New Hampshire DOT

Research Record

New Hampshire's Concrete Aggregate and Alkali-Silica Reactivity

Statewide Assessment of Fine and Coarse Concrete Aggregate

Final Report

Prepared by the New Hampshire Department of Transportation, in cooperation with the
U.S. DOT, Federal Highway Administration

Technical Report Documentation Page

1. Report No.
FHWA-NH-RD-12323N

2. Gov. Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
NEW HAMPSHIRE'S CONCRETE AGGREGATE AND ALKALI-SILICA REACTIVITY- STATEWIDE ASSESSMENT OF FINE AND COARSE CONCRETE AGGREGATE

5. Report Date
December 2, 2002

6. Performing Organization Code

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8. Performing Organization Report No.

9. Performing Organization Name and Address
NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION
PO BOX 483, 11 STICKNEY AVENUE
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10. Work Unit No. (TRAIS)

11. Contract or Grant No.
12323N, SPR-0004(17)

12. Sponsoring Agency Name and Address
NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION
PO BOX 483, 11 STICKNEY AVENUE
CONCORD, NH 03302-0483

13. Type of Report and Period Covered
FINAL REPORT

14. Sponsoring Agency Code

15. Supplementary Notes
In cooperation with the FEDERAL HIGHWAY ADMINISTRATION, PRIORITY TECHNOLOGY PROGRAM

16. Abstract

Alkali-silica reactivity (ASR) has become a major concern with regards to long-term durability of concrete structures in New Hampshire. Many concrete structures built by the New Hampshire Department of Transportation (NHDOT) show visible distress. The cause of this distress has been suspected to be deleterious ASR expansion or other destructive processes in conjunction with ASR. Verification of an association between ASR and visual observations of deterioration within the structures has not been done.

The objectives of this research were the following:

- Determine the potential for the development of alkali-silica reactivity in concrete using fine and coarse aggregates in New Hampshire
- Confirm the presence and extent of alkali-silica reactivity (ASR) in existing NHDOT concrete structures
- Identify the types of rocks in New Hampshire that are potentially reactive
- Evaluate the need for an additional study to determine the amount of admixtures required for the minimization of ASR in new concrete within New Hampshire

The research demonstrated that a significant number of the concrete aggregates within New Hampshire are potentially reactive (0.1% or greater elongation at 14 days). The presence of ASR within the laboratory constructed mortar bars made with potentially reactive aggregates was confirmed through petrographic thin section analysis. ASR gel was also confirmed within selected concrete bridges through uranyl acetate UV-light testing as well as core sampling and petrographic thin section analysis. Based on the research findings a Phase 2 study is recommended which would evaluate different admixtures for their effectiveness in mitigating the development of ASR in new concrete.

17. Key Words
Alkali-silica reactivity, petrographic thin section, cement, uranyl acetate UV-light, expansion, potentially reactive, ASR, aggregates, mortar bar, fluorescence

18. Distribution Statement
No Restrictions. This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virgina, 22161

19. Security Classif. (of this report)
UNCLASSIFIED

20. Security Classif. (of this page)
UNCLASSIFIED

21. No. of Pages
43

22. Price

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December 2, 2002

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ACKNOWLEDGEMENT

Funding for his research has been provided by the New Hampshire State Planning and Research Program (SP&R) and is being administered through the FHWA. The authors would like to thank Margaret Thomson, PENN DOT, Peter Beblowski, NHDOT, Alan Lugg, NHDOT and Todd Belanger, NHDOT, for their contributions to the research.

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EXECUTIVE SUMMARY

Alkali-silica reactivity (ASR) has become a major concern with regards to long-term durability of concrete structures in New Hampshire. Many concrete structures built by the New Hampshire Department of Transportation (NHDOT) show visible distress. The cause of this distress has been suspected to be deleterious ASR expansion or other destructive processes in conjunction with ASR. Verification of an association between ASR and visual observations of deterioration within the structures has not been done. The objectives of this research were to: Determine the potential for the development of ASR in concrete made from fine and coarse aggregates available in New Hampshire; Confirm the presence and extent of ASR in existing NHDOT concrete structures; Identify the types of rocks that are potentially reactive in New Hampshire and evaluate the need for additional research to determine the amount of admixtures required for the minimization of ASR in new concrete within New Hampshire. This research demonstrated that a significant number of the concrete aggregates within the state of New Hampshire are potentially reactive. The presence of ASR within the laboratory constructed mortar bars made with potentially reactive aggregates was confirmed through petrographic thin section analysis. ASR gel was also confirmed within selected concrete bridges through uranyl acetate UV-light testing as well as core sampling and petrographic thin section analysis. Based on the research findings a phase 2 study is recommended, which would evaluate different admixtures for their effectiveness in mitigating the development of ASR in new concrete.

INTRODUCTION

Alkali-silica reactivity (ASR) has become a major concern with regards to long-term durability of concrete structures in New Hampshire. There are verified cases of ASR distress in concrete pavements and structures in the New England region, several confirmed cases of ASR within New Hampshire and concrete runways with severe ASR deterioration at the Pease International Trade Port in Portsmouth, NH. There are known reactive aggregates from nearby states with similar composition to concrete aggregates utilized in New Hampshire. In addition, many existing New Hampshire Department of Transportation (NHDOT) concrete bridge structures of varying age and type show visible distress. It has been suspected that ASR in conjunction with other destructive processes has caused deleterious expansion of the concrete. Data was not available to corroborate the association of ASR with the visual observations of deterioration in existing NHDOT concrete structures.

Construction costs for new concrete structures have risen significantly. Repairs to existing concrete structures can be expensive and difficult to execute. One method to control escalating costs is to increase the design life of transportation structures. A key factor in extending the useful life of these concrete structures is to minimize ASR distress.

The potential impact of ASR on concrete durability in New Hampshire, the need to evaluate the potential ASR reactivity of concrete aggregates in the state, the need to determine the extent of the ASR problem in existing concrete structures and the need to control ASR reactivity in new concrete structures, prompted this research.

BACKGROUND

Deleterious ASR expansion was first recognized as a destructive process in Portland cement concrete in the late 1930’s. Since then, it has been identified in varying degrees of severity in most areas of the country. Expansive ASR is a two-step physical/chemical process. The first step is a reaction between the silica (usually provided by the aggregate) and the alkali hydroxides (usually provided by the cement paste) to form an ASR gel. The second step occurs when the ASR gel absorbs moisture and swells, which may cause cracking, pop outs, spalling, differential movement, and loss of strength in the concrete. According to a 1995 FHWA-SHRP Showcase (*1*), the following three conditions must be met for the entire process to occur:

1. Reactive form of silica in the aggregates.

2. Sufficient alkali.

3. Sufficient moisture.

The potential for ASR to occur in concrete structures increases when the total alkali content of the cement is greater than 0.6%. Most of the cements utilized in New Hampshire have this characteristic. Moisture and reactive forms of silica are also readily available throughout the state.

Concrete aggregates in New Hampshire are produced from natural bank-run sand and gravel, and from crushed stone quarries. The sands and gravels, deposited primarily by the glaciers during the ice age, vary greatly in particle sizes and mineral composition. Based on Goldthwait's (*2*) 1948 Mineral Resource Survey, most stones have been deposited within ten miles of their original bedrock source (map 1). Sand sized particles on the other hand tend to travel much further from their source location. Quartz is the most abundant mineral followed by feldspar in the state's sand and gravel deposits. Granite bedrock occurs throughout most of the state and is the primary source of the feldspar minerals. Metamorphic rocks are the primary bedrock in the northern and southeastern areas of the state, and along the Connecticut River Valley on the western border. The local bedrock in these areas is the source of the quartz grains along with the slate and schist chips, which are the predominant components of the sand deposits in those regions. Microcrystalline quartz is a common constituent of the sand deposits, which originated from the break down of these metamorphic rocks.

The crushed stone quarries in the state are commonly located in the bedrock formations composed of igneous rocks such as granites, syenites, monzonites, granodiorites and diorites or metamorphic rocks such as gneisses, quartzites, amphibolites, phyllites and schists (map 2). The bedrock aggregate sources throughout New Hampshire vary widely in rock type, crystal grain size, mineral composition, grade of metamorphism and degree of weathering. Crushed stone materials are frequently used in conjunction with sand and gravel aggregates.

Individual concrete aggregate producers in the state often utilize multiple sources of both crushed and bank-run materials. Some manufacturers of aggregate materials blend different rock types during the production of their crushed stone products. In summary, the types and composition of the aggregates can vary significantly within a single source and between sources across the state.

OBJECTIVES

The objectives of this research will help in determining if the aggregates produced within the state promote ASR and if existing NHDOT concrete structures exhibit some level of deleterious ASR. The objectives were the following:

1. Determine the potential for alkali-silica reactivity of the fine and coarse concrete aggregates utilized in New Hampshire through ASTM C1260-94 *(3)* accelerated mortar bar testing.

2. Confirm the presence of ASR in existing NHDOT concrete structures utilizing the uranyl acetate UV-light testing method and through the examination of concrete cores utilizing stereoscopic and polarized light microscopy techniques.

3. Determine the extent and severity of alkali-silica reactivity (ASR) in NHDOT concrete structures.

4. Identify the types of rocks that are potentially reactive in New Hampshire.

5. Evaluate the need for additional research to determine the minimum amount of admixtures needed to significantly minimize ASR within new concrete structures built in New Hampshire.

METHODOLOGY

This research utilized the ASTM C1260 accelerated mortar bar test method *(3)* to assess the potential reactivity of the concrete aggregates. Although this method is thought to be severe, it was selected for its quick results and its ability to identify slowly reacting aggregates. Portland Type II Blue Circle Cement with a total alkali content of 0.55% was used as the standard cement for preparation of all the mortar bars (see table below). Each test series consisted of three sample aggregates with a standard aggregate and two test samples. Each sample aggregate consisted of four 1"X1"X11.25" mortar bars. The mortar bars for each aggregate sample were immersed in 1N sodium hydroxide solution in individual containers. The three containers were placed in a water bath to maintain the storage temperature at 80 degrees centigrade during the test period. The standard aggregate utilized throughout the research study had a 14-day expansion of 0.074% and was a manufactured fine concrete aggregate composed of gneiss and granite.

Oxide Analysis	**Percent**
SiO_2	21.7%
Al_2O_3	4.5%
Fe_2O_3	3.2%
MgO	3.3%
SO_3	3.1%
CaO	64.8%
K_2O	0.43%
TiO_2	-
Na_2O	0.27%
SrO	0.09%
P_2O_5	-
Mn_2O_3	0.03%
ZnO	0.01%
Cr_2O_3	0.04%
Compound Composition	**Percent**
C_3S	55%
C_3A	6.5%
Ignition Loss	**1.17%**
Insoluble Residue	**0.18%**

Composition of standard cement

(Blue Circle Type II)

A selected number of bridges throughout the state were investigated for ASR distress. Visual observations and uranyl acetate UV-light testing were conducted and concrete cores were collected. The visual analysis consisted of observing unique crack patterns and deterioration on the surface of the concrete. The uranyl acetate UV-light method as described in Stark's 1991 handbook *(4)*, consisted of grinding a small section of the concrete surface with a bush hammer and then spraying uranyl acetate onto the freshly fractured surface. The presence of ASR gel reaction products can be detected with an ultra violet light box. ASR gel fluoresces as a yellowish-green color under the UV light. The concrete cores were analyzed visually and with stereoscope and petrographic microscopes. Precipitates collected from the voids within the concrete were analyzed through a grain mount procedure utilizing a petrographic microscope. Dispersion oils with a known index of refraction were used to determine the index of refraction of the precipitates.

Preparation of the hardened cement concrete samples followed the guidelines in the U.S. Department of Transportation, Petrographic Manual , FHWA-RD-97-146 *(5)*. Thin sections of the concrete mortar bars and core samples were prepared by cutting the concrete into small one inch cubes with a diamond saw lubricated with water. The cubes were then dried and impregnated with a thinned epoxy resin, using a vacuum desiccator. The samples were air-dried overnight and then lapped with three levels of diamond disks using a specimen polisher until a surface was perfectly flat and smooth. The flat and smooth sides of the cubes were epoxied to a glass slide and allowed to cure overnight. The samples were then cut and ground to approximately 30-microns in thickness using a thin section machine with a diamond saw and grinding wheel. Final polishing of the thin section was accomplished by hand using water and 600 grit silicon carbide on a thick piece of glass. Once the thin section was polished to ≤ 30 microns in thickness, a cover slip was placed on the thin section using Crossmon's Mounting Medium, which has a refractive index of 1.54.

A polarized-light microscope was used to conduct a petrographic analysis on the mortar bars that tested as potentially reactive (expansion of 0.10 % or greater at 14 days) and on the concrete cores taken from the selected bridges suspected of ASR distress. The petrographic examinations were conducted to identify the reacting aggregates within the concrete, ASR gel and the micro-structural distress caused by ASR. Standards utilized as a guide in the petrographic examinations included ASTM C295-98, Standard Guide for Petrographic Examination of Aggregates for Concrete *(6)*, and ASTM C856-95, Standard Practice for Petrographic Examination of Hardened Concrete *(7)*.

RESULTS

ASTM C1260 Accelerated Mortar Bar Testing of Concrete Aggregates and Petrographic Examination of Mortar Bars

Sixty-seven concrete fine and coarse aggregates were tested utilizing the ASTM C1260 *(3)* accelerated mortar bar test method to determine their potential for alkali-silica reactivity. Approximately 24% of the aggregates had expansions of 0.10% or greater at 14 days (table 1). The 14-day expansions for the potentially reactive aggregates ranged from 0.11% to 0.29%. The publication for the FHWA-SHRP Showcase *(1)* states that some aggregates with a 14-day expansion as low as 0.08% have caused deleterious ASR. Five of the tested aggregates had expansions greater than 0.08 percent and less than 0.10 percent at 14 days.

Samples that tested as potentially reactive included fine and coarse concrete aggregates from both bank-run sources and rock quarries. The potentially reactive aggregates were composed of both igneous and metamorphic rocks. In general, most of the reactive aggregates were located along the Connecticut River Valley, the southern third of the state and the southeastern section of New Hampshire. Based on the state's geology and the mineralogical composition of the bedrock, reactive aggregates could be encountered at any location within the state.

The petrographic examination of positive mortar bars revealed that all the aggregates with ASTM C1260 *(3)* test results of 0.10% or greater contain some level of ASR gel within the concrete. Table 2 summarizes the thin section analysis results for these mortar bars. The thin sections were prepared from cross-sectional cubes cut from random areas within the middle portions of the mortar bars. The presence of ASR gel was determined as slight, moderate or severe by either identifying material within the thin sections that was ASR gel or by identifying features that are commonly associated with ASR, such as microcracks, reaction rims and darkened cement paste. Through thin section analysis, the mineral most often associated with ASR was found to be microcrystalline quartz and the most common ASR feature was found to be microcracking with ASR gel infilling (figure1). Many of the microcracks contained various amounts of ASR gel, calcium hydroxide and ettringite. Another common ASR feature found within the thin sections were voids, which contained ASR gel and other secondary deposits (figure 2). In general, thin sections showing the most severe ASR were from mortar bars prepared with fine aggregates that tested as highly reactive in the ASTM C1260 test *(3)*. Thin sections showing moderate ASR were generally from mortar bars prepared with coarse aggregates that were moderate to highly reactive in the ASTM C1260 test *(3)*.

