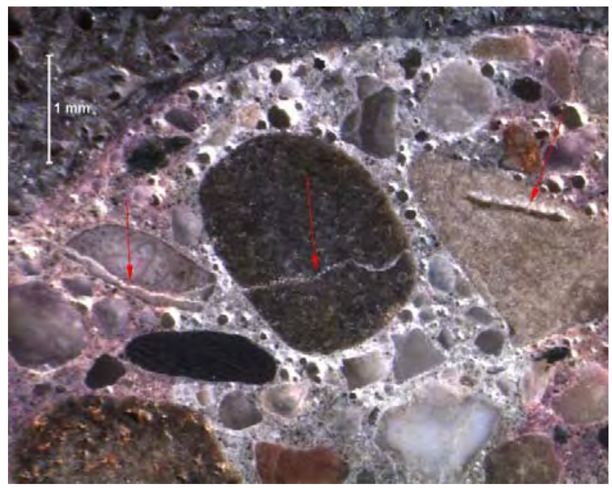
Southeast Michigan Local Road Concrete Pavement Durability Study

Final Report
July 2006



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National Concrete Pavement Technology Center
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July 2006

Sponsored by
the Michigan Concrete Paving Association

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About the National Concrete Pavement Technology Center
The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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Introduction

Counties and cities in Southeast Michigan have used concrete pavements for nearly 100 years to provide long-lasting, durable streets and roads. Issues of concrete durability have arisen with some of the pavements built after 1990. In order to evaluate the causes of spalling and other deterioration methods, the National Concrete Pavement Technology Center (CP Tech Center) was asked to study the concrete from a number of the pavements, evaluate the causes of the distress, and offer recommendations for improvements. Of particular concern are the roles of coarse aggregate type (limestone or blast furnace slag), alkali-silica reactivity (ASR), and the air entrainment system in the hardened concrete on the joint deterioration distresses that are being observed.

Problem Statement

Hundreds of local arterial and residential concrete street projects have been built in Wayne, Oakland, and Macomb Counties in Southeast Michigan over many years. Unfortunately, a number of these projects constructed since 1991 and some prior to that, have experienced early distress. The types of distress include joint spalls, mid-panel cracks, and punch-outs. Joint spalling and other joint deterioration have been of particular concern. Michigan Concrete Paving Association engineers have expressed concern about issues of reactivity between the cementitious material and aggregate, as well as concern regarding incompatibilities from some admixtures. Several forensic investigations by local agencies have identified inadequate air systems in the failing areas and should also be investigated.

Also of concern is the impact of blast furnace slag coarse aggregate on the observed deterioration. Some engineers in Michigan believe the properties of this material have contributed to early deterioration. Some petrographic analysis by Michigan Tech has shown unhydrated cement around aggregate particles, possibly indicating excessive absorption.

Research Objectives

The following are overall objectives of this study:

1. Evaluate the condition of the concrete on a selected number of projects that include deteriorated areas and sound concrete. This may include projects that do not show any early deterioration.
2. Determine the cause or causes of the deterioration.
3. Provide recommendations of changes in materials and/or construction practice that could eliminate or minimize the likelihood of reoccurrence of the deterioration mechanism.

Scope of Work

Step 1. Obtain information on Southeast Michigan projects

The Michigan Concrete Paving Association (MCPA), in cooperation with Macomb, Oakland, and Wayne County personnel, chose twelve projects that represented a cross section of conditions of pavement exhibiting early pavement deterioration, predominantly at the joints. The projects included in this study are listed in Table 1. MCPA then obtained detailed information from both contractor and agency construction records for each project.

Table 1. Projects included in this study

County	City/Township	Street/Highway	Year Paved
Wayne	Novi/Northville	Base Line Road	1994
	Belleville	Belleville Road	1995
	Farmington Hills	8 Mile Road	1996
Oakland	Franklin	12 Mile Road	1999
	Madison Heights	Campbell Road	1999
	Madison Heights	Campbell Road	1984
	Troy	Big Beaver Road	1995
	Troy	Dequindre Road	1996
Macomb	Fraser/Roseville	13 Mile Road	1992
	Fraser/Roseville	13 Mile Road	1994
	Clinton Township	Utica Road	1995
	Fraser	Utica Road	1994

Step 2. Obtain cores for investigation

Jim Grove, principal investigator (PI) for this research, visited these projects on November 17 and 18, 2005. The projects were located in three counties and fourteen cities or townships. Twenty-three cores were obtained by county or city personnel from twelve different projects. Each project was examined, pertinent information obtained, and pavement conditions were rated. The cores from these projects were provided to the PI for analysis.

Step 3. Analysis of the cores

The cores were then delivered to American Engineering Testing in St. Paul, Minnesota, for petrographic analysis on December 7, 2005. A complete petrographic analysis, including air void analysis, evidence of carbonation, cracking identification, and any non-uniform hydration, was completed on each core. The report of the analyses was received on February 3, 2006. The core analyses are contained in Appendix B.

Step 4. Prepare a report

A report that details the results of the analysis (the present document) will be provided to the Michigan Concrete Paving Association. This report includes findings from the investigation, recommendations for changes in materials specifications, and recommendations for improvements in construction practices. A presentation of the study results to the MCPA Board of Directors, staff, and local agency officials by the principal investigator will also be a part of this project. A preliminary report of the findings was presented at the MCPA Annual Workshop on February 15-16, 2006.

Discussion

The projects represented a spectrum of pavement conditions. The project conditions ranged from some staining with little to no deterioration, to extensive cracking and deep spalled areas of an inch or more either side of the joint and equally as deep or deeper. Similarity in the distress observed in each project seemed to indicate some commonality of the distress mechanisms may exist between most projects.

There are five areas of interest that are most likely key contributors to the deterioration that has developed. The durability of the slag aggregate has been thought by some to be an issue. Expansive mechanisms of alkali silica reactivity (ASR), sulfate attack (ettringite formation), and freeze-thaw deterioration all have been identified in many of the cores. Also, construction-related issues relating to lack of an adequate, uniform air void system and a lack of consistent, sufficiently low water-cement ratio were identified in some cores. Often it is difficult to identify the initiating cause of the deterioration. Once cracking is initiated, other mechanisms begin and contribute to the deterioration. Therefore, it is important to address each of the issues identified in order to ensure that in future projects none of them will be able to compromise the pavement durability.

Interestingly enough, one core (Core 6) contained evidence of all the problems and likely deterioration mechanisms identified in the core analyses. It showed surface cracking, ASR filled cracks, ettringite filled air voids, and air void clustering.

Appendix A contains a summary of all the information assembled and developed for this study. It summarizes information from three sources. The first section lists the project information as obtained by MCPA from the counties and cities, based on project records of the agencies and contractors. The second section summarizes the findings of the petrographic core analysis. The third lists the evaluation of pavement condition based on the field observations. Note that the freeze/thaw resistant row in the table simply indicates whether the spacing factor was 0.008 inches or less. Another row identifies other problems that may exist within the air system. Those anomalies were identified in the core analysis.

Overall Condition

A field review of each project was performed to evaluate the condition of the pavements that were a part of this study. Examples are presented in Figures 1 and 2. Cores were taken from each project and evaluated petrographically in order to determine the condition and identify deterioration mechanisms. These two observations, the visual field observation of the concrete pavement and the microscopic analysis of the concrete pavement core, were not always consistent.

Figure 1. 12 Mile Road in Franklin, six years old

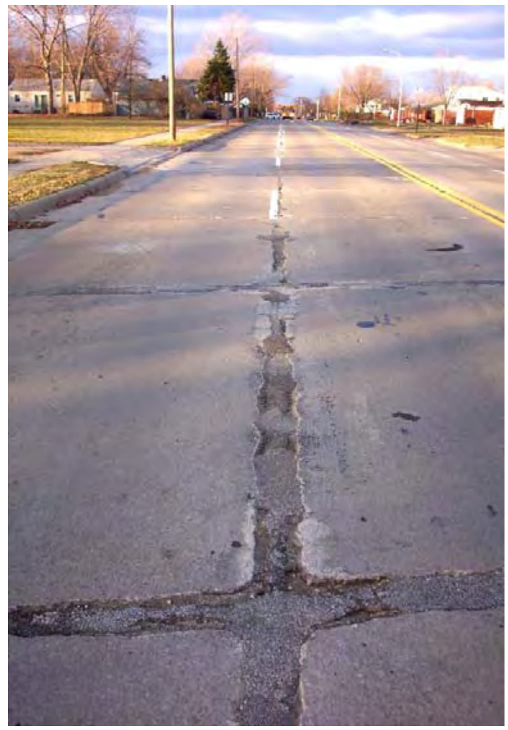


Figure 2. Campbell Road in Madison Heights, twenty-one years old

Table 2 and Figure 3 present the condition of the concrete pavement based on visual field observation and petrographic core analysis.

Table 2. Comparison of concrete pavement condition determined by field observation and core analysis

	Condition Rating		
	Good	**Moderate**	**Poor**
Concrete condition by field observation	79%	4%	17%
Concrete condition by core analysis	26%	13%	61%

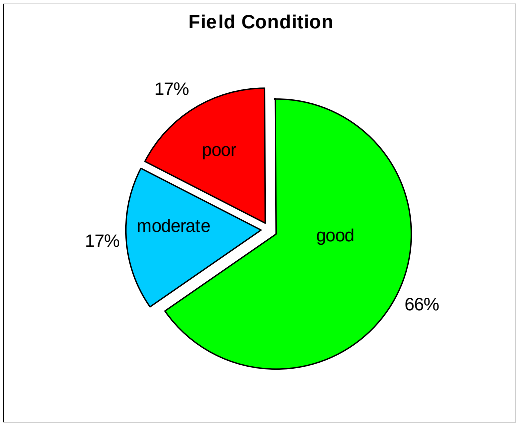


Figure 3 (a). Condition of the concrete pavement based on visual field observation

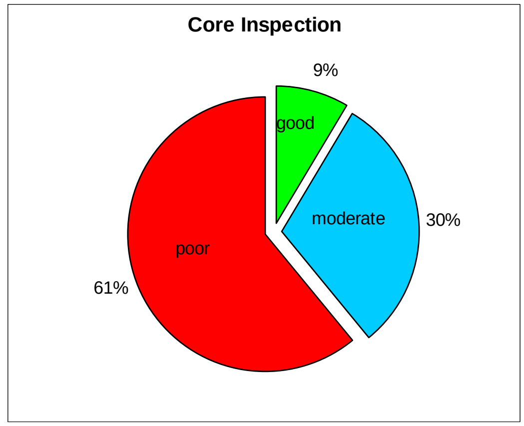


Figure 3 (b). Condition of the concrete pavement based on core inspection and analysis

A correlation of the age of the projects to the condition of the concrete pavements shows a very minor relationship between age of the pavement and its condition when determined by field observation, but no relationship of age to condition when determined by core analysis (see Figure 4).

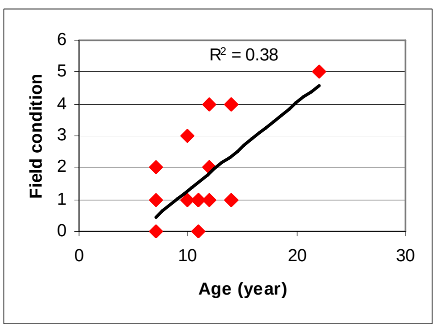


Figure 4 (a). Age vs. concrete pavement condition as determined by field observation

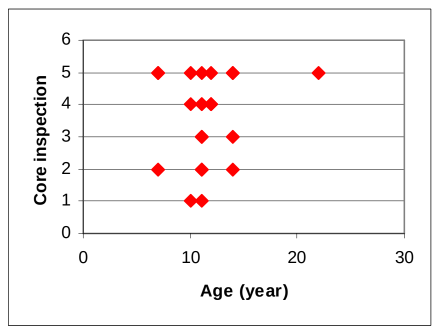


Figure 4 (b). Age vs. concrete pavement condition as determined by core analysis

No clear relationship could be determined between concrete pavement condition and the deterioration mechanisms reported, despite best efforts to assemble the relevant materials and construction information. This being a rather small sample, it may not be surprising that clear trends are not present. Therefore, each mechanism must be studied and corrective measures implemented to reduce those negative effects on the concrete.

Coarse Aggregate

The slag aggregate has long been used in concrete pavements in Michigan. There were very few limestone aggregate projects included in this study. Only four pavements out of the twelve that were studied contained limestone coarse aggregate. Therefore, it is not possible to make any statistically valid conclusions from the data. Concrete pavement condition data by aggregate type are presented in Figure 5.

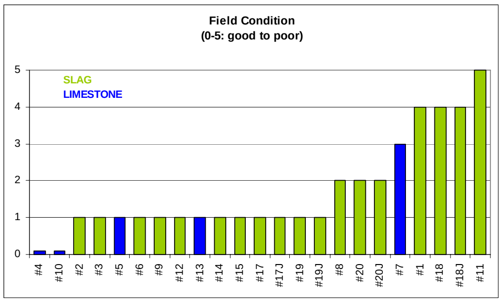


Figure 5 (a). Field-determined concrete pavement condition showing type of coarse aggregate

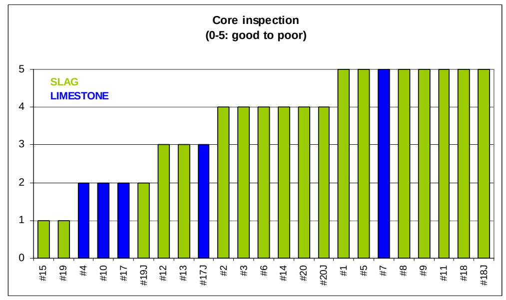


Figure 5 (b). Core-determined concrete pavement condition showing type of coarse aggregate

Problems were observed in the limestone concrete as well as the slag concrete. The two pavements that were in the best condition, as determined by visual observation, contained limestone. The other two limestone pavements, though, were in no better condition than a number of pavements made with slag aggregate. The two projects with concrete in the best condition, as determined by core analysis, contained slag aggregate. Therefore, it was determined that the cause of the distress was not specifically a coarse aggregate issue.

The core analysis did find issues of drying around most slag particles, indicating dry aggregate in an absorptive state at the time of construction. The core analysis found the aggregate to be “dry at the time of batching” in almost every core containing slag aggregate. This adversely affects the concrete in a number of ways. It deprives the cement particles of water in the area of the aggregate particles, thereby depriving it of the water needed for extensive hydration. This compromises both strength and porosity. This dry aggregate can also have a negative effect on the air entraining system, as discussed below. Discussion at the Michigan Concrete Paving Association Annual Workshop indicated that the dry aggregate problem had been addressed in more recent construction projects through diligent wetting of the stockpiles.

Recently, interest has arisen within the concrete community to investigate the contention that an aggregate that is highly absorptive can provide a significant benefit to concrete during the curing process if the pores are fully saturated. Diligent wetting of the stockpiles, as has been reported as current practice for slag aggregate would provide that condition. This benefit also could be realized from a very porous limestone aggregate. The theory proposes that this abundance of water within the aggregate promotes hydration of the cement beyond the normal curing period and increase both strength and reduces permeability.

Metal inclusions were found in the slag aggregate. These are somewhat unusual since the steel production process attempts to minimize that occurrence. There is little evidence that these have played a significant role in the deterioration process. Likely their role is secondary after other mechanisms have initiated the cracking, which allows water into the concrete. Of the twelve projects using slag aggregate, six were found to contain metal inclusions.

Some projects containing slag aggregates appear to be performing well after ten years of service while others have not. This inconsistency in performance indicates that if slag aggregate is used, the unique features of this material require due diligence during the material selection and construction process.

Alkali Silica Reactivity

Alkali silica reactivity (ASR) and the expansive product formed by this reaction causes cracking in concrete. This cracking allows water to ingress into the concrete. If the air void system is marginal, this ingress of water will exacerbate freeze-thaw damage and result in continued and progressive cracking. It is not possible to tell whether ASR or freeze-thaw expansion was the initiating cause of the cracking in the pavements studied, but either mechanism, or a combination of the two, is the most likely source of the expansive forces that have led to the spalling found at many joints. Figure 6 shows the ASR jell within the cracks and around the aggregate particles.

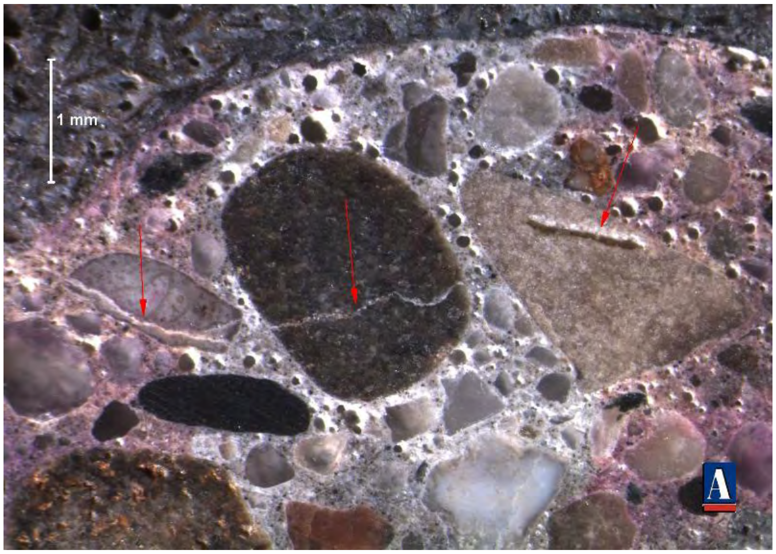


Figure 6. ASR filled cracks and rims

ASR was found, to some degree, in all twenty-three cores. A significant amount of chert was found in the fine aggregate. This material is very reactive and was determined to be the predominate cause of this deterioration mechanism. Unfortunately, that material is predominant in the sand available in the Detroit area. Therefore, alternative sand sources are not a practical alternative. Mitigation of this destructive force must lie in the use of cementitious materials, supplementary cementitious materials (SCMs), or admixtures that can be effective in stopping the ASR.

The use of a low alkali cement to reduce the total alkali loading is a positive step. But as was seen in Core 10, this was not sufficient to overcome the degree of reactivity found in the local sands. The total alkali in the system is the key factor. The amount of cement in the mix, along with the amount of alkali in the cement, determines how much alkali is available to react with the sand. Therefore, a lower cement content in the mix, along with substituting SCMs for a portion of the cement, would be very beneficial.

Class F fly ash, ground granulated blast furnace slag (GGBFS), and silica fume are the most likely SCMs that could be used in a practical way to mitigate the ASR. Testing of sands will indicate the amount of SCMs needed to mitigate the expansive mechanisms. In some cases, these amounts could be rather high. If this is the case, blended cements should be investigated, in cooperation with the area cement companies. If blended cements can be obtained, ternary concrete mixes may be the optimum way to mitigate the ASR and at the same time minimize high volumes of any one SCM. The SCMs can also work in tandem. The use of a ternary mixture provides the benefit of higher SCM mitigation without the risk often associated with the high volume of a single SCM. The blended cement also allows flexibility to the contactor to vary the total SCM content in the mix in order to meet project requirements.

The use of lithium in concrete to mitigate the expansion is being investigated with significant research effort. Unfortunately, a number of issues still stand in the way of a practical application of this alternative, not the least of which is cost.

