	3.999	2111	1857	1677

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 24
Mix Date: Tuesday, May 12, 2009
Mix Time: 11:40 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 13, 2009	0.0875	0.0392	0.0483	0.0970	0.0392	0.0578	0.0932	0.0392	0.0540	0.0534
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 09, 2009	0.0862	0.0378	0.0010	0.0957	0.0378	0.0010	0.0933	0.0378	0.0150	0.0057
32	Saturday, June 13, 2009	0.0829	0.0352	-0.0060	0.0924	0.0352	-0.0060	0.0900	0.0352	0.0080	-0.0013
35	Tuesday, June 16, 2009	0.0825	0.0352	-0.0100	0.0920	0.0352	-0.0100	0.0896	0.0352	0.0040	-0.0053
42	Tuesday, June 23, 2009	0.0818	0.0351	-0.0160	0.0914	0.0351	-0.0150	0.0890	0.0351	-0.0010	-0.0107
56	Tuesday, July 07, 2009	0.0811	0.0352	-0.0240	0.0907	0.0352	-0.0230	0.0883	0.0352	-0.0090	-0.0187
84	Tuesday, August 04, 2009	0.0794	0.0351	-0.0400	0.0890	0.0351	-0.0390	0.0864	0.0351	-0.0270	-0.0353
140	Tuesday, September 29, 2009	0.0786	0.0349	-0.0460	0.0883	0.0349	-0.0440	0.0857	0.0349	-0.0320	-0.0407
252	Tuesday, January 19, 2010	0.0785	0.0350	-0.0480	0.0882	0.0350	-0.0460	0.0857	0.0350	-0.0330	-0.0423
476	Tuesday, August 31, 2010	0.1439	0.1004	-0.0480	0.1537	0.1004	-0.0450	0.1513	0.1004	-0.0310	-0.0413

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, June 09, 2009	4.026	4.010	2420	2108	3.988	4.035	2036	1779	1944
91	Tuesday, August 11, 2009	4.009	4.020	1085	947	4.029	4.007	1211	1055	1001
365	Wednesday, May 12, 2010	4.011	4.008	1183	1035	4.005	3.999	1140	1001	1018

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 25
Mix Date: Thursday, May 14, 2009
Mix Time: 9:18 AM

SHRINKAGE TESTING - ASTM C157

INITIAL READINGS

	Reference Bar Length (in.) 10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, May 15, 2009	0.0745	0.0392	0.0353	0.1181	0.0391	0.0790	0.0794	0.0391	0.0403	0.0515

LENGTH CHANGE CALCULATIONS

		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, June 11, 2009	0.0710	0.0351	0.0060	0.1150	0.0351	0.0090	0.0765	0.0351	0.0110	0.0087
32	Monday, June 15, 2009	0.0702	0.0351	-0.0020	0.1141	0.0351	0.0000	0.0757	0.0351	0.0030	0.0003
35	Thursday, June 18, 2009	0.0699	0.0351	-0.0050	0.1139	0.0351	-0.0020	0.0754	0.0351	0.0000	-0.0023
42	Thursday, June 25, 2009	0.0695	0.0352	-0.0100	0.1135	0.0352	-0.0070	0.0750	0.0352	-0.0050	-0.0073
56	Thursday, July 09, 2009	0.0681	0.0352	-0.0240	0.1120	0.0352	-0.0220	0.0734	0.0352	-0.0210	-0.0223
84	Thursday, August 06, 2009	0.0674	0.0351	-0.0300	0.1113	0.0351	-0.0280	0.0727	0.0351	-0.0270	-0.0283
140	Thursday, October 01, 2009	0.0667	0.0349	-0.0350	0.1106	0.0349	-0.0330	0.0720	0.0349	-0.0320	-0.0333
252	Thursday, January 21, 2010	0.0655	0.0350	-0.0480	0.1104	0.0350	-0.0360	0.0716	0.0350	-0.0370	-0.0403
476	Thursday, September 02, 2010	0.1321	0.1002	-0.0340	0.1758	0.1002	-0.0340	0.1372	0.1002	-0.0330	-0.0337

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, June 11, 2009	4.008	4.023	2147	1872	4.025	4.000	2276	1988	1930
91	Thursday, August 13, 2009	4.011	4.026	692	603	3.997	4.018	711	623	613
365	Friday, May 14, 2010	4.009	4.015	206	180	3.999	4.003	250	220	200