Some thin sections exhibiting slight ASR were prepared with either fine or coarse aggregate that tested as moderately to highly reactive in the ASTM C1260 test *(3)*.

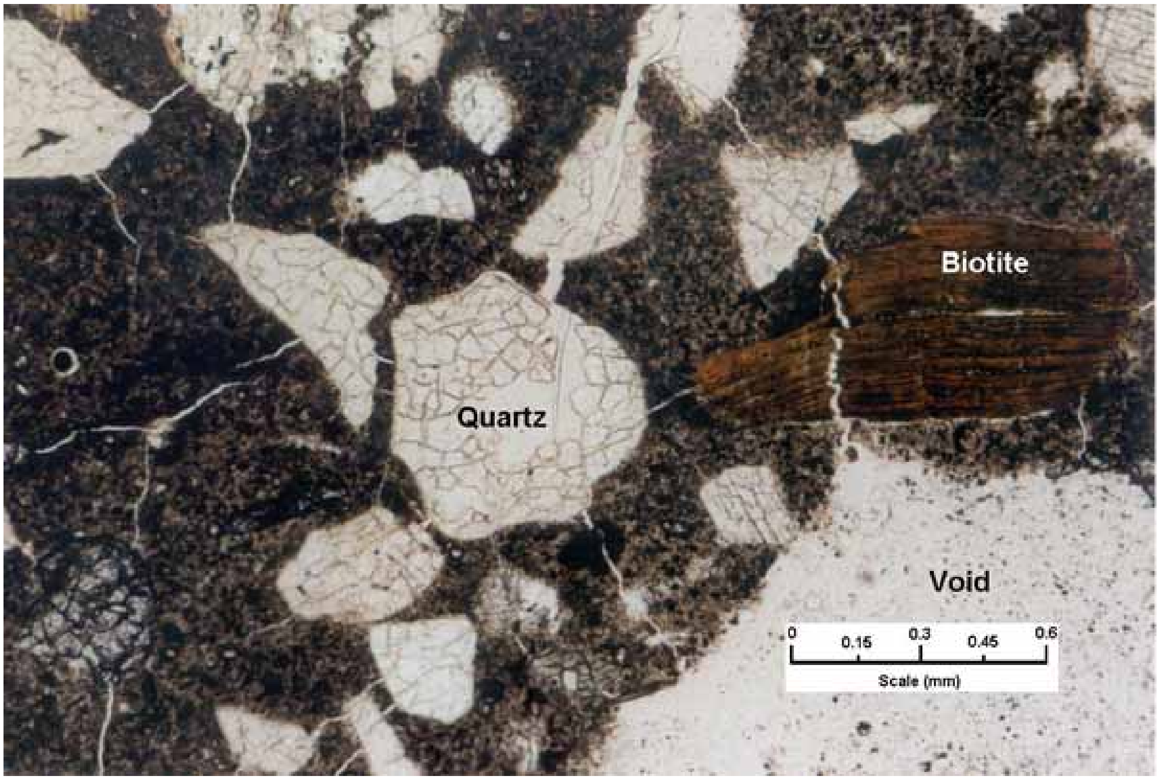

Figure 1 – Mortar bar photomicrograph after ASTM C1260 test, plane light, 50x magnification (Pit #48).

Thin section analysis revealed that the fine aggregates were predominately made up of the minerals quartz, chlorite and several varieties of both feldspar and mica. The coarse aggregates were predominately made up of the rocks granite, gneiss, schist and rhyolite. In most cases, the microcracks originated within the microcrystalline quartz particles and traveled through the paste and into voids or other aggregate particles. Microcracks were also observed within the rock types of granite and schist, and the mineral chlorite. In some of the thin sections, darkened paste was observed around some of the aggregates and microcracks suggesting that ASR gel could also be present within the cement paste. Thin section analysis also revealed secondary deposits of calcium hydroxide, calcium carbonate, alkali silica gel and ettrignite within the voids and microcracks.

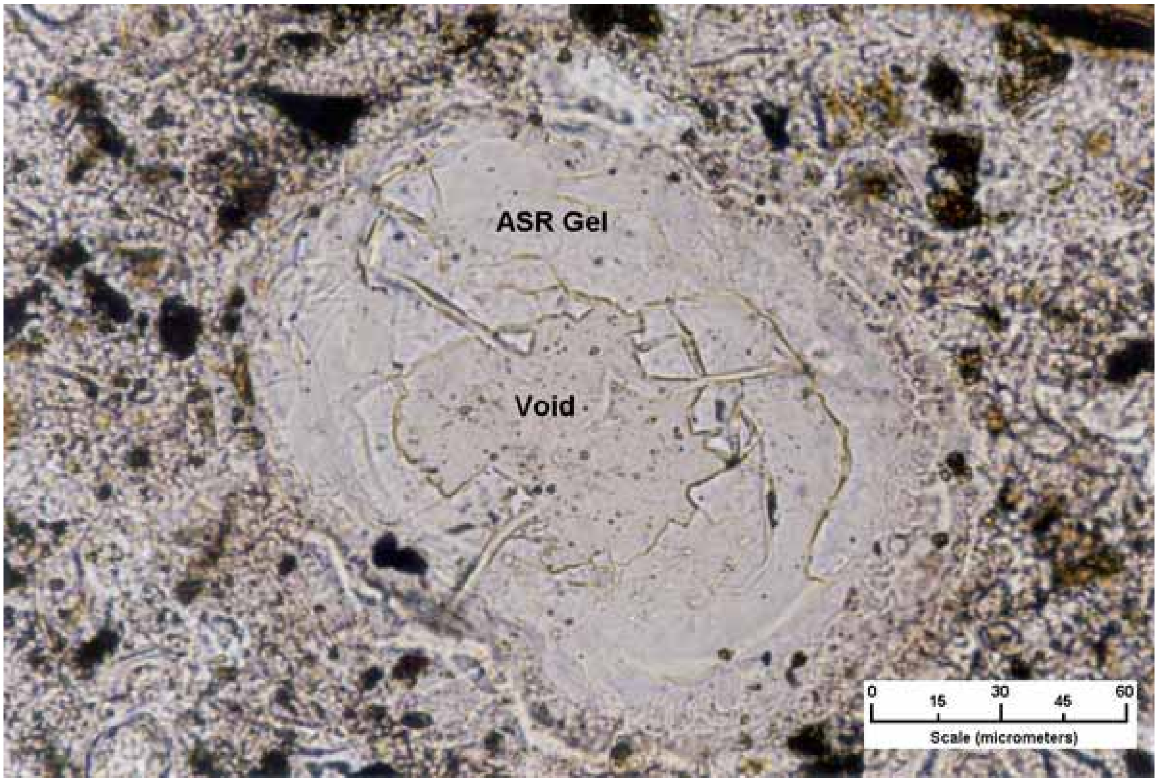

Figure 2 – Plane light, 500x magnification, ASR filled void (Pit #34).

Testing of Existing Bridges for the Presence of ASR

A total of thirty-four highway bridges and three railroad bridges were tested for the presence of ASR gel (map 3). The bridges were selected by different NHDOT bureaus and ranged in age from 21 to 102 years. Eighteen of the bridge structures were overpasses and nineteen were over water. There were several types of structures: five concrete rigid frames, two concrete T-beams, two prestressed concrete girders, twenty steel I-beam girders with concrete decks, three concrete arches, four concrete abutments and piers with steel frames, and one concrete box. Surface map cracking with white precipitates exuding from the cracks was observed in a number of the bridge abutments, wingwalls (figure 3) and one concrete parapet wall. Also observed were spalling and popouts, which are common signs of distress in Stark's 1991 Handbook *(4)*. Longitudinal cracking was noted on several concrete girders, the underside of several bridge decks and some concrete piers. At least nine of the bridge structures had suffered extensive damage from expansive ASR, and were in need of repair or replacement. Visible distress in the concrete, caused by or in part by deleterious ASR, was observed in bridge structures of various ages. The most severe ASR induced damage occurred in the concrete arches and along the lower portions of the abutments, piers and wingwalls, where the structures were in contact with moisture for long periods of time. Moisture appeared to be a critical factor in the degree and rate of deterioration for these structures. A unique crack pattern was observed in at least ten existing bridge structures located along I-89 in Springfield, New Hampshire. The cracks occur in the top flange of the prestressed concrete girders (figure 4). The cracking generally ran parallel to the longitudinal axis of the girders and along its entire length. Cracks in the exterior girders tended to be wider and more extensive than the cracks in the interior girders.

Figure 3 – Frankenstein Trestle, Crawford Notch, southeastern abutment, wingwall. Map cracking with white precipitate exuding from cracks (August 2001)

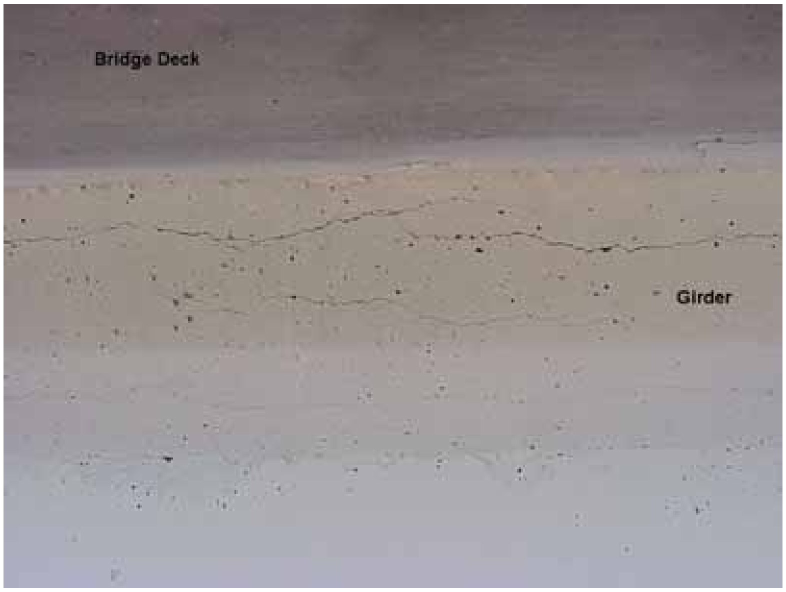

Figure 4 – Cracking parallel to the longitudinal axis of prestressed concrete girder. Springfield, NH, bridge # 053/050.

The uranyl acetate UV-light method was conducted in the field on all thirty-seven bridges and on the concrete cores taken from seven of the bridge sites. Varying amounts of ASR gel were identified within the concrete from many of the bridge structures. Uranyl acetate UV-light testing confirmed the presence of ASR gel on the concrete cores taken from the prestressed concrete girders on the two I-89 bridges. The aggregate particles in the concrete cores that generally exhibited florescence were composed of quartz, granite, gneiss, amphibolite and schist. The ASR gel deposits occurred in several forms: localized microcracks, air voids, the interior of certain aggregate particles, peripheral bands around some aggregate particles (photo 15), and as a broad film over fractured surfaces. The florescence ranged from isolated areas of subdued florescence to areas of bright florescence covering 85% of the fractured face. Through the uranyl acetate UV-light method, each bridge was assigned to one of three categories (slight, moderate or severe) based upon the amount and intensity of the observed florescence. There were eleven slight, thirteen moderate and thirteen severe ratings. There was a correlation between the degree of observed florescence and the proximity of the structure to a water body. In some instances, the accompanying visible distress (map cracking, spalling, popouts) was not observed on the concrete structure. Sometimes it was difficult to correlate the intensity of the florescence and the amount of surface area involved to the extent of visible damage within the concrete structure. Many of the bridge structures have had some level of remediation, repairs or partial reconstruction that may have covered or eliminated the visible distress induced by the expansion of ASR gel.

Two-inch concrete core samples from 10 bridge sites were collected using a small gasoline powered diamond bit core driller. Water was used to cool the drill bit and flush the cuttings during the coring procedure. All the core samples were analyzed with a stereoscope and petrographic microscope, and macroscopically with the naked eye. Table 3 contains a generalized summary of the analysis results. Two of the Grantham bridges were combined within the table because of similar results. All of the core samples exhibited some voids and microcraking that contained secondary deposits. Some of these deposits appeared as a clear waxy precipitate under stereoscopic view (photo 12). In addition, cracking was observed on many of the core samples once they had been polished and viewed under the stereoscopic microscope (figure 5).

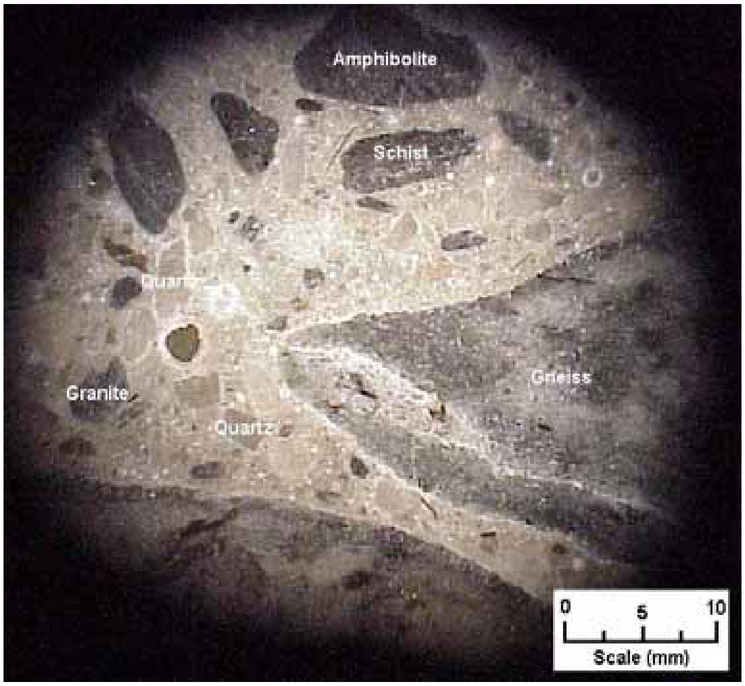

Figure 5 – Grantham Bridge 053/050 over I-89, stereoscopic view on polished surface.

Microcracking extending from coarse aggregate particle through paste and void into another coarse aggregate particle.

LIMITATIONS

Since the ASTM C1260 *(3)* test is severe, aggregates that perform well in the field can sometimes test potentially reactive. The materials from a single aggregate source can sometimes vary in mineral composition. In addition, some aggregate producers utilize multiple sources and blend the materials together in varying percentages. There can be a great deal of variability from some aggregate producers making it difficult to obtain representative aggregate samples.

The NHDOT does not have an existing database containing the type and source of concrete aggregate utilized in past Portland cement structures. Therefore, there is no method for correlating specific aggregate material sites to the concrete's past performance. In addition, the aggregate sources tested under this research study may not have existed or may not have been utilized at the time of construction.

The uranyl acetate UV-light method can be difficult to interpret and is not definitive. Some aggregates and minerals fluoresce naturally when viewed under a UV light. These areas should be identified before applying the uranyl acetate solution. Sometimes the uranyl acetate can be absorbed into the cement matrix and/or into the hydration compounds resulting in a dull, light fluorescence, which could be mistaken for ASR gel. In some cases, there did not appear to be a correlation in the amount and intensity of the fluorescence to the degree of distress in the concrete. In addition, the presence of ASR gel does not mean that distress or deterioration in the concrete will develop. The uranyl acetate UV-light method is an excellent tool for identifying ASR gel, but without other investigative methods, it alone can't determine whether destructive ASR has occurred.