Air System

Freeze-thaw resistance is absolutely essential to concrete durability in areas with harsh winter climates. Protection is accomplished through an air system within the concrete that provides an escape mechanism for the expansive forces when water freezes. This air system must be uniform throughout the concrete and contain small-sized bubbles at proper spacing in order to accomplish this protection.

The air systems of the pavements examined in this study are summarized in Figures 7, 8, and 9. The air system was not adequate to protect the concrete in 39% of the cores, based on bubble spacing factor. The air system analysis found only 22% of the cores to have an adequate, well-developed air system. The remaining cores had air systems with adequate spacing but had anomalies that put the pavement at risk of early deterioration. There was an uneven distribution of the air bubbles found in 22%, and 13% displayed the uneven disruption and also experienced clumping or coalescing of the air bubbles. One core was reported to have a coarse air system but this was not determined to be a concern. Overall, more than three quarters of the cores were vulnerable to cracking caused by freeze-thaw damage.

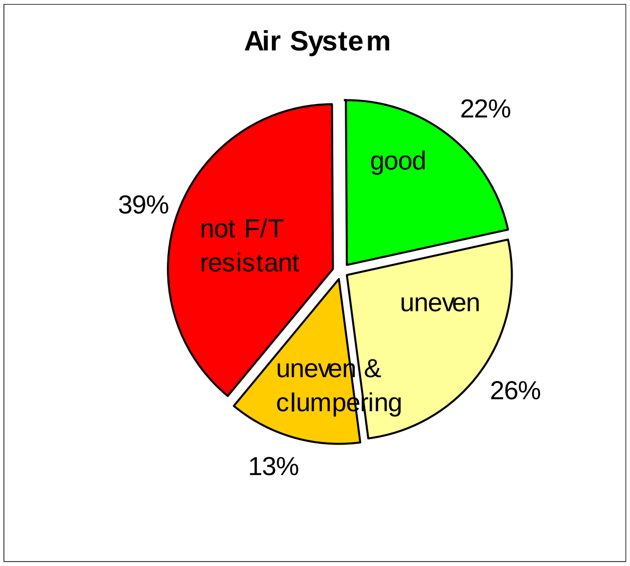


Figure 7. Air system quality of pavements studied

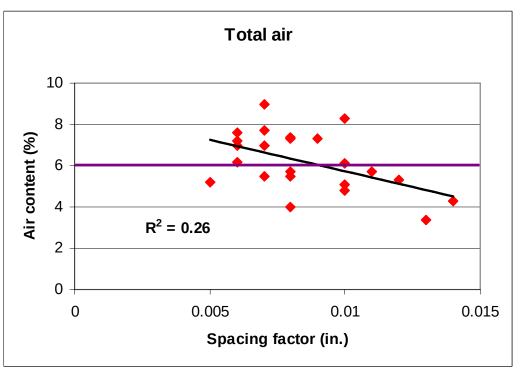


Figure 8. Total air in the concrete vs. spacing factor

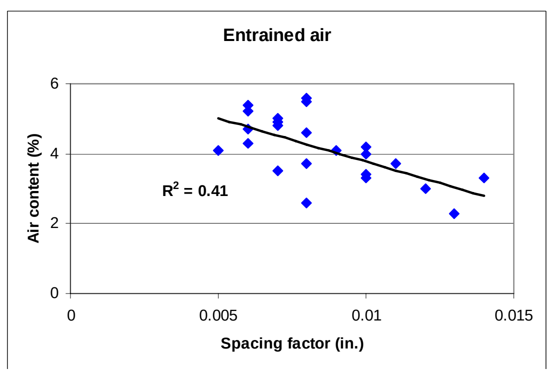


Figure 9. Entrained air in the concrete vs. spacing factor

The uneven distribution of air is normally associated with mixing problems, but it may also stem from chemical incompatibility among the cementitious materials and the admixtures. If mixing was the issue, either the concrete was not mixed sufficiently and needed to be mixed longer or the mixer was not well maintained and did not mix properly. Over-vibration of the concrete during construction can also cause variability of the air within the pavement. Whatever the causes, the situation can result in low air presence in areas of the concrete and thereby contribute to increased risk of freeze-thaw damage.

The clumping or coalescing that was identified has been identified by some to be a phenomenon often associated with the use of synthetic based or other non-vinsol resin based air entraining admixtures. These generally are less soluble than the traditional vinsol resin based products. Their use may require more attention to the other components in the mix to ensure they are effective in producing the very stable air bubbles they are known for.

The coalescing may also be associated with the problem of absorptive or dry aggregate. Water moves toward absorptive aggregate and carries the admixture with it. Non vinsol resins are not as soluble as vinsol resins so they may accumulate at the aggregate surface as water is absorbed. This would cause a disproportionate amount of admixture and thereby create bubbles near the surface of the aggregate as the mixing continues. Others believe that the movement of water toward the aggregate may carry the bubbles toward the aggregate surface, resulting in coalescing. Either way, dry aggregate can play a part in this phenomenon. Figure 10 shows air bubble coalescence.

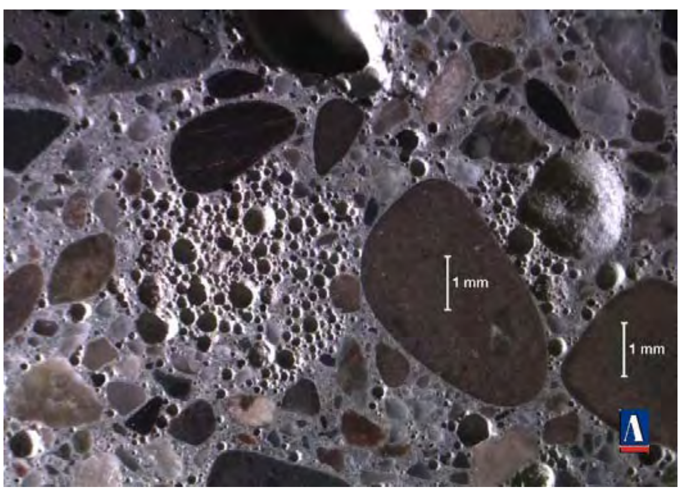


Figure 10. Air bubble coalescence in Core 6

Although not a problem for the air system itself, two cores were found to have many large entrapped air voids. These are not helpful in providing freeze-thaw resistance for the concrete, but as long as there is a sufficient number and a proper spacing of the smaller size bubbles, the concrete can be durable. The presence of these large bubbles is an indication of a lack of proper consolidation of the concrete.

Numerous problems have been identified relative to the air system in the pavements studied. The excessive spacing factor may relate to inadequate mixing, the dry aggregate, or an admixture problem. The clustering or coalescing may be cased by the admixture itself, mixing issues, or the dry aggregate. The entrapped air is a sign of inadequate consolidation. Most of these causes are construction related, and therefore an examination of current practices should be undertaken.

Ettringite

The petrographic analysis identified ettringite deposits filling air voids to some degree in every core (see example in Figure 11). Although ettringite is a normal reaction product of the cement hydration process, when excessive amounts are formed or are produced at later ages, they can fill some of the air and pore spaces. Ettringite is not considered an expansive mechanism by most experts but can be a determent to concrete durability if it adversely affects the air system. There is no clear evidence that filling of the air voids was the initiating cause of the deterioration or that it plays a significant role in the continuing cracking that has been observed. The likely scenario is that the cracks were caused by one of the expansive mechanisms, which allowed water into the concrete. The water then "accelerates the rate at which ettringite leaves its original location in the paste to go into solution and recrystalize in larger spaces such as air voids or cracks." (Kosmatka, Kerkhoff, and Panarese 2002). With ettringite being identified in every core, though, its presence can not to be ignored.

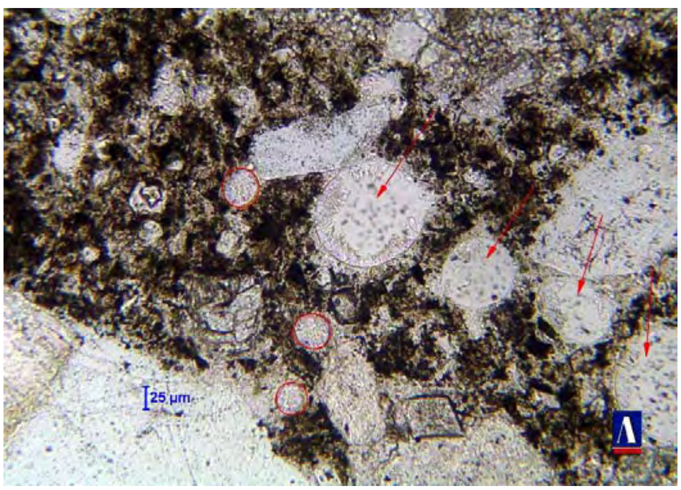


Figure 11. Ettringite-filled air voids

Type II cements can be used to reduce the amount of aluminates in the cement. In the cores investigated, even though ettringite is present in every core, it is not filling all the pores in any core and only the smallest in many cores. However, it would appear that other deterioration mechanisms play a much greater role in compromising the pavements' durability. Therefore, it would be prudent to take actions that deal with those issues before extra money is spent on Type II cement.

It should also be noted that slag aggregate adds sulfur, one of the major components of ettringite, to the system, but that in and of itself may not be a significant factor in the cracking mechanism. Aluminates need to be present to form the excess ettringite. Unless the ettringite interferes with the air system, it is not likely to play a significant role in the deterioration process.

Reducing the potential for ettringite growth is important but not critical since it is likely that this problem will be minor if the other deterioration mechanisms are dealt with.

Water-Cement Ratio

Core 17J was taken through a construction joint. The two halves of the core were constructed at different times. The photos of the core show significantly more deterioration on one side of the joint than on the other side. See Figure 12. The petrographer indicated that the water cement ratio was much greater on the side with the extensive cracking, likely in excess of 0.50. Water cement ratios that high may have a reduced resistance to freeze-thaw deterioration and in this case did show extensive cracking.

Figure 12. High water-cement ratio and cracking left half of the cold joint

It is not unusual to find a higher water content in the concrete in the area of a construction joint. If it is excessive, it can and in this case did lead to early deterioration or exacerbate the problem if something else initiated the cracking.

Surface Cracking

Microcracks at the surface were identified in all projects. Half the cores had several of these cracks; the rest had either only a few cracks or many cracks. The extent of the cracking ranged from four cores with cracks extending from the surface, down to a depth of 4 mm or less, to two cores with cracks extending 28 mm into the pavement. These are significant but too general to shed light on the cause. They may result from the previously discussed expansive forces at work within the pavement or from mix workability causes. An unworkable mix can lead to over finishing and tearing of the surface. Gap gradations, incompatibilities between the cementitious materials and the admixtures, and a dry absorptive aggregate are often what contribute to poor workably. Another possible cause could be insufficient curing, which leads to plastic shrinkage cracking. The presence of the cracks is significant. Attention needs to be focused on the likely causes of these and the other forms of the deterioration.

Cores of Particular Interest

Two cores are particularly noteworthy:

- **Core 10** has three features that should improve its performance. It contains limestone aggregate, which removes the water absorption issue. It used low alkali cement, which has a positive effect on ASR. It also contained a Type II cement, which would positively impact the resistance to any ettringite growth. Unfortunately, there was evidence of uneven distribution of the air system. This core was in better condition than most and the pavement was in better condition than all but one other, but cracking was found in the top inch of the core and ASR was identified within the core. It could be concluded that even with the measures stated above, they were not sufficient to prevent some amount of expansive damage.

- **Core 14** is puzzling. It is one of only two containing fly ash, yet it contains a large amount of ASR gel. It has a good air system, no ettringite was noted, and the pavement was in relatively good condition. The amount of fly ash used was 15% to 20%, which may have not been sufficient to mitigate the ASR reaction of the particular sand. Therefore, this core is not helpful in providing insight into the effectiveness of fly ash to mitigate the ASR problem. Also other factors may be contributing to the ASR formation. Other cores within the same project have much less ASR. This was a staged construction project, so different factors may have been involved in the different stages that were not noted in the information available.

Recommendations

The projects evaluated in this study exhibited multiple deterioration mechanisms. This is not an unusual finding. When early distress is found in a pavement, multiple mechanisms are often present. The difficultly lies in determining which was the initiating cause and which was the result of the initiating cause. Many times that can never be determined with any degree of certainty. Therefore, it is prudent to take steps to reduce the factors that lead to each of the mechanisms to ensure that none of them is able to initiate the deterioration process. Therefore, recommendations are offered to address each of the findings described above.

The deterioration mechanisms can be grouped into two categories. Some are related to the materials used in the concrete. Others are related to the construction practices that were used during construction. Everyone involved in the construction process plays a role in all of them. In general, the specifying agencies normally develop the specifications for the materials and the contractors are responsible for the construction process. Therefore, cooperation between industry and owner agencies will be needed to address both materials and construction issues evidenced by the core analyses.

Materials

1. The greatest materials issue appears to be ASR related to sand. This was found, to some degree, in every core. Class F fly ash, GGBFS, and silica fume are the most likely materials that could be used in a practical way to mitigate the ASR. Even though their availability in the Detroit area has been minimal in the past, a fresh look at how they may be obtained, through discussions with cementitious suppliers, is essential. Since they will be used in place of some of the cement in a mix, and because some are less expensive than cement, they may be more practical than many would first think. Blended cements are used regularly in many parts of the country. The cement companies should be approached as partners to assist in this effort to solve this durability problem.

   Testing of the sands will indicate the amount of the SCM needed to mitigate the expansive mechanisms. In some cases, these amounts could be rather high. If this is the case, blended cements should be investigated, in cooperation with the area cement companies. If blended cements can be obtained, ternary concrete mixes may be the optimum way to mitigate the ASR and at the same time minimize high volumes of any one SCM. The SCMs can also work in tandem. The use of a ternary mixture provides the benefit of higher SCM mitigation without the risk often associated with the high volume of a single SCM. The blended cement also allows flexibility to the contactor to vary the total SCM content in the mix in order to meet project requirements.

2. The other major deterioration mechanism is the air system within the concrete. A number of air issues were identified. Mixing is often the first place to look when problems of either inadequate bubble spacing or uneven distribution arise. Compliance with minimum mixing time specifications needs to be emphasized. As mentioned above, absorptive aggregate can adversely affect the air system, so preventing this situation is critical. Synthetic or non-vinsol air entraining agents were present in the cores showering clustering. Assistance from the technical representatives of the admixture companies in the area need to be obtained to address problems that arise with unstable air, nonuniform air or coalescing of the air bubbles.

3. Workable mixes are critical to long-term performance. Well-graded aggregates, low water-cement ratios, and the use of SCMs will help ensure this. The mixes were generally well graded but only one project contained an SCM, that being fly ash.

4. Slag aggregate can be used to produce durable concrete. The inherent property of high absorption and therefore a propensity to move toward an absorptive state is a significant challenge. Wetting the stockpile will be critical to prevent water absorption. Concrete strength, low permeability, and an effected air system all to some degree depend on eliminating this absorptive problem.

Construction

1. The largest construction issue noted relates to the air system. A number of construction approaches, in addition to the air system recommendations above, can be adopted to ensure that a proper air system is developed:

    a. One simple and rather inexpensive recommendation is to raise the required air content of the mix. All the cores with total air content in excess of six percent contained an acceptable bubble spacing factor. Therefore, to simply raise the required air content that is a part of the current specifications can play a role in improving this important aspect of the air system, the bubble spacing. The only negative side of this is a small reduction in strength. A small loss of strength is well worth the increase in durability.
    b. Testing the air content behind the paver should be implemented. The total air contents identified in the cores is from the in-place pavement. Most specifications define the point of testing for air content ahead of the paver. This has resulted in many pavements with passing air tests that still experience shortened lives. Leaving the point of acceptance ahead of the paver is a practical necessity but regular checking of the air content behind the paver is very important.
    c. Continued use of the air void analyzer (AVA) as a process control tool should be encouraged. The total air content is not the whole answer. The Michigan Concrete Paving Association has purchased an AVA unit to

monitor paving projects. The AVA gives invaluable information, but a hard and fast definition of the line between good versus bad concrete is not well defined at this time. Therefore, the AVA's use as a monitoring tool is the appropriate approach until more research is complete.

2. Curing is critical to good performance and durability. Renewed emphasis on good curing practices needs to be a priority. Poor curing leads to plastic surface cracks, which opens the concrete up to water intrusion. That water is the mechanism that feeds many of the deterioration mechanisms identified in this report.

References

Kosmatka, S. B. Kerkhoff, and W. Panarese. 2002. *Design and Control of Concrete Mixtures.* 14th edition. Product Code EB001. Skokie, IL: Portland Cement Association.

