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16. Abstract

This study was initiated by the Michigan Department of Transportation (MDOT) to investigate concerns raised by members of Michigan's aggregate industry regarding the validity of moisture conditioning methods employed by MDOT's freeze-thaw testing program for coarse aggregates used in Portland cement concrete.

Task 1 of this study, to date, documents the laboratory absorption contents, for the five coarse aggregates incorporated into the US-23 Aggregate Test Road, after the first of three years of continuous soaking in water. The findings from this task show that the rate of absorption for each coarse aggregate tested in this study is source-dependent. The soaking period necessary to achieve approximately 90 percent of vacuum saturation was shown to be approximately 30 days for the four geologically natural aggregates, and one year for the manufactured aggregate source. The geologically natural aggregates achieved nearly 100 percent of their respective vacuum saturation levels of absorption after one year of continuous soaking in water.

Task 2 of this study was intended to address industry concerns that moisture contents achieved by the department's laboratory-induced vacuum saturation method for moisture conditioning are excessive compared to those which would otherwise be observed in nature. It is shown by this task that the levels of absorption observed naturally in-situ are similar to those attained in the laboratory using the department's vacuum saturation method.

Task 3 of this study was intended to document whether or not the department's laboratory-induced vacuum saturation moisture conditioning method artificially stresses the inner macrostructure of blast furnace slag coarse aggregate; hence, altering the ultimate absorption potential for the aggregate samples use to fabricate laboratory freeze-thaw test specimens. The findings from this task show that the vacuum saturation method for moisture conditioning coarse aggregates prior to laboratory freeze-thaw testing does not alter the pore characteristics of the typical gravel, carbonate, or blast-furnace slag coarse aggregates historically used in MDOT concrete pavements.

17. Key Words Absorption Capacity, Aggregates, Blast-Furnace Slag, Freeze-Thaw, Moisture Conditioning, Portland Cement Concrete, Vacuum Saturation	18. Distribution Statement No restrictions. This document is available to the public through the Michigan Department of Transportation.

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MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT

Absorption Capacity of Coarse Aggregates for Portland Cement Concrete

First Year Report

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Testing and Research Section
Construction and Technology Division
Research Report R- 1482

Lansing, Michigan
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Acknowledgement

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Executive Summary

This study was initiated by the Michigan Department of Transportation (MDOT) to investigate concerns raised by members of Michigan's aggregate industry regarding the validity of moisture conditioning methods employed by MDOT's freeze-thaw testing program for coarse aggregates used in Portland cement concrete.

Task 1 of this study, to date, documents the laboratory absorption contents, for the five coarse aggregates incorporated into the US-23 Aggregate Test Road, after the first of three years of continuous soaking in water. These absorption levels were reported as a percentage of each respective material's laboratory-induced vacuum saturated absorption level.

The findings from this task show that the rate of absorption for each coarse aggregate tested in this study is source-dependent. At 24 hours of soaking, the geologically natural sources reported from 62- to 78 percent of their respective vacuum saturated levels of absorption; the manufactured aggregate reported 33 percent. The soaking period necessary to achieve approximately 90 percent of vacuum saturation was shown to be approximately 30 days for the four geologically natural aggregates, and one year for the manufactured aggregate source. The geologically natural aggregates achieved nearly 100 percent of their respective vacuum saturation levels of absorption after one year of continuous soaking in water.

Task 2 of this study was intended to address industry concerns that moisture contents achieved by the department's laboratory-induced vacuum saturation method for moisture conditioning are excessive compared to those which would otherwise be observed in nature. In other words, it was hypothesized that a typical naturally occurring geologic formation will never achieve vacuum saturation levels of moisture, even when submerged below the static water table for a significant period of geologic time.

The findings from this task show that the naturally occurring in-situ moisture contents for each sampled source, regardless of their reference relative to the static water table, were nearly equivalent to their respective laboratory-induced vacuum saturated absorption levels. For one source, the naturally occurring moisture content below the static water table reported 104 percent of its respective vacuum saturated level of absorption. Hence, it is shown by this study that vacuum saturated levels of absorption can be achieved naturally in-situ, without artificial means.

Task 3 of this study was intended to document whether or not the department's laboratory-induced vacuum saturation moisture conditioning method artificially stresses the inner macrostructure of blast furnace slag coarse aggregate; hence, altering the ultimate absorption potential for the aggregate samples use to fabricate laboratory freeze-thaw test specimens.

The findings from this task show that the vacuum saturation method for moisture conditioning coarse aggregates prior to laboratory freeze-thaw testing does not alter the pore characteristics of the typical gravel, carbonate, or blast-furnace slag coarse aggregates historically used in MDOT concrete pavements.

Objective

This absorption study is being conducted (with reference to concrete coarse aggregate) to determine if various soaking periods can achieve saturation levels created by the department's vacuum saturation moisture condition method used in the Michigan Test Method, MTM 113.

Introduction

The method for moisture conditioning coarse aggregates prior to cyclic laboratory freeze-thaw testing has been an issue of concern, from the aggregate producer's perspective, for many years. Aggregate producer's concerns stem from questions raised as to whether the actual absorbed moisture content of the coarse aggregate within the in-service concrete pavement achieves "critical saturation". In addition, some aggregate producers have expressed concerns that the department's vacuum saturation method for moisture conditioning may artificially stress the inner macrostructure of some aggregate types.

