GREAT FALLS CIVIC CENTER FRIEZE VENEER REPORT

MALISANI INC.

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Malisani Inc. Installation Report

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DATE: 11/28/2016

TO: **MR. GREGORY T. DOYON, GREAT FALLS CITY MANAGER**

FROM: TONY MALISANI, MALISANI INC

RE: GREAT FALLS CIVIC CENTER FRIEZE/INSTALLATION REPORT

Mr Doyon:

As specified we removed one piece of the exterior veneer from the entrance frieze of the Great Falls Civic Center. The installation of this piece had no masonry anchorage or vertical restraints. Please see photos 1, 3 and 4. The cladding was set in a concrete mortar with no attempt to adhere the piece to the substrate. Please see photo 2.

We cut a one inch section from the piece and submitted that for petrographic analysis to Minerology Inc. The completed report is contained on pages two through sixteen. Included with this report are three samples of the cladding material as was submitted for testing.

Sincerely,

Tony Malisani

Minerology Inc. Report

Great Falls Civic Center

Job # CGF-4418

Concrete Core Evaluation

Requested by:
Tony Malisani
Malisani, Inc.

Mineralogy, Inc. Number 16296

Date: November 15,

2016 Submitted by:

Timothy B. Murphy

Mineralogy, Inc.
3321 East 27th Street
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Introduction

A single concrete slab section from the Civic Center located in Great Falls, MT has been submitted for petrographic analysis in order to evaluate the mix design properties and cohesive integrity of the concrete. The investigation has included x-ray diffraction and thin section petrography. The XRD test method evaluates the crystalline mineral composition and has been applied for both the topping cement layer and concrete substrate materials from this slab section. The thin section petrographic analysis has been preformed in general accordance with optical microscopy techniques set forth in ASTM C856 (Standard Practice for the Petrographic Examination of Hardened Concrete).

Summary

The principle findings of the concrete slab investigation are summarized as follows:

- The slab section consists of a 4" wide X 3.75" high X 1" thick rectangular block of concrete provided from an undisclosed location within the Civic Center structure. The cross section is capped by a white to yellow-gray topping cement layer overlying

light to medium gray concrete substrate materials containing an abundance of granule to pebble-sized igneous rock fragments (RFs).

- The topping cement layer is ~ 16 mm thick, porous, well consolidated, and well adhered to the concrete substrate. The topping cement exhibits an aggregate composition dominated by marble RFs coupled with minor amounts of limestone and chert. The cement paste is white & contains significant amounts of calcium aluminate + microcrystalline calcite. The exposure surface of the topping cement materials exhibits a ICRI CSP 5 profile with parallel ridges and troughs indicative of shot-blast surface preparation.
- The concrete substrate materials that underlie the topping cement layer are ~ 80 mm thick, porous, grain-supported, granule & pebble-rich, very poorly sorted, and well consolidated. The aggregate fraction is dominated by igneous RFs together with subordinate amounts of chert, silty-shale, quartzite, quartz and feldspar.
- No indications of alkali silica aggregate corrosion or cohesive strain related to expansive aggregate deformation are indicated within either the topping cement or concrete substrate materials within this slab.
- Patchy carbonation of the paste materials occurs throughout the thin section and locally penetrates to depths that locally exceed 25 mm BTC (below top of the core).
- The contact surface between the topping cement and the concrete substrate is sound and well-knit together. No indications of detachment stress are evident in the macroscopic slab or petrographic thin section.
- Macroporosity is visually estimated to range form ~15-20% within the topping cement and substrate materials from this slab. The widespread distribution of airentrapment macropores suggest that the concrete substrate and topping cement materials are relatively permeable. In the absence of a sub-slab vapor barrier, the concrete substrate & topping cement materials are capable of transmitting significant amounts of moisture vapor into the building envelope.