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO.	080739
Mix Number	Mix 26
Mix Date	Thursday, May 14, 2009
Mix Time	10:30 AM

SHRINKAGE TESTING - ASTM C157

Reference Bar Length (in.): 10

INITIAL READINGS

Specimen Age	Test date	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, May 15, 2009	0.0758	0.0391	0.0367	0.0658	0.0391	0.0267	0.0802	0.0392	0.0410	0.0348

LENGTH CHANGE CALCULATIONS

Specimen Age	Test date	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, June 11, 2009	0.0731	0.0351	0.0130	0.0635	0.0351	0.0170	0.0763	0.0351	0.0020	0.0107
32	Monday, June 15, 2009	0.0727	0.0351	0.0090	0.0632	0.0351	0.0140	0.0760	0.0351	-0.0010	0.0073
35	Thursday, June 18, 2009	0.0726	0.0351	0.0080	0.0630	0.0351	0.0120	0.0758	0.0351	-0.0030	0.0057
42	Thursday, June 25, 2009	0.0724	0.0352	0.0050	0.0627	0.0351	0.0090	0.0756	0.0352	-0.0060	0.0027
56	Thursday, July 09, 2009	0.0712	0.0352	-0.0070	0.0612	0.0352	-0.0070	0.0744	0.0352	-0.0180	-0.0107
84	Thursday, August 06, 2009	0.0707	0.0351	-0.0110	0.0605	0.0351	-0.0130	0.0739	0.0351	-0.0220	-0.0153
140	Thursday, October 01, 2009	0.0699	0.0349	-0.0170	0.0596	0.0349	-0.0200	0.0731	0.0349	-0.0280	-0.0217
252	Thursday, January 21, 2010	0.0693	0.0350	-0.0240	0.0589	0.0350	-0.0280	0.0724	0.0350	-0.0360	-0.0293
476	Thursday, September 02, 2010	0.1348	0.1002	-0.0210	0.1241	0.1002	-0.0280	0.1378	0.1002	-0.0340	-0.0277

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs	
28	Thursday, June 11, 2009	4.008	4.020	440	384	4.023	4.005	531	463	424	
91	Thursday, August 13, 2009	4.001	4.019	NA	NA	4.008	4.026	333	290	290	P1 invalid RLV.
365	Friday, May 14, 2010	4.003	4.012	206	180	4.011	4.007	235	206	193	

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 27.1
Mix Date: Thursday, June 04, 2009
Mix Time: 10:10 AM

SHRINKAGE TESTING - ASTM C157

Specimen Age	Test date	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
	Reference Bar Length (in.): 10	**INITIAL READINGS**									
		(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Friday, June 05, 2009	0.0602	0.0382	0.0220	0.0465	0.0383	0.0082	0.0623	0.0383	0.0240	0.0181
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Thursday, July 02, 2009	0.0572	0.0352	0.0000	0.0441	0.0352	0.0070	0.0593	0.0352	0.0010	0.0027
32	Monday, July 06, 2009	0.0562	0.0352	-0.0100	0.0431	0.0352	-0.0030	0.0584	0.0352	-0.0080	-0.0070
35	Thursday, July 09, 2009	0.0550	0.0352	-0.0220	0.0419	0.0352	-0.0150	0.0572	0.0352	-0.0200	-0.0190
42	Thursday, July 16, 2009	0.0544	0.0350	-0.0260	0.0412	0.0350	-0.0200	0.0567	0.0350	-0.0230	-0.0230
56	Thursday, July 30, 2009	0.0539	0.0352	-0.0330	0.0406	0.0352	-0.0280	0.0562	0.0352	-0.0300	-0.0303
84	Thursday, August 27, 2009	0.0528	0.0349	-0.0410	0.0401	0.0349	-0.0300	0.0552	0.0349	-0.0370	-0.0360
140	Thursday, October 22, 2009	0.0521	0.0350	-0.0490	0.0388	0.0350	-0.0440	0.0544	0.0350	-0.0460	-0.0463
252	Thursday, February 11, 2010	0.0517	0.0348	-0.0510	0.0385	0.0348	-0.0450	0.0541	0.0348	-0.0470	-0.0477
476	Thursday, September 23, 2010	0.1169	0.0998	-0.0490	0.1042	0.0998	-0.0380	0.1195	0.0998	-0.0430	-0.0433