It is expected that this project will progress in three tasks over three years, beginning in late fall, 2004.

Background

MDOT initiated it's freeze-thaw testing program in 1954. This program is designed as an accelerated method to numerically rate concrete coarse aggregates. The objective of this testing program is not intended to produce results which may correlate to actual field performance. Rather, it is a tool used as an accelerated means to quantify the risk to the department against the potential for premature freeze-thaw related concrete pavement and structure deterioration. The ASTM C-666 test method titled *"Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing"*, reinforces this principle by stating that "This standard testing method is not intended to provide a quantitative measure of the length of service that may be expected from a type of concrete". Subsection 3.2 of the ASTM C-666 test method states the following:

"It is assumed that the procedures will have no significant damaging effects on frost-resistant concrete which may be defined as: (1) concrete not critically saturated with water (that is, not sufficiently saturated to be damaged by freezing), and (2) concrete made with frost resistant aggregates and having an adequate air-void system that has achieved appropriate maturity and thus will prevent critical saturation by water under common conditions."

The MDOT standard freeze-thaw testing program uses the ASTM C-666 as its platform. In addition, three Michigan Test Methods (MTM 113, 114, and 115) were developed to institute particular requirements for preparation and testing of the specimens, which are otherwise not detailed in the ASTM C-666 test method. The associated Michigan Test Methods are briefly described as follows:

MTM 113 - *Michigan Test Method for Selection and Preparation of Coarse Aggregate Samples for Freeze-Thaw Testing*: This method covers the procedures for securing samples of coarse aggregate, methods of processing and conditioning for freeze-thaw testing in concrete, and related tests required to provide detailed information about the aggregate under consideration.

MTM 114 - *Michigan Test Method for Making Concrete Specimens for Freeze-Thaw Testing of Concrete Coarse Aggregate*: This method describes the procedure for making concrete beams to be tested according to MTM 115, for determining the durability of concrete coarse aggregate in freezing and thawing. The method includes criteria for design of the concrete mixture, testing of the freshly mixed concrete, fabrication of specimens, and tests for strength of hardened concrete.

MTM 115 - *Michigan Test Method for Testing Concrete for Durability by Rapid Freezing in Air and Thawing in Water*: This method describes the procedure for testing concrete beams to evaluate their durability in rapid freezing and thawing, specifically for the evaluation of coarse aggregate used in the concrete. The method uses concrete beam specimens prepared according to MTM 114 and describes the freeze thaw cycling and evaluation of the beams by length change (dilation) procedures. This method conforms to the general requirements of ASTM C-666, Procedure B.

The MTM 113 describes the procedures for moisture conditioning coarse aggregate prior to their incorporation into concrete freeze-thaw test specimens. The moisture conditioning procedures vary depending on whether the coarse aggregate is a naturally originating material or a manufactured (blast furnace slag) product.

If the coarse aggregate consists of gravel, crushed stone, or crushed concrete, the material is enclosed in a chamber and subjected to a vacuum equivalent to 96.2 kPa for one hour. The chamber is then flooded with water while maintaining a minimum vacuum of 94.6 kPa until the aggregate is completely immersed. The vacuum is then released and the aggregate is soaked for 23 hours. At the end of the 24 hour period, the excess water is drained and the concrete is batched.

If the coarse aggregate consists of blast furnace slag, the moisture condition consists of only a standard 24-hour soak; not subjected to vacuum. At the end of the 24 hour period, the excess water is drained and the concrete is batched.

The department's current minimum threshold limits for freeze-thaw durability were validated through a study conducted around 1980 by the Research Laboratory relative to the field performance of selected pavements constructed in the 1960's. This study of 20 year old vintage pavements indicated that some built with aggregates only marginally exceeding the freeze-thaw durability factor of 20 (maximum 0.067 percent dilation per 100 cycles) required essentially 100 percent joint replacement due to freeze-thaw action. It was also found that while these in-service pavements were experiencing holistic joint deterioration, adjacent pavements constructed with aggregate from sources with a high freeze-thaw durability factor of 70, or greater (maximum 0.013 percent dilation per 100 cycles) had almost no freeze-thaw damage after 20 years. These findings corroborated the long-standing position held by the department regarding the validity of the laboratory freeze-thaw durability factor of 20 (maximum 0.067 percent dilation per 100 cycles) and its relationship to a minimum allowable threshold for adequate 20 year field performance.

Throughout the past decade, it has been observed by the department's technical experts that several concrete pavements have not performed up to expectations. These deficiencies in performance have not only been in terms of reduced anticipated pavement service life, but also have been relative to the extent of unanticipated repairs necessary to maintain safe travel for the motoring public.