Concrete cores and thin sections only sample a very small area of the concrete structure or mortar bar being examined. Therefore, it can be difficult to obtain a representative sample and to capture existing ASR gel. It is possible that the areas actually analyzed do not fully represent the sample as a whole. Areas chosen for analysis might have missed the presence of ASR gel or ASR like features within the concrete or these areas could possibly be the only location where ASR is occurring. Our thin section machine utilizes water to flush the concrete cuttings in the process of reducing the sample to a 30-micron thick slice of concrete. Using water to flush the cuttings presents a risk of removing the ASR gel during the sample preparation process. In an attempt to preserve the ASR gel and to fill-in the voids, the concrete samples were impregnated with multiple applications of epoxy resin prior to mounting them on the glass slide.

Often, multiple mechanisms may be the cause of the concrete's deterioration making it difficult to visually determine which deterioration mechanism is the culprit. In some cases, one deterioration mechanism may create the conditions for another to start. All factors must be considered and a combination of visual, macroscopic and microscopic examinations must be conducted.

CONCLUSIONS AND RECOMMENDATIONS

ASTM C1260 *(3)* accelerated mortar bar testing has shown that a significant number of the concrete aggregates within New Hampshire are potentially reactive (0.10% or greater elongation at 14 days). The presence of expansive ASR gel within the potentially reactive mortar bars was confirmed through petrographic thin section analysis. The rock types of the potentially reactive aggregates were identified as granite, rhyolite, quartzite, granitic gneiss, gneiss, amphibolite, phyllite and schist. In most cases, microcrystalline quartz was the constituent that contributed to the reactivity. The highest concentration of reactive aggregates was generally along the Connecticut River Valley, the southern section of the state and the southeastern section of New Hampshire. The degree of potential reactivity generally correlates with the degree of metamorphism. In comparison, the rock types found to be potentially reactive in New Hampshire correspond closely with the reactive rock types that typically occur in the Atlantic Seaboard *(1)*.

The uranyl acetate UV-light method has confirmed the presence of ASR gel in varying amounts in many of the existing NHDOT bridges. Thin section analysis of the concrete cores taken from some bridges has verified the existence of expansive ASR gel at the microscopic level. Thin section analysis of the mortar bars revealed that the aggregates derived from the metamorphic rocks tended to have a higher occurrence of microcracks and that microcrystalline quartz was the predominate mineral associated with the formation of ASR gel. Concrete on a number of the tested bridges had visible distress and deterioration. There was a good correlation between the composition of the aggregate particles that contributed to ASR distress in existing structures and the types of aggregates that were potentially reactive in the laboratory.

It is recommended that a database be established to track the service performance of concrete structures, relating it to factors such as the concrete aggregate source, cement source and the total alkali content of the cement. Over time this information could be helpful in making decisions regarding the performance of different concrete aggregates.

Since the ASTM C 1260 accelerated mortar bar test *(3)* is a severe test, verifying the reactivity of the aggregates (expansion of 0.10% or greater at 14 days) with the ASTM C 1293-01 *(8)* test should be considered. Information from ASTM C 1293 *(8)* testing would provide a more comprehensive evaluation of the state's aggregates and would strengthen the findings of this study.

In summary, deleterious ASR expansion is present in a number of the Department's concrete structures, which has negatively impacted their overall condition. ASR induced distress has resulted in costly repairs for some structures and has significantly reduced the service life of others. Based on the findings of this research, a phase 2 ASR research study is recommended. The Phase 2 study would evaluate different admixtures for their effectiveness in mitigating the development of ASR in new concrete. Upon completion of the Phase 2 study, a specification could be written stating the minimum amounts of admixtures to be used in concrete mixes that utilize reactive aggregates.

IMPLEMENTATION PLAN

The ASR test equipment and petrographic microscope have already been utilized in determining the existence of ASR induced distress in existing concrete structures. That information has been used in formulating remedial measures for several highway and railroad concrete bridges. Based on the findings from this research a phase 2 study has been undertaken to evaluate different admixtures for their effectiveness in mitigating the development of ASR in new concrete. Equipment purchased under this research project will need to be maintained and upgraded as necessary to conduct the phase 2 research study and to continue our in house capability.

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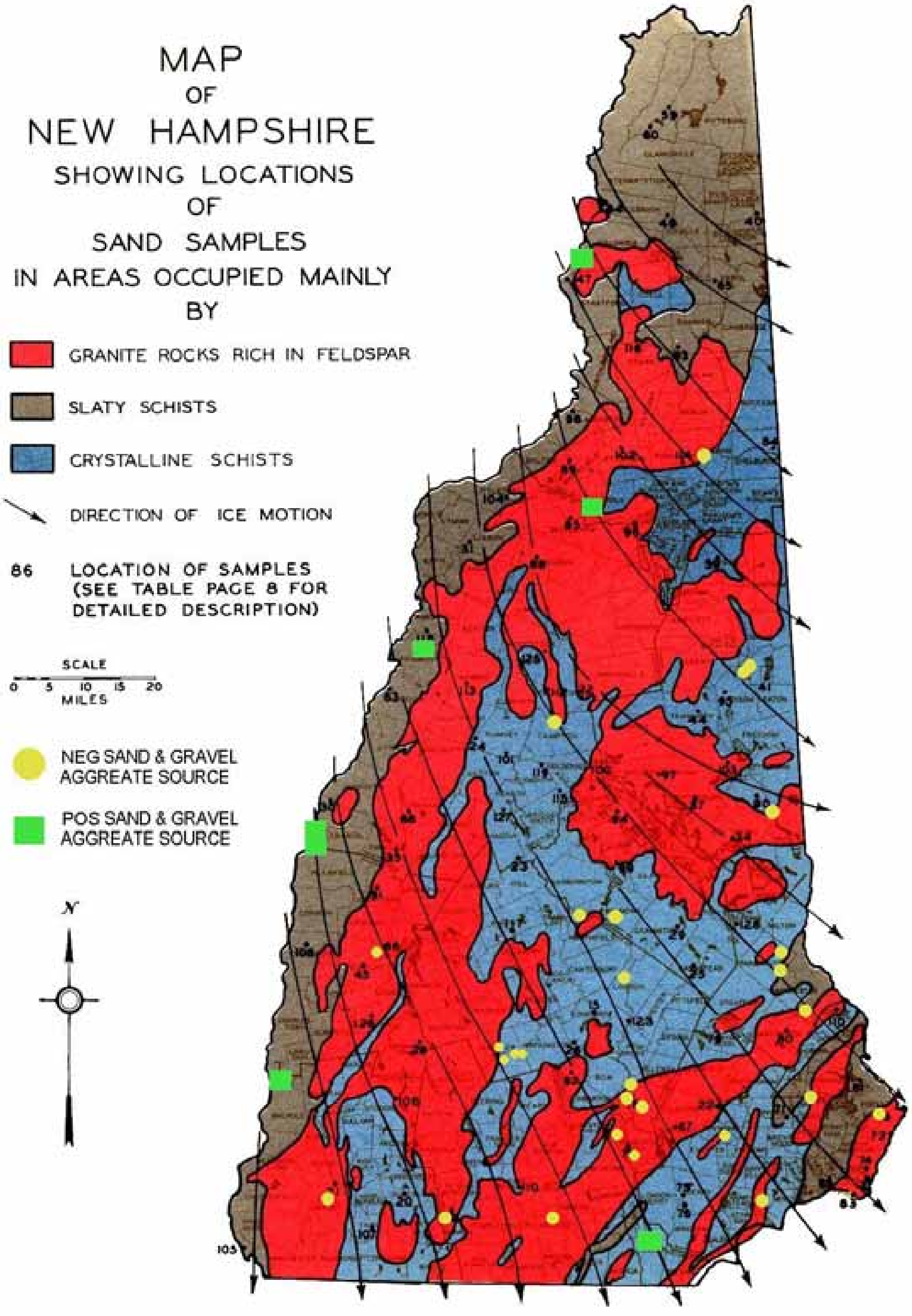
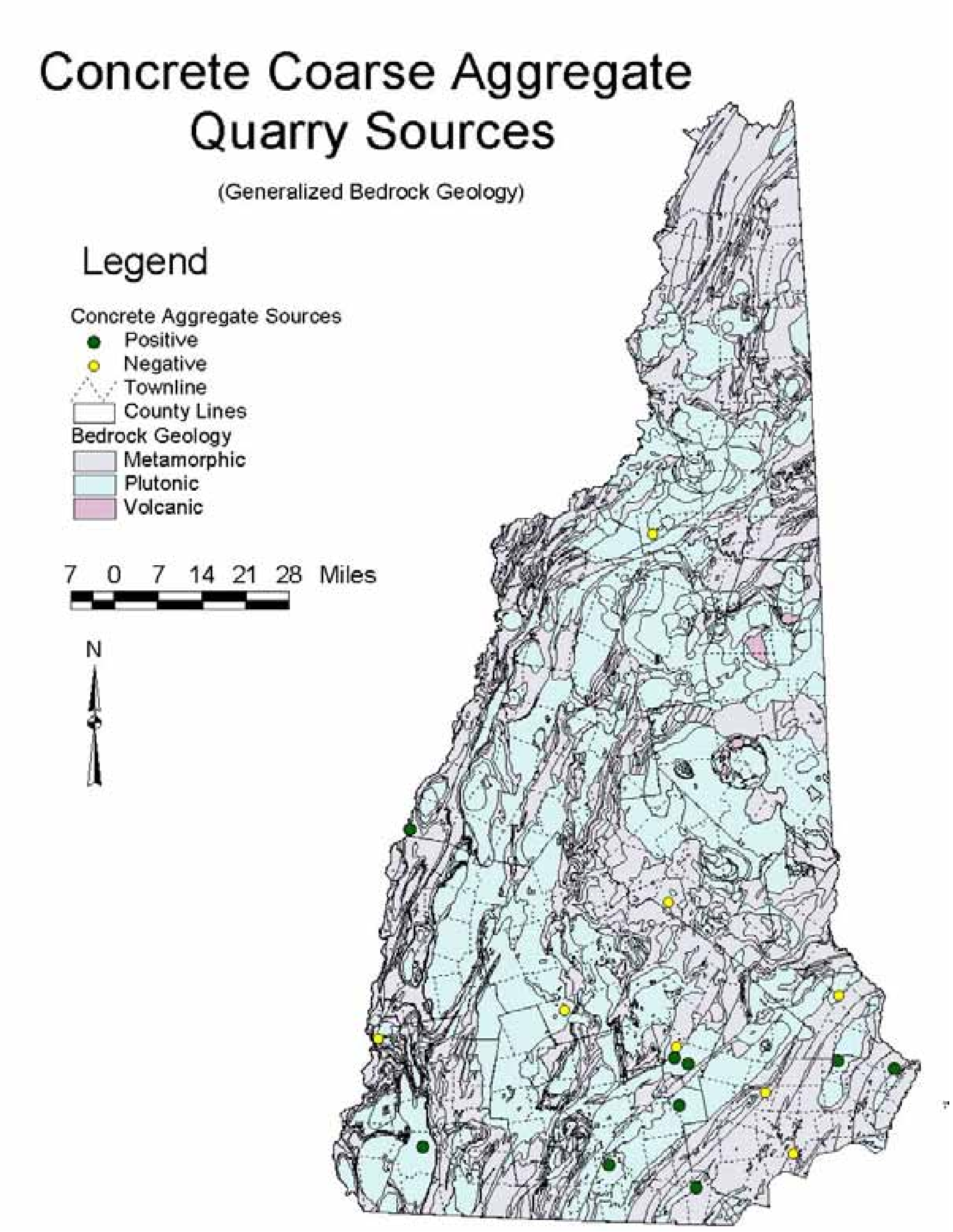
APPENDIX A - MAPS

Map 1 – Sand & Gravel Aggregate Sources
Map 2 – Concrete Coarse Aggregate Quarry Sources
Map 3 – Bridge Location Map



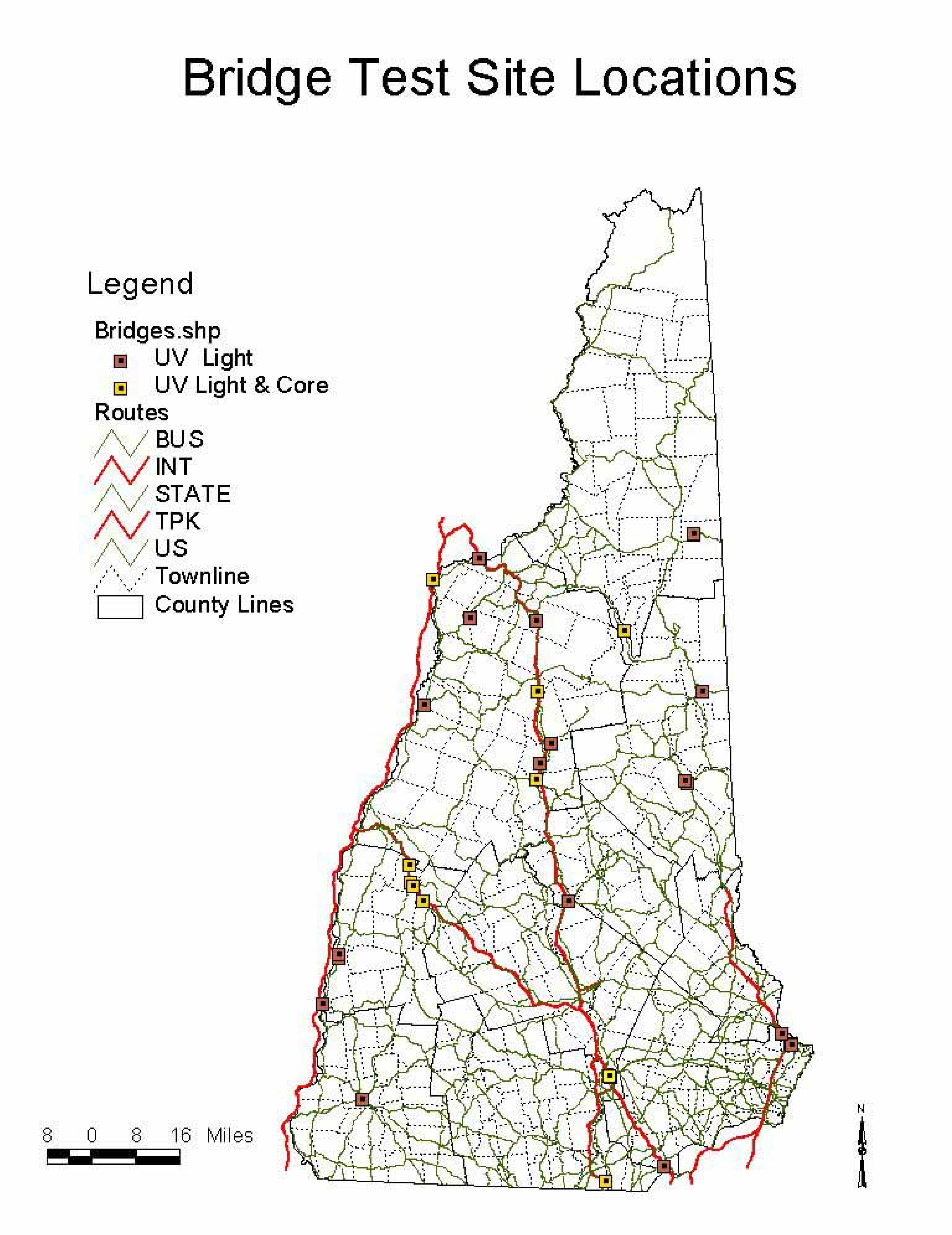
Map 1 – Sand & gravel aggregate sources

Sand & gravel aggregate sources (fine and coarse) with positive and negative ASTM C1260 results. Base map is taken from the 1948 Mineral Resource Survey (Goldthwait, etal).