Appendix A. Summary of Project Information, Core Analysis, and Field Observation

	Wayne County Concrete Pavement Cores						
Core ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Project Record							
Date paved	1994	1994	May 1995	Nov-95	May-95	1996	1996
Contractor	Eastern Concrete Paving Co.	Eastern Concrete Paving Co.	Eastern Concrete Paving Co.	Eastern Concrete Paving Co.	Eastern Concrete Paving Co.	John Carlo	John Carlo
Paving Conditions	-	-	-	-	-	-	-
General Location	Base Line Rd between Novi Rd and Meadowbrook EBL	Base Line Rd between Novi Rd and Meadowbrook WBL	Belleville Road between I-94 and Quirk Rd, near sta. 45+00 NBL	Belleville Road between I-94 and Quirk Rd, near sta. 45+00 SBL	Belleville Rd south of Quirk Rd, before bridge SBL	8Mi Rd west of Farmington RD EBL	8Mi Rd west of Farmington RD WBL
SCM	No	No	No	No	No	No	No
Coarse Agg	Levy Trenton 6AA Slag	Levy Trenton 6AA Slag	Levy Trenton 6AA Slag	1 Thompson Mcully Limestone	Levy Trenton 6AA Slag	Levy Trenton 6AA Slag	Limestone
Fine Agg	Lyons Sand Gravel	Lyons Sand Gravel	Milford Sand Gravel	Milford Sand Gravel	Milford Sand Gravel	-	-
Cement	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1
Admix Air	WR Grace Daravair	WR Grace Daravair	WR Grace Daravair	WR Grace Daravair	WR Grace Daravair	Axim AE 260	Axim AE 260
Admix H_2O Reducer	Grace WRDA-82	Grace WRDA-82	Grace WRDA-82	Grace WRDA-82	Grace WRDA-82	Axim 1000n	Axim 1000n
Plain/Reinforced	Reinforced	Reinforced	Reinforced	Reinforced	Reinforced	Reinforced	Reinforced
DeIcing	County Salt	County Salt	-	-	-	Salt	Salt
JointType and Sealant	-	-	-	-	-	Trans - 11/16" Neoprene / Longit. - Hot Pour	-
Joint Spacing	-	-	-	-	-	-	-
Tie bars	-	-	-	-	-	#5 Epoxy Coated	#5 Epoxy Coated
Pavement Thickness	9"	9"	9"	9"	9"	-	-
Traffic	-	-	-	-	-	-	-
Substructure	21AA Agg. Base	21AA Agg. Base	21AA Agg. Base	21AA Agg. Base	21AA Agg. Base	21AA Agg. Base	21AA Agg. Base
Notes	-	-	-	-	-	-	-

	Wayne County Concrete Pavement Cores						
Core ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Petrographic Analysis							
Air System							
Air Content %	5.3	7.4	5.7	7.3	4.8	7.3	7.0
Entrained %	3.0	5.6	4.6	5.5	3.3	4.1	4.9
Entrapped %	2.3	1.8	1.1	1.8	1.5	3.2	2.1
Spec. Surface (in^2/in^3)	377	470	510	490	490	450	570
Spacing factor (in)	0.012	0.008	0.008	0.008	0.010	0.009	0.007
Paste Content % est.	27	26	23	26	26	26	27
Freeze/Thaw Resistant	No	Yes	Yes	Yes	No	No	Yes
Anomaly in Air Void System	-	uneven dist.	uneven dist.	uneven dist.	uneven dist. / coalescence	uneven dist.	uneven dist.
Paste Hardness (1-3, 1 medium- 3 hard)	2	2	2	1	1	2	2
Secondary Deposits							
Etringite (0-5: 0 little or lined, 1 fills to 25µm, 2 fills to 50µm, 3 fills to 100µm, 4 fills to 150µm, 5 fills large poors)	3	1	2	2	2	2	2
ASR Degree (0-5: 0 negligible - 5 severe)	1	0	2	1	3	2	3
Overall Concrete Condition (0-5: 0 very good - 5 poor)	5	4	4	2	5	4	5
Field Condition							
Surface condition (0-5: 0 no cracking - 5 severe spalled joints)	4	1	1	0	1	1	3

	Oakland County Concrete Pavement Cores							
Core ID	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Project Record								
Date paved	1999	1999	Phase I 6/22/-6/28/99 Phase II 8/9-8/12/99	Aug/Sept 1984	1995	1995	1995	1996
Contractor	Tony Angelo	Tony Angelo	Florence Cement	Tony Angelo	AJAX	AJAX	AJAX	John Carlo
Paving Conditions	Sta 1 60-75 F Sta 2 65-85 F Cen Lan 65-85 F	Sta 1 60-75 F Sta 2 65-85 F Cen Lan 65-85 F	Phase I and II warm, sunny, partly cloudy 70-80s F	60-85 F	70-85 F	70-85 F	70-85 F	68-70 F
General Location	12 Mile Rd east of Inkster near San Marion Dr EBL	12 Mile Rd east of Inkster near San Marion Dr WBL	Campbell Rd north of 12 mi Rd, NBL	Campbell RD-Madison Heights 13-14 Mi, NBL	Big Beaver Rd at Lakeview Rd EBL, far left turn lane	Big Beaver Rd at Lakeview Rd EBL, second left turn lane	Big Beaver Rd at Lakeview Rd EBL	Dequindre Rd south of Big Beaver Rd SBL at Stratford Rd
SCM	No	No	No	No	No	Fly ash	Fly ash	No
Coarse Agg	6AA Levy (Slag)	6AA Levy (Slag)	6AA Presque Isle Limestone Pit #71-47	6AA EDW C. Levy PLT 1	6AA Levy (Slag)	6AA Levy (Slag)	6AA Levy (Slag)	6AA Levy Dix #1
Fine Agg	2NS Holly Sand and Gravel	2NS Holly Sand and Gravel	2NS Bed Rock Express Pit #63-119	2NS Natural EDW Levy	2NS Holly Sand and Gravel	2NS Holly Sand and Gravel	2NS Holly Sand and Gravel	2NS oakland Sand and Gravel
Cement	Southdown Type 1	Southdown Type 1	LaFarge Low Alkali- Type II	Type 1 Dundee	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1	Lafarge Type 1, Detroit
Admix Air	Daravair 1400 (1.1-1.2oz cwt)	Daravair 1400 (1.1-1.2oz cwt)	Master Builders AE Pave Air	Darawair, W R Grace	Catexol AE 260 (1.5oz cwt)	Catexol AE 260 (1.5oz cwt)	Catexol AE 260 (1.5oz cwt)	AXIM Catexol AE 260 (0.75oz cwt)
Admix H_2O Reducer	WDA Daracem 65 (3.0-6.0oz cwt)	WDA Daracem 65 (3.0-6.0oz cwt)	Master Builders WR 220N	WRDA 20, W R Grace	WRDA Hycl (3.0oz cwt)	WRDA Hycl (3.0oz cwt)	WRDA Hycl (3.0oz cwt)	AXIM Catexol 1000N (2.0oz cwt)
Plain/Reinforced	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
DeIcing	Salted, Heavy at times	Salted, Heavy at times	Salt	Salted	-	-	-	-
JointType and Sealant	Transv- Sawed Random Skewed 11/16 Neoprene Long- Sawed sealed HPRA	Transv- Sawed Random Skewed 11/16 Neoprene Long- Sawed sealed HPRA	Conventional Transverse Neoprene Longitudinal Hot Pour Rubber	Conventional HPRA	-	-	-	-
Joint Spacing	14'-18'	14'-18'	15" skewed	20'	Random Transverse and Long	Random Transverse and Long	Random Transverse and Long	-
Tie bars	-	-	-	-	-	-	-	-
Pavement Thickness	10"	10"	9"	8"	10"	10"	10"	10"
Traffic	-	-	7000 ADT	-	-	-	-	-
Substructure	8" Dense Graded/6" Open Graded	8" Dense Graded/6" Open Graded	8" 5G, 8" 21AA	6" 22A Gravel	8" Dense Graded/6" Open Graded	8" Dense Graded/6" Open Graded	8" Dense Graded/6" Open Graded	8" Dense Graded/6" Open Graded
Notes	-	-	-	-	High Air Contents and High Mix temp	High Air Contents and High Mix temp	High Air Contents and High Mix temp	-

	Oakland County Concrete Pavement Cores							
Core ID	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Petrographic Analysis								
Air System								
Air Content %	3.4	4.3	7.2	6.1	6.2	7.6	5.2	7.0
Entrained %	2.3	3.3	5.4	4.0	5.2	4.3	4.1	4.7
Entrapped %	1.1	1.0	1.8	2.1	1.0	3.3	1.0	2.3
Spec. Surface (in^2/in^3)	430	370	670	420	660	630	970	610
Spacing factor (in)	0.013	0.014	0.006	0.010	0.006	0.006	0.005	0.006
Paste Content % est.	27	26	23	22	25	27	25	22
Freeze/Thaw Resistant	No	No	Yes	No	Yes	Yes	Yes	Yes
Anomaly in Air Void System	coarse	uneven dist.	uneven dist.	-	uneven dist.	uneven dist. / coalescence	-	entrapped
Paste Hardness (1-3, 1 medium, 3 hard)	1	1	1	1	2	1	1	3
Secondary Deposits								
Etringite (0-5: 0 little or lined, 1 fills to 25µm, 2 fills to 50µm, 3 fills to 100µm, 4 fills to 150µm, 5 fills large poors)	1	2	1	3	2	1	0	1
ASR Degree (0-5: 0 negligible - 5 severe)	1	1	1	3	1	1	4	0
Overall Concrete Condition (0-5: 0 very good - 5 poor)	5	5	2	5	3	3	4	1
Field Condition								
Surface condition (0-5: 0 no cracking - 5 severe spalled joints)	2	1	0	5	1	1	1	1

	Macomb County Concrete Pavement Cores							
Core ID	**17**	**17J**	**18**	**18J**	**19**	**19J**	**20**	**20J**
Project Record								
Date paved	Phase I 6/12-7/1/92 Phase II 8/26-9/2/92	Phase I 6/12-7/1/92 Phase II 8/26-9/2/92	Phase I 6/26-6/28/95 Phase II 8/29-9/1/92	Phase I 6/26-6/28/95 Phase II 8/29-9/1/92	Phase I 9/23-9/24, 10/6-10/10/95 Phase II 11/6-11/14/95	Phase I 9/23-9/24, 10/6-10/10/95 Phase II 11/6-11/14/95	Phase I 6/2-6/8/94 Phase II 8/6-8/15/94	Phase I 6/2-6/8/94 Phase II 8/6-8/15/95
Contractor	Tony Angelo	Tony Angelo	John Carlo Inc	John Carlo Inc	Tony Angelo	Tony Angelo	John Carlo Inc	John Carlo Inc
Paving Conditions	PH I 55-80 P. Sunny PH II 57-76 P. Sunny	PH I 55-80P. Sunny PH II 57-76 P. Sunny	PH I 68-83 Sunny PHII 69-84 Sunny	PH I 68-83 Sunny PHII 69-84 Sunny	PH I 47-66 P. Sunny PH II 31-43 P. Sunny	PH I 47-66 P. Sunny PH II 31-43 P. Sunny	PH I 50-78 sunny PH II 56-77 P. sunny	PH I 50-78 sunny PH II 56-77 P. sunny
General Location	13 Mile Road, Hayes to GTRR station 55+53 EBL	13 Mile Road, Hayes to GTRR station 55+53 EBL at Joint	13 Mile Rd, Utica to Gratiot, west of Kelly EBL	13 Mile Rd, Utica to Gratiot, west of Kelly EBL At joint	Utica Rd 15 mi to Metro Parky North of Moravian SBL	Utica Rd 15 mi to Metro Parky North of Moravian SBL At joint	Utica Rouad, 14-15 mi SBL	Utica Rouad, 14-15 mi SBL At joint
SCM	No	No	No	No	No	No	No	No
Coarse Agg	6AA Limestone, Rockwood Stone Pit #58-08 (sp Gr 2.56 ABS 3.59)	6AA Limestone, Rockwood Stone Pit #58-08 (sp Gr 2.56 ABS 3.59)	6AA B. F. Slag E.C. Levy (pit #82-19)	6AA B. F. Slag E.C. Levy (pit #82-19)	6AA B. F. Slag E.C. Levy (pit #82-19)	6AA B. F. Slag E.C. Levy (pit #82-19)	6AA B. F. Slag E.C. Levy (pit #82-19)	6AA B. F. Slag E.C. Levy (pit #82-19)
Fine Agg	2NS-Sand Salem S&G (pit#63-56)	2NS-Sand Salem S&G (pit#63-56)	2NS Sand Oakland S&G (pit#63-102) Sp Gr 2.63 ABS 1.12	2NS Sand Oakland S&G (pit#63-102) Sp Gr 2.63 ABS 1.12	2NS-Sand	2NS-Sand	2NS-Sand	2NS-Sand
Cement	Medusa Type I (5.6 sack/cyd +water reducer)	Medusa Type I (5.6 sack/cyd +water reducer)	Portland Type I Holman (5.6 sack/cyd+water reducer)	Portland Type I Holman (5.6 sack/cyd+water reducer)	Portland Type I Essroc (5.6 sack/cyd+water reducer)	Portland Type I Essroc (5.6 sack/cyd+water reducer)	Portland Cement Type I Dundee	Portland Cement Type I Dundee
Admix Air	Daravair, W.R. Grace (.75-1.5oz/100% cement)	Daravair, W.R. Grace (.75-1.5oz/100% cement)	Catexol R, Type AE, Axim 1.2oz/100# Cement	Catexol R, Type AE, Axim 1.2oz/100# Cement	Daravair 1000 1.2oz/100# cement	Daravair 1000 1.2oz/100# cement	Catexol 260, Type AE, Axim AEA 1.5oz/100# Cement	Catexol 260, Type AE, Axim AEA 1.5oz/100# Cement
Admix H_2O Reducer	-	-	Catexol 1000N Type A Axim 2.0oz/100# Cement	Catexol 1000N Type A Axim 2.0oz/100# Cement	WRDA 20, Type A 2.5oz/100#cement	WRDA 20, Type A 2.5oz/100#cement	Catexol, 1000L Type A WR 2.0 oz/100#cement	Catexol, 1000L Type A WR 2.0 oz/100#cement
Plain/Reinforced	Plain	Plain	Plain	Plain	Plain	Plain	Plain	Plain
DeIcing	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl	Ca/Na Cl
JointType and Sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant	Conventional, hot rubbr sealant
Joint Spacing	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed	14-17 ft skewed
Tie bars	Yes (32-54 in spacing)	Yes (32-54 in spacing)	Yes (32-54 in spacing)	Yes (32-54 in spacing)	Yes	Yes	Yes	Yes
Pavement Thickness	9"	9"	9"	9"	9"	9"	9"	9"
Traffic	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks	High Volume w/10% Trucks
Substructure	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase with edgedrain	Slagcrete Base & sand subbase	Slagcrete Base & sand subbase
Noted Problems	-	-	-	-	-	-	-	-

	Macomb County Concrete Pavement Cores							
Core ID	**17**	**17J**	**18**	**18J**	**19**	**19J**	**20**	**20J**
Petrographic Analysis								
Air System								
Air Content %	8.3	7.7	5.5	5.5	9.0	5.7	4.0	5.1
Entrained %	4.2	5.0	3.5	3.7	4.8	3.7	2.6	3.4
Entrapped %	4.1	2.7	2.0	1.8	4.2	2.0	1.4	1.7
Spec. Surface (in^2/in^3)	390	520	700	560	450	390	620	460
Spacing factor (in)	0.010	0.007	0.007	0.008	0.007	0.011	0.008	0.010
Paste Content % est.	26	23	26	23	22	22	25	25
Freeze/Thaw Resistant	No	Yes	Yes	Yes	Yes	No	Yes	No
Anomaly in Air Void System	-	uneven dist. / coalescence	-	-	entrapped	-	uneven dist. / coalescence	coalescence
Paste Hardness (1-3, 1 medium, 3 hard)	3	3	3	3	3	3	3	3
Secondary Deposits								
Etringite (0-5: 0 little or lined, 1 fills to 25µm, 2 fills to 50µm, 3 fills to 100µm, 4 fills to 150µm, 5 fills large poors)	2	3	2	3	2	4	2	2
ASR Degree (0-5: 0 negligible - 5 severe)	1	0	4	1	1	1	3	3
Overall Concrete Condition (0-5: 0 very good - 5 poor)	2	3	5	5	1	2	4	4
Field Condition								
Surface condition (0-5: 0 no cracking - 5 severe spalled joints)	1	1	4	4	1	1	2	2

Appendix B. Petrographic Analyses of Pavement Cores (performed by American Engineering Testing)

AMERICAN PETROGRAPHIC SERVICES, INC.

REPORT OF CONCRETE TESTING

PROJECT:

MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY
OAKLAND COUNTY
MACOMB COUNTY

REPORTED TO:

NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DRIVE, SUITE 3100
AMES IA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: FEBRUARY 2, 2006

INTRODUCTION

This report presents the results of laboratory work performed by our firm on twenty-three concrete core samples submitted to us by Mr. Jim Grove of the National Concrete Pavement Technology Center on December 7, 2005. We understand the concrete cores were obtained from exterior concrete pavement that is currently under evaluation. The concrete was reportedly placed between 1992 and 1999. The scope of our work was limited to performing petrographic analysis testing to document the overall quality and condition of the concrete.

CONCLUSIONS

Based on our observations, test results, and past experience, our conclusions are as follows:

1. The overall quality of the concrete was variable, generally ranging from fair to poor. The cement paste was relatively dense and hard with carbonation that was generally ranged from negligible to 1/4" depth spiking to 7/8" along subvertical microcracking. The concrete was placed with a low slump. The crushed carbonate aggregate in cores #4, 7, 10, 17, and 17J was relatively hard, appeared sound, and durable. The coarse aggregate in the eighteen other cores is comprised of blast furnace slag. We observed large steel inclusions within the blast furnace slag aggregate that have corroded; producing cracking (cores #13 and 18).

   Further, the slag aggregate may be a source of sulfur that is contributing to the development of significant ettringite deposition in the air void system.

2. The concrete contained air void systems that generally were consistent with current technology for resistance to freeze-thaw deterioration. However, moderate to extensive secondary ettringite deposition, that has lined and filled entrained voids, has compromised

the effectiveness of the air void system, and therefore, the durability of the concrete. In addition, two cores contained little to virtually no purposeful air entrainment in specific elevations within the concrete. Core #1 contains approximately 2% total air in the top approximately 3". Core #2 contains little purposeful entrained air below approximately 3-7/8" depth.

3. Deicer distress (see pages 9-14 in the enclosed book, "Ettringite; Cancer of Concrete") was documented in the four cores taken through deteriorating joints. We consider the deterioration to be moderate. We expect joint deterioration to continue with exposure to moisture, natural deicer, and freezing conditions.

4. Alkali-silica reactivity (ASR) is occurring to some degree in all twenty-three cores. The offending material is a significant quantity of chert in the fine aggregate. Our judgment of the severity of ASR in the cores is classified in the following table:

Sample No.	**Degree of ASR**
1	Minor
2	Negligible
3	Minor to moderate
4	Minor
5	Moderate
6	Minor to moderate
7	Moderate
8	Minor
9	Minor to negligible
10	Minor
11	Moderate
12	Minor
13	Minor
14	Moderate to severe
15	Negligible
17	Minor
17J	Negligible
18	Moderate to severe
18J	Minor
19	Minor to negligible
19J	Minor to negligible
20	Moderate
20J	Moderate

Moderate to severe judgments are reserved for the observation of extensive, continuous, mostly horizontal micro and macrocracking emanating from or proceeding through many chert particles, producing bulk expansion, and coupled with large deposits of silica gel product.

SAMPLE IDENTIFICATION

Sample No.	Original Sample Dimensions
1	125 mm (4-15/16") diameter by 245 mm (9-5/8") long
2	125 mm (4-15/16") diameter by 245 mm (9-5/8") long
3	125 mm (4-15/16") diameter by 228 mm (9") long
4	125 mm (4-15/16") diameter by 245 mm (9-5/8") long
5	125 mm (4-15/16") diameter by 238 mm (9-3/8") long
6	125 mm (4-15/16") diameter by 275 mm (10-13/16") long
7	125 mm (4-15/16") diameter by 285 mm (11-1/4") long
8	149 mm (5-5/8") diameter by 270 mm (10-5/8") long
9	149 mm (5-5/8") diameter by 294 mm (11-9/16") long
10	146 mm (5-3/4") diameter by 235 mm (9-1/4") long
11	146 mm (5-3/4") diameter by 213 mm (8-3/8") long
12	149 mm (5-5/8") diameter by 264 mm (10-3/8") long
13	149 mm (5-5/8") diameter by 267 mm (10-1/2") long
14	149 mm (5-5/8") diameter by 293 mm (11-9/16") long
15	149 mm (5-5/8") diameter by 270 mm (10-5/8") long
17	149 mm (5-5/8") diameter by 257 mm (10-1/8") long
17J	149 mm (5-5/8") diameter by 240 mm (9-7/16") long
18	149 mm (5-5/8") diameter by 238 mm (9-3/8") long
18J	149 mm (5-5/8") diameter by 241 mm (9-1/2") long
19	149 mm (5-5/8") diameter by 225 mm (8-7/8") long
19J	149 mm (5-5/8") diameter by 221 mm (8-11/16") long
20	149 mm (5-5/8") diameter by 230 mm (9-1/16") long
20J	149 mm (5-5/8") diameter by 233 mm (9-3/16") long

TEST RESULTS

Our complete petrographic analysis test results appear on the attached sheets entitled 00 LAB 001 "Petrographic Examination of Hardened Concrete, ASTM:C856." A brief summary of the general concrete properties is as follows:

1. The coarse aggregate in eighteen of the cores was comprised of 3/4" to 1" maximum sized blast furnace slag. Crushed carbonate comprised the coarse aggregate in cores #4, 7, 10, 17,

and 17J. In general, the aggregate was fairly well graded with fair to good overall distribution.