The vacuum saturation method for moisture conditioning, as described above, has been a part of the department's standard procedures for laboratory freeze-thaw testing since the program's inception in 1954. Threshold limits for freeze-thaw dilation, as part of the standard specifications for concrete coarse aggregate freeze-thaw quality, are directly influenced by the aggregate's porosity, permeability, structural toughness, as well as the moisture content. Vacuum saturation provides a means of rapidly achieving critical saturation. If modifications to the moisture conditioning protocol are instituted without complete correlation of its impact toward measurable dilation results after 300 cycles of freezing and thawing, all current department specification limits for concrete coarse aggregate freeze-thaw quality would be obsolete. This would leave the department without a test method for concrete coarse aggregate freeze-thaw durability, nullifying its historically enforceable specification requirements.

Research Plan by Tasks

It is anticipated that this study will encompass the following tasks. The duration for the entire study is estimated to be approximately three (3) years.

Task 1: The five coarse aggregate sources (which were incorporated into the Southbound US-23 Aggregate Test Road in Monroe County) were secured by the department at the time of pavement reconstruction in 1992. Several cubic yards of each material were obtained from the project. These five aggregates were then transported to the Construction and Technology laboratory, and sealed in independent weather-tight bins for future use. The five bin sources (two quarried carbonates: France Stone (Silica), ASN: 93-03, and Holloway Sand and Gravel/Rockwood Stone, ASN: 58-08; two gravels: Bundy Hill, ASN: 30-35, and American Aggregates (Milford), ASN: 63-97; and one blast furnace slag: McClouth Steel/Levy Plant # 4, ASN: 82-22) will be subjected to varying periods of soaking for this task.

Each aggregate source will be sampled, oven dried, then split into five representative specimens of approximately 4000 grams for each test (soaking period). It is anticipated that the soaking periods will include 1-day, 7-days, 30-days, 90-days, 180-days, 1-year, and 3-years. An additional five representative specimens from each aggregate source will be vacuum saturated as a basis for comparison. Table 1 describes the allocation of test specimens for each soaking period.

Task 2: Two gravel sources which are geologically located both above and beneath the static water table will be selected for sampling and tested to determine their naturally occurring in-situ moisture contents.

Each aggregate source will be sampled and immediately sealed in air tight containers so as to preserve its inherent moisture content. For the aggregate materials naturally immersed beneath the static water table, care will be taken to ensure that the samples are fully immersed in water at all times. The sealed sample containers will then be transported to the Construction and Technology laboratory for further testing and evaluation.

At the laboratory, representative materials from each of the two gravel sources which were mined beneath the static water table will be individually wet-sieved through the 1-inch and No. 4 sieves to selectively capture representative particle sizes constituting approximately that of a typical concrete coarse aggregate gradation. The wet-sieved samples from each of the two aggregate sources will then be immediately portioned into five specimens of approximately 4000 grams each. Each specimen will be immediately towel-dried to remove free moisture, then weighed. Remaining materials will also be wet-sieved, as described above, oven-dried, then processed into specimens for long-term soaking in the same manner as described in Task 1. In addition, five representative specimens from each of the two sources will be vacuum saturated as a basis for comparison. Table 1 describes the allocation of test specimens for each soaking period.

Representative materials sampled from the gravel sources which were mined above the static water table will be individually sieved through the 1-inch and No. 4 sieves to selectively capture representative particle sizes constituting approximately that of a typical concrete coarse aggregate gradation. The sample will then be immediately portioned into five specimens of approximately 4000 grams each. If there is evidence of free moisture on the aggregate particle's surface, the specimens will be towel-dried prior to weighing. Remaining materials will also be sieved, as described above, oven-dried, then processed into specimens for long-term soaking in the same manner as described in Task 1. In addition, five representative specimens from each of the two sources will be vacuum saturated as a basis for comparison. Table 1 describes the allocation of test specimens for each soaking period.

Table 1: Aggregate Source Test Specimens versus Soaking Period

		Soaking Period							
Task	Source	1-Day t_1	7-Day t_7	30-Day t_{30}	90-Day t_{90}	180-Day t_{180}	1-Year t_{360}	3-Year t_{1080}	Vac.Sat.
1	30-35b	5	5	5	5	5	5	5	5
1	58-08b	5	5	5	5	5	5	5	5
1	63-97b	5	5	5	5	5	5	5	5
1	82-22b	5	5	5	5	5	5	5	5
1	93-03b	5	5	5	5	5	5	5	5
2	41-16 $_{above}$	5	5	5	5	5	5	5	5
2	63-48 $_{above}$	5	5	5	5	5	5	5	5
2	41-16 $_{below}$	5	5	5	5	5	5	5	5
2	63-48 $_{below}$	5	5	5	5	5	5	5	5
Total		45	45	45	45	45	45	45	45

Task 3: This task is intended to measure whether the department's vacuum saturation moisture conditioning method artificially stresses the inner macrostructure of blast furnace slag coarse aggregate.

Thirty specimens of blast furnace slag (ASN: 82-22) of approximately 4000 grams will be oven-dried to equilibrium. Each specimen will then be moisture conditioned using the 24-hour soaking method (first cycle). After 24 hours, the specimens will be towel-dried and weighed. They will then be oven-dried to determine their percent absorption (24-hour soak method). The oven-dried specimens will then be moisture conditions using the department's vacuum saturation method. After vacuum saturation, the specimens will be oven-dried to equilibrium. Each specimen will again be moisture conditioned using the 24-hour soaking method (second cycle). After 24 hours, the specimens will be towel-dried and weighed. They will then be oven-dried to determine their percent absorption (24-hour soak method). The percent absorptions between the first and second cycles of moisture conditioning (24-hour soak method) will be statistically analyzed to determine whether vacuum saturation artificially altered the inner macrostructure of the aggregate particles.