X-ray Diffraction

The results of the x-ray diffraction mineralogical analysis are summarized in Table I. The topping cement and concrete substrate materials were analyzed separately given the contrasts in color & aggregate composition. The topping cement exhibits a calciterich mineralogy (~58%), with modest amounts of quartz (11%), feldspar (including albite and microcline; 10%), dolomite (4%), and amorphous material (10%). Minor amounts of portlandite, calcium aluminate, larnite, alite, and ettringite are also present as cement components. The mineralogy of the concrete substrate is dominated by feldspar [including albite (35%) and microcline (12%)]. The substrate also contains significant amounts of amorphous material (volcanic glass + non-crystalline calcium silicate hydrate; 20%), quartz (17%), clay minerals and mica (5%), calcite (4%), augite (3%), and magnetite (1%). Minor crystalline phases present in the concrete substrate include portlandite, calcium aluminate, and alite.

Table I

	Sample ID	Topping Cement	Concrete Substrate
	Lab ID	16296-01A	16296-01B
Mineral Constituents	Chemical Formula	Relative Abundance (%)	
Quartz	SiO_2	11	17
Albite	$(Na,Ca)AlSi_3O_8$	7	35
Microcline	$KAlSi_3O_8$	3	12
Calcite	$CaCO_3$	58	4
Dolomite	$(Ca,Mg)(CO_3)_2$	4	
Augite	$Ca(Fe,Mg)Si_2O_6$		3
Magnetite	alpha-Fe_3O_4		1
Portlandite	$Ca(OH)_2$	2	1
Alite	Ca_3SiO_5	1	1
Larnite	beta-Ca_2SiO_4	2	
Calcium Aluminate	$CaAl_2O_4$	2	1
Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 25H_2O$	<0.5	
Clay Minerals / Mica			5
Amorphous		10	20
TOTAL		100	100

Thin Section Petrography

The thin section petrographic analysis provides a microscopic evaluation of the mineralogy, texture, and fabric of the concrete in general accordance with optical microscopy techniques described in ASTM C856 (Standard Practice for the Petrographic Examination of Hardened Concrete). Images of the polished slab as well as representative photomicrographs for the thin section sample prepared for this slab are provided in Appendix I. The following discussion highlights the most significant findings of the petrographic analysis.

Core ID	Sample 1
Lab ID	16296-01
ICRI Surface Profile	CSP 5
Carbonation Depth (mm)	>25 mm BTC
Water / Cement Ratio	~ 0.50

Air-Entrapment Macroporosity (%)	~15-20%
Aggregate / Cement Ratio	~ 3.8 / 1

Macroscopic Core Properties

The subject specimen consists of a rectangular block of concrete [~4" wide X 3.75" high X 1" thick (10 cm X 9.5 cm X 2.5 cm)]. The slab section includes a topping cement layer that is white to light to yellow gray (N9 to 5 Y 8/1) that overlies a concrete substrate material with dark gray to reddish brown igneous RFs cemented with a matrix of very light gray (N8) portland cement. Both the topping cement and concrete substrate are porous and contain significant amounts of intergranular (air-entrapment) macroporosity. The upper surface of the topping cement exhibits a CSP 4-5 profile with parallel ridges and troughs attributed to shot-blast surface preparation. Carbonation is extensive throughout the slab section owing to the porous nature of the concrete substrate. Carbonation penetrates to depths that exceed 25-30 mm below the top surface of the concrete. No embedded steel is present in this concrete sample. The base of the slab is granular with no indications of a sub-slab vapor barrier. It is not clear if this macroscopic section of concrete comprises a full or partial cross section of the Civic Center slab.

Fabric & Texture

The aggregate materials in the topping cement are coarse-grained, poorly sorted, subangular, and grain-supported. The cement paste materials are microcrystalline to very finely crystalline and are well-adhered to the aggregate grain surfaces. The maximum aggregate grain diameter within the topping cement materials is ~6.3 mm . The concrete substrate is grain-supported, coarse-grained, very poorly sorted, granule and pebble-rich, and macroporous. The maximum grain diameter of the concrete substrate materials is ~19 mm.