2. Fly ash pozzolanic was observed in concrete samples #13 and 14 only.

3. The paste color of the cores was mottled dark blue-gray and tannish gray with the slump estimated to be low (0" to 2").

4. The paste hardness of the cores was judged to be medium to hard with the paste/aggregate bond considered good.

5. The depth of carbonation was up to 7/8" maximum depth, following subvertical microcracking at the surface.

6. The water/cementitious ratio of the cores was estimated at between 0.36 to 0.45 with approximately 7-13% unhydrated cement particles and a purposeful addition of fly ash pozzolan in cores #13 and 14.

Air Content Testing
See attached data sheets.

TEST PROCEDURES

Laboratory testing was performed on December 7, 2005 and subsequent dates. Our procedures were as follows:

Petrographic Analysis
A petrographic analysis was performed in accordance with APS Standard Operating Procedure 00 LAB 001, "Petrographic Examination of Hardened Concrete," ASTM:C856-latest revision. The petrographic analysis consisted of reviewing cement paste and aggregate qualities on a whole basis as well as on a cut/polished section. The depth of carbonation was documented using a phenolphthalein indicator solution applied on a freshly cut and polished surface of the concrete sample. The water/cement ratio of the concrete was estimated by viewing a thin section of the concrete under an Olympus BH-2 polarizing microscope at magnification up to 1000x. Thin section analysis was performed in accordance with APS Standard Operating Procedure 00 LAB 013, "Determining the Water/Cement of Portland Cement Concrete, APS Method." The samples are first highly polished, then epoxied to a glass slide. The excess sample is cut from the glass and the slide is polished until the concrete reaches 25 microns or less in thickness.

Air Content Testing
Air content testing was performed using APS Standard Operating Procedure 00 LAB 003, "Microscopical Determination of Air Void Content and Parameters of the Air Void System in Hardened Concrete, ASTM:C457-latest revision." The linear traverse method was used. The concrete cores were cut perpendicular with respect to the horizontal plane of the concrete as placed and then polished prior to testing.

REMARKS

The test samples will be retained for a period of at least thirty days from the date of this report. Unless further instructions are received by that time, the samples may be discarded. Test results relate only to the items tested. No warranty, express or implied, is made.

Report Prepared By:

Scott F. Wolter, P.G.
President
MN License No. 30024

Richard D. Stehly, P.E., FACI
MN Lic. No. 12856

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-19-05 / 1/19/06
Sample Identification:	#1	Performed by:	C. Tillema / G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 245 mm (9-5/8") x 124 mm (4-7/8") x 52 mm (2-1/16") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 245 mm (9-5/8") long core.

2. Surface Conditions:

   Top: Rough, screeded, broomed, scaled and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: A 6 mm (1/4") diameter steelmesh member paired with a 10 mm (3/8") steelmesh member were observed approximately 108 mm (4-1/4") depth from the top surface. No corrosion observed.

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Approximately 25% of the original top surface has shallowly scaled away. Several fine, subvertical microcracks proceed from the top surface up to 3 mm (1/8") maximum depth. Carbonation proceeds up to 3 mm (1/8") depth from the top surface. The concrete above approximately 75 mm (3") does not appear purposely air entrained; containing approximately 2% air. The remaining concrete below 3" may have originally contained an air void system considered freeze-thaw durable. However, most of the smaller air voids (<100 μm) are filled by secondary ettringite. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Fair overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	5.3% total, performed on concrete below 75 mm (3") depth
2.	Depth of carbonation:	Up to 3mm (1/8") depth from the top surface
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Mottled dark blue-gray and dark tannish-gray
6.	Paste hardness:	Medium-hard
7.	Paste proportions:	25% to 27%
8.	Microcracking:	Several fine, subvertical microcracks proceed from the top surface up to 3 mm (1/8") maximum depth. Subhorizontal microcracking proceeds across most of the diameter to the core within 6 mm (1/4") of the top surface, proceeding through several reactive chert fine aggregate particles. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9.	Secondary deposits:	White ettringite was observed filling most of the smallest air voids, <100 μm in size, and lining most of the larger air voids. Clear alkali-silica-gel lines several fine air void spaces proximate to reactive chert fine aggregate particles within the top 12 mm (1/2").
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.38 to 0.43 with approximately 9-11% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites- well to fully; Belites- well

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-19-05/1-19-06
Sample Identification:	#2	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 241 mm (9-1/2") x 124 mm (4-7/8") x 54 mm (2-1/8") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 245 mm (9-5/8") long core.

2. Surface Conditions:

   Top: Rough, screeded, broomed, and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: 10 mm (3/8") diameter steelmesh was observed approximately 95 mm (3-3/4") depth from the top surface. No corrosion observed.

4. General Physical Conditions: The top surface has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate particles. A few subvertical microcracks proceed from the top surface up to 6 mm (1/4") maximum depth. Carbonation proceeds up to 3 mm (1/8") depth from the top surface. The concrete was purposely air entrained. However, the concrete below approximately 98 mm (3-7/8") depth contains little purposeful air entrainment. No obvious cold joint was observed. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Good overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with fair overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good to fair overall distribution.

III. Cementitious Properties

1. Air Content:	7.4% total (performed within the top 98 mm (3-7/8") of the sample)
2. Depth of carbonation:	Negligible up to 3 mm (1/8") depth from the top surface
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled dark blue-gray and dark tannish-gray
6. Paste hardness:	Medium-hard
7. Paste proportions:	24% to 26%
8. Microcracking:	A few subvertical microcracks proceed from the top surface up to 6 mm (1/4") maximum depth. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9. Secondary deposits:	White ettringite was observed filling most of the smallest air voids and thinly lining many of the larger air voids. Clear alkali-silica-gel lines a single void space at approximately 29 mm (1-1/8") depth from the top surface.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.38 to 0.43 with approximately 9-11% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites-well to fully; Belites-well to fully

IV. Conclusions

The general overall quality of the concrete was fair to poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-20-05/1-19-06
Sample Identification:	#3	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 225 mm (8-7/8") x 124 mm (4-7/8") x 52 mm (2-1/16") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 229 mm (9") long core.

2. Surface Conditions:

   Top: Rough, screeded, broomed and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: A 32 mm (1-1/4") diameter epoxy coated rebar was observed approximately 95 mm (3-3/4") depth from the top surface. No corrosion observed.

4. General Physical Conditions: The top surface, partially covered by pink marking paint, has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate particles. Few subvertical microcracks proceed from the top surface up to 2 mm (1/16") maximum depth. Carbonation ranged from negligible up to 3 mm (1/8") depth and intermittently up to 8 mm (5/16") depth from the top surface. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, uneven distribution of the entrained air voids was observed throughout the sample. Numerous, subhorizontally oriented microcracks, were observed proceeding through numerous reactive fine aggregate particles in the top 19 mm (3/4") of the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.7% total
2. Depth of carbonation:	Negligible up to 3 mm (1/8") depth and intermittent up to 8 mm (5/16") depth
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Medium blue-gray; dark tannish-gray within the top 35 mm (1-3/8") and dark blue-gray within the bottom 73 mm (2-7/8") of the sample.
6. Paste hardness:	Medium-hard
7. Paste proportions:	21% to 23%
8. Microcracking:	Few subvertical microcracks proceed from the top surface up to 2 mm (1/16") depth. Numerous, subhorizontally oriented microcracks, were observed between 5 mm (3/16") and 17 mm (11/16") depth from the top surface, proceeding through numerous reactive fine aggregate particles. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9. Secondary deposits:	White acicular ettringite was observed lining many air voids throughout the sample and commonly filling air void spaces <50 μm in size. Clear to white alkali-silica-gel fills several microcracks and void spaces and lines few void spaces within the top approximately 20 mm (13/16") of the sample.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites-well to mostly fully; Belites-well to fully

IV. Conclusions

The general overall quality of the concrete was fair to poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-20-05/12-19-06
Sample Identification:	#4	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 243 mm (9-9/16") x 124 mm (4-7/8") x 54 mm (2-1/8") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 245 mm (9-5/8") long core.

2. Surface Conditions:

   Top: Rough, irregular, screeded and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface, partially covered by pink marker paint, has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate particles. Few subvertical microcracks proceed from the top surface up to 22 mm (7/8") maximum depth. Carbonation ranged from negligible up to 11 mm (7/16") depth along subvertical microcracking. The concrete was purposely air entrained and overall contains an air void system generally considered freeze-thaw resistant. However, uneven distribution of the entrained air voids was observed in the sample. A zone of darker colored paste exhibiting gradually lessening volume of air voids (with depth) proceeds up to 95 mm (3-3/4") depth from the top surface before clearly reverting back to a larger volume. No distinct cold joint was observed. The presence of many large entrapped sized void spaces throughout the concrete suggest the sample is somewhat under consolidated. Several chert, fine aggregate particles exhibit mild reactivity within the top approximately 75 mm (3") of the sample. Good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized crushed carbonate. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	7.3% total
2. Depth of carbonation:	Ranged from negligible up to 11 mm (7/16") depth along subvertical microcracking. Also, carbonation occurs along the perimeters of many carbonate coarse aggregates throughout the sample.
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Light to medium gray with a crudely layered appearance; tan in carbonated areas
6. Paste hardness:	Medium
7. Paste proportions:	24% to 26%
8. Microcracking:	Several subvertical microcracks proceed from the top surface up to 22 mm (7/8") maximum depth. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9. Secondary deposits:	White acicular ettringite was observed lining many air voids, and filling some air voids <50 μm in size, throughout the sample. Clear to white alkali-silica-gel lines a few air voids within the top approximately 76 mm (3") of the sample, proximate to a few reactive fine aggregate particles.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.37 to 0.42 with approximately 11-13% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites-well to fully; Belites- moderate

IV. Conclusions

The general overall quality of the concrete was fair to good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-21-05/1-20-06
Sample Identification:	#5	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 238 mm (9-3/8") x 124 mm (4-7/8") x 56 mm (2-3/16") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 238 mm (9-3/8") long core.

2. Surface Conditions:

   Top: Rough, irregular, screeded and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: 6 mm (1/4") diameter steelmesh was observed approximately 124 mm (4-7/8") depth from the top surface. Minor corrosion observed.

4. General Physical Conditions: The top surface, partially covered by pink marker paint, has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate surfaces. Several fine, subvertical microcracks proceed from the top surface up to 4 mm (5/32") maximum depth. Carbonation ranged from negligible up to 3 mm (1/8") depth along subvertical microcracking. The concrete was purposely air entrained, but no longer contains an air void system considered freeze-thaw resistant. Many air voids are partially to completely filled by secondary ettringite. Most void <50 μm in diameter were filled. Also, uneven distribution of the entrained air voids was observed throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Numerous subhorizontal microcracks were observed concentrated within the top approximately 12", proceeding through numerous reactive fine aggregate particles, mostly cherts. Chert reactivity was not obvious below approximately 38 mm (1-1/2") depth. Darker colored, denser paste observed in many concave coarse aggregate notches suggest the porous coarse aggregate was dry at the time of batching. Dark blue staining of the paste suggests the release of sulfur from the coarse aggregate. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural, quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content: 4.8% total
2. Depth of carbonation: Ranged from negligible up to 3 mm (1/8") depth along subvertical microcracking
3. Pozzolan presence: None observed
4. Paste/aggregate bond: Good
5. Paste color: Medium blue-gray becoming tannish-gray within the top 44 mm (1-3/4")
6. Paste hardness: Medium
7. Paste proportions: 25% to 27%
8. Microcracking: Several fine, subvertical, microcracks proceed from the top surface up to 4 mm (5/32") maximum depth. Numerous subhorizontal microcracks were observed between 3 mm (1/8") and 38 mm (1-1/2") depth from the top surface. Microcracking proceeds through the paste and reactive fine chert aggregate particles. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9. Secondary deposits: Clear to white alkali-silica-gel was observed lining many and filling few void spaces and filling subhorizontal microcracks within the top 38 mm (1-1/2") of the sample. White acicular ettringite fills many of the smallest air voids (<50 μm) and lines some larger void spaces below approximately 38 mm (1-1/2") depth from the top surface.
10. Slump: Estimated, low (0-2")
11. Water/cement ratio: Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12. Cement hydration: Alites-well to mostly fully; Belites-well to fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-21-05/12-20-06
Sample Identification:	#6	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 273 mm (10-3/4") x 122 mm (4-13/16") x 51 mm (2") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 275 mm (10-13/16") long core.

2. Surface Conditions:

   Top: Rough, screeded, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface, partially covered by pink marker paint, has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregates. Many fine, subvertical microcracks proceed from the top surface up to 4 mm (5/32") maximum depth. Carbonation ranged from negligible up to 2 mm (1/16") depth. Orange-brown corrosion product fills a subvertical microcrack proceeding from the top surface up to 2 mm (1/16") depth and stains the surrounding paste. The corrosion product was produced by metal inclusions with in a slag coarse aggregate particle proximate to the top surface. The concrete was purposely air entrained, but no longer contains an air void system considered freeze-thaw resistant. Most air void spaces < 50 μm in diameter were filled with secondary ettringite. Uneven distribution of the entrained air voids was observed throughout the sample and clumping of the entrained air was observed between approximately 70 mm (2-3/4") and 171 mm (6-3/4") depth from the top surface. Several subhorizontal microcracks were observed within the top approximately 25 mm (1") of the sample, proceeding through many reaction chert, fine aggregate particles. The presence of many large, entrapped sized air voids in the midsection of the core suggests the concrete was somewhat under consolidated. Darker colored, denser paste observed in many concave coarse aggregates notches suggests the porous coarse aggregate was dry at the time of batching. Dark blue staining of the paste suggests the release of sulfur from the coarse aggregate. Poor overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural, quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1.	Air Content:	7.3% total
2.	Depth of carbonation:	Ranged from negligible up to 2 mm (1/16") depth
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Mottled medium blue-gray and tannish-gray
6.	Paste hardness:	Medium-hard
7.	Paste proportions:	24% to 26%
8.	Microcracking:	Many fine, subvertical drying shrinkage microcracks proceed from the top surface up to 4 mm (5/32") maximum depth. Fine microcracking was observed within several brown to black shaley fine aggregate particles scattered throughout the sample. Several subhorizontal microcracks, proceeding through many chert fine aggregate particles, were observed concentrated in the top approximately 24 mm (15/16").
9.	Secondary deposits:	Orange-brown corrosion product, generated by a metal inclusion in a slag coarse aggregate particle, fills a subvertical microcrack with the top 2 mm (1/16") of the sample staining the surrounding paste. White acicular ettringite thinly lines many air voids throughout the sample and fills most air voids <50 μm in size.
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites-well to mostly fully; Belites-well to fully

IV. Conclusions

The general overall quality of the concrete was fair to poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-22-05/1-20-06
Sample Identification:	#7	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 276 mm (10-7/8") x 124 mm (4-7/8") x 59 mm (2-5/16") thick polished section that was cut from the original 125 mm (4-15/16") diameter x 286 mm (11-1/4") long core.

2. Surface Conditions:

   Top: Rough, irregular, screeded, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface, partially covered by pink marker paint, has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate particles. Many fine, subvertical microcracks proceed from the top surface up to 7 mm (9/32") maximum depth. Many subhorizontal microcracks were observed concentrated in the top 25 mm (1") of the sample, proceeding through many reactive chert, fine aggregate particles. ASR gel fills microcracks and lines void spaces proximate to the reactive particles. Carbonation ranged from negligible up to 5 mm (3/16") depth along subvertical microcracking. The concrete was purposely air entrained and overall contains an air void system generally considered freeze-thaw resistant. However, uneven distribution of the entrained air voids was observed throughout the sample. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized crushed carbonate. Fairly well graded with fair overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	7.0% total
2.	Depth of carbonation:	Ranged from negligible up to 5 mm (3/16") depth along subvertical microcracking
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Fair
5.	Paste color:	Medium gray
6.	Paste hardness:	Medium-hard
7.	Paste proportions:	27% to 29%
8.	Microcracking:	Many fine, subvertical microcracks proceed from the top surface up to 7 mm (9/32") maximum depth. Many subhorizontal microcracks were observed concentrated in the top 25 mm (1") of the sample, proceeding through the paste and many chert, fine aggregate particles. Fine microcracks were observed within numerous darker colored shaley, fine aggregates within the top approximately 38 mm (1-1/2").
9.	Secondary deposits:	White acicular ettringite was observed filling many air voids <50 μm in diameter throughout the sample and lining many larger air voids below approximately 51 mm (2") depth. Clear to white alkali-silica-gel lines many void spaces and fills many microcracks in the top approximately 25 mm (1").
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites-mostly fully; Belites-well to fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-22-05/1-24-06
Sample Identification:	#8	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 276 mm (10-7/8") x 143 mm (5-5/8) x 57 mm (2-1/4") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 270 mm (10-5/8") long core.

2. Surface Conditions:

   Top: Rough, irregular, screeded, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate mortar erosion/traffic wear, exposing many fine aggregates. Many fine, subvertical microcracks proceed from the top surface up to 12 mm (1/2") maximum depth. Carbonation ranged from negligible up to 6 mm (1/4") depth along subvertical microcracking. The concrete appears purposely air entrained, but does not contain an air void system considered freeze-thaw resistant. The air void system becomes somewhat coarser below approximately 102 mm (4") depth from the top surface. No definite cold joint was observed. Several fine discontinuous subhorizontal microcracks were observed in the top approximately 25 mm (1"); proceeding through reactive fine, chert aggregate particles. The propensity of reactive particles appears concentrated in the top approximately 56 mm (2-3/16") with only minor occurrences scattered through the rest of the sample. Darker colored, denser paste observed concentrated in many concave coarse aggregate notches suggest the porous coarse aggregate was dry at the time of batching. Blue staining of the concrete paste suggests liberation of sulfur from the blast furnace slag aggregate. Fair to good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with fair overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content:	3.4% total
2. Depth of carbonation:	Ranged from negligible up to 6 mm (1/4") depth along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled medium gray and medium blue-gray becoming tannish-gray within the top 29 mm (1-1/8") and tan in carbonated areas
6. Paste hardness:	Medium
7. Paste proportions:	26% to 28%
8. Microcracking:	Several fine, subvertical microcracks proceed from the top surface up to 12 mm (1/2") maximum depth. A few fine, discontinuous subhorizontal microcracks were observed in the top approximately 25 mm (1") proceeding through reactive fine, chert aggregate particles. Several fine microcracks observed within scattered dark colored shaley fine aggregates throughout the sample.
9. Secondary deposits:	White, acicular clumps of ettringite were observed lining many void spaces and partly filling some of the smallest air voids throughout the sample. Clear to white alkali-silica-gel lines numerous void spaces proximate to reactive, chert, fine aggregate particles.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-3-06/1-24-06
Sample Identification:	#9	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 291 mm (11-7/16") x 149 mm (5-7/8") x 67 mm (2-5/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 294 mm (11-9/16") long core.