Task 4:..The data generated from Tasks 1 through 3 will be compiled, statistically analyzed, and reported. Interim reports will be presented after the 90- day soaking period results are compiled and analyzed, and also at one year. A final report will be issued at the end of three years.

Implementation of Results

If it is found that vacuum saturated moisture content levels for concrete coarse aggregates can be achieved in the laboratory using a soaking period other than 24 hours, the department's standard procedures for moisture condition (as described in MTM 113) could potentially be modified to reflect uniformity for all aggregate types, regardless of their origin. However, any potential modifications to the department's current protocol for concrete aggregate freeze-thaw testing would have to be indisputably justified, and, further, would require thorough investigation through correlation testing.

Research Findings to Date

Task 1: Absorption Testing of Bin Sources.

To date, the five coarse aggregate bin sources representing the US-23 Aggregate Test Road were tested in accordance with the work plan. Figure 1 shows the relationships between each aggregate source's absorption results at each of the designated soaking periods.

As shown in Figure 1, the absorption rate for each coarse aggregate tested in this study is dependent on the respective source. At 24 hours of soaking, the geologically natural sources (ASN: 30-35, 58-08, 63-97, and 93-03) reported from 62- to 78 percent of their respective laboratory-induced vacuum saturated level of absorption. In contrast, the manufactured aggregate (ASN: 82-22) reported 33 percent of its respective vacuum saturated level of absorption. The soaking period necessary to achieve approximately 90 percent of vacuum saturation was shown to be approximately 30 days for the four geologically natural materials compared to one year for the manufactured aggregate source. The geologically natural sources virtually achieved vacuum saturation levels of absorption after one year of continuous soaking.

Task 2: Absorption Testing of Gravel Sources Above and Below the Static Water Table.

The two gravel sources selected for this task were chosen based on the availability of materials to be sampled from both above and below the static water table. The intent of this task was to quantify whether there is correlation between a natural aggregate's laboratory-induced vacuum saturated moisture content and its naturally occurring in-situ level of absorption attained over geologic time.

Figure 2 is intended to graphically document the rate of absorption for the two aggregate sources, each sampled from above as well as below static water table locations. Figure 3 compares the as-sampled in the field moisture content versus the respective laboratory-induced vacuum saturated absorption. It was noted that the vacuum saturated absorption results for ASN: 41-16 were near identical for both the above and below the static water table samples. This indicates that the mineralogical compositions for the two samples were similar. However, it was noted that the two vacuum saturated absorption results for ASN: 63-48 were quite different. This indicates that there may be variations between mineralogical compositions within this particular source. It is, therefore, surmised that the material corresponding to the above water table sample for ASN 63-48 contained a disproportion of higher absorptive particles compared to the sample extracted from below the water table. Regardless, it was shown that the as-sampled in the field moisture contents for each sample were nearly equivalent to their respective vacuum saturated levels. Hence, this study documents that vacuum saturated absorption content levels can be achieved naturally in-situ, without artificial means.

Task 3: 24-Hour Absorption Before and After Vacuum Saturation.

Figure 4 shows the graphical representation of the differences between the before and after vacuum saturation absorptions capacities (24-hour soaking method) for the five aggregate sources.

As documented below, it was shown that the difference between the absorption capacities (24-hour soaking, before vacuum saturation versus after vacuum saturation) are statistically insignificant, regardless of the aggregate type or source used in this study. Hence, this study documents that the laboratory-induced vacuum saturation method for moisture conditioning does not alter the pore characteristics of the typical gravel, carbonate, or blast-furnace slag coarse aggregates historically used in MDOT concrete pavements.

A reasonable assumption can be made that the mean values representing each of the two data sets are expected to be related and within the same bound of variation. With this in mind, the statistical analysis method selected for this task was the Standard Error of Difference Between Means.

$$SE\,(diff) = \sqrt{\left(\frac{\sigma_1^{\,2}}{n_1}\right) + \left(\frac{\sigma_2^{\,2}}{n_2}\right)}$$

The 95% confidence interval (z = 1.96) for the difference in means is represented by the following equation:

$$\Delta \bar{x} \pm z(SE)$$

Source: Bundy Hill (Natural Gravel), ASN: 30-35.

Statistical Analysis of BVS:

X_{bvs} = 0.87
σ = 0.06073
Med. = 0.86

Statistical Analysis of AVS:

X_{avs} = 0.87
σ = 0.05662
Med. = 0.88

$SE(diff) =$ 0.0107

$\Delta \bar{x}$ = 0.00

$\Delta \bar{x} \pm z(SE)$ = 0.00 ± 1.96(0.0107) = -0.02 and 0.02

This represents that there is a 95% confidence that the data and sample means will vary from -0.02 to 0.02%. For the purpose of the data for BVS vs. AVS, this is insignificant and practically the same result may be obtained from either data set. Hence, the analysis shows that there is no statistical significance between the two data sets and that the vacuum saturation method for moisture conditioning did not artificially alter the absorption capacity as represented by the 24-hour soaking method for ASN: 30-35.