Map 2 – Quarry aggregate sources

Quarry aggregate sources with positive and negative ASTM C1260 results. Base map is a generalized bedrock geology map *(9)* of New Hampshire (Lyons, etal).



Map 3 – Bridge Test Site Locations

Some location points may consist of multiple test sites.

APPENDIX B - TABLES

TABLE 1 – Alkali-silica Reactivity ASTM 1260 Aggregate Screening Research
TABLE 2 – Summary of Thin Section Analysis for All Positive ASTM 1260 Samples
TABLE 3 – Generalized Core Sample Analysis Results
TABLE 4 – ASR Testing of Selected NHDOT Bridges
(Uranyl Acetate UV Light Method)

Table 1 - Alkali-silica Reactivity ASTM C1260 Aggregate Screening Research

AGGREGATE SOURCE	**QUARRY OR PIT**		**14 DAY % EXPANSION**		**QUARRY- Rock Type PIT- Br**
	Fine	**Coarse**	**Fine**	**Coarse**	
Wilton, NH	Quarry A		0.074%		Q-Gneiss/Granite
Belmont/Loudon, NH	Pit #1	Quarry B	0.056%	0.065%	P-Br, Q-Schist/Granite/Pegmatite
Rochester, NH	Pit #2	Quarry C	0.041%	0.055%	P-Br, Q-Granite
Campton, NH	Pit #3	Pit #4	0.050%	0.062%	P-Br, P-Br
Farmington, NH	Pit #5	Pit #6	0.043%	0.040%	P-Br, P-Br
Raymond, NH	Pit #7	Quarry D	0.077%	0.040%	P-Br, Q-Granite/Grabbro
Conway, NH	Pit #8	Pit #9	0.059%	0.065%	P-Br, P-Br
Columbia, NH	**Pit #10**	**Pit #11**	**0.193%**	**0.150%**	P-Phyllite/Schist
Henniker, NH	Pit #12	**Pit #13**	0.056%	**0.091%**	P-Br, P-Br
Conway NH	Pit #14	Pit #15	0.058%	0.051%	P-Br, P-Br
Newport, NH	Pit #16	Pit #17	0.057%	0.047%	P-Br, P-Br
Swanzey/Westmoreland, NH	Pit #18	**Quarry E**	0.065%	**0.179%**	P-Br, Q-Quartzite/Amphibolite/ Gneiss/Phyllite
Walpole, NH	**Pit #19**	Quarry F	**0.145%**	0.050%	P-Br, Q-Schist
Loudon, NH	Pit #20	Pit #21	0.039%	0.053%	P-Br, P-Br
Manchester, NH	Pit #22	Pit #23	0.071%	0.056%	P-Br, P-Br
Henniker, NH	Pit #24	**Pit #25**	0.070%	**0.085%**	P-Br, P-Br
Gorham, NH	Pit #26	Pit #27	0.048%	0.047%	P-Br, P-Br
Wilton, NH	Pit #28	**Quarry G**	0.073%	**0.197%**	P-Br, Q-Serpentinite/Gneiss
Peterborough, NH	Pit #29	Pit #30	0.059%	0.067%	P-Br, P-Br
Henniker, NH	Pit #31	Quarry H	0.059%	0.073%	P-Br, Q-Quartz Monzonite w/ graphite intrusions
Hooksett, NH		**Quarry I**		**0.219%**	Q-Granite/Quartz Schist/ Pegmatite
Hudson, NH	**Pit #32**	**Quarry J**	**0.125%**	**0.109%**	P-Br, Q-Granitic Gneiss
Portsmouth, NH		**Quarry K**		**0.188%**	Q-Quartzite/Amphibolite/Basalt
Lebanon, NH	**Pit #33**	**Quarry L**	**0.290%**	**0.097%**	P-Br, Q-Amphibolite/ Gneiss/Meta-rhylolite
Manchester, NH	Pit #34	Quarry M	0.076%	**0.121%**	P-Br, Q-Granite
Manchester, NH	Pit #34	**Quarry M**	0.08%	**0.118%**	P-Br, Q-Granite
Henniker, NH	Pit #35	**Pit #36**	0.067%	**0.081%**	P-Br, P-Br
North Haverhill, NH	**Pit #37**	**Pit #38**	**0.138%**	**0.119%**	P-Br, P-Br
Newmarket, NH	Pit #39	**Quarry N**	0.063%	**0.175%**	P-Br, Q-Phyllite Schist
Ossipee, NH	Pit #40	Pit #41	0.043%	0.067%	P-Br, P-Br
Farmington, NH	Pit #42	Pit #43	0.038%	0.036%	P-Br, P-Br
Hooksett/Allestown, NH	Pit #44	Quarry O	0.069%	0.052%	P-Br, Q-Granite
Tilton, NH	Pit #45	Pit #46	0.058%	0.061%	P-Br, P-Br
Kingston, NH	Pit #47	**Quarry P**	0.059%	**0.084%**	P-Br, Q-Granite/Quartzite/Schist/ Rhylolite/Pegmatite
Lebanon, NH	**Pit #48**	Pit #49	**0.246%**	0.073%	P-Br, P-Br
Carroll, NH	**Pit #50**	Quarry Q	**0.132%**	0.050%	P-Br, Q-Gneiss

Aggregate considered potentially reactive, if the % expansion after 14 days is 0.10 % or greater.
Metamorphic rocks with % expansion after 14 days at 0.08 % to 0.099 %, may be potentially reactive.
Quarry-Rock type=Q-rock type, Pit-Bankrun Materials=P-Br

Table 2 – Summary of Thin Section Analysis for All Positive ASTM C1260 Samples

SOURCE	AGG (F/C)	QTZ (%)	ASR	ASR MINERAL ASSOCIATIONS	ASR ASSOCIATED FEATURES	ADDITIONAL MINERALS
Wilton, NH (Quarry A)	F	40	Moderate	Micro Qtz, Muscovite	Microcracks	Pl, Mu, Or, Cl, Bi
Lebanon, NH (Quarry L)	C	25	Slight	Qtz, Micro Qtz	Microcracks, Voids	Ho, B, Ch, Pl, Mu
North Haverhill, NH (Pit #37)	F	40	Slight	Qtz, Micro Qtz	Microcracks, Voids	Mi, Pl, Bi, Mu, Ho, Ch
Lebanon, NH (Pit #33)	F	50	Severe	Micro Qtz, Plag	Microcracks, Voids	Mi, Pl, Mu, Ho, Bi, Ch
Columbia, NH (Pit #10)	F	30	Slight	Qtz, Micro Qtz	Microcracks	Pl, Mu, Bi, Mi
Lebanon, NH (Pit #48)	F	55	Severe	Micro Qtz, Plag, Mica	Microcracks, Voids, Darkened Paste	Mu, Ho, Mi, Bi, Pl, Ch
Manchester, NH (Quarry M)	C	50	Severe	Micro Qtz	Microcracks	Mu, Pl, Or, Bi
Carroll, NH (Pit #50)	F	45	Slight	Micro Qtz	Microcracks, Voids	Pl, Mi, Mu, Bi
North Haverhill, NH (Pit #38)	C	60	Slight	Qtz	Voids, Darkened Paste, Microcracks	Pl, Mi, Mu, Bi, Ho, Ch
Columbia, NH (Pit #11)	C	40	Slight	Qtz, Micro Qtz	Voids, Darkened Paste, Microcracks	Mi, Pl, Mu, Bi, Ch, Ho
Portsmouth, NH (Quarry K)	C	15	Slight	Qtz, Micro Qtz	Voids, Darkened Paste, Microcracks	Ho, Mi, Pl, Bi
Walpole, NH (Pit #19)	F	45	Slight	Qtz	Microcracks, Voids	Ch, Bi, Mi, Mu, Pl
Hudson, NH (Pit #32)	F	50	Slight	Qtz	Microcracks, Darkened Paste	Pl, Mu, Mi, Bi
Wilton, NH (Quarry G)	C	40	Moderate	Qtz	Microcracks, Voids, Darkened Paste	Mu, Ch, Bi, Mi, Pl
New Market, NH (Quarry N)	C	65	Slight	Qtz, Micro Qtz	Voids, Microcracks	Bi, Mu, Ch, Pl
Westmoreland, NH (Quarry E)	C	50	Slight	Qtz	Microcracks, Darkened Paste	Ch, Mu, Bi, Pl
Hudson, NH (Quarry J)	C	65	Moderate	Qtz, Micro Qtz	Microcracks, Voids, Darkened Paste	Ch, Mu, Mi, Pl
Manchester, NH (Pit #34)	F	55	Slight	Qtz	Microcracks, Voids	Bi, Pl, Mu, Mi
Hooksett, NH Quarry I)	C	55	Moderate	Micro Qtz	Voids, Darkened Paste, Microcracks	Mu, Pl, Mi

Bi = Biotite, Cl = Chlorite, Ho = Hornblende, Mi = Microcline, Pl = plagioclase, Mu = muscovite, Or = Orthoclase

TABLE 3 – Generalized Core Sample Analysis Results

		Bridges								
Measured Parameters		**110/125**	**125/070**	**117/083**	**Salem**	**112/147**	**Plymouth**	**Frank**	**Swim**	**Grantham**
Visual Observations	**Cracking**	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
	Scaling	Yes	No	No	Yes	Yes	Yes	Yes	No	No
	Popouts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Staining	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes
	2^{ndy} Deposits	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Composition	GR / Mafic	GR / Meta	GR / Meta	GR	GR / AM	GR / Meta / QZ	QZ / GR	QZ	GR / AM / SH
	Grading	Sand – 1.5”	Sand – 0.5”	Sand – 0.5”	Sand – 0.5”	Sand - 0.75”	Sand – 2.0”	Sand – 3.0”	Sand – 2.0”	Sand – 0.75”
	Color Change	Yes	No	No	Yes	Yes	No	No	No	No
	Honey Combing	No	No	No	Mod - Heavy	Slight - Mod	Slight	No	No	No
	Deterioration	A/P Interface	No	Cracking	Rusty	Cracking	Brittle	Crumbling	A/P Interface	Sound
Stereo Observations	**Reaction Rims**	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
	Deter. Particles	Yes	No	No	No	No	Yes	No	No	No
	Hardness	Soft	Hard	Hard	Soft	Hard	Moderate	Soft	Hard	Hard
	Separations	Few	None	None	None	Yes	Yes	Yes	Yes	No
	Bleeding	Yes	Clear Gel	Clear Gel	Rust	None	Yes	No	Yes	No
	Carbonation	Yes	No	No	Yes	No	Yes	No	Yes	Yes
	Fractures	Yes	No	No	No	Yes / Large	Yes	Yes	Yes	Yes
	2^{ndy} Deposits	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Miscellaneous	Viscous Dep.	Viscous Dep.	Viscous Dep.	None	None	None	Appears WT	Appears WT	None
Thin Section Observations	**FA Comp.**	QZ, FS, MI	QZ, FS	QZ, FS	QZ, FS, MU	QZ, FS, MU	QZ, MU, FS,CL	BI, QZ, FS	QZ ,MU ,FS,BI	QZ, MI, FS,CL
	A/C Reaction	DP	RR	RR	Micro-cracks	Micro-cracks	Micro-cracks	Micro-cracks	Yes	Yes
	A Alteration	Cracking	No	No	DB	None	Cracking	Cracking	Cracking	Cracking
	CA Comp.	GR, Gneiss	GR / Meta	GR / Meta	GR	Mica Schist	Granite	RY	GR / Gneiss	GR/SH/AM
	A/C Reaction	DP	RR	RR	Micro-cracks	Reaction Rim	Micro-cracks	Micro-cracks	Yes	Yes
	Aggregate Alt	Cracking	No	No	DB	None	Cracking	Cracking	Cracking	Cracking
	Micro-cracking	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	CH	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
	Fractures (mm)	0.005 - 0.4	0.02	0.005 – 0.02	≤ 0.01	0.01 – 0.1	0.005 – 0.01	0.01	0.01 – 0.1	0.01 – 0.02
	Fracture Origins	QZ	QZ, Meta, CL	A/P/V/A	QZ, GR	Schist & QZ	QZ	QZ	A/P/A	QZ & GR
	2^{ndy} Deposits	CH, AS, ET	CH	AS, ET	AS, CH, CC	AS, ET	AS, CH, ET	AS, ET, CH	AS, CH	AS
	Void Frequency	Moderate	Numerous	Numerous	Numerous	Moderate	Few	Few	Moderate	Few
	Void Size (mm)	0.068 – 1.2	0.04 – 1.3	0.03 – 1.1	0.05 - 0.4	0.03 – 0.5	0.2 – 0.6	≤ 0.5	0.08 – 0.6	0.6
	Void Deposits	CH, ET, ASR	ET, AS	AS, ET	AS, CH, CC	AS, ET	CH, ET	ET, CH	AS, CH	AS, CH

__A__=Aggregate, __Alt__=Alteration, __AS__=Alkali Silica Gel, __AM__=Amphibolite, __BI__=Biotite, __CC__=Calcium Carbonate, __CH__=Calcium Hydroxide, __CL__=Chlorite, __Comp__=Composition, __DB__=Darkened Aggregate Boundries, __Dep__=Deposit, __Deter__=Deteriorated, __DP__=Darkened Paste, __ET__=Ettrignite, __FA__=Fine Aggregate, __C__=Cement, __CA__=Coarse Aggregate, __FS__=Feldspar, __GR__=Granite, __Meta__=Metamorphic, __MI__=Mica, __MU__=Muscovite, __P__=Paste, __QZ__=Quartz, __RR__=Reaction Rim, __RY__=Rhyolite, __SH__=Schist, __V__=Voids, __WT__=White.

