NEW HAMPSHIRE'S CONCRETE AGGREGATE AND ALKALI-SILICA REACTIVITY

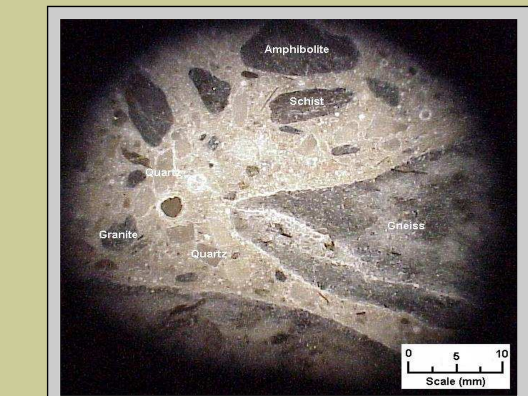
White precipitate exuding from map cracking of abutment wing wall, Frankenstein Trestle, Crawford Notch

White precipitate lining pop-outs Swimming Hole Bridge, Woodstock

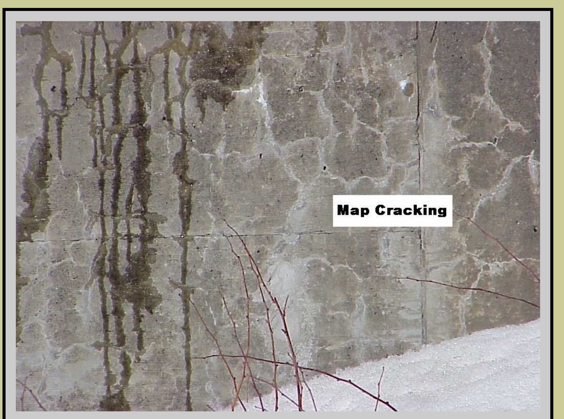
INTRODUCTION

Alkali-silica reactivity (ASR) expansion is a destructive, two-step physical/chemical process occurring in Portland cement concrete. 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 ASR gel absorbs moisture and swells, resulting in cracking, pop-outs, spalling, differential movement, and loss of strength in the concrete. These defects in turn allow chlorides and other contaminants to attack the reinforcing steel and promote the overall deterioration of the structure.

ASR is a major concern with regard to long-term durability of concrete structures in New Hampshire. Many existing 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 expansion of the concrete. The three conditions that must be met for deleterious ASR expansion to occur are a reactive form of silica in the aggregates, sufficient alkali and available moisture. All three are readily available throughout the state.



Stereoscopic view on polished surface; micro-cracking extending from coarse aggregate particle through paste and void into another coarse aggregate particle



Wing wall map cracking I-89 Northbound, Grantham

PHASE 1 OBJECTIVES

- Determine the potential for the development of ASR in concrete made with New Hampshire aggregates
- Confirm the presence and extent of ASR in existing NHDOT concrete structures
- Identify the types of rocks in New Hampshire that are potentially ASR reactive

PHASE 1 FINDINGS

- ASTM C1260 accelerated mortar bar testing showed approximately 25% of the concrete aggregates within New Hampshire are potentially reactive
- The uranyl acetate UV-light method confirmed the presence of ASR gel in many of the existing NHDOT bridges
- Thin section analysis of concrete cores taken from some NHDOT bridges verified the existence of expansive ASR gel at the microscopic level

Polarized-light microscope, used to conduct petrographic analysis

UV-light box used to detect ASR gel after freshly fractured concrete surface is sprayed with uranyl acetate