Source: Holloway/Rockwood Stone (Quarried Carbonate), ASN: 58-08.

Statistical Analysis of BVS:

X = 2.35
σ = 0.0687
Med. = 2.35

Statistical Analysis of AVS:

X = 2.36
σ = 0.0686
Med. = 2.37

$SE(diff) =$ 0.0125

$\Delta \bar{x} = 0.01$

$\Delta \bar{x} \pm z(SE) = 0.01 \pm 1.96(0.0125) = -0.01$ and 0.03

This represents that there is a 95% confidence that the data and sample means will vary from -0.01 to 0.03%. For the purpose of the data for BVS vs. AVS, this is insignificant, and practically the same result may be obtained from either data set. Hence, the analysis shows that there is no statistical significance between the two data sets and that the vacuum saturation method for moisture conditioning did not artificially alter the absorption capacity as represented by the 24-hour soaking method for ASN: 58-08.

Source: American Aggregate (Milford) (Natural Gravel), ASN: 63-97.

Statistical Analysis of BVS:

X = 1.16
σ = 0.0735
Med. = 1.15

Statistical Analysis of AVS:

X = 1.15
σ = 0.0755
Med. = 1.16

$SE(diff) =$ 0.0136

$\Delta \bar{x} = 0.01$

$\Delta \bar{x} \pm z(SE) = 0.01 \pm 1.96(0.0136) = -0.02$ and 0.04

This represents that there is a 95% confidence that the data and sample means will vary from -0.02 to 0.04%. For the purpose of the data for BVS vs. AVS, this is insignificant, and practically the same result may be obtained from either data set. Hence, the analysis shows that there is no statistical significance between the two data sets and that the vacuum saturation method for moisture conditioning did not artificially alter the absorption capacity as represented by the 24-hour soaking method for ASN: 63-97.

Source: McClouth Steel/Levy Plant # 4 (Blast Furnace Slag), ASN: 82-22.

Statistical Analysis of BVS:

X = 2.42

Statistical Analysis of AVS:

X = 2.52

σ = 0.0943
Med. = 2.41

σ = 0.0616
Med. = 2.53

$SE(diff) =$ 0.0145

$\Delta \bar{x} = 0.10$

$\Delta \bar{x} \pm z(SE) = 0.10 \pm 1.96(0.0145) = 0.07$ and 0.13

Since both values are positive, it can be surmised that 0.07 is numerically equivalent to zero; thus, the mean for the BVS data set can also be considered the lower bound for this analysis.

This represents that there is a 95% confidence that the data and sample means will vary from 0.00 to 0.13%. For the purpose of the data for BVS vs. AVS, this is insignificant, and practically the same result may be obtained from either data set. Hence, the analysis shows that there is no statistical significance between the two data sets and that the vacuum saturation method for moisture conditioning did not artificially alter the absorption capacity as represented by the 24-hour soaking method for ASN: 82-22.

Source: France Stone (Silica) (Quarried Carbonate), ASN: 93-03.

Statistical Analysis of BVS:

X = 2.35
σ = 0.0816
Med. = 2.35

Statistical Analysis of AVS:

X = 2.32
σ = 0.0704
Med. = 2.33

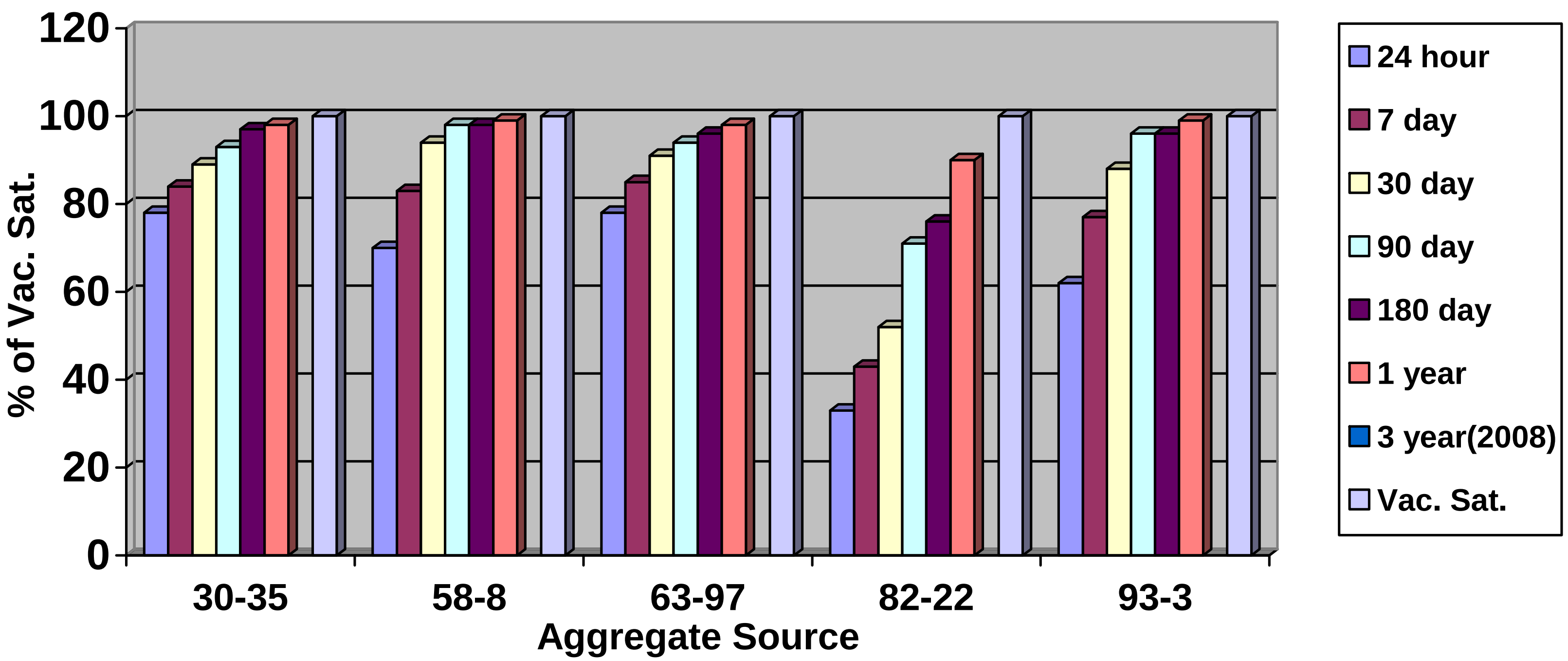
$SE(diff) =$ 0.0139

$\Delta \bar{x} = 0.02$

$\Delta \bar{x} \pm z(SE) = 0.02 \pm 1.96(0.0139) = -0.01$ and 0.05

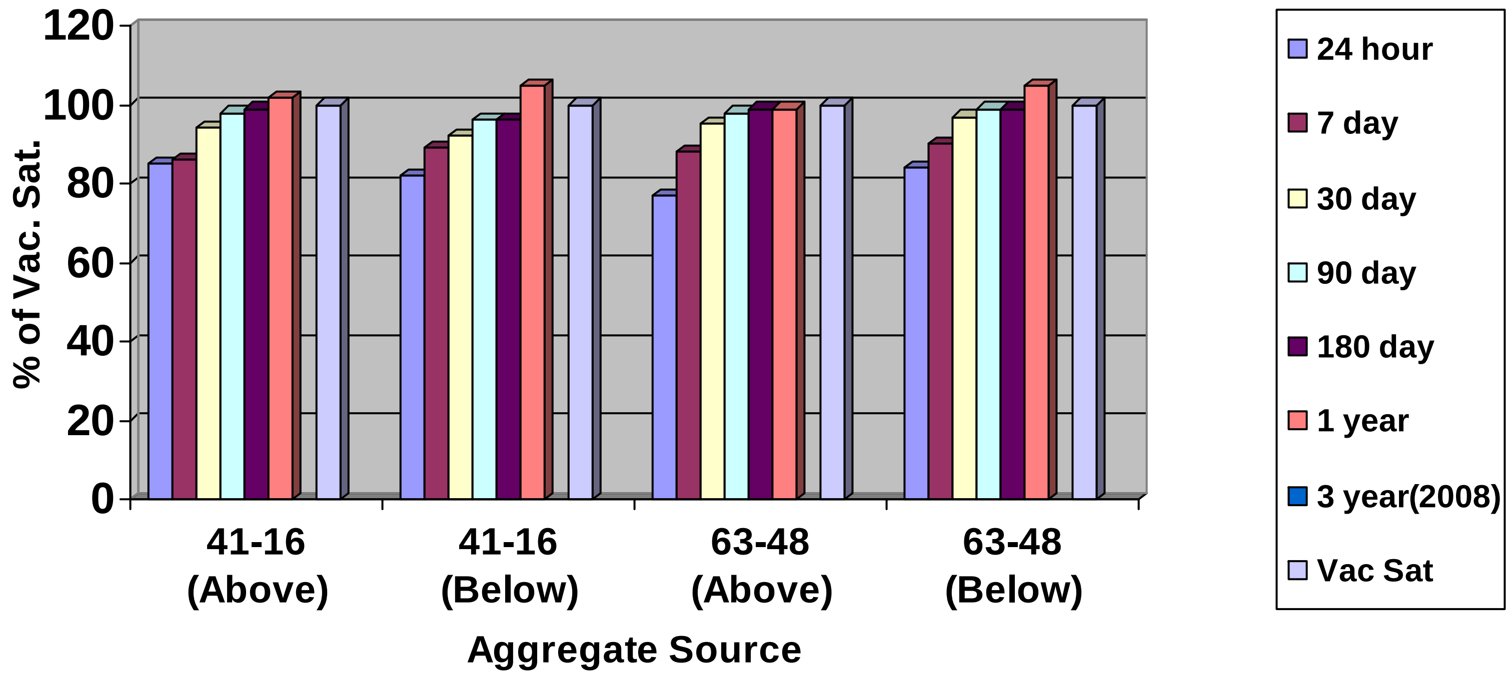
This represents that there is a 95% confidence that the data and sample means will vary from -0.01 to 0.05%. For the purpose of the data for BVS vs. AVS, this is insignificant, and practically the same result may be obtained from either data set. Hence, the analysis shows that there is no statistical significance between the two data sets and that the vacuum saturation method for moisture conditioning did not artificially alter the absorption capacity as represented by the 24-hour soaking method for ASN: 93-03.