Table 4 - ASR Testing of Selected N.H. Bridges Uranyl Acetate UV Light Method

TOWN	BRIDGE # (year built)	ROUTE	GENERAL CONDITION (type of structure)	ASR PRESENT	DESCRIPTION OF ASR GEL DEPOSIT
Campton	112/079 (1968)	I-93 S.B. over Blair Road	No visible cracks at test location (CRF)	Slight	Film over 10-15% of surface (fine aggregate)
Campton	113/078 (1968)	I-93 N.B. over Blair Road	No visible cracks at test site (CRF)	Slight	Film over 10-15% of surface (fine aggregate)
Campton	153/147 (1927)	NH Rte 175 over Mad River	Spalling and calcite deposits (ARCH)	Severe	North Side- film over 25-30% of surface (fine aggregate) South Side- film over 50% of surface (fine aggregate) A few granitic particles yellow green; microcracks between particles and peripheral band around portions of some coarse, dark mafic aggregates
Charlestown	076/090 (1930)	NH Rte. 12A/CURW over railroad	Extensive cracking, spalling and white precipitate; bridge very poor condition (CTB)	Slight	Yellow-green on several coarse dark mafic aggregates; a few white aggregate particles and small microcracks above and below one large dark coarse aggregate are greenish-yellow; all coarse aggregate particles are rounded gravel stone; only 3-5% of surface area is greenish-yellow
Charlestown	064/090 (1937)	N.H. Rte. 12A over Ox Brook	Site A- very fine hairline cracking Site B- Alligator cracking Older concrete- spalling and calcite deposits Bridge deck- spalling and exposed rebar (IBC)	Severe	Site A- film over 20-25% of fine aggregate matrix Sit B- Florescence on peripheral of many coarse aggregate particles and a few quartz particles Coarse aggregate is rounded gravel stone
Charlestown	243/045 (1970)	N.H. Rte. 12A/NH Rte. 12 & CURW overpass	Bridge deck shows reflection cracking; some spalling and calcium deposits (IBC)	Slight	Two coarse aggregates with bright greenish-yellow; florescence on peripheral of a few coarse aggregates; no florescence film on fine aggregate matrix
Conway	152/098 (1972)	US Rte. 302 over Saco River	No visible cracks (IBC)	Slight	Yellow-green in interior and peripheral band of few coarse aggregates; no background; most coarse aggregate particles are granitic and quartz
Franconia	134/085	Bike Path, Old US Rte 3	Severe map cracking (alligator cracking) and white precipitate (ARCH)	Severe	Bright yellow-green over 75% to 85% of surface; peripheral band around most coarse aggregates particles: in microcracks and interior of coarse aggregates
Grantham	117/083	I-89 NB bridge over NH Route 10	Some map cracking on both abutments; white precipitate exuding from some cracks (IBC)	Slight	Very minor florescence

TABLE 4 (continued)

TOWN	BRIDGE #	ROUTE	GENERAL CONDITION	ASR PRESENT	DESCRIPTION ASR GEL DEPOSIT
Grantham	125/070	Bridge over I-89	Map cracking on sidewalk and northwest facing bridge facies; white precipitate exuding from some cracks; core samples taken from sidewalk and facies (IBC)	Severe	UV test conducted on concrete cores only; some florescence on interior of coarse aggregates and reaction rims around some coarse aggregates; extensive florescence on portions of the cement paste; coarse aggregate particles are granitic and metamorphic rocks; a few voids lined with clear to milky white precipitates; a few small microcracks in matrix
Grantham	112/147	I-93 NB Bridge over Fyre Lane	Map cracking on abutments and wing walls; white precipitate exuding from some cracks (BOX)	Moderate	Florescence of fine aggregate matrix; peripheral bands around some coarse aggregate particles; ASR gel in microcracks in matrix
Harts Location	Railroad Bridge	Frankenstein Trestle	Tested southern abutment and southern pier; large rounded coarse aggregate particles; concrete in very poor condition; severe crumbling and spalling of concrete (C/S)	Severe	A few reaction rings around coarse aggregate particles and large section of matrix florescence
Keene	120/076 (1967)	NH Rte. 9/10/12 over West Street	Spalling upper center of northern abutment, rebar exposed; white precipitate (IBC)	Moderate	Peripheral of several coarse dark mafic aggregates (metamorphic rock ?); microcracks between coarse aggregate particles; several milky white quartz particles are greenish-yellow; estimated 15-20% of surface
Landaff	074/159 (1920)	Syms Noyes Road over Mill Brook	Large open cracks in abutments and underneath deck; large amount of white precipitate; cement is soft; soil washed out in southwestern corner (ARCH)	Moderate	Dull green over entire background (fine aggregate); a few coarse particles (quartz) are bright yellow-green; portion of periphery of one coarse aggregate particle
Littleton	104/136 (1981)	I-93 S.B. over Connecticut River	Some surface cracking (IBC)	Slight	Minor yellow-green in microcracks and a few coarse sand grain size quartz particles; estimated 5-10% of surface
Littleton	105/135 (1976)	I-93 N.B. over Connecticut River	Hairline surface cracks; overall good condition ((IBC)	Slight	Very weak light green film over small section of fine aggregate matrix; a few coarse sand size particles are greenish-yellow; less than 5% of surface
Littleton	109/134	Old bridge over Connecticut River	Large alligator cracks (8”-12”); spalling (IBC)	Severe	Peripheral of several coarse dark gray aggregate particles (metavolcanics) and in microcracks; also a few light colored coarse aggregate particles (granitic); estimated 15-20% of surface area

TABLE 4 (continued)

TOWN	BRIDGE #	ROUTE	GENERAL CONDITION	ASR PRESENT	DESCRIPTION OF ASR GEL DEPOSIT
Manchester	123/118 (1967)	I-93 N.B. viaduct over Stevens Pond	No visible cracks at test location; some white precipitate (IBC)	Moderate	Peripheral band around coarse dark mafic aggregates (gneiss?); in microcracks between aggregates; a few bright yellow-green spots interior of coarse aggregate particles (granite and quartz): esitimated 15-20% of surface
Manchester	124/119 (1967)	I-93 S.B. viaduct over Stevens Pond	No visible cracks at test location (IBC)	Moderate	Several coarse aggregate particles display peripheral yellow-green; some microcracks between coarse aggregates are greenish-yellow
Manchester	127/122 (1967)	I-93 S.B. viaduct over Stevens Pond	Fine alligator cracking (IBC)	Severe	Peripheral and interior of many coarse aggregates are greenish-yellow; microcracks between coarse aggregates; estimated 40-45% of surface; many of the coarse aggregates are light gray to brown granitic particles
Monroe NH/Barnet VT	110/125	Bridge over Connecticut River	Severe map cracking on both abutments and center pier; white precipitate exuding from cracks; severe cracking on center pier (C/S)	Moderate	A few coarse aggregate particles, florescence of cracks in the surrounding cement paste and sections of the fine aggregate matrix
Nashua-Hudson	157/059 (1973)	Circum. over Merrimack River	Very minor cracking at abutment corner; no spalling; minor white precipitate (IBC)	Severe	A dull green film over 30-35% of fine aggregate matrix; a few quartz or granitic particles are yellow-green
Newington	112/107 (1956)	Spaulding Turnpike over Woodbury Ave.	No visible cracks at test location; spalling and white precipitate at southern abutment (IBC)	Slight	Only a few specks of bright yellow green (quartz particles)
Ossipee	175/238 (1969)	NH Rte. 16 over NH Rte 25	Arcuate pattern leading to spalling; exposed rebar; white precipitate (IBC)	Severe	Yellow green film surrounds and intersects a cement like aggregate (15-20% of surface); greenish-yellow over fine aggregate matrix, estimated 50% of surface area
Ossipee	165/248 (1970)	NH Rte. 16 & 25 over old Routes 16 & 25	Some spalling; trace of white precipitate; a few pieces of rebar exposed (IBC)	Moderate	Yellow-green around old pieces of cement, not inside, 30-35% jigsaw pattern; two or three pieces of coarse sand to fine gravel size particles display greenish-yellow inside aggregate (quartz?); appears that ASR Gel interconnects old pieces of cement; no ASR Gel inside old cement; film covers 10-15% surface; dark mafic aggregate (5%) show no signs of ASR; most of the coarse aggregate is granitic or felsic

TABLE 4 (continued)

TOWN	BRIDGE #	ROUTE	GENERAL CONDITIONS	ASR PRESENT	DESCRIPTION OF ASR GEL DEPOSIT
Piermont	056/078 (1936)	NH Rte. 10 over Bean Brook	Longitudinal cracking on pier tested; some spalling on piers; white precipitate on deck; concrete guard rail and parapet wall severely deteriorated (CTB)	Slight	Two microcracks and one coarse aggregate particle are greenish-yellow; small portion of fine aggregate matrix is light green; estimated 5% of surface
Plymouth	Railroad Bridge	Bridge over Baker River	Tested southern abutment; cracks with some white precipitate (C/S)	Slight	Some reaction rims around coarse aggregate particles, florescence on portion of fine aggregate matrix and few small aggregate particles
Portsmouth	206/121 (1970)	I-95 N.B. over Woodbury Av	No visible cracks at test location (CRF)	Moderate	Light greenish-yellow peripheral band around some coarse, dark mafic aggregate particles
Portsmouth	206/122 (1970)	I-95 S.B. over Woodbury Av	No visible cracks at test location; minor white deposit western edge (CRF)	Slight to moderate	A few small aggregate particles and microcracks are bright yellow-green; film of florescence over matrix of fine aggregate
Portsmouth	205/116 (1950)	Woodbury Ave/ US Rte 1 Bypass overpass	A few long vertical cracks visible on abutment face; long cracks on deck (CRF)	Moderate	Site A- film over fine aggregate matrix with numerous specks of bright yellow-green Site B- film over some fine aggregate matrix; a few specks of bright yellow-green; peripheral band around one coarse aggregate particle
Salem		Bridge over I-93	Test conducted on a piece of concrete that fell off the bridge (IBC)	Moderate	Peripheral reaction rings with ASR gel around coarse aggregate particles; ASR gel in microcracks that cut across matrix.
Shelburne	075/110 (1973)	North Road over Androscoggin River	No visual cracking at test location; large near vertical crack at northeastern wing wall (IBC)	Moderate	Film over fine aggregate matrix; a few specks interior of coarse aggregate particles; minor peripheral of coarse aggregate particles and microcracks
Shelburne	075/113 (1900)	North Road over Androscoggin River	Severe spalling on wingwalls; large continuous horizontal cracks on piers; calcium deposits (IBC)	Severe	Dull green film over most of fine aggregate matrix, estimated 70-75% of surface; a few coarse aggregate particles show greenish-yellow around periphery and in interior; Granitic rock-peripheral; Metamorphic rock (gneiss or schist) - interior of aggregate particle; coarse aggregate is gravel stone up to 6 inches+ in diameter

TABLE 4 (continued)					
TOWN	**BRIDGE #**	**ROUTE**	**GENERAL CONDITION**	**ASR PRESENT**	**DESCRIPTION OF ASR GEL DEPOSIT**
Springfield	052/050	I-89 SB Bridge over Stony Brook Road	Longitudinal cracks on the top flange of prestressed concrerte girders; cracks run parallel to the longitudinal axis of the girders along their entire length; cracks in the exterior girders appear to be wider and more extensive than cracks in the interior girders (PSC)	Moderate to Severe	Reaction rims along the periphery of numerous coarse aggregate particles; extensive microcracking thorough the paste from aggregate particle to aggregate particle; one crack extending through a dark green, coarse aggregate particle (amphibolite or gneiss); reaction rim, infilling in the micro-cracks and a few aggregate particles fluoresced under UV light; the coarse aggregate particles along the main crack were fractured and weathered
Springfield	053/050	I-89 NB Bridge over Stony Brook Road	Longitudinal cracks on the top flange of prestressed concrerte girders; cracks run parallel to the longitudinal axis of the girders along their entire length; cracks in the exterior girders appear to be wider and more extensive than cracks in the interior girders; the main longitudinal crack in area of the test measured approximately .030 inches in width (PSC)	Moderate to Severe	The coarse aggregate particles are predominately dark colored metamorphic rocks (amphibolite, gneiss, shist) and some light colored igneous rocks (granites); reaction rims along the periphery of a few aggregate particles; few micro-cracks passing through paste and into coarse aggregate particles; reaction rims, in-filling in micro-cracks and portions of the fine aggregate matrix fluoresced under the UV light; some ASR gel filled micro-cracks originate in aggregate particles (quartz and granite) and extend through the surrounding paste to other aggregate particles; secondary deposits in voids consist of calcium hydroxide and ASR gel
Tilton	100/061 (1961)	US 3/ NH Rte. 11 over I-93	vertical cracking at base of columns, parallel with longitudinal dimension; some spalling (IBC)	Moderate	Dull green over 30% of fine aggregate matrix
Woodstock	Railroad Bridge	Swimming Hole Bridge over Pemigewasset River	Very soft concrete; large rounded, coarse aggregate particles; concrete crumbling; map cracking with white precipitate; severe spalling (C/S)	Severe	Florescence - reaction rings peripheral of coarse aggregates and inside of pop-outs; 85% of fine aggregate matrix yellow-green florescence

Note: The amount and intensity of florescence was assigned to one of three categories (slight, moderate, severe)

Type of bridge

- CRF = Concrete rigid frame
- CTB = Concrete T-beam
- IBC = Steel I-beam girder with concrete deck
- ARCH = Concrete arch
- Box=Concrete box
- PSC=Prestressed concrete girder
- C/S= Concrete abutments and/or piers with steel frame

APPENDIX C - PHOTOGRAPHS

ASR Bridge Photographs
Bridge Photo Micrographs
ASR Core and Concrete Sample – Bridge Photographs
ASR UV Light Photographs
Mortar Bar Photo Micrographs

ASR BRIDGE PHOTOGRAPHS

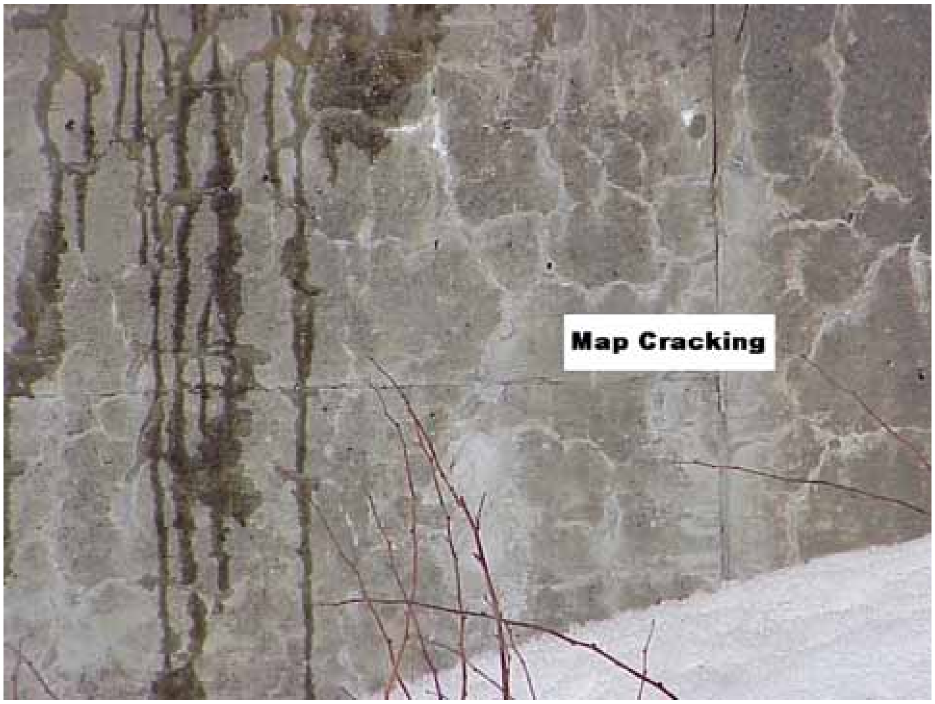


Photo 1 – Map cracking on wing wall, I-89 Northbound bridge over Frye Lane, Grantham, NH.

Photo 2 - Map cracking on facies, bridge over I-89 in Grantham, NH.

ASR BRIDGE PHOTOGRAPHS

Photo 3 - Map cracking on sidewalk, bridge over I-89 in Grantham, NH.

Photo 4 – Map cracking on bridge pier over Connecticut River in Monroe, NH.

ASR BRIDGE PHOTOGRAPHS (continued)

Photo 5 – Map cracking and deterioration of concrete on Connecticut River bridge pier in Monroe, NH.