Aggregate

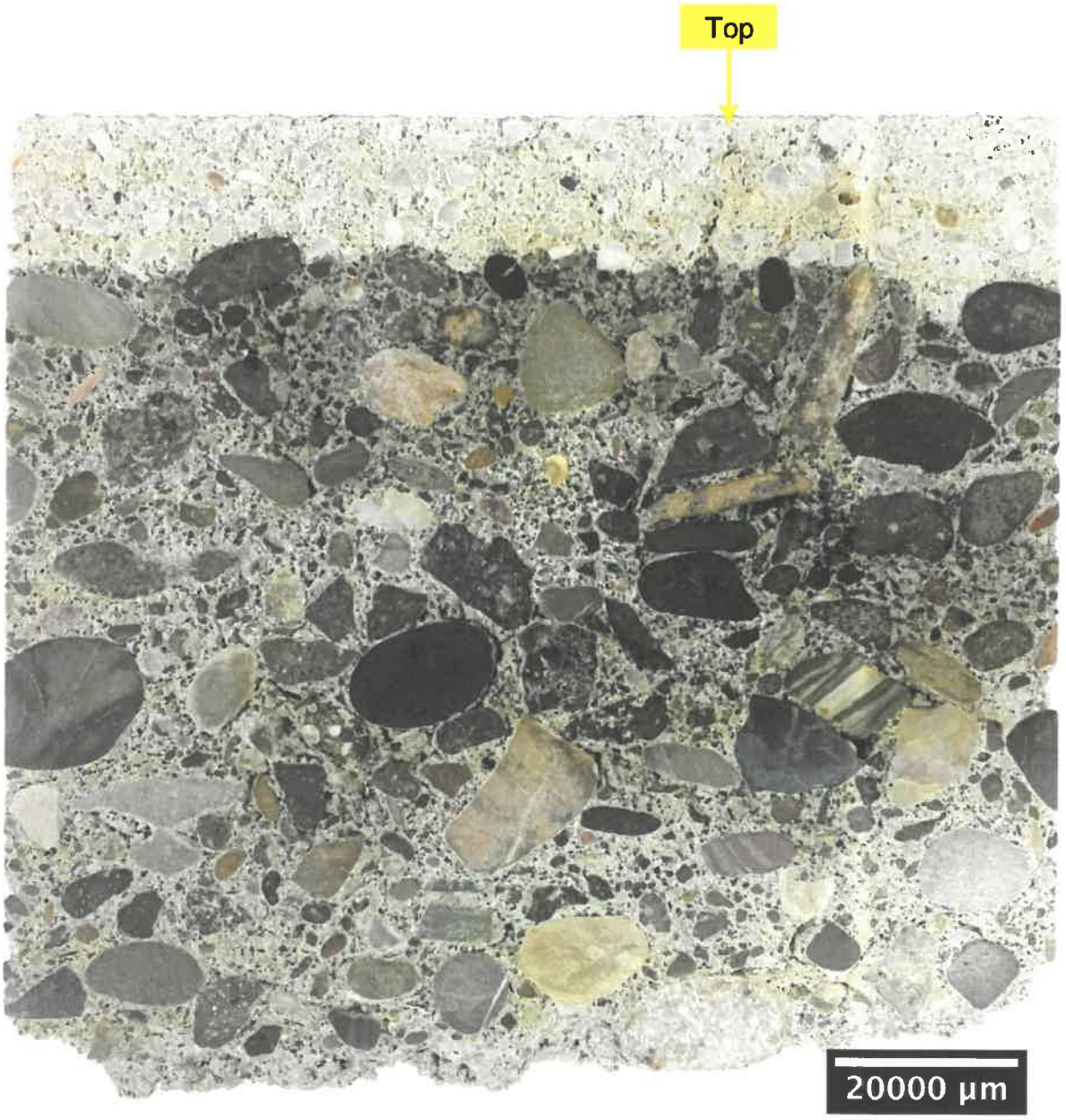
The topping cement materials exhibit an aggregate fraction that accounts for ~65-67% of the bulk volume and is dominated by marble and limestone RFs coupled with minor amounts of chert and granite RFs. The sand fraction (within the topping cement) includes quartz, marble, chert, and feldspar. In contrast, aggregate materials within the concrete substrate account for ~59-61% of the bulk volume, with coarse aggregate fraction dominated by igneous RFs. Chert, silty shale, metaquartzite RFs, coupled with quartz and feldspar sand grains are also present within the concrete substrate.