Figure 1: Task 1: Summary of Percent Vacuum Saturation



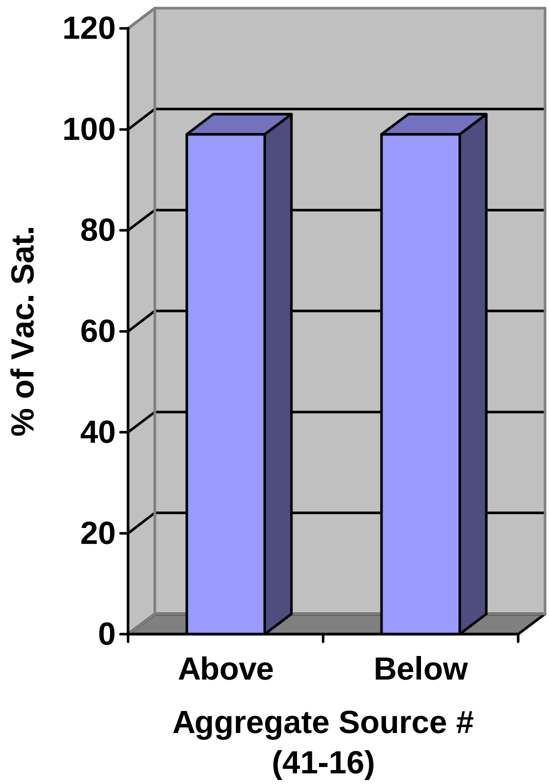
Source	30-35		58-8		63-97		82-22		93-3	
Soaking Period	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*
24-h	0.91	78	2.38	70	1.18	78	2.34	33	2.42	62
7-d	0.97	84	2.80	83	1.29	85	3.07	43	2.99	77
30-d	1.03	89	3.19	94	1.37	91	3.70	52	3.39	88
90-d	1.07	93	3.32	98	1.41	94	5.08	71	3.71	96
180-d	1.12	97	3.33	98	1.45	96	5.44	76	3.74	96
1-y	1.14	98	3.35	99	1.48	98	6.43	90	3.82	99
3-y										
Vac. Sat	1.16		3.39		1.51		7.13		3.87	

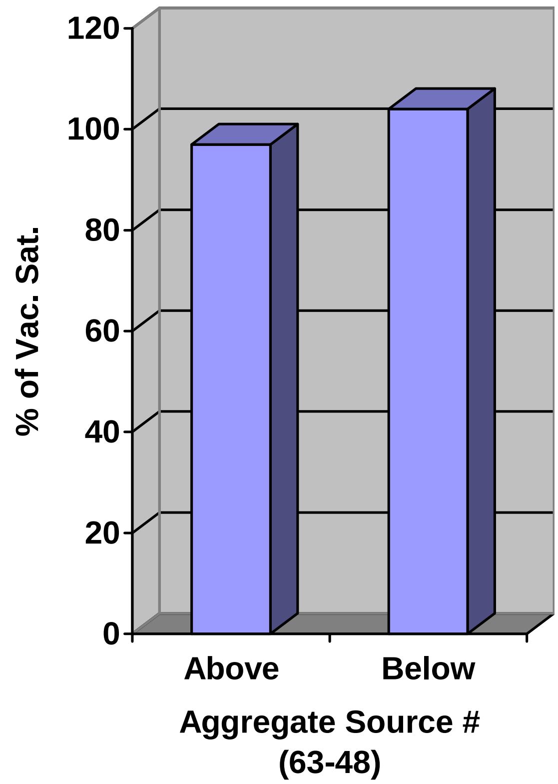
Figure 2: Task 2: Summary of Percent Vacuum Saturation (Sources Sampled Above and Below Static Water Table)



Source	41-16(Above)		41-16(Below)		63-48(Above)		63-48(Below)	
Soaking Period	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*	*Abs. %*	*% of Vac. Sat.*
24-h	1.18	85	1.16	82	1.29	77	1.09	84
7-d	1.20	86	1.26	89	1.46	88	1.17	90
30-d	1.30	94	1.30	92	1.57	95	1.26	97
90-d	1.36	98	1.36	96	1.62	98	1.28	99
180-d	1.38	99	1.36	96	1.65	99	1.29	99
1-y	1.41	102	1.49	105	1.64	99	1.36	105
3-y								
Vac. Sat	1.39		1.41		1.66		1.30	

Figure 3: Task 2: As Sampled Absorption Percent of Vacuum Saturation Sampled Above and Below Static Water Table.