BRIDGE PHOTOMICROGRAPHS

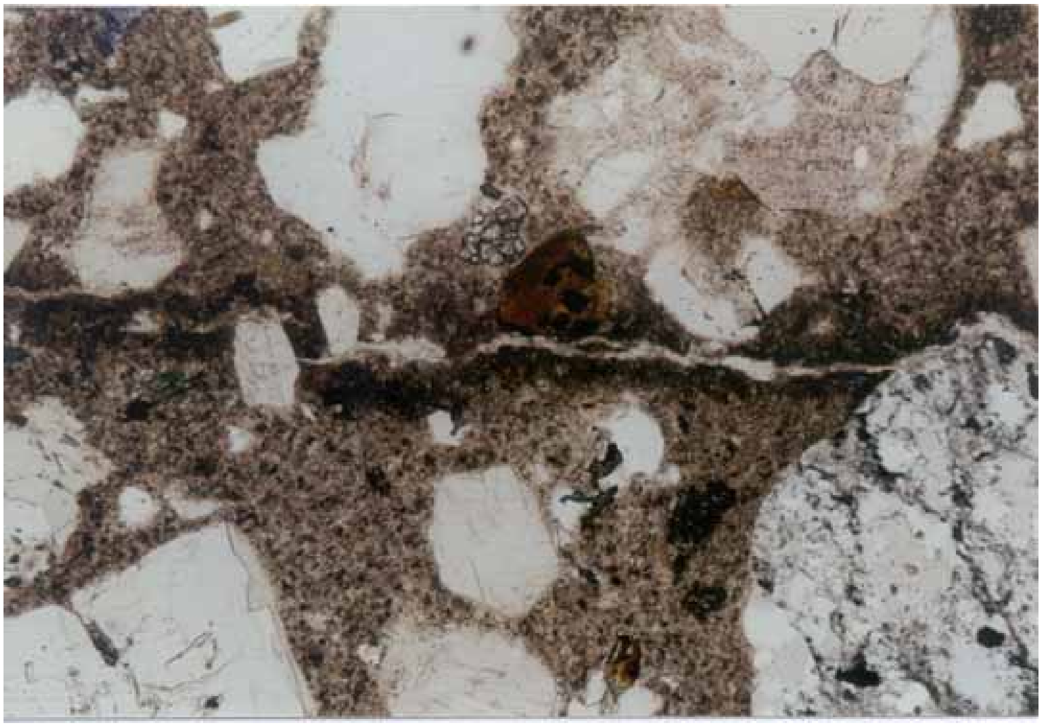


Photo 6 – Micro crack surrounded by darkened paste with crack extending from granite particle, through cement paste, into quartz particle and then continuing through concrete paste, plane light, 50X, bridge over Connecticut River in Monroe , NH.

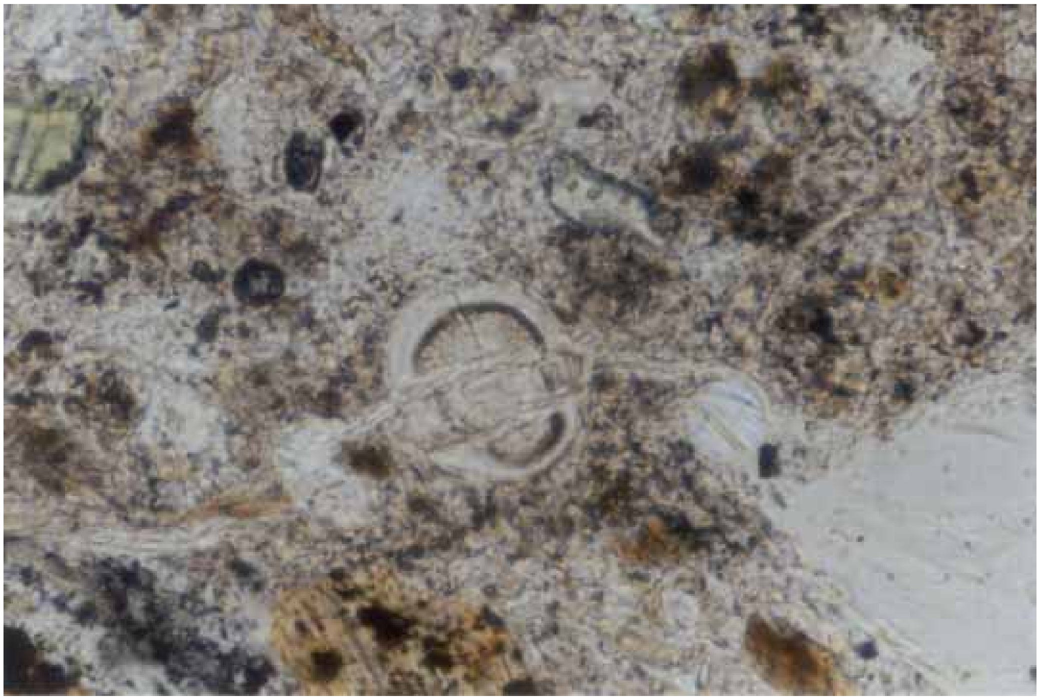


Photo 7- Micro crack extending from quartz particle, through cement paste, into ASR gel filled void and continuing through cement paste, plane light, 500X, Grantham NH.

BRIDGE PHOTOMICROGRAPHS (continued)

Photo 8 – ASR gel filled micro cracks extending from quartz particle into surrounding cement paste, plane light, 200X, southern abutment, Plymouth railroad bridge.

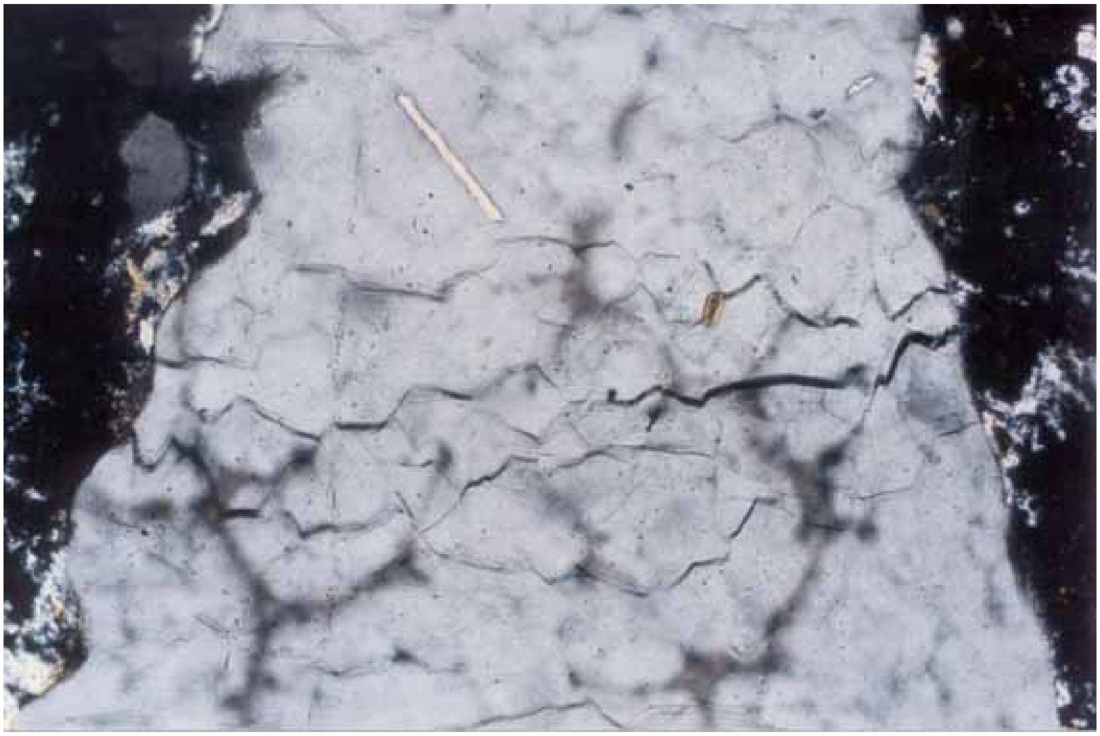


Photo 9 – Same as photo 8, cross-polarized light.

BRIDGE PHOTOMICROGRAPHS (continued)

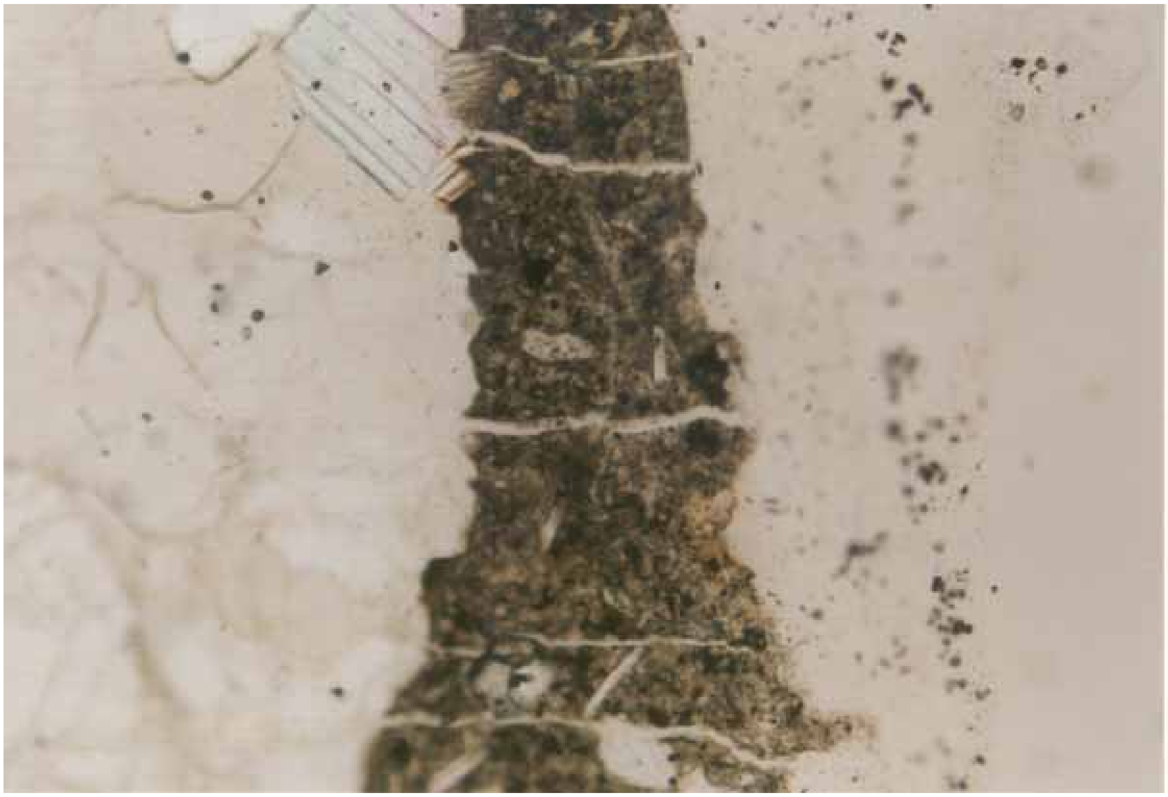


Photo 10 – Micro cracks filled with ASR gel and calcium hydroxide, cracks extending from granite particle, through cement paste and into another granite particle, plane light, 100X.

ASR CORE AND CONCRETE SAMPLE BRIDGE PHOTOGRAPHS

Photo 11 – Voids coated with precipitate having vitreous luster, stereoscopic view, 10X, I-89 southbound bridge over Stoney Brook Road in Grantham, NH.

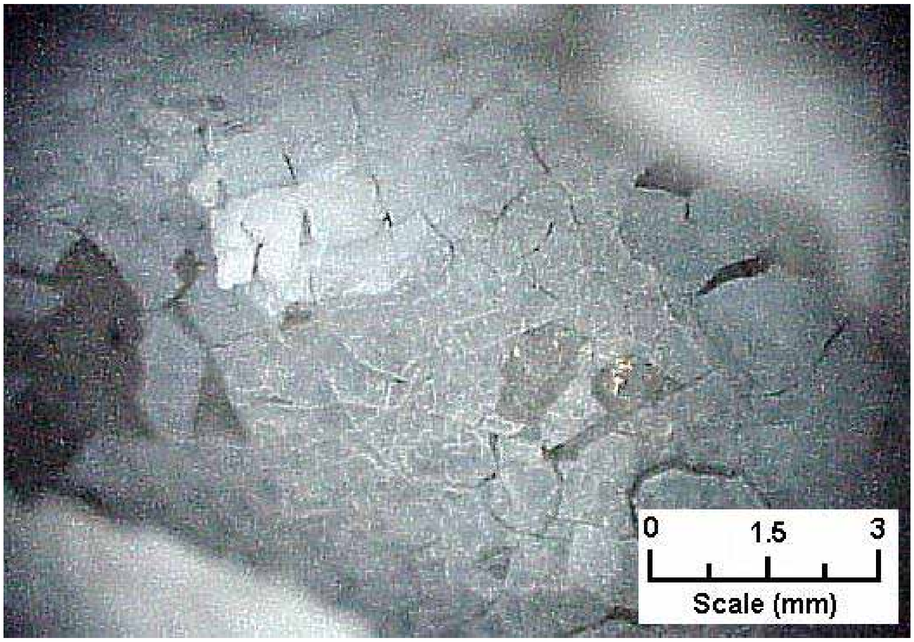


Photo 12 – Stereoscopic view of white to clear waxy precipitate lining void within cement core sample taken from Grantham Bridge (125/070) over I-89, 20X.

ASR CORE AND CONCRETE SAMPLE BRIDGE PHOTOGRAPHS (continued)

Photo 13 – White precipitate lining pop outs in concrete core taken from southern abutment of Swimming Hole Bridge over Pemigewasset River in Woodstock, NH.

ASR UV LIGHT PHOTOGRAPHS

Photo 14 – Reaction rims around aggregate particles in piece of concrete from bridge over I-93 in Salem, NH, plane light.

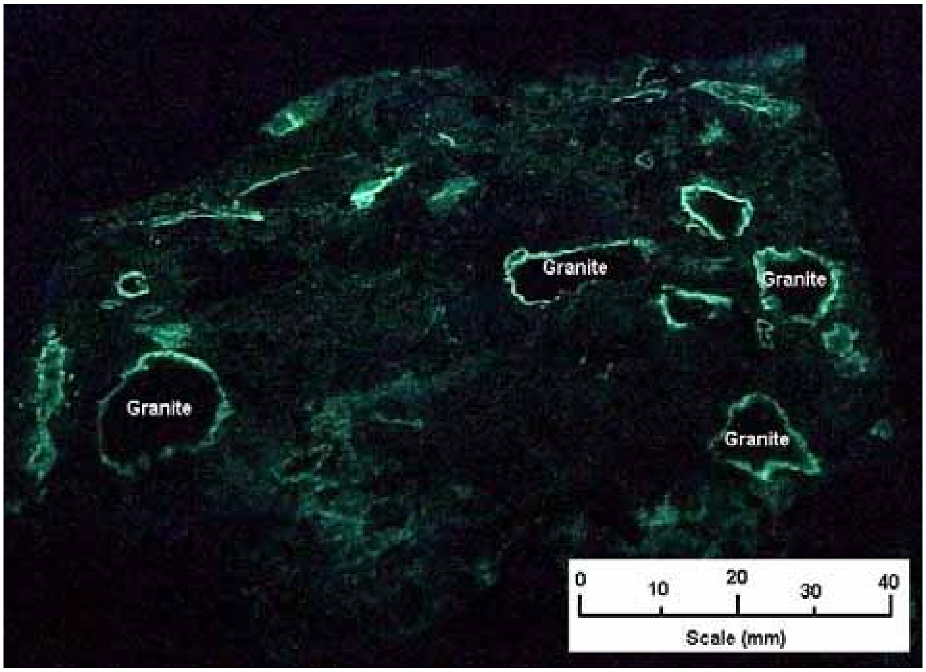


Photo 15 – UV light analysis on piece of cement from a bridge over I-93 in Salem, NH. Same concrete sample as shown in photo 14.