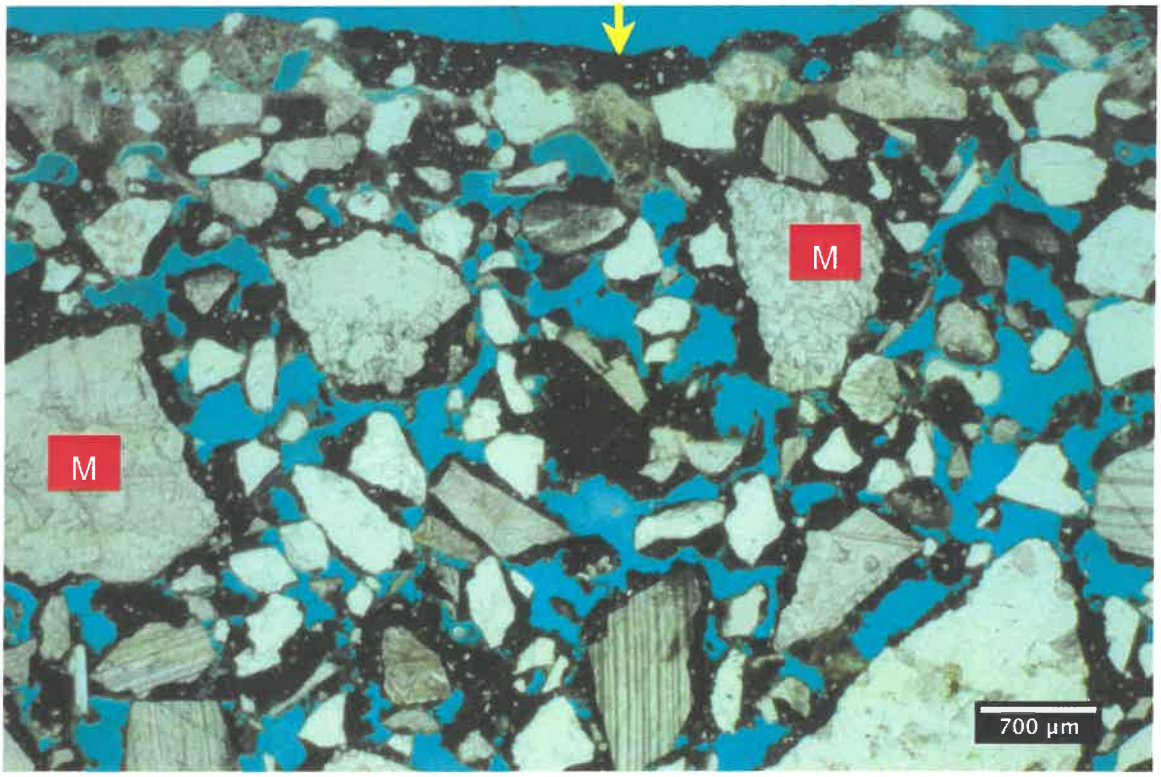
Cement Paste Constituents

Cement materials within the topping and substrate layers comprise ~15-16% of the bulk volume. The paste constituents include calcite, amorphous calcium silicate hydrate, calcium aluminate, portlandite, alite, and larnite. The water/cement ratio for this mix design is ~0.50.