2. Surface Conditions:

   Top: Rough, irregular, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate mortar erosion/traffic wear, exposing many fine aggregates. Several subvertical microcracks proceed from the top surface up to 28 mm (1-1/8") maximum depth. Carbonation was mostly 1 mm (1/32") up to 3 mm (1/8") and proceeds up to 14 mm (9/16") depth along subvertical microcracking. The concrete appears purposely air entrained, but does not contain an air void system considered freeze-thaw resistant. Many air voids <50 µm in size are filled with secondary ettringite. Also, uneven distribution of the entrained air voids was observed throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with fair overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content:	4.3% total
2. Depth of carbonation:	Mostly ranged from 1 mm (1/32") up to 3 mm (1/8") depth and proceeds up to 14 mm (9/16") depth along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled medium gray and medium blue-gray becoming dark tannish-gray within the top 83 mm (3-1/4")
6. Paste hardness:	Medium
7. Paste proportions:	24% to 26%
8. Microcracking:	Several subvertical microcracks proceed from the top surface up to 28 mm (1-1/8") maximum depth. Microcracking was observed within most of the black, shaley, fine aggregate particles throughout the sample.
9. Secondary deposits:	White acicular ettringite was observed lining many void spaces and filling many air voids <50 µm in diameter throughout the sample. Scattered, isolated occurrences of alkali-silica-gel lined voids were observed scattered in the sample. The offending particles were not obvious.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- well to mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-24-06
Sample Identification:	#10	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 225 mm (8-7/8") x 144 mm (5-11/16") x 65 mm (2-9/16") thick polished section that was cut from the original 146 mm (5-3/4") diameter x 235 mm (9-1/4") long core.

2. Surface Conditions:

   Top: Rough, irregular, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate mortar erosion/traffic wear, exposing many fine aggregates. Several fine, subvertical microcracks proceed from the top surface up to 8 mm (5/16") maximum depth. Carbonation ranges from negligible up to 8 mm (5/16") depth along subvertical microcracking. The concrete appears purposely air entrained and contains an air void system considered freeze-thaw durable. However, uneven distribution of the entrained air voids was observed throughout the sample. Numerous chert, fine aggregate particles exhibit reactivity in the top approximately 25 mm (1") of the sample. Fine microcracking and gel lined void spaces were observed concentrated in this zone. Fair to good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized crushed carbonate. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall distribution.

III. Cementitious Properties

1. Air Content:	7.2% total
2. Depth of carbonation:	Ranged from negligible up to 8 mm (5/16") depth along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Medium gray
6. Paste hardness:	Medium
7. Paste proportions:	21% to 23%
8. Microcracking:	Several fine, subvertical microcracks proceed from the top surface up to 8 mm (5/16") maximum depth. A few, short, fine, subhorizontal microcracks proceed through several reactive, chert fine aggregate particles in the top 25 mm (1") of the core.
9. Secondary deposits:	Clear to white alkali-silica-gel was observed lining several air voids within the top 25 mm (1") of the sample. White acicular ettringite lines scattered void spaces throughout the sample and most void spaces within the bottom approximately 25 mm (1").
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.40 to 0.45 with approximately 7-9% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- well to mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was fair to good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-24-06
Sample Identification:	#11	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 206 mm (8-1/8") x 144 mm (5-11/16") x 71 mm (2-13/16") thick polished section that was cut from the original 146 mm (5-3/4") diameter x 213 mm (8-3/8") long core.

2. Surface Conditions:

   Top: Rough, screeded and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface, partially covered by pink marker paint, has undergone moderate mortar erosion/traffic wear, exposing many fine aggregates. Several microcracks observed on the top surface reflect into several subvertical microcracks proceeding up to 14 mm (9/16") maximum depth. The microcracks proceed through the paste and few coarse aggregate particles. Carbonation ranges from 1 mm (1/32") up to 14 mm (9/16") depth along subvertical microcracking. Many subhorizontal microcracks, often filled by alkali-silica-gel, were observed between 5 mm (3/16") and 45 mm (1-13/16") depth from the top surface. These microcracks proceed through the paste and many reactive chert fine aggregate particles. The concrete was purposely air entrained but, no longer contains an air void system, overall, considered freeze-thaw durable. Ettringite lines most void spaces and fills most air voids < 100 μm in size at depth in the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with fair overall distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content:	6.1% total
2. Depth of carbonation:	Ranged from 1 mm (1/32") up to 14 mm (9/16") depth along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Tannish-gray becoming medium blue-gray below approximately 48 mm (1-7/8") depth and tan in carbonated areas
6. Paste hardness:	Medium
7. Paste proportions:	20% to 22%
8. Microcracking:	Several microcracks observed on the top surface reflect into several subvertical microcracks proceeding up to 14 mm (9/16") maximum depth. These microcracks proceed through the paste and few coarse aggregate particles. Many subhorizontal microcracks, often partially filled by alkali-silica-gel, were observed between 5 mm (3/16") and 45 mm (1-13/16") depth from the top surface. These microcracks proceed through the paste and many reactive chert fine aggregate particles. Internal microcracking (only) was observed in chert, fine aggregates to approximately 55 mm (2-3/16") depth. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present throughout the sample.
9. Secondary deposits:	Clear to white alkali-silica-gel was observed lining several void spaces and filling subhorizontal microcracks within the top 45 mm (1-3/4") of the sample. Scattered occurrences of ASR gel-filled void spaces were observed up to approximately 152 mm (6") depth. White acicular ettringite lines most void spaces and fills most of the smallest air voids (<100 μm diameter) below approximately 19 mm (3/4").
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.40 to 0.45 with approximately 7-9% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-24-06
Sample Identification:	#12	Performed by:	C. Tillema/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 257mm (10-1/8") x 149 mm (5-7/8") x 70 mm (2-3/4") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 264 mm (10-3/8") long core.

2. Surface Conditions:

   Top: Rough, irregular, tined and mortar eroded/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate mortar erosion/ traffic wear, exposing many fine aggregate particles. Several subvertical microcracks proceed from the top surface up to 13 mm (1/2") maximum depth. The microcracks proceed through the paste and few slag coarse aggregate particles. Carbonation proceeds up to 5 mm (3/16") depth. A few fine, discontinuous subhorizontal microcracks, proceeding through the paste and many reactive fine, chert aggregate particles were observed at up to 16 mm (5/8") depth from the top surface. Evidence of any chert, fine aggregate reactivity was rare below 27 mm (1-1/16") depth from the top surface. The concrete was purposely air entrained and contains an air void system considered freeze-thaw durable. However, uneven distribution of the entrained air voids was observed throughout the sample. Few slag coarse aggregate particles contain metal inclusions. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Fair overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized light weight aggregate made up of blast furnace slag. Fairly well graded with fair overall distribution.

2. Fine: Natural, quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content:	6.2% total
2. Depth of carbonation:	Up to 5 mm (3/16") depth
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled dark tannish-gray and medium blue-gray; tan in carbonated areas
6. Paste hardness:	Medium-hard
7. Paste proportions:	23% to 25%
8. Microcracking:	Several subvertical microcracks proceed from the top surface up to 13 mm (1/2") maximum depth. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample. A few fine, subhorizontal microcracks proceed across much of the diameter of the core up within the top 16 mm (5/8") of the sample; proceeding through numerous reactive chert, fine aggregate particles.
9. Secondary deposits:	White acicular ettringite thinly lines most void spaces throughout the sample and commonly fills air voids <50 μm in diameter. Clear alkali-silica-gel partially fills a subvertical microcrack at approximately 4 mm (5/32") depth. Gel product lines several void spaces proximate to reactive chert, fine aggregate particles in the top approximately 27 mm (1-1/16"). An unidentified white secondary deposit partially to completely fills many void spaces within the bottom 4 mm (5/32") of the sample.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.40 to 0.45 with approximately 7-9% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was fair.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-25-06
Sample Identification:	#13	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 264 mm (10-3/8") x 149 mm (5-7/8") x 67 mm (2-5/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 267 mm (10-1/2") long core.

2. Surface Conditions:

   Top: Rough, irregular tined and mortar erosion/traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate mortar eroded/traffic wear, exposing many fine aggregate surfaces. A few subvertical microcracks proceed from the top surface up to 18 mm (11/16") maximum depth. Carbonation ranged from 1 mm (1/32") up to 18 mm (11/16") depth from the top surface along subvertical microcracking. Several subhorizontal microcracks were observed within the top surface up to 44 mm (1-3/4") depth, proceeding through numerous reactive fine chert aggregate particles. Extensive alkali-silica reaction of fine chert aggregate particles was observed throughout the sample. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, poor distribution and clumping of the entrained air voids was observed scattered throughout the sample. Orange-brown corrosion product fills to lines several microcracks between 20 mm (13/16") and 44 mm (1-3/4") depth from the top surface, staining the surrounding paste. The corrosion product was produced by a large metal inclusion within a coarse slag aggregate particle. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Fair overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content: 7.6% total
2. Depth of carbonation: Ranged from 1 mm (1/32") up to 18 mm (11/16") depth from the top surface along subvertical microcracking
3. Pozzolan presence: A purposeful addition of flyash was observed
4. Paste/aggregate bond: Good
5. Paste color: Mottled tannish-gray and dark blue-gray becoming tan in carbonated areas
6. Paste hardness: Medium
7. Paste proportions: 27% to 29%
8. Microcracking: A few subvertical microcracks proceed from the top surface up to 18 mm (11/16") maximum depth. Several subhorizontal microcracks were observed within the top up to 44 mm (1-3/4") of the sample. Fine microcracking was observed within and proceeding shallowly from reactive chert, fine aggregate particles throughout the sample.
9. Secondary deposits: White ettringite was observed partially lining to filling air voids between 5 mm (3/16") and 44 mm (1-3/4") depth from the top surface appearing to concentrate proximate to coarse slag aggregate particles. Extensive white to clear silica gel was observed lining numerous air voids and microcracking within and proximate to reactive fine chert aggregate particles throughout the entire depth of the sample. Corrosion product fills microcracking proximate to/within a coarse aggregate containing a large metal inclusion at 25 mm (1") depth from the top surface.
10. Slump: Estimated, low (0-2")
11. Water/cementitious ratio: Estimated at between 0.36 to 0.41 with approximately 10-12% unhydrated or residual portland cement clinker particles and a purposeful addition of fly ash.
12. Cement hydration: Alites- well to fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was fair.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-25-06
Sample Identification:	#14	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 287 mm (11-5/16") x 149 mm (5-7/8") x 73 mm (2-7/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 294 mm (11-9/16") long core.

2. Surface Conditions:

   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Many subvertical microcracks proceed from the top surface up to 14 mm (9/16") maximum depth before intersection subhorizontal microcracks. Carbonation ranged from 1 mm (1/32") up to 14 mm (9/16") depth from the top surface along the subvertical microcracking. Numerous, discontinuous, subhorizontal microcracks were observed up to 175 mm (6-7/8") depth; mostly filled with ASR gel and proceeding through numerous reactive fine, chert aggregate particles. Numerous gel filled void spaces were observed proximate to reactive chert particles below 175 mm (6-7/8") depth. However, more continuous microcracks were absent. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1.	Air Content:	5.2% total
2.	Depth of carbonation:	Ranged from 1 mm (1/32") up to 14 mm (9/16") depth from the top surface along subvertical microcracking
3.	Pozzolan presence:	A purposeful addition of flyash was observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Mottled tannish-gray and dark blue-gray becoming tan in carbonated areas
6.	Paste hardness:	Medium
7.	Paste proportions:	23% to 25%
8.	Microcracking:	Many subvertical microcracks proceed from the top surface up to 14 mm (9/16") maximum depth before intersecting subhorizontal microcracks. Numerous, discontinuous, subhorizontal microcracks were observed up to 176 mm (6-15/16") depth; proceeding through numerous reactive chert, fine aggregate particles. Fine microcracking was observed within many of the black, shaley, fine aggregate particles present in the sample.
9.	Secondary deposits:	Extensive white to clear silica gel was observed partially lining to filling numerous air voids and microcracking within and proximate to reactive fine chert aggregate particles throughout the sample. Little ettringite was detected.
10.	Slump:	Estimated, low (0-2")
11.	Water/cementitious ratio:	Estimated at between 0.36 to 0.41 with approximately 9-11% unhydrated or residual portland cement clinker particles and a purposeful addition of fly ash.
12.	Cement hydration:	Alites- well to fully; Belites- well

IV. Conclusions

The general overall quality of the concrete was fair to poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	1-4-06/1-25-06
Sample Identification:	#15	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 268 mm (10-9/16") x 149 mm (5-7/8") x 75 mm (2-15/16") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 270 mm (10-5/8") long core.

2. Surface Conditions:

   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Many subvertical drying shrinkage microcracks proceed from the top surface up to 17 mm (11/16") maximum depth. Carbonation ranged from 1 mm (1/32") up to 7 mm (9/32") depth from the top surface along subvertical microcracking. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. The presence of many large entrapped sized air voids throughout the sample suggests the sample is somewhat under consolidated. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Fair overall distribution.

III. Cementitious Properties

1. Air Content:	7.0% total
2. Depth of carbonation:	Ranged from 1 mm (1/32") up to 7 mm (9/32") depth from the top surface along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Tannish-gray mottled with medium to dark blue-gray within the bottom 108 mm (4-1/4")
6. Paste hardness:	Hard
7. Paste proportions:	20% to 22%
8. Microcracking:	Several fine subvertical drying shrinkage microcracks proceed from the top surface up to a 47 mm (1-7/8") maximum depth. A few chert, fine aggregates and soft, dark colored shale particles exhibit internal microcracking.
9. Secondary deposits:	White ettringite was observed lining to partially lining some of the larger air voids and commonly fills many of the smallest air voids, <25 μm in size, scattered throughout the sample below 83 mm (3-1/4") depth from the top surface.
10. Slump:	Estimated, low (1-3")
11. Water/cement ratio:	Estimated at between 0.42 to 0.47 with approximately 6-8% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- well to mostly fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-27-05/1-26-06
Sample Identification:	17	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 256 mm (10-1/16") x 149 mm (5-7/8") x 78 mm (3-1/16") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 257 mm (10-1/8") long core.

2. Surface Conditions:
Top: Rough, irregular tined and traffic worn surface
Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Several fine subvertical microcracks proceed from the top surface up to 13 mm (1/2") maximum depth. Carbonation ranged from 1 mm (1/32") up to 23 mm (7/8") depth from the top surface along subvertical microcracking. Carbonation was also observed intermittently around the perimeters of many coarse carbonate particles. Bluish staining of the paste surrounding scattered blast furnace slag coarse aggregates suggests liberation of sulfur. The concrete was purposely air entrained, but overall does not contain an air void system considered freeze-thaw resistant in severe environments. Many of the smaller air void spaces (<50 µm) were partially to completely filled by secondary ettringite. The presence of many large entrapped sized air voids throughout the sample suggests the sample is somewhat under consolidated. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Isolated occurrences of alkali silica reaction (ASR) of chert, fine aggregate particles were observed scattered in the sample. No bulk expansion (cracking) was evident. Good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized crushed carbonate with a some blast furnace slag particles. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	8.3% total
2. Depth of carbonation:	Ranged from 1 mm (1/32") up to 23 mm (7/8") depth from the top surface along subvertical microcracking. Carbonation was also observed intermittently around the perimeters of many coarse and fine carbonate particles.
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled medium gray to medium blue-gray surrounding scattered blast furnace slag aggregates; tan in carbonated areas
6. Paste hardness:	Hard
7. Paste proportions:	24% to 26%
8. Microcracking:	Several fine subvertical microcracks proceed from the top surface up to 13 mm (1/2") maximum depth.
9. Secondary deposits:	White ettringite was observed lining to partially filling most of the larger air voids and filling most of the smaller air voids <50 µm in size, below 25 mm (1") depth from the top surface. White to clear silica gel was observed lining or filling few air voids proximate to several reactive fine aggregate particles scattered in the sample. Approximately 80% of the bottom surface was covered with white carbonate substance.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.38 to 0.43 with approximately 9-14% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- well to mostly fully; Belites- moderate to fully

IV. Conclusions
The general overall quality of the concrete was fair to good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-22-05/1-26-06
Sample Identification:	17J	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 256 mm (10-1/16") x 149 mm (5-7/8") x 64 mm (2-1/2") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 256 mm (10-1/16") long core.

2. Surface Conditions:

   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing numerous fine aggregate surfaces. The core was taken through a construction joint. An approximately 12 mm (1/2") wide and 64 mm (2-1/2") deep saw-cut defines the construction joint. The joint was filled with a black elastomeric sealant. Vertical spalling/scaling was observed up to approximately 19 mm (3/4") depth from the construction joint into one of the concretes; proceeding through several coarse aggregate particles. The other concrete exhibits shallow scaling on its formed surface; with some subparallel microcracking (incipient scaling) up to 6mm (1/4") depth from the formed surface. Carbonation ranged from 1 mm (1/32") up to 6 mm (1/4") depth from the top surface. Carbonation was also observed intermittently around the perimeters of many coarse carbonate particles. Secondary ettringite is not present in carbonated areas. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, poor distribution and clumping was observed scattered throughout the sample. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized crushed carbonate with few blast furnace slag particles. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	7.7% total
2.	Depth of carbonation:	Ranged from 1 mm (1/32") up to 6 mm (1/4") depth from the top surface. Carbonation was also observed intermittently around the perimeters of many coarse carbonate particles.
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Mottled medium gray and medium blue-gray becoming tan in carbonated areas
6.	Paste hardness:	Hard
7.	Paste proportions:	21% to 23%
8.	Microcracking:	Several subvertical microcracks proceed from the top surface up to 3 mm (1/8") maximum depth.
9.	Secondary deposits:	White ettringite was observed lining many of the larger air voids, partially filling the smaller air voids, and filling most of the smallest air voids up to 100µm in size, below 12 mm (1/2") depth. Most void spaces within the two concretes, within 10 mm (3/8") of the control joint, are filled with secondary ettringite.
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.41 to 0.46 with approximately 6-8% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites- mostly to fully; Belites- mostly fully

IV. Conclusions

The general overall quality of the concrete was fair.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-21-05/1-26-06
Sample Identification:	18	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 237 mm (9-5/16") x 149 mm (5-7/8") x 76 mm (3") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 238 mm (9-3/8") long core.

2. Surface Conditions:
   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Several subvertical microcracks proceed from the top surface up to 11 mm (7/16") maximum depth before intersecting subhorizontal microcracking. Carbonation ranged from 1 mm (1/32") up to 6 mm (1/4") depth. Orange-brown corrosion product fills to lines several microcracks between 20 mm (13/16") and 44 mm (1-3/4") depth from the top surface and staining the surrounding paste. The corrosion product was produced by corrosion of a metal inclusion within a slag coarse aggregate particle at 9 mm (3/8") depth from the top surface. Many subhorizontal microcracks were observed scattered within the top 79 mm (3-1/8") of the sample, proceeding through numerous reactive chert, fine aggregate particles. Internally microcracked chert fine aggregate particles are common to 110 mm (4-5/16") depth. The concrete was purposely air entrained and contains an air void system considered freeze-thaw resistant. However, many of the air voids were lined to filled by secondary ettringite. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.5% total
2. Depth of carbonation:	Ranged from 1 mm (1/32") up to 6 mm (1/4") depth from the top surface
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Tannish-gray becoming mottled with medium blue-gray below approximately 52 mm (2") depth, concentrated around blast furnace slag coarse aggregate particles
6. Paste hardness:	Hard
7. Paste proportions:	25% to 27%
8. Microcracking:	Several fine subvertical drying shrinkage microcracks proceed from the top surface up to 11 mm (7/16") maximum depth. Many subhorizontal microcracks were observed scattered within the top 79 mm (3-1/8") of the sample, proceeding through numerous reactive chert, fine aggregate particles. Internally microcracked chert fine aggregate particles are common to 110 mm (4-5/16") depth
9. Secondary deposits:	White ettringite was observed lining to filling numerous air voids and filling most of the smallest air voids <50 µm in size, below 4 mm (5/32") depth from the top surface becoming more prevalent with depth. White to clear silica gel was observed partially lining to filling air void spaces and microcracks proximate to the numerous reactive fine aggregate particles.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.41 to 0.46 with approximately 6-8% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- mostly fully; Belites- mostly fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-20-05/1-26-06
Sample Identification:	18J	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 238 mm (9-3/8") x 149 mm (5-7/8") x 78 mm (3-1/16") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 241 mm (9-1/2") long core.