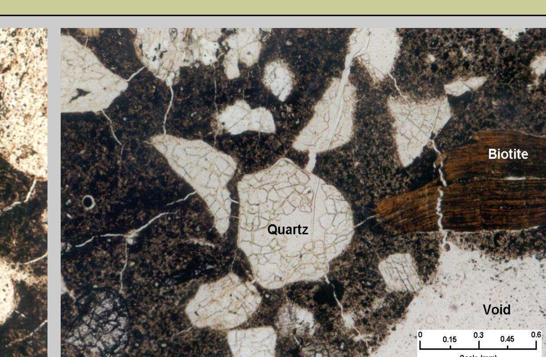
PHASE 2 OBJECTIVES

- Evaluate different admixtures for their effectiveness in mitigating the development of ASR in concrete made with reactive New Hampshire aggregates
- Verify the minimum amounts of admixture(s) needed to reduce ASR expansion to less than 0.1% in concrete made with reactive NH aggregates

PHASE 2 FINDINGS

- The ASTM C1260 accelerated mortar bar testing and petrographic thin section analyses showed that ASR expansion in concrete made with the most reactive NH aggregates can be successfully mitigated with admixtures.
- Cement replacement of 20% Class F fly ash or 50 to 60% Ground Granulated Blast-Furnace Slag (GGBFS) reduced the ASTM C1260 expansion to less than 0.1% in cement with the most reactive NH aggregate.
- A higher dosage (35%) of Class C fly ash is required to mitigate the same reactive aggregate.
- Ternary cements and 15% cement replacement with metakaolin were effective in mitigating ASR.
- Silica fume blended cement was effective in reducing ASR expansion below 0.1% with some reactive aggregates, but not with the most reactive NH aggregates.
- The type of aggregate and the alkali level in the cement, both affect the minimum levels of admixtures needed to successfully mitigate ASR.

Micro-cracks extending from aggregate particles through cement paste and into other aggregate particles



Mortar bar photomicrograph showing ASR gel filled micro-cracks extending through aggregate particles and into surrounding cement paste

Viewing concrete surface through UV-light box

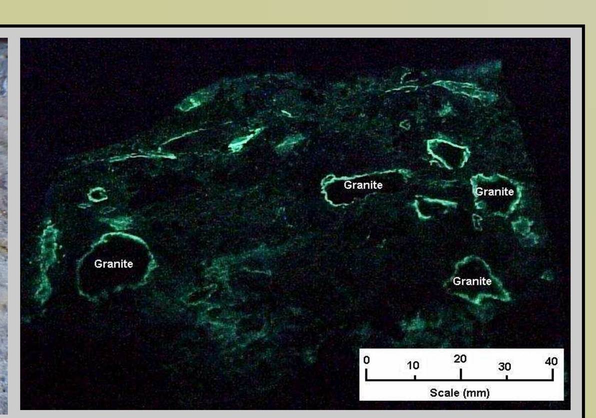
BENEFITS

This study has identified ASR aggregate sources in New Hampshire. The Department now avoids their use in its concrete structures.

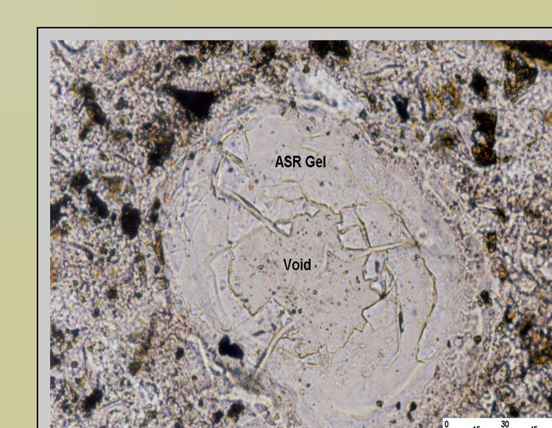
Avoidance can be costly when the desired non-reactive aggregates are not locally available. The Department also has the alternative of controlling the reactivity of aggregates by utilizing mitigating admixtures in its concrete mixes.

Diminishing the development of ASR distress in new concrete in New Hampshire will help to preserve the design life and reduce repairs to transportation structures, resulting in significant cost savings.

Reaction rims around aggregate particles in concrete from I-93 bridge, Salem



ASR gel deposits in peripheral bands around some aggregate particles exhibit florescence under UV light



Plane light, 500X magnification ASR-filled void

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