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Thursday, July 02, 2009	4.009	4.017	2649	2313	4.008	4.013	3950	3454	2883
91	Thursday, September 03, 2009	3.991	3.986	1985	1755	3.991	3.990	1870	1651	1703
400	Friday, July 09, 2010	3.999	4.007	1352	1187	3.997	4.002	1355	1191	1189

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 28
Mix Date: Tuesday, May 19, 2009
Mix Time: 11:07 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 20, 2009	0.1312	0.0383	0.0929	0.0881	0.0383	0.0498	0.0682	0.0383	0.0299	0.0575
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 16, 2009	0.1283	0.0351	0.0030	0.0854	0.0351	0.0050	0.0654	0.0351	0.0040	0.0040
32	Saturday, June 20, 2009	0.1275	0.0351	-0.0050	0.0846	0.0351	-0.0030	0.0646	0.0351	-0.0040	-0.0040
35	Tuesday, June 23, 2009	0.1272	0.0351	-0.0080	0.0843	0.0351	-0.0060	0.0644	0.0351	-0.0060	-0.0067
42	Tuesday, June 30, 2009	0.1268	0.0352	-0.0130	0.0840	0.0352	-0.0100	0.0640	0.0352	-0.0110	-0.0113
56	Tuesday, July 14, 2009	0.1252	0.0352	-0.0290	0.0824	0.0352	-0.0260	0.0625	0.0352	-0.0260	-0.0270
84	Tuesday, August 11, 2009	0.1243	0.0349	-0.0350	0.0815	0.0349	-0.0320	0.0614	0.0349	-0.0340	-0.0337
140	Tuesday, October 06, 2009	0.1235	0.0349	-0.0430	0.0807	0.0349	-0.0400	0.0607	0.0349	-0.0410	-0.0413
252	Tuesday, January 26, 2010	0.1234	0.0349	-0.0440	0.0805	0.0349	-0.0420	0.0605	0.0349	-0.0430	-0.0430
476	Tuesday, September 07, 2010	0.1888	0.0999	-0.0400	0.1458	0.0999	-0.0390	0.1261	0.0999	-0.0370	-0.0387

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, June 16, 2009	4.012	4.019	3026	2639	4.014	4.023	3224	2808	2723
91	Tuesday, August 18, 2009	4.010	3.991	1197	1052	3.998	4.025	1263	1104	1078
365	Wednesday, May 19, 2010	4.011	4.002	368	322	3.997	3.999	370	326	324

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 29
Mix Date: Tuesday, May 26, 2009
Mix Time: 10:28 AM

SHRINKAGE TESTING - ASTM C157

	Reference Bar Length (in.)	INITIAL READINGS									
	10	**Specimen 1**	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
Specimen Age	**Test date**	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 27, 2009	0.1041	0.0382	0.0659	0.0367	0.0382	-0.0015	0.0704	0.0382	0.0322	0.0322
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	**Reference Bar 1**	**Δ Length 1**	**Specimen 2**	**Reference Bar 2**	**Δ Length 2**	**Specimen 3**	**Reference Bar 3**	**Δ Length 3**	**Average**
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 23, 2009	0.1018	0.0351	0.0080	0.0333	0.0351	-0.0030	0.0682	0.0351	0.0090	0.0047
32	Saturday, June 27, 2009	0.1011	0.0352	0.0000	0.0326	0.0352	-0.0110	0.0675	0.0352	0.0010	-0.0033
35	Tuesday, June 30, 2009	0.1008	0.0352	-0.0030	0.0323	0.0352	-0.0140	0.0672	0.0352	-0.0020	-0.0063
42	Tuesday, July 07, 2009	0.1003	0.0352	-0.0080	0.0318	0.0352	-0.0190	0.0667	0.0352	-0.0070	-0.0113
56	Tuesday, July 21, 2009	0.0985	0.0351	-0.0250	0.0300	0.0351	-0.0360	0.0651	0.0351	-0.0220	-0.0277
84	Tuesday, August 18, 2009	0.0974	0.0349	-0.0340	0.0290	0.0349	-0.0440	0.0639	0.0349	-0.0320	-0.0367
140	Tuesday, October 13, 2009	0.0966	0.0349	-0.0420	0.0282	0.0349	-0.0520	0.0632	0.0349	-0.0390	-0.0443
252	Tuesday, February 02, 2010	0.0962	0.0349	-0.0460	0.0277	0.0349	-0.0570	0.0628	0.0349	-0.0430	-0.0487
476	Tuesday, September 14, 2010	0.1617	0.0999	-0.0410	0.0931	0.0999	-0.0530	0.1284	0.0999	-0.0370	-0.0437