ASR UV LIGHT PHOTOGRAPHS (continued)

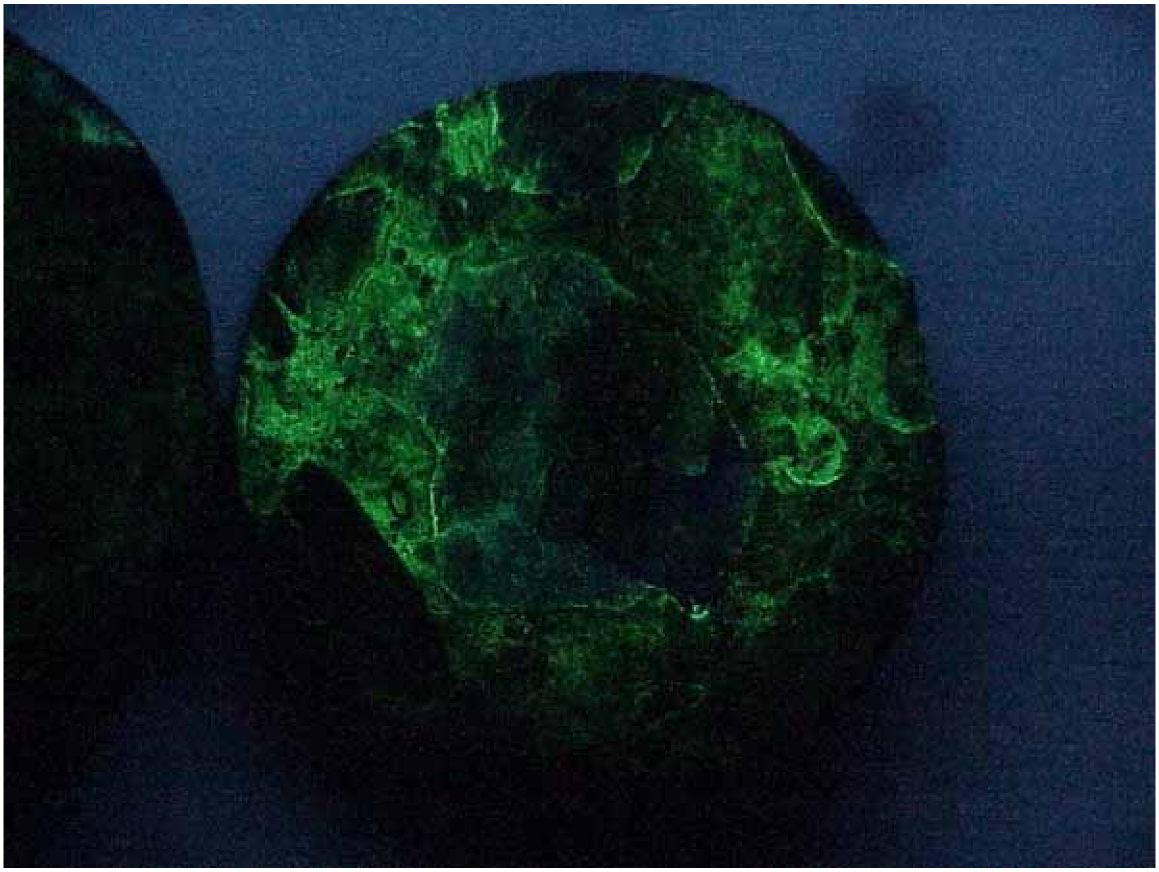


Photo 16 – Concrete core sample treated with uranyl acetate; concrete paste and rim around large aggregate particle fluoresce under UV light, I-89 bridge in Grantham, NH.

MORTAR BAR PHOTOMICROGRAPHS

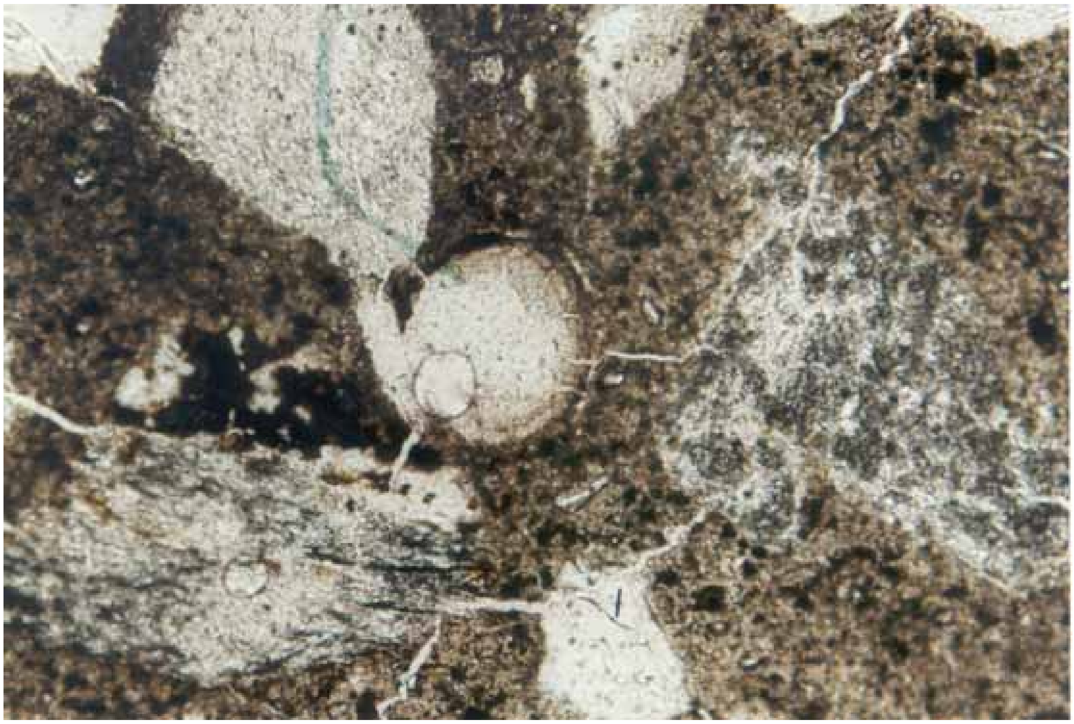


Photo 17 – Micro cracks extending from aggregate particles into cement paste and into ASR gel filled void, plane light, 50X, Pit #33, fine aggregate, Lebanon, NH.

Photo 18 – Micro cracks extending from aggregate particles (igneous and metamorphic rocks), through cement paste and into other aggregate particles, plane light, 50X, pit #33 fine aggregate, Lebanon, NH.

MORTAR BAR PHOTOMICROGRAPHS (continued)

Photo 19 – Micro cracks extending from granite and quartz particles into cement paste, plane light, 100X, pit #33 fine aggregate, Lebanon, NH.

Photo 20 – Same as photo 19 in cross-polarized light.

MORTAR BAR PHOTOMICROGRAPHS (continued)

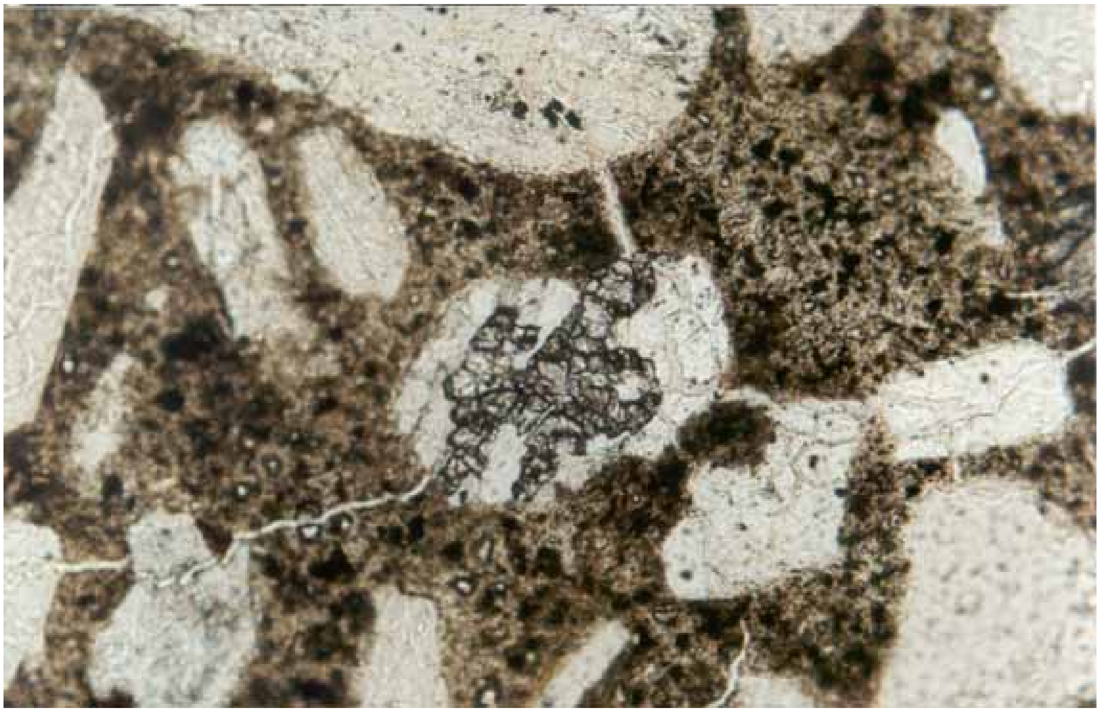


Photo 21 – Micro cracks extending from chemically altered quartz particle, into and through cement paste, into other quartz and granite particles, pit #33 fine aggregate, Lebanon, NH.

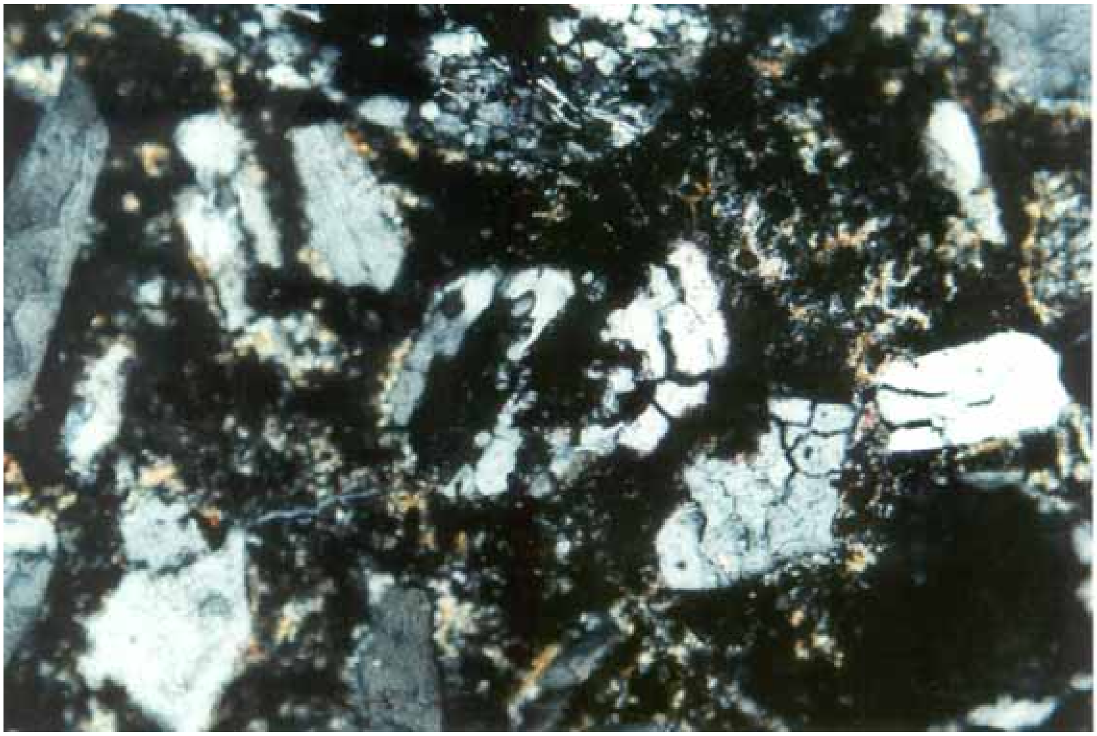


Photo 22 – Same as photo 21 in cross-polarized light.

MORTAR BAR PHOTOMICROGRAPHS (continued)

Photo 23 – Micro cracks in quartz and muscovite particles, through cement paste, plane light, 100X, quarry A, manufactured sand, Wilton. NH.

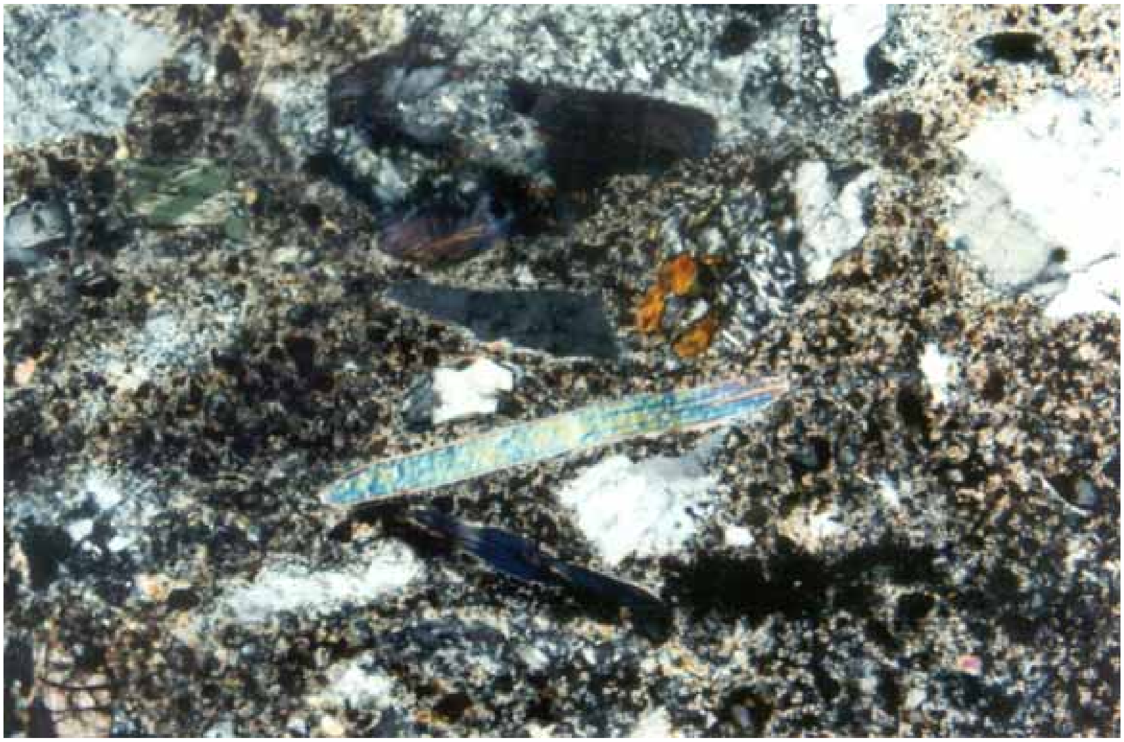


Photo 24 – Same as photo 23 in cross-polarized light.