2. Surface Conditions:
   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Approximately 80% of the top surface has deeply spalled away (up to 19 mm (3/4") depth) along an approximately 64 mm (2-1/2") deep saw-cut joint. Bituminous material was observed filling in the spalled area. A subvertical macrocrack proceeds from the saw-cut/spalled joint through the entire depth of the core, proceeding through several coarse aggregate particles. Numerous, predominantly subhorizontal microcracks were observed within the top approximately 45 mm (1-3/4") depth with concentration along the saw-cut joint/spall becoming subvertical with depth of the sample. Carbonation ranged from 1 mm (1/32") up to 9 mm (3/8") depth from the top surface along subvertical microcracking. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, many of the small entrained air voids were partially to completely filled by secondary ettringite. Most void spaces within 10 mm (3/8") of the control joint are completely filled with secondary ettringite. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	5.5% total
2.	Depth of carbonation:	Ranged from 1 mm (1/32") up to 9 mm (3/8") depth from the top surface along subvertical microcracking
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Tannish-gray becoming mottled with medium blue-gray below approximately 44 mm (1-3/4") depth and tannish gray along the subvertical macrocrack
6.	Paste hardness:	Hard
7.	Paste proportions:	21% to 23%
8.	Microcracking:	A subvertical macrocrack proceeds from the saw-cut joint through the entire depth of the core, proceeding through several coarse aggregate particles. A few subvertical microcracks proceed from the top surface up to 10 mm (3/8") maximum depth. Numerous, predominantly subhorizontal microcracks were observed within the top approximately 45 mm (1-3/4") depth with concentration along the saw-cut joint/spall; becoming subvertical with depth in the sample.
9.	Secondary deposits:	White ettringite was observed filling many of the smallest air voids <100 µm in size, and partially filling most other air voids below 2 mm (1/16") depth. Most void spaces within 10 mm (3/8") of the control joint are completely filled with secondary ettringite White to clear silica gel was observed partially lining to partially filling a few air voids and microcracking within and proximate to the reactive fine aggregate particles.
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.41 to 0.46 with approximately 6-8% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites- mostly fully; Belites- mostly fully

IV. Conclusions

The general overall quality of the concrete was poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-20-05/1-30-06
Sample Identification:	19	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 229 mm (9") x 149 mm (5-7/8") x 76 mm (3") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 229 mm (9") long core.

2. Surface Conditions:
Top: Rough, irregular milled and traffic worn surface
Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has been milled away to an unknown depth. The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Several subvertical microcracks proceed from the top surface up to 28 mm (1-1/8") maximum depth. Carbonation ranged from negligible up to 8 mm (5/16") depth from the top surface along subvertical microcracking. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, many air voids <50 µm in size were partially to completely filled by secondary ettringite. Several isolated occurrences of ASR gel-filled void spaces were observed scattered in the sample; proximate to reactive chert fine aggregate particles. The presence of many large entrapped sized air voids throughout the sample suggests the sample is somewhat under consolidated. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Good overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	9.0% total
2. Depth of carbonation:	Ranged from negligible up to 7 mm (9/32") depth from the top surface along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Medium gray becoming mottled with medium to dark blue-gray below approximately 52 mm (2") depth
6. Paste hardness:	Hard
7. Paste proportions:	20% to 22%
8. Microcracking:	Several subvertical, drying shrinkage microcracks proceed from the top surface up to 28 mm (1-1/8") maximum depth. Fine internal microcracks were observed in scattered reactive chert fine aggregate particles.
9. Secondary deposits:	White ettringite was observed partially lining to partially filling numerous air voids and filling many the smallest air voids <50 µm in size, below 10 mm (3/8") depth from the top surface. White to clear silica gel was observed lining or filling several air voids proximate to the reactive chert fine aggregate particles. White bladed calcium hydroxide was observed partially filling a few entrapped sized void spaces scattered throughout the sample.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.36 to 0.44 with approximately 8-12% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- well to fully; Belites- well

IV. Conclusions

The general overall quality of the concrete was good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-20-05/1-30-06
Sample Identification:	19J	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 219 mm (8-5/8") x 149 mm (5-7/8") x 73 mm (2-7/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 221 mm (8-11/16") long core.

2. Surface Conditions:
   Top: Rough, irregular milled and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has been milled away to an unknown depth. The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. An approximately 13 mm (1/2") wide and up to 24 mm (15/16") deep saw-cut joint was observed in the top surface. The joint was filled with a black elastomeric sealant. A subvertical macrocrack proceeds from the saw-cut joint through the entire depth of the core, proceeding through several coarse aggregate particles. Incipient scaling/spalling was observed in the concrete within 10 mm (3/8") of the macrocrack. Several subvertical drying shrinkage microcracks proceed from the top surface up to 3 mm (1/8") depth. Carbonation ranged from negligible up to 3 mm (1/8") depth from the top surface along subvertical microcracking. The concrete was purposely air entrained but no longer contains an air void system considered freeze-thaw resistant. Many of the air voids were partially to completely filled by secondary ettringite. Most void spaces within 5 mm (3/16") of the control joint were completely filled with secondary ettringite. Blebs of metal were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Fair overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1.	Air Content:	5.7% total
2.	Depth of carbonation:	Ranged from negligible up to 3 mm (1/8") depth from the top surface along subvertical microcracking
3.	Pozzolan presence:	None observed
4.	Paste/aggregate bond:	Good
5.	Paste color:	Mottled medium gray and medium blue-gray
6.	Paste hardness:	Hard
7.	Paste proportions:	20% to 22%
8.	Microcracking:	A subvertical macrocrack proceeds from the saw-cut joint through the entire depth of the core, proceeding through several coarse aggregate particles. Numerous microcracks (incipient scaling/spalling) were observed proximate (within 10 mm) and subparallel to the macrocrack. Several subvertical microcracks proceed from the top surface up to 3 mm (1/8") depth.
9.	Secondary deposits:	White ettringite was observed filling many of the smallest air voids <120 µm in size, and lining to partially filling many of the larger air voids scattered throughout the sample; filling most void spaces with 5 mm (3/16") o the control joint. White to clear silica gel was observed partially filling a few air voids proximate to scattered reactive chert fine aggregate particles.
10.	Slump:	Estimated, low (0-2")
11.	Water/cement ratio:	Estimated at between 0.38 to 0.43 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12.	Cement hydration:	Alites- well to fully; Belites- well to fully

IV. Conclusions

The general overall quality of the concrete was fair to good.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-19-05/1-30-06
Sample Identification:	20	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 229 mm (9") x 149 mm (5-7/8") x 79 mm (3-1/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 230 mm (9-1/16") long core.

2. Surface Conditions:
Top: Rough, irregular tined and traffic worn surface
Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. Several subvertical microcracks proceed from the top surface up to 11 mm (7/16") maximum depth. Carbonation ranged from 1 mm (1/32") up to 7 mm (9/32") depth from the top surface along subvertical microcracking. Several, relatively continuous subhorizontal microcracks were observed between 5 mm (3/16") up to 45 mm (1-3/4") depth from the top surface proceeding through numerous reactive fine, chert aggregate particles. The concrete was purposely air entrained and overall contains an air void system considered freeze-thaw resistant. However, poor distribution and clumping of the entrained air was observed throughout the sample. Also, many of the smallest entrained air voids were partially to completely filled by secondary ettringite. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 25 mm (1") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	4.0% total
2. Depth of carbonation:	Ranged from mostly 1 mm (1/32") up to 7 mm (9/32") depth from the top surface along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Tannish-gray becoming mottled with medium blue-gray below approximately 57 mm (2-1/4") depth
6. Paste hardness:	Hard
7. Paste proportions:	23% to 25%
8. Microcracking:	Several subvertical microcracks proceed from the top surface up to 11 mm (7/16") maximum depth. Several, relatively continuous, subhorizontal microcracks were observed between 5 mm (3/16") and 45 mm (1-3/4") depth from the top surface proceeding through numerous reactive, chert fine aggregate particles. Fine internal microcracking was observed in chert particles at up to 60 mm (2-3/8") depth.
9. Secondary deposits:	White to clear ettringite was observed partially lining several of the larger air voids and filling many of the smallest air voids <50 µm in size, below 6 mm (1/4") depth from the top surface. White to clear silica gel was observed partially filling microcracks and air voids within and proximate to the reactive fine, chert aggregate particles in the top approximately 45 mm (1-3/4") of the sample. Other isolated void fillings were observed scattered throughout the rest of the core.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.38 to 0.43 with approximately 8-10% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- mostly fully; Belites- mostly fully

IV. Conclusions

The general overall quality of the concrete was fair to poor.

00 LAB 001 Petrographic Examination of Hardened Concrete
ASTM: C-856

Job No.	10-04139	Date:	12-19-05/1-30-06
Sample Identification:	20J	Performed by:	K. Morel/G. Moulzolf

I. General Observations

1. Sample Dimensions: Our analysis was performed on a 232 mm (9-1/8") x 149 mm (5-7/8") x 67 mm (2-5/8") thick polished section that was cut from the original 149 mm (5-7/8") diameter x 233 mm (9-3/16") long core.

2. Surface Conditions:
   Top: Rough, irregular tined and traffic worn surface
   Bottom: Rough, irregular formed surface; placed on grade

3. Reinforcement: None observed

4. General Physical Conditions: The top surface has undergone moderate traffic wear, exposing many fine aggregate surfaces. An approximately 13 mm (1/2") wide and up to 32 mm (1-1/4") deep saw-cut joint was observed cut into the top surface. Approximately 10% of the top surface has deeply spalled away along the joint. The saw cut was mostly filled with a black elastomeric sealant. Approximately 35% of the top surface was covered with remnants of the sealant. A subvertical macrocrack proceeds from the saw-cut joint through the entire depth of the core, proceeding through several coarse aggregate particles. Numerous microcracks (incipient scaling) were observed subparallel and proximate to the macrocrack. A noticeable loss of concrete mass was observed, most likely <6 mm (1/4"). Several subvertical microcracks proceed from the top surface up to 18 mm (11/16") maximum depth. Carbonation ranged from 1 mm (1/32") up to 6 mm (1/4") depth from the top surface along subvertical microcracking. Several subhorizontal microcracks were observed between 4 mm (5/32") up to 73 mm (2-7/8") depth from the top surface; procceding through numerous reactive, chert fine aggregate particles. The concrete was purposely air entrained but no longer contains an air void system considered freeze-thaw resistant. Clumping of entrained air was observed throughout the sample and the air entrainment appears to increases with depth of the sample. Many of the smaller air voids were partially to completely filled by secondary ettringite; especially those <50 µm in diameter. Metal inclusions were observed within a few slag coarse aggregate particles scattered throughout the sample. Darker colored, denser paste surrounding many coarse aggregates suggests the relatively porous particles were dry at the time of batching. Also, bluish staining of the surrounding paste suggests liberation of sulfur from the coarse aggregates. Poor overall condition.

II. Aggregate

1. Coarse: 19 mm (3/4") maximum sized lightweight aggregate made up of blast furnace slag. Fairly well graded with good overall uniform distribution.

2. Fine: Natural quartz, feldspar, and lithic sand that was fairly well graded. The grains were mostly rounded particles. Good overall uniform distribution.

III. Cementitious Properties

1. Air Content:	5.1% total
2. Depth of carbonation:	Ranged from 1 mm (1/32") up to 6 mm (1/4") depth from the top surface along subvertical microcracking
3. Pozzolan presence:	None observed
4. Paste/aggregate bond:	Good
5. Paste color:	Mottled medium gray to medium blue gray, becoming tannish-gray within the top 32 mm (1-1/4") depth and along the subvertical macrocrack
6. Paste hardness:	Hard
7. Paste proportions:	23% to 25%
8. Microcracking:	A subvertical macrocrack proceeds from the saw-cut joint through the entire depth of the core, proceeding through several coarse aggregate particles. Numerous microcracks (incipient scaling) were observed subparallel and proximate to the macrocrack. Several subvertical microcracks proceed from the top surface up to 18 mm (11/16") depth. Many subhorizontal microcracks were observed between 4 mm (5/32") and 73 mm (2-7/8") depth from the top surface proceeding through numerous reactive, chert fine aggregate particles.
9. Secondary deposits:	White ettringite was observed partially lining many of the larger air voids and filling most of the smaller air voids <50 µm in size, below 3 mm (1/8") depth. White bladed calcium hydroxide was observed partially filling several air voids within the bottom 7 mm (9/32") depth of the sample. Clear silica gel was observed partially lining or filling void spaces and microcracks proximate to and proceeding through the reactive, chert fine aggregate particles.
10. Slump:	Estimated, low (0-2")
11. Water/cement ratio:	Estimated at between 0.39 to 0.44 with approximately 7-9% unhydrated or residual portland cement clinker particles.
12. Cement hydration:	Alites- fully; Belites- mostly fully

IV. Conclusions

The general overall quality of the concrete was fair to poor.

AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #1

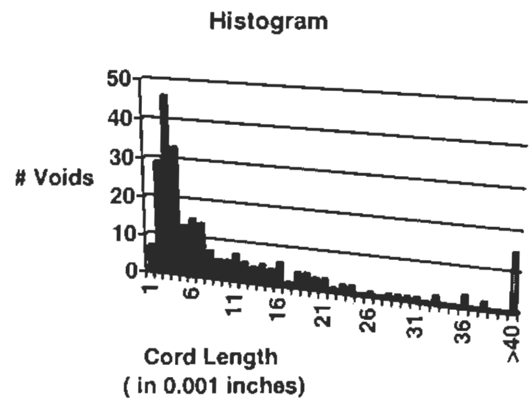
Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance. Test was performed below 75 mm (3") depth from the top of the sample.

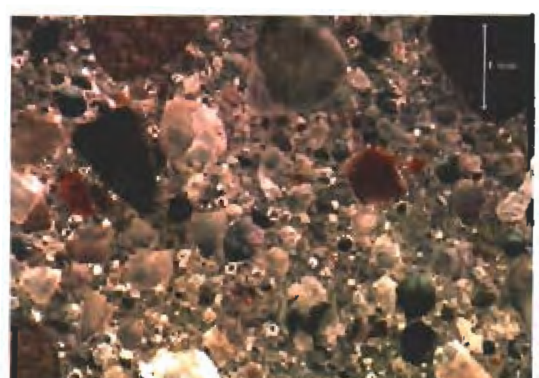
Sample Data:

Description:	Hardened Concrete Core
Dimensions:	125mm (4-15/16") diameter by 245mm (9-5/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.3
Entrained, % ≤ 0.040"	3.0
Entrapped, %> 0.040"	2.3
Air Voids/inch	5.00
Specific Surface, in2/in3	377
Spacing Factor, inches	0.012
Paste Content, % estimated	27.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/19/2005





Magnification: 30x
Description: Overall hardened air content, 5.3% total

American Petrographic Services, Inc.

AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENTS
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE:JANUARY 6, 2006

Sample ID: #2

Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance. Test was performed within the top 98 mm (3-7/8") of the sample.

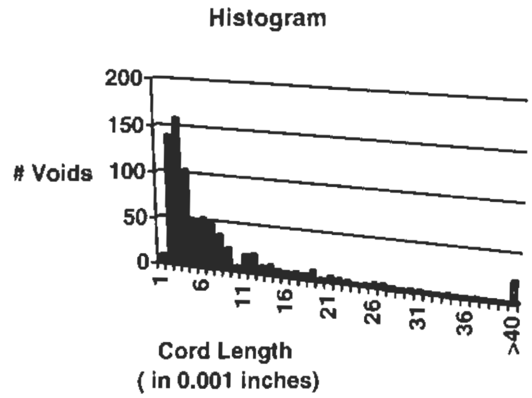
Sample Data:

Description: Hardened Concrete Core

Dimensions: 125mm (4-15/16") diameter by 245mm (9-5/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.4
Entrained, % ≤ 0.040"	5.6
Entrapped, %> 0.040"	1.8
Air Voids/inch	8.66
Specific Surface, in2/in3	470
Spacing Factor, inches	0.008
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	90
Test Date	12/20/2005



Magnification: 30x
Description: Overall hardened air content, 7.4% total

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AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

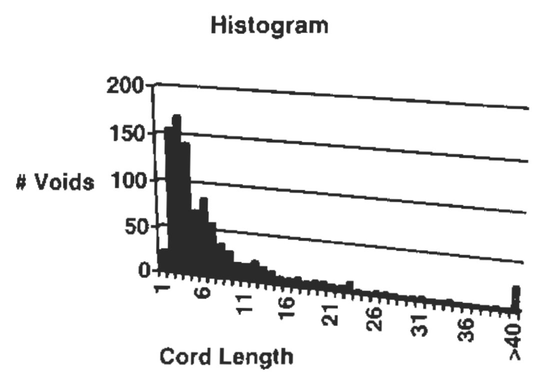
Sample ID: #3

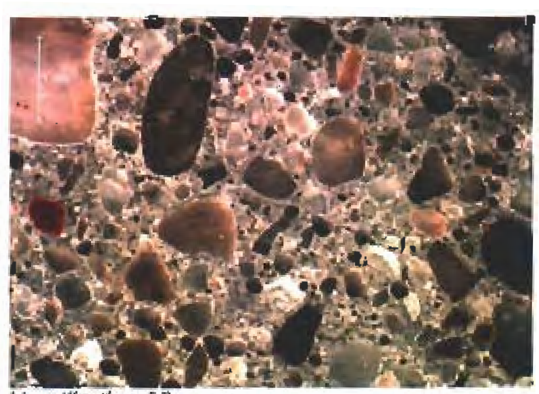
Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

Sample Data:
Description: Hardened Concrete Core
Dimensions: 125mm (4-15/16") diameter by 228 mm (9") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.7
Entrained, % ≤ 0.040"	4.6
Entrapped, %> 0.040"	1.1
Air Voids/inch	7.18
Specific Surface, in2/in3	510
Spacing Factor, inches	0.008
Paste Content, % estimated	23.0
Magnification	50x
Traverse Length, inches	133
Test Date	12/20/2005





Magnification: 30x
Description: Overall hardened air content, 5.7% total

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AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #4

Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

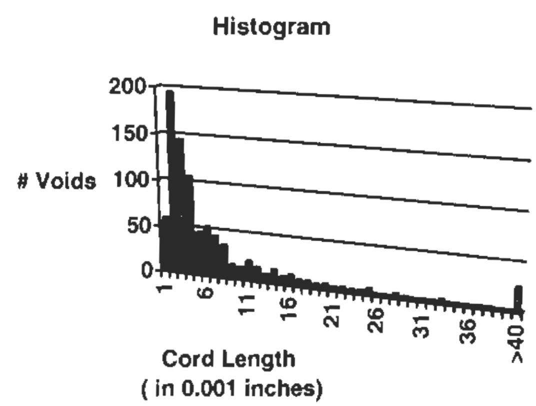
Sample Data:

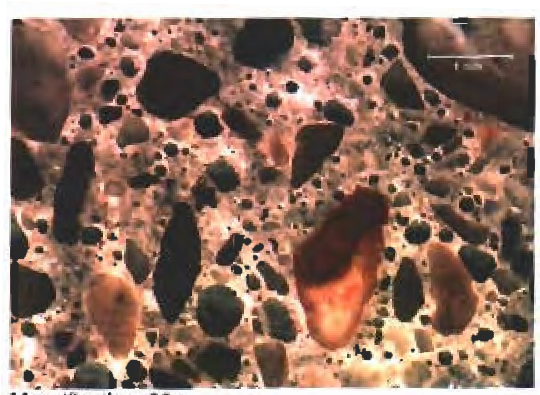
Description: Hardened Concrete Core

Dimensions: 125mm (4-15/16") by 245mm (9-5/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.3
Entrained, % ≤ 0.040"	5.5
Entrapped, %> 0.040"	1.8
Air Voids/inch	8.99
Specific Surface, in2/in3	490
Spacing Factor, inches	0.008
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/21/2005





Magnification: 30x
Description: Overall hardened air content, 7.3% total

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AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #5

Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

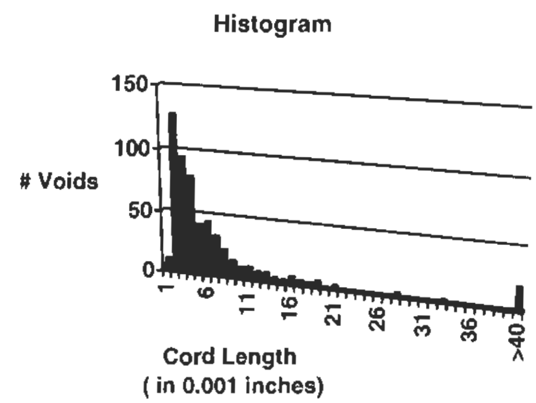
Sample Data:

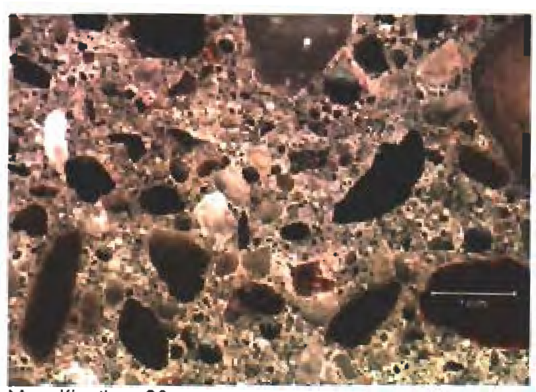
Description: Hardened Concrete Core

Dimensions: 125mm (4-15/16") diameter by 238mm (9-3/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	4.8
Entrained, % ≤ 0.040"	3.3
Entrapped, %> 0.040"	1.5
Air Voids/inch	5.86
Specific Surface, in2/in3	490
Spacing Factor, inches	0.010
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	95
Test Date	12/21/2005





Magnification: 30x
Description: Overall hardened air content, 4.8% total

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AIR VOID ANALYSIS

PROJECT:
MICHIGAN CONCRETE PAVEMENT
WAYNE COUNTY

REPORTED TO:
NATIONAL CONCRETE PAVEMENT TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: #6

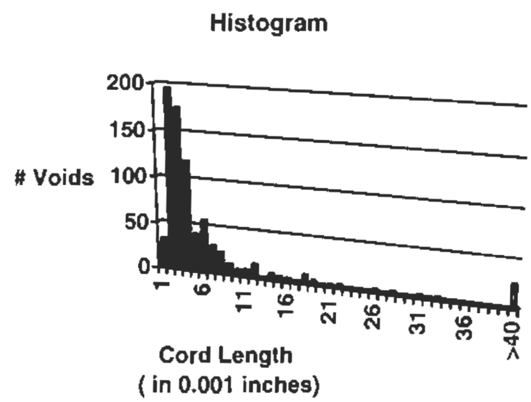
Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

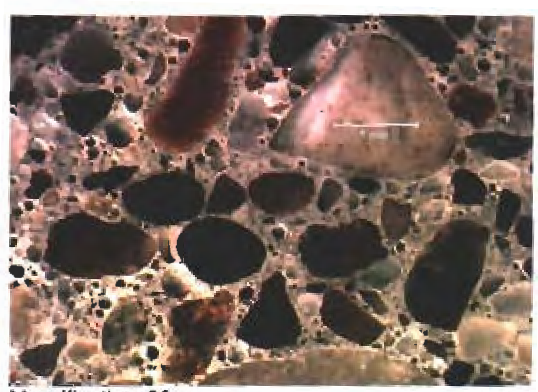
Sample Data:

Description: Hardened Concrete Core
Dimensions: 125mm (4-15/16") diameter by 275mm (10-13/16") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.3
Entrained, % ≤ 0.040"	4.1
Entrapped, %> 0.040"	3.2
Air Voids/inch	8.18
Specific Surface, in2/in3	450
Spacing Factor, inches	0.009
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/22/2005





Magnification: 30x
Description: Overall hardened air content, 7.3% total

AIR VOID ANALYSIS

American Petrographic Services, Inc.

PROJECT:
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WAYNE COUNTY

REPORTED TO:
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IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: DECEMBER 6, 2005

Sample ID: #7

Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

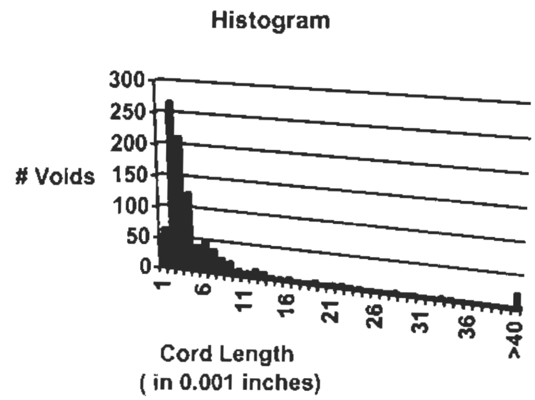
Sample Data:

Description: Hardened Concrete Core

Dimensions: 125mm (4-15/16") diameter by 285 (11-1-4") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.0
Entrained, % ≤ 0.040"	4.9
Entrapped, %> 0.040"	2.1
Air Voids/inch	9.99
Specific Surface, in2/in3	570
Spacing Factor, inches	0.007
Paste Content, % estimated	27.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/22/2005



Magnification: 30x
Description: Overall hardened air content, 7.0% total

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AIR VOID ANALYSIS

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REPORTED TO:
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IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #8

Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

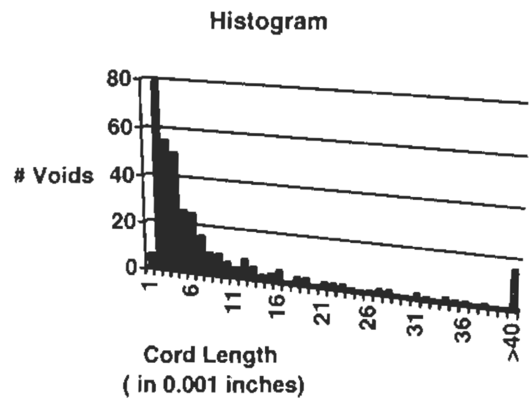
Sample Data:

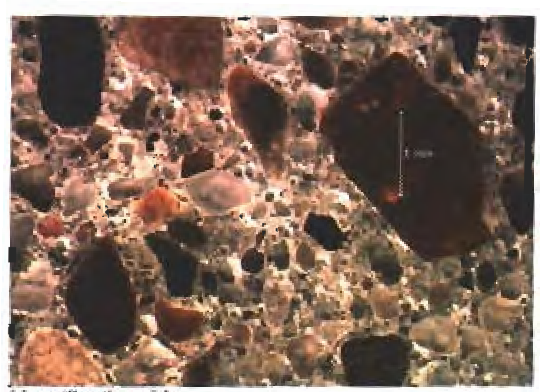
Description: Hardened Concrete Core

Dimensions: 150mm (5-7/8") diameter by 270mm (10-5/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	3.4
Entrained, % ≤ 0.040"	2.3
Entrapped, %> 0.040"	1.1
Air Voids/inch	3.65
Specific Surface, in2/in3	430
Spacing Factor, inches	0.013
Paste Content, % estimated	27.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 3.4% total

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AIR VOID ANALYSIS

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2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #9

Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

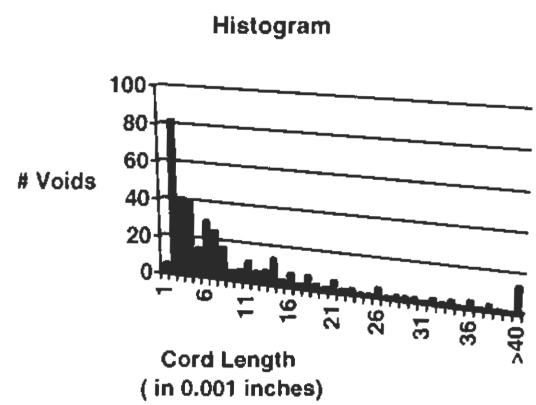
Sample Data:

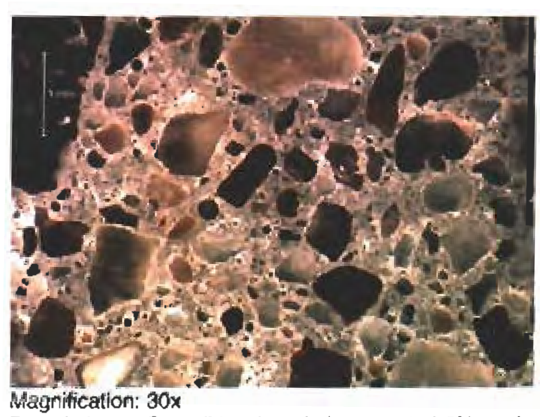
Description: Hardened Concrete Core

Dimensions: 150mm (5-7/8") diameter by294mm (11-9/16") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	4.3
Entrained, % ≤ 0.040"	3.3
Entrapped, %> 0.040"	1.0
Air Voids/inch	3.98
Specific Surface, in2/in3	370
Spacing Factor, inches	0.014
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/03/2006





Magnification: 30x
Description: Overall hardened air content, 4.3% total

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2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: #10

Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

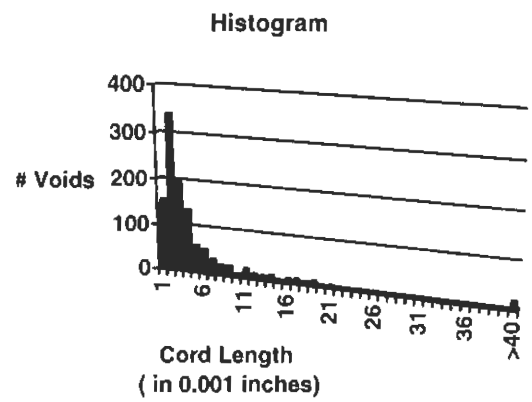
Sample Data:

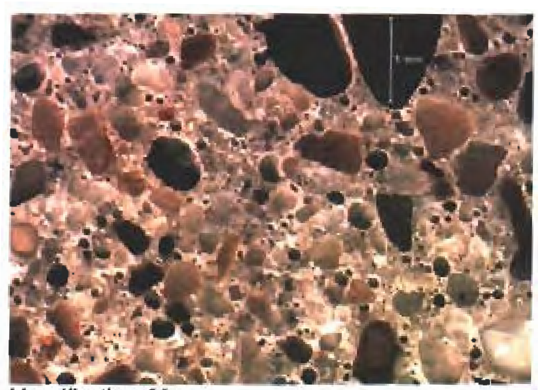
Description: Hardened Concrete Core

Dimensions: 146mm (5-3/4") diameter by 235mm (9-1/4") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.2
Entrained, % ≤ 0.040"	5.4
Entrapped, %> 0.040"	1.8
Air Voids/inch	11.97
Specific Surface, in2/in3	670
Spacing Factor, inches	0.006
Paste Content, % estimated	23.0
Magnification	50x
Traverse Length, inches	95
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 7.2% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: #11

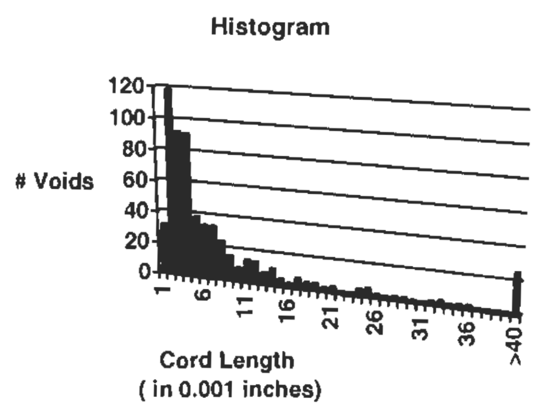
Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

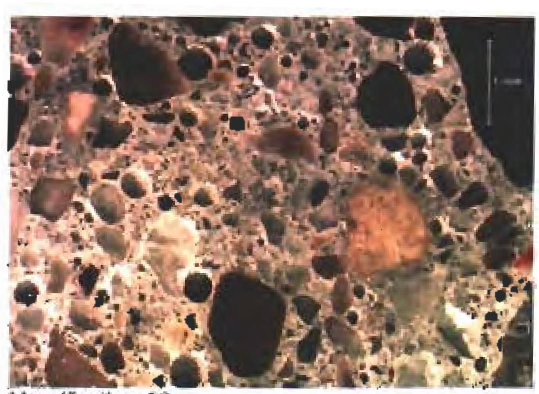
Sample Data:

Description: Hardened Concrete Core
Dimensions: 146mm (5-3/4") diameter by 213mm (8-3/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	6.1
Entrained, % ≤ 0.040"	4.0
Entrapped, %> 0.040"	2.1
Air Voids/inch	6.33
Specific Surface, in2/in3	420
Spacing Factor, inches	0.010
Paste Content, % estimated	22.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 6.1% total

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ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #12

Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

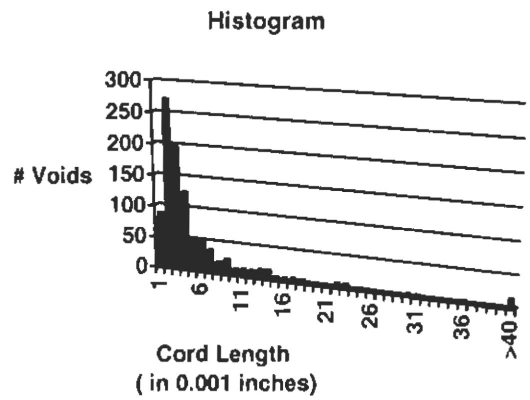
Sample Data:

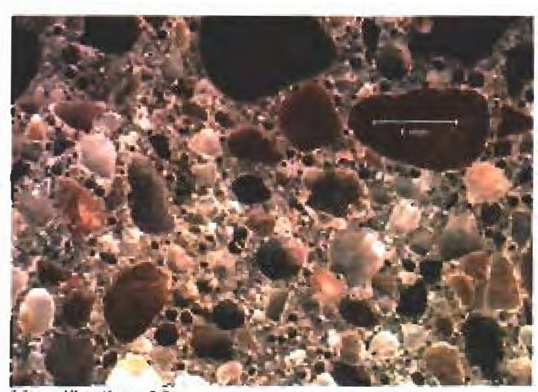
Description: Hardened Concrete Core

Dimensions: 150mm (5-7/8") diameter by 264mm (10-3/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	6.2
Entrained, % ≤ 0.040"	5.2
Entrapped, %> 0.040"	1.0
Air Voids/inch	10.21
Specific Surface, in2/in3	660
Spacing Factor, inches	0.006
Paste Content, % estimated	25.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/05/2006





Magnification: 30x
Description: Overall hardened air content, 6.2% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

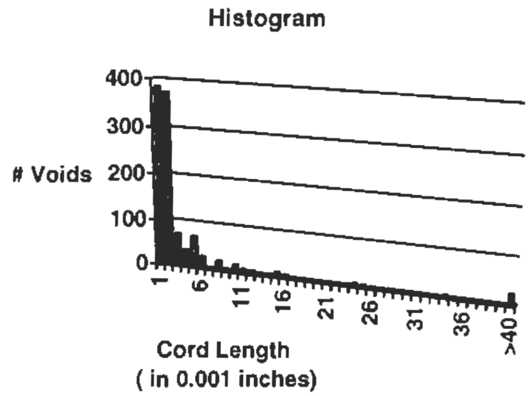
Sample ID: #13

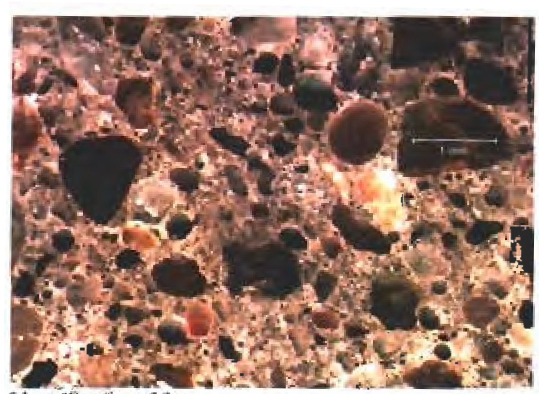
Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

Sample Data:
- Description: Hardened Concrete Core
- Dimensions: 151mm (5 15/16") diameter x 267mm (10 1/2") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.6
Entrained, % ≤ 0.040"	4.3
Entrapped, %> 0.040"	3.3
Air Voids/inch	11.89
Specific Surface, in2/in3	630
Spacing Factor, inches	0.006
Paste Content, % estimated	27.0
Magnification	50x
Traverse Length, inches	92
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 7.6% total

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ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: #14

Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

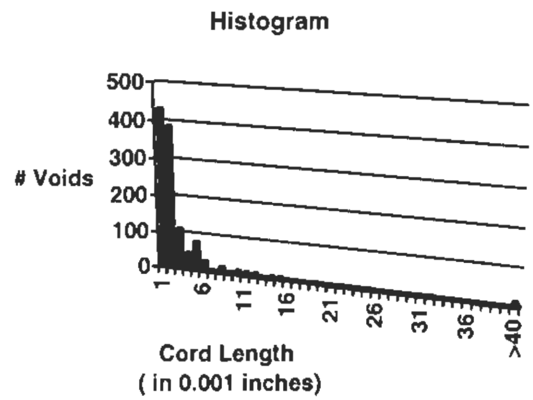
Sample Data:

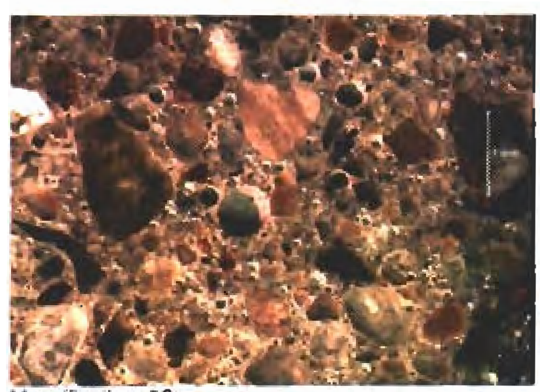
Description: Hardened Concrete Core

Dimensions: 151mm (5 15/16") diameter x 294mm (11 9/16")