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202

Specimen Age	**Test date**	**Specimen P1 Diameter 1 (.001 in.)**	**Specimen P1 Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**	**Specimen P2 Diameter 1 (.001 in.)**	**Specimen P2 Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**	**Average Coulombs**
28	Tuesday, June 23, 2009	4.012	4.019	2172	1894	4.009	4.017	2102	1836	1865
91	Tuesday, August 25, 2009	3.975	4.028	1815	1594	3.998	3.988	1817	1603	1598
365	Wednesday, May 26, 2010	3.999	4.006	1315	1154	3.999	4.002	1404	1234	1194

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

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

BCD JOB NO. 080739

Mix Number: Mix 30
Mix Date: Tuesday, May 26, 2009
Mix Time: 3:32 PM

SHRINKAGE TESTING - ASTM C157											
	Reference Bar Length (in.)	INITIAL READINGS									
	10	Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
Specimen Age	Test date	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	(.0001 in.)	(.0001 in.)	Inches	Inches
1	Wednesday, May 27, 2009	0.1048	0.0382	0.0666	0.0468	0.0382	0.0086	0.0877	0.0382	0.0495	0.0416
		LENGTH CHANGE CALCULATIONS									
		Specimen 1	Reference Bar 1	Δ Length 1	Specimen 2	Reference Bar 2	Δ Length 2	Specimen 3	Reference Bar 3	Δ Length 3	Average
		(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.0001 in.)	(.0001 in.)	(0.001%)	(.01%)
28	Tuesday, June 23, 2009	0.1038	0.0351	0.0210	0.0459	0.0351	0.0220	0.0851	0.0351	0.0050	0.0160
32	Saturday, June 27, 2009	0.1035	0.0352	0.0170	0.0456	0.0352	0.0180	0.0849	0.0352	0.0020	0.0123
35	Tuesday, June 30, 2009	0.1033	0.0352	0.0150	0.0455	0.0352	0.0170	0.0847	0.0352	0.0000	0.0107
42	Tuesday, July 07, 2009	0.1031	0.0352	0.0130	0.0452	0.0352	0.0140	0.0844	0.0352	-0.0030	0.0080
56	Tuesday, July 21, 2009	0.1018	0.0351	0.0010	0.0440	0.0351	0.0030	0.0831	0.0351	-0.0150	-0.0037
84	Tuesday, August 18, 2009	0.1011	0.0349	-0.0040	0.0432	0.0349	-0.0030	0.0824	0.0349	-0.0200	-0.0090
140	Tuesday, October 13, 2009	0.1001	0.0349	-0.0140	0.0423	0.0349	-0.0120	0.0815	0.0349	-0.0290	-0.0183
252	Tuesday, February 02, 2010	0.0992	0.0349	-0.0230	0.0415	0.0349	-0.0200	0.0805	0.0349	-0.0390	-0.0273
476	Tuesday, September 14, 2010	0.1644	0.0999	-0.0210	0.1067	0.0999	-0.0180	0.1454	0.0999	-0.0400	-0.0263

Note: Lowest Reading Value Recorded (Minimum)

PERMEABILITY - ASTM C 1202										
Specimen Age	Test date	Specimen P1 Diameter 1 (.001 in.)	Specimen P1 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Specimen P2 Diameter 1 (.001 in.)	Specimen P2 Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs	Average Coulombs
28	Tuesday, June 23, 2009	4.017	4.013	512	447	4.018	4.005	551	482	464
91	Tuesday, August 25, 2009	4.004	3.989	386	340	4.011	4.005	382	334	337
365	Wednesday, May 26, 2010	4.000	4.003	270	237	4.007	4.002	301	264	251