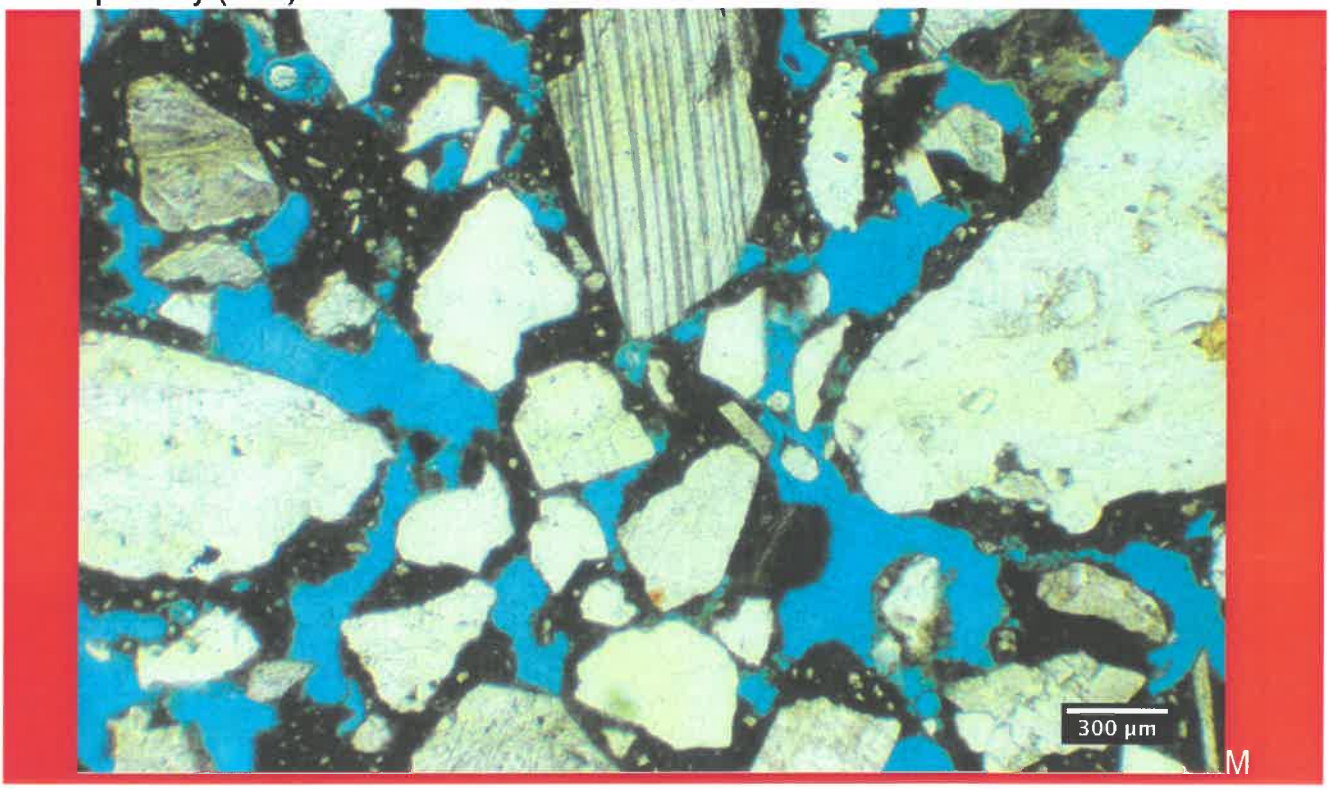
Pore System

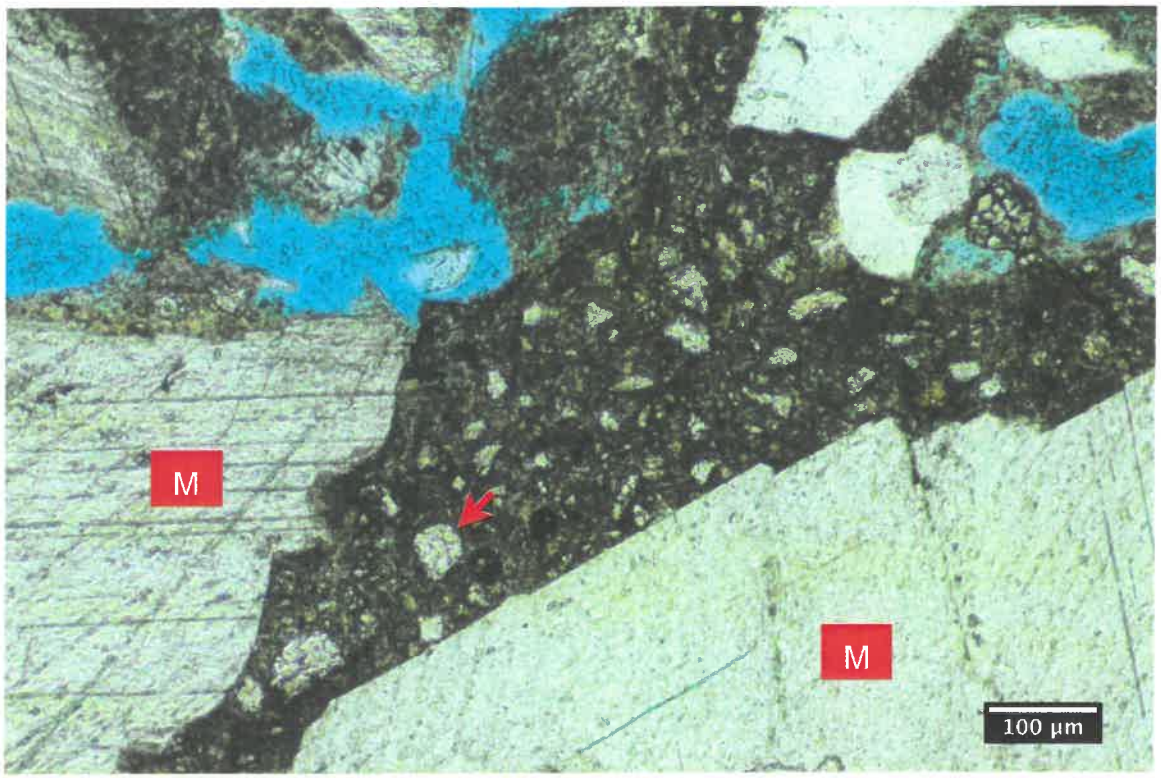
Void types include air-entrapment macropores and intercrystalline microporosity. Macroporosity accounts for ~15-20% of the bulk volume with some of the largest voids detected within the concrete substrate portion of the profile. The air-entrapment macropores are widely distributed & appear moderately well-interconnected. The porous and (apparently) permeable character of the topping cement & substrate materials are likely to permit the free and efficient movement of moisture vapor within the concrete slab.
Sample 1; MI#16296-01 - Macro