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.2
Entrained, % ≤ 0.040"	4.1
Entrapped, %> 0.040"	1.0
Air Voids/inch	12.49
Specific Surface, in2/in3	970
Spacing Factor, inches	0.005
Paste Content, % estimated	25.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 5.2% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: #15

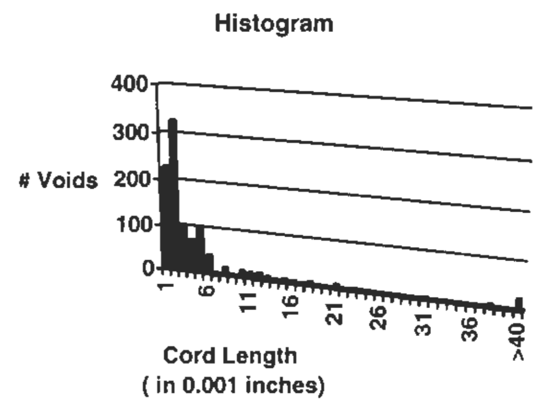
Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

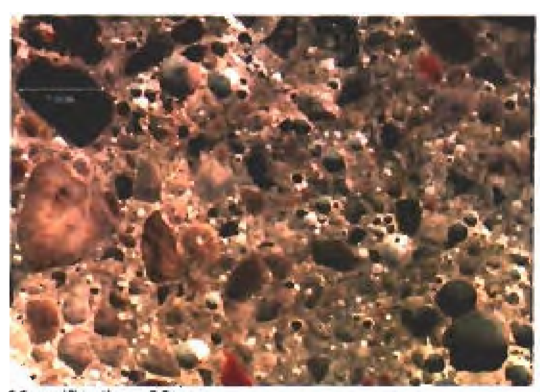
Sample Data:

Description: Hardened Concrete Core
Dimensions: 151mm (5 15/16") diameter x 270mm (10 5/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.0
Entrained, % ≤ 0.040"	4.7
Entrapped, %> 0.040"	2.3
Air Voids/inch	10.58
Specific Surface, in2/in3	610
Spacing Factor, inches	0.006
Paste Content, % estimated	22.0
Magnification	50x
Traverse Length, inches	96
Test Date	01/04/2006





Magnification: 30x
Description: Overall hardened air content, 7.0% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: 17

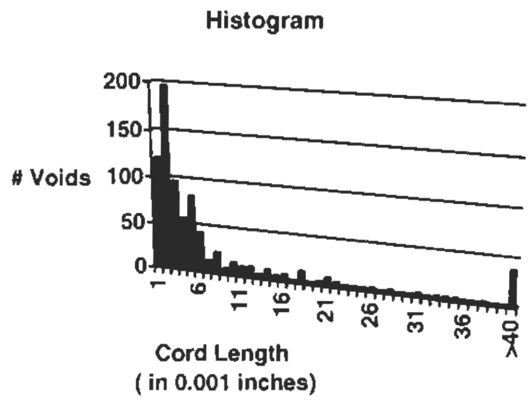
Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

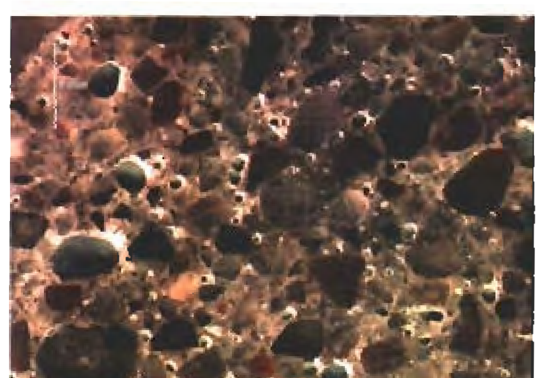
Sample Data:

Description: Hardened Concrete Core
Dimensions: 151mm (5 15/16") diameter x 257mm (10 1/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	8.3
Entrained, % ≤ 0.040"	4.2
Entrapped, %> 0.040"	4.1
Air Voids/inch	8.09
Specific Surface, in2/in3	390
Spacing Factor, inches	0.010
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/27/2005





Magnification: 30x
Description: Overall hardened air content, 8.3% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

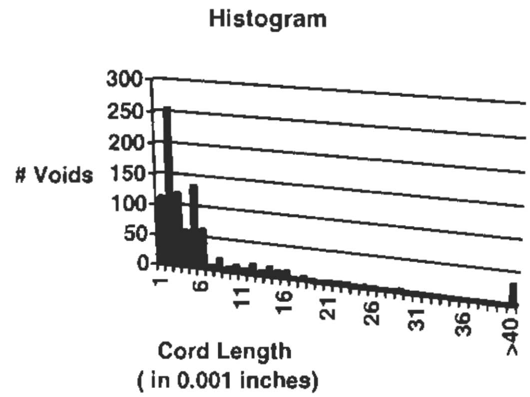
Sample ID: 17J

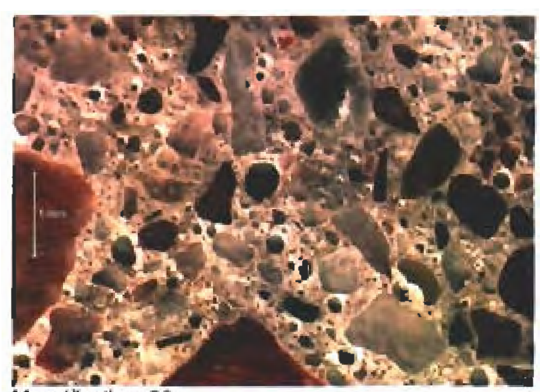
Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

Sample Data:
- Description: Hardened Concrete Core
- Dimensions: 151mm (15/16") diameter x 56mm (10 1/16') long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	7.7
Entrained, % ≤ 0.040"	5.0
Entrapped, %> 0.040"	2.7
Air Voids/inch	10.08
Specific Surface, in2/in3	520
Spacing Factor, inches	0.007
Paste Content, % estimated	23.0
Magnification	50x
Traverse Length, inches	92
Test Date	12/22/2005





Magnification: 30x
Description: Overall hardened air content, 7.7% total

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ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: 18

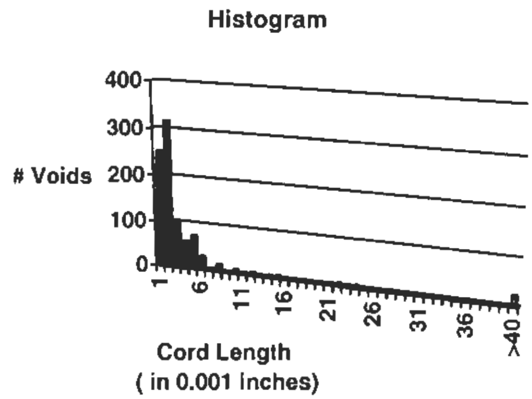
Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

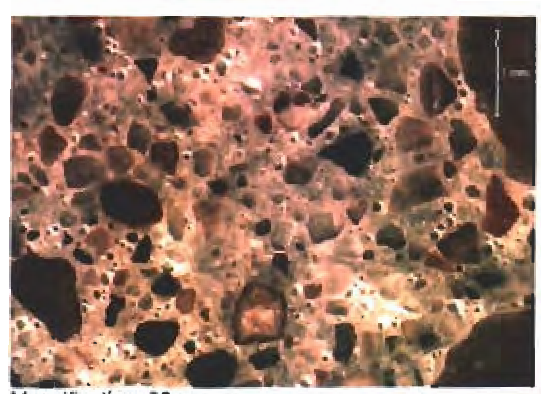
Sample Data:

Description: Hardened Concrete Core
Dimensions: 151mm (5 15/16") diameter x 238mm (9 3/8") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.5
Entrained, % ≤ 0.040"	3.5
Entrapped, %> 0.040"	2.0
Air Voids/inch	9.65
Specific Surface, in2/in3	700
Spacing Factor, inches	0.007
Paste Content, % estimated	26.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/22/2005





Magnification: 30x
Description: Overall hardened air content, 5.5% total

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ATTN: JIM GROVE

APS JOB NO: 10-04139

DATE: JANUARY 6, 2006

Sample ID: 18J

Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

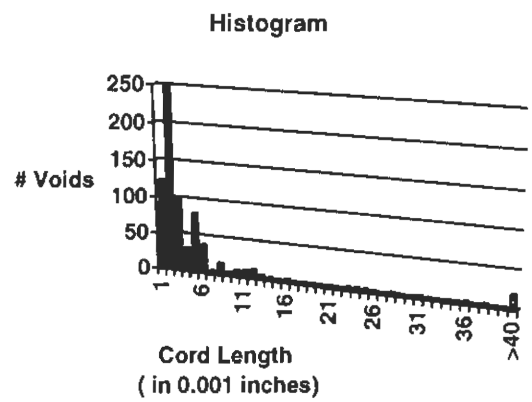
Sample Data:

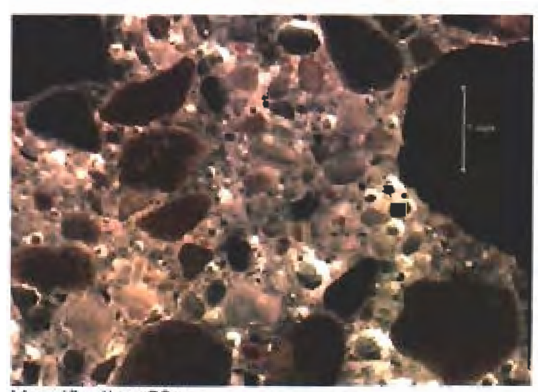
Description: Hardened Concrete Core

Dimensions: 151mm (5 15/16") diameter x 241mm (9 1/2") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.5
Entrained, % ≤ 0.040"	3.7
Entrapped, %> 0.040"	1.8
Air Voids/inch	7.75
Specific Surface, in2/in3	560
Spacing Factor, inches	0.008
Paste Content, % estimated	23.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/20/2005





Magnification: 30x
Description: Overall hardened air content, 5.5% total

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TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

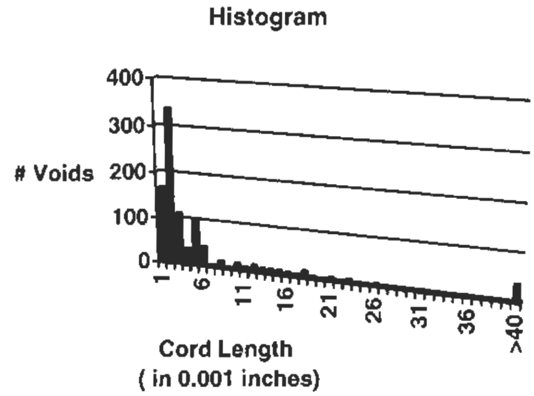
Sample ID: 19

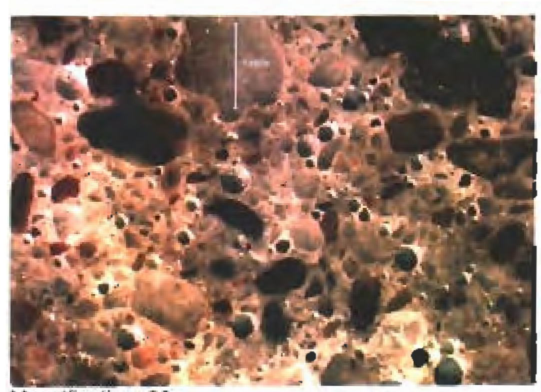
Conformance: The sample contains an air void system which is generally consistent with current technology for freeze-thaw resistance.

Sample Data:
Description: Hardened Concrete Core
Dimensions: 151mm (5 15/16") diameter x 229mm (9") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	9.0
Entrained, % ≤ 0.040"	4.8
Entrapped, %> 0.040"	4.2
Air Voids/inch	10.18
Specific Surface, in2/in3	450
Spacing Factor, inches	0.007
Paste Content, % estimated	22.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/20/2005





Magnification: 30x
Description: Overall hardened air content, 9.0% total

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AIR VOID ANALYSIS

American Petrographic Services, Inc.

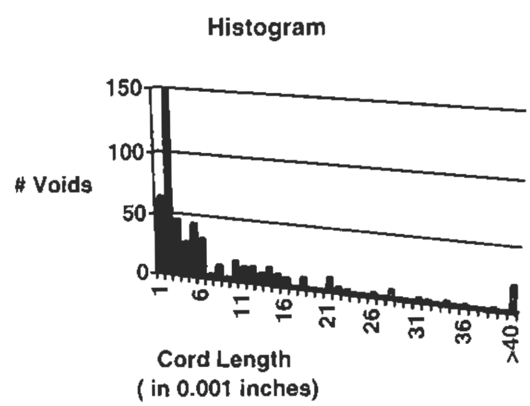
PROJECT:
MICHIGAN CONCRETE PAVEMENT
MACOMB COUNTY

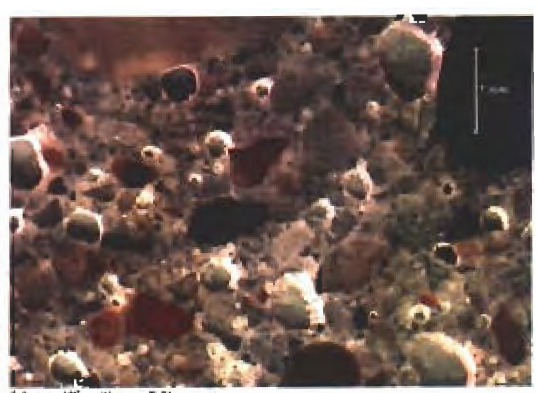
REPORTED TO:
NATIONAL CONCRETE PAVEMENT
TECHNOLOGY CENTER
IOWA STATE UNIVERSITY
2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID:	19J
Conformance:	The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.
Sample Data:	
Description:	Hardened Concrete Core
Dimensions:	151mm (5 15/16") diameter x 221mm (8 11/16") long
Test Data:	ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R
Air Void Content %	5.7
Entrained, % ≤ 0.040"	3.7
Entrapped, %> 0.040"	2.0
Air Voids/inch	5.55
Specific Surface, in2/in3	390
Spacing Factor, inches	0.011
Paste Content, % estimated	22.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/20/2005





Magnification: 30x
Description: Overall hardened air content, 5.7% total

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AIR VOID ANALYSIS

PROJECT:	REPORTED TO:
MICHIGAN CONCRETE PAVEMENT MACOMB COUNTY	NATIONAL CONCRETE PAVEMENT TECHNOLOGY CENTER IOWA STATE UNIVERSITY 2901 SOUTH LOOP DR., SUITE 3100 AMES, IOWA 50010-8634
	ATTN: JIM GROVE
APS JOB NO: 10-04139	**DATE:** JANUARY 6, 2006

Sample ID: 20

Conformance: The sample contains an air void system which is consistent with current technology for freeze-thaw resistance.

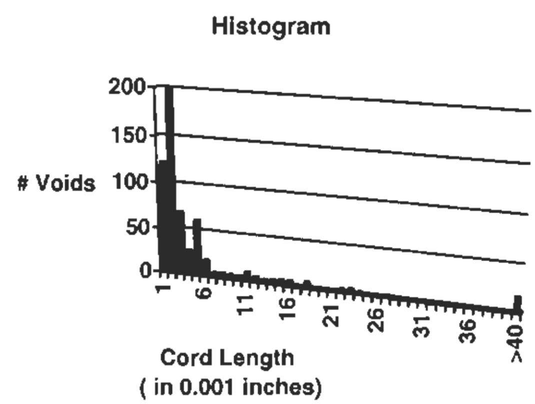
Sample Data:

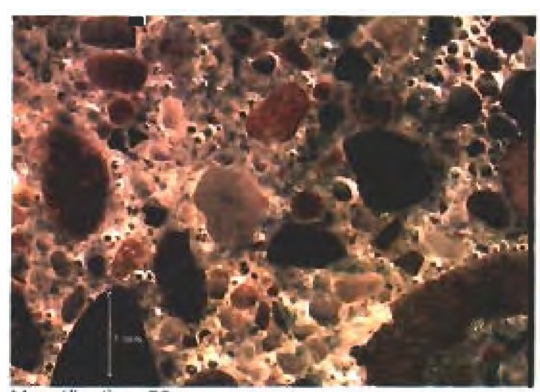
Description: Hardened Concrete Core

Dimensions: 151mm (5 15/16") diameter x 230mm (9 1/16") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	4.0
Entrained, % ≤ 0.040"	2.6
Entrapped, %> 0.040"	1.4
Air Voids/inch	6.08
Specific Surface, in2/in3	620
Spacing Factor, inches	0.008
Paste Content, % estimated	25.0
Magnification	50x
Traverse Length, inches	96
Test Date	12/19/2005





Magnification: 30x

Description: Overall hardened air content, 4.0% total

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AIR VOID ANALYSIS

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MICHIGAN CONCRETE PAVEMENT
MACOMB COUNTY

REPORTED TO:
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2901 SOUTH LOOP DR., SUITE 3100
AMES, IOWA 50010-8634

ATTN: JIM GROVE
DATE: JANUARY 6, 2006

APS JOB NO: 10-04139

Sample ID: 20J

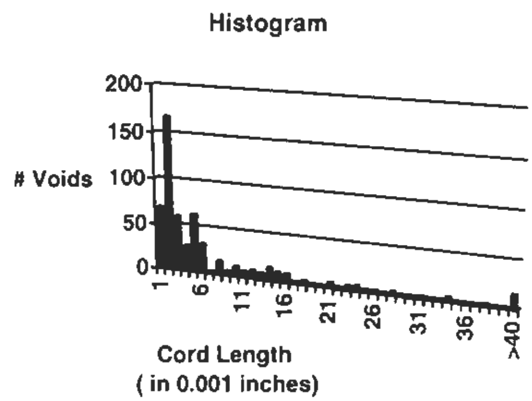
Conformance: The sample contains an air void system which is not consistent with current technology for freeze-thaw resistance.

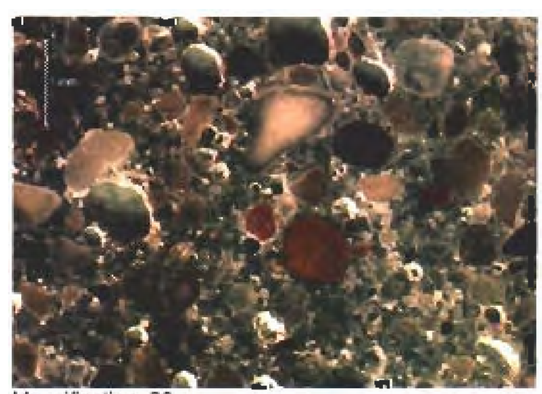
Sample Data:

Description: Hardened Concrete Core
Dimensions: 151mm (5 15/16") diameter x 233mm (9 3/16") long

Test Data: ASTM:C457 Linear Traverse Method, APS SOP 00LAB003 and ACI 116R

Air Void Content %	5.1
Entrained, % ≤ 0.040"	3.4
Entrapped, %> 0.040"	1.7
Air Voids/inch	5.95
Specific Surface, in2/in3	460
Spacing Factor, inches	0.010
Paste Content, % estimated	25.0
Magnification	50x
Traverse Length, inches	92
Test Date	12/19/2005





Magnification: 30x
Description: Overall hardened air content, 5.1% total