MORTAR BAR PHOTOMICROGRAPHS (continued)

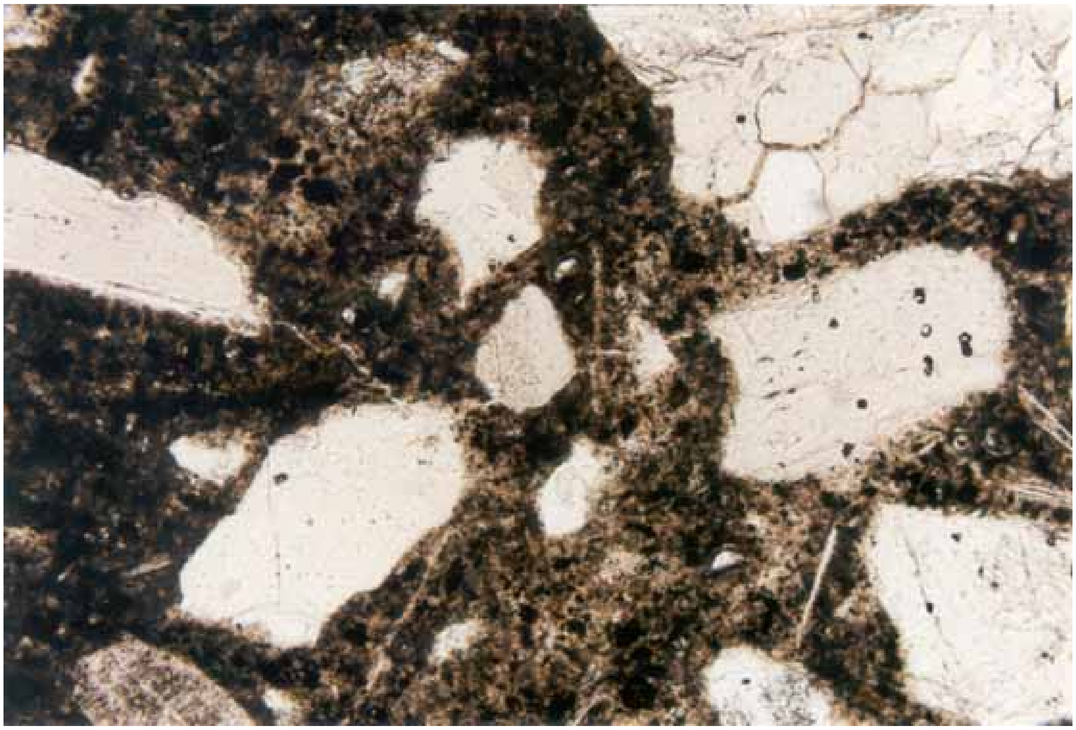


Photo 25 – Micro cracks in quartz, granite and muscovite particles traveling through cement paste, plane light, 200X, quarry J.

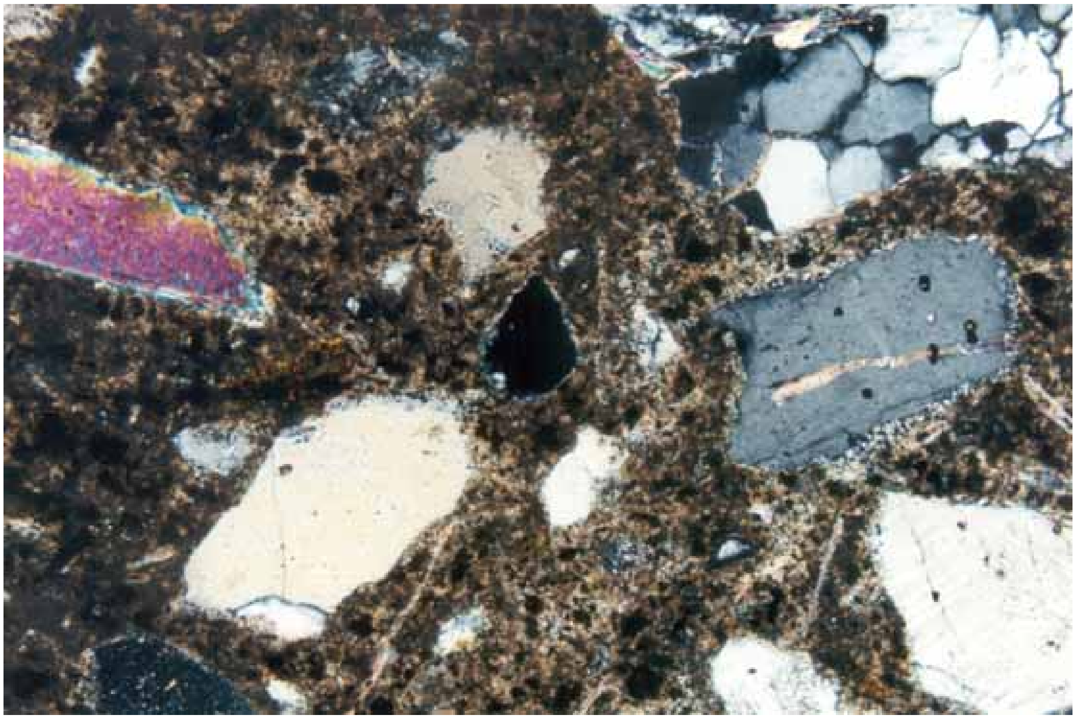


Photo 26 – Same as photo 25 in cross-polarized light.

MORTAR BAR PHOTOMICROGRAPHS (continued)

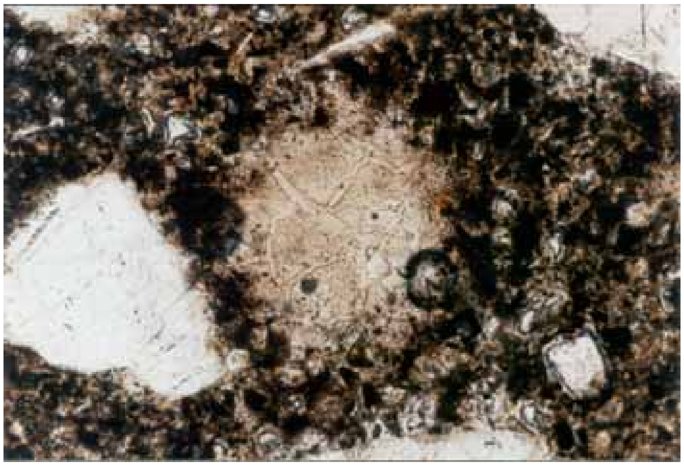


Photo 27 – ASR gel filled void, plane light, 200X, quarry J.

Photo 28 – Micro cracks and ASR gel in voids, cement paste and aggregate particles, plane light, 100X, quarry J, coarse aggregate.

Photo 29 – Micro cracks in cement paste, muscovite and granite aggregate particles, plane light, 50X, quarry M, coarse aggregate.

MORTAR BAR PHOTOMICROGRAPHS (continued)

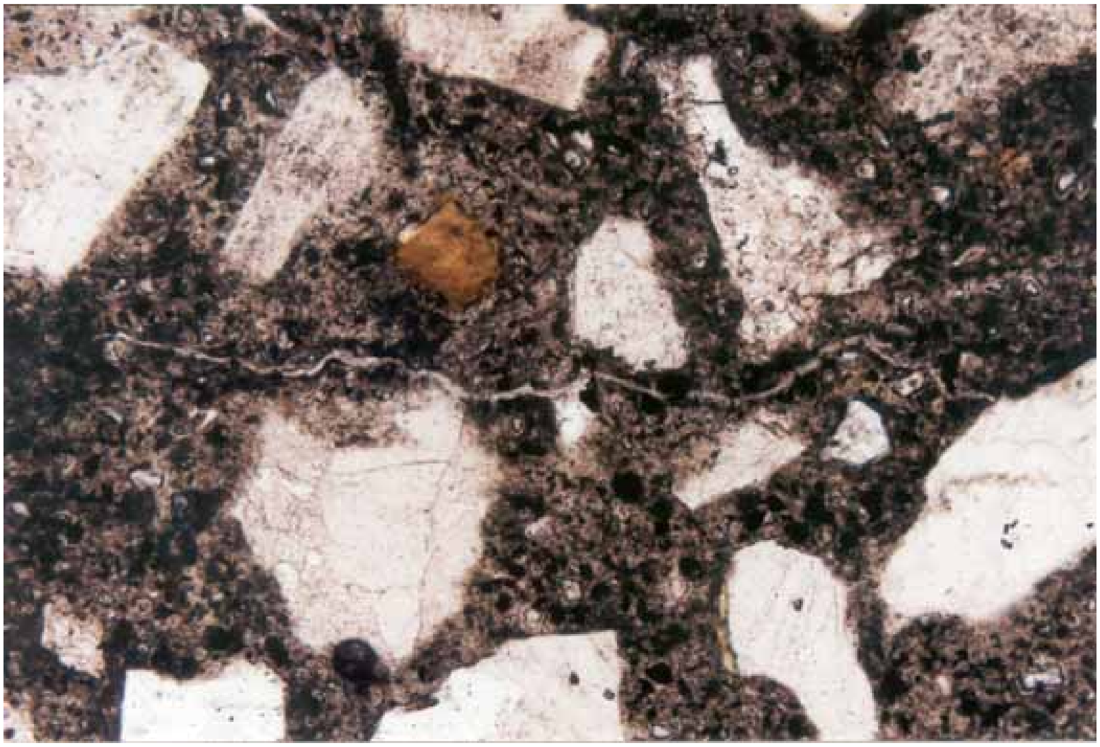


Photo 30 – Micro crack with darkened paste extending from quartz particle and traveling into cement paste, plane light, 100X, quarry G, coarse aggregate.

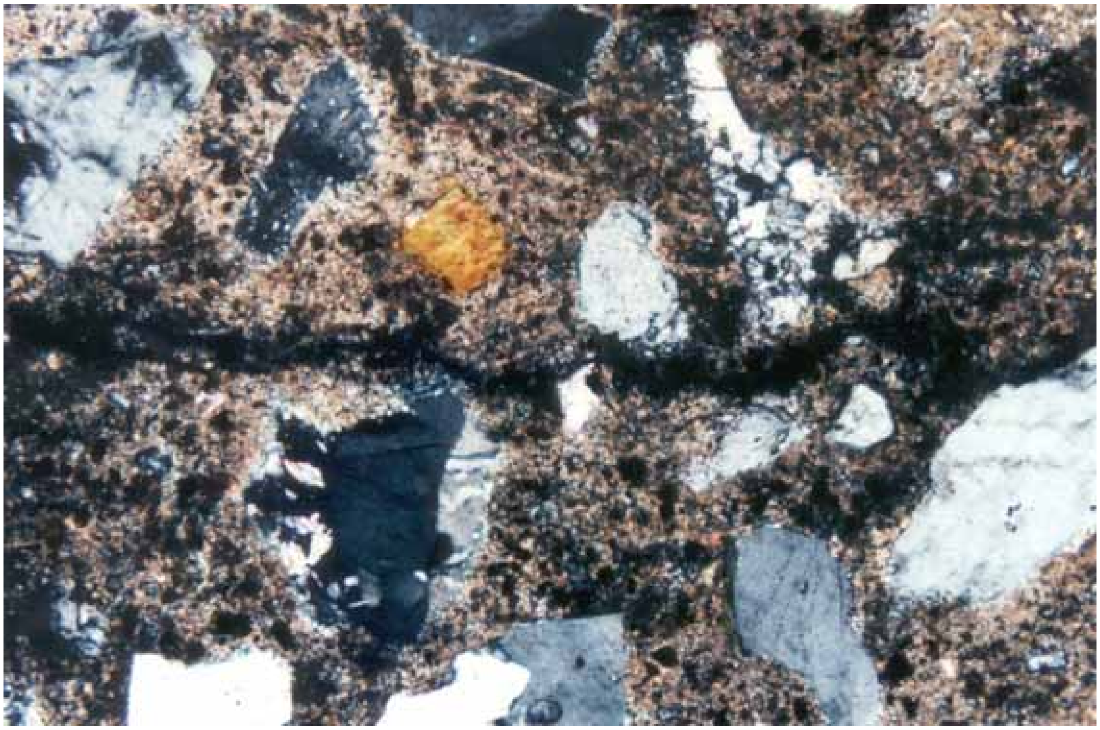


Photo 31 – Same as photo 30 in cross-polarized light.

MORTAR BAR PHOTOMICROGRAPHS (continued)

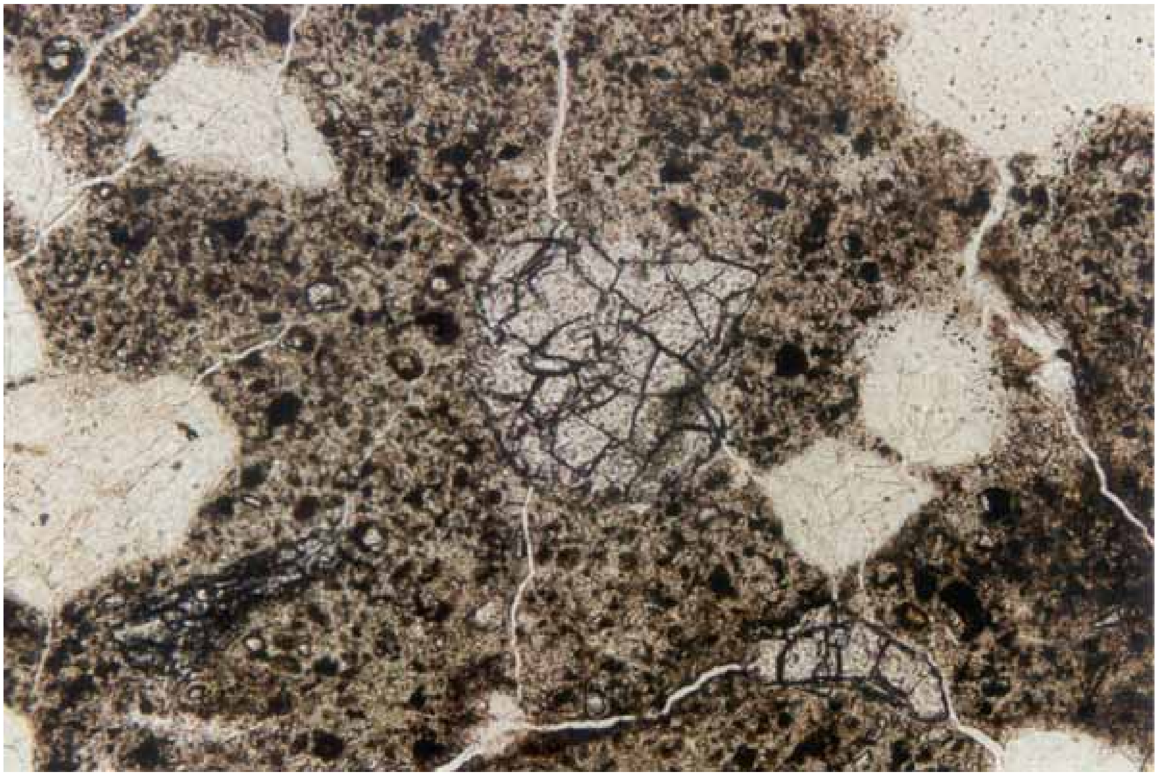


Photo 32 – Microcracks emanating from chemically altered aggregate into cement paste and quartz aggregate, plane light, 100X, pit #48, fine aggregate.