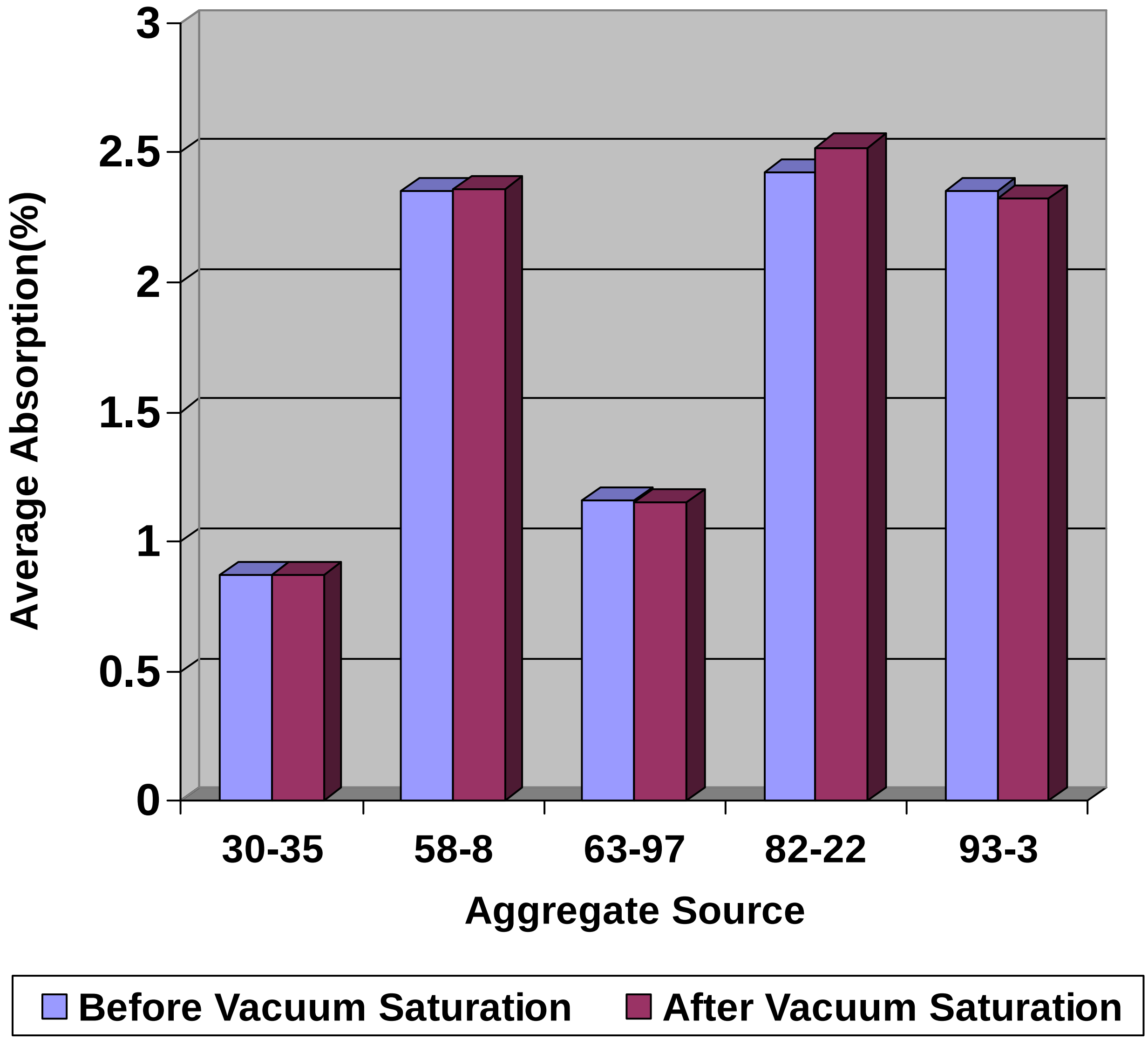




41-16 (Above)		41-16 (Below)		63-48* (Above)			63-48 (Below)		
Abs. %	**% of Vac. Sat.**	**Abs %**	**% of Vac. Sat.**	**Abs %**	**Vac. Sat. Abs. %**	**% of Vac. Sat.**	**Abs %**	**Vac. Sat. Abs. %**	**% of Vac. Sat.**
1.38	**99**	**1.39**	**99**	**1.61**	**1.66**	**97**	**1.35**	**1.30**	**104**

* The material representing "Above" the static water table for this aggregate source was sampled from a location within the pit with slightly different physical properties than the material sampled from "Below" the static water table.

Figure 4: Task 3: 24 Hr. Absorption Results Before and After Vacuum Saturation.



Data Averages

Source	30-35	58-8	63-97	82-22	93-3
Before Vac.Sat.	**0.87**	**2.35**	**1.16**	**2.42**	**2.35**
After Vac. Sat	**0.87**	**2.36**	**1.15**	**2.52**	**2.32**

Future Research Activities:

The next cycle of testing for this study will be the three year absorption testing for the five coarse aggregate sources included in Task 1, as well as similar testing for the materials representing the above and below static water table conditions for the two coarse aggregate sources included in Task 2. This testing will commence in January, 2008 and will be completed by mid-June.

Upon completion of the above mentioned tasks, a final report will be written, thus, completing this study.