Top
20000 µm

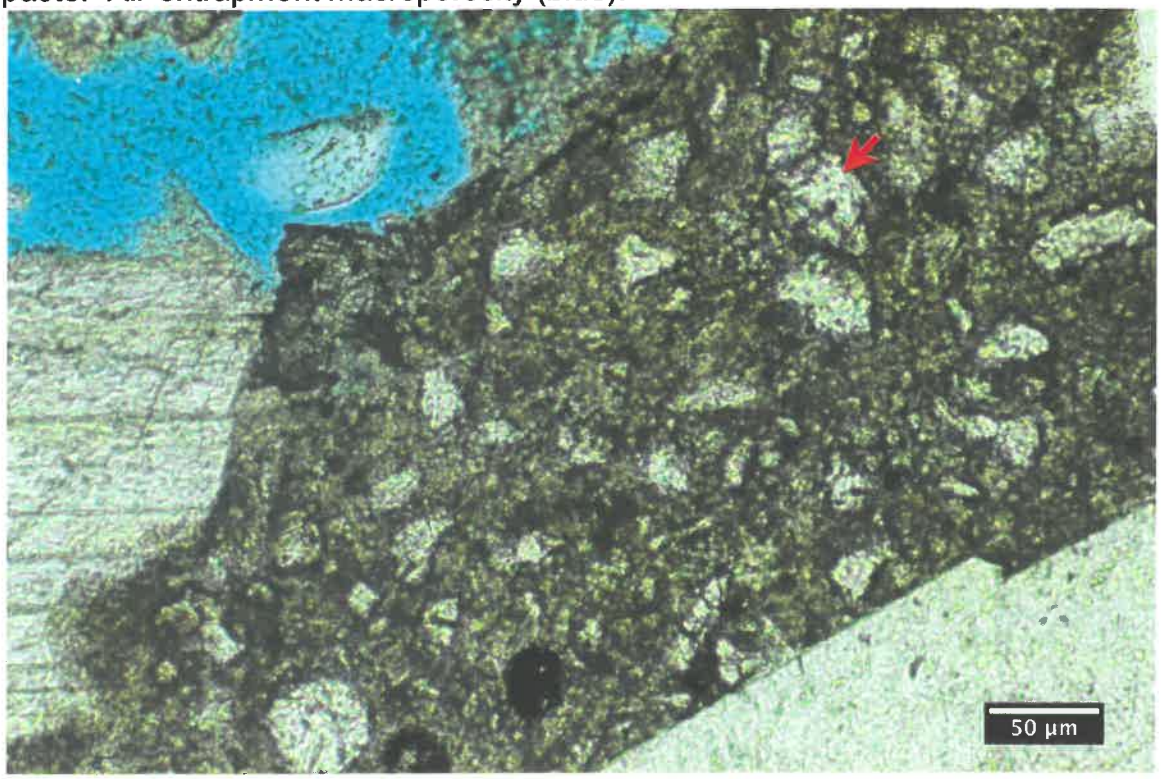


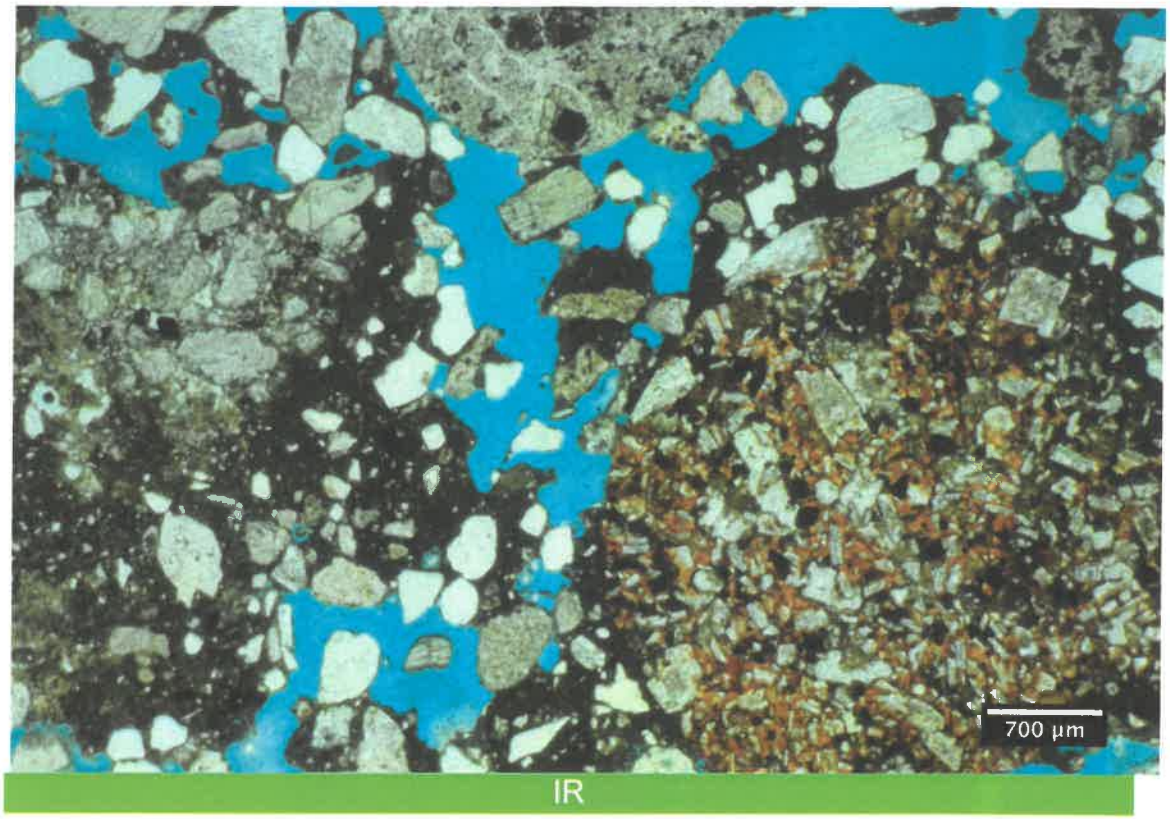
Marble RF's = 'M', ICRI CSP 5 surface profile (yellow arrow). Air-entrapment macroporosity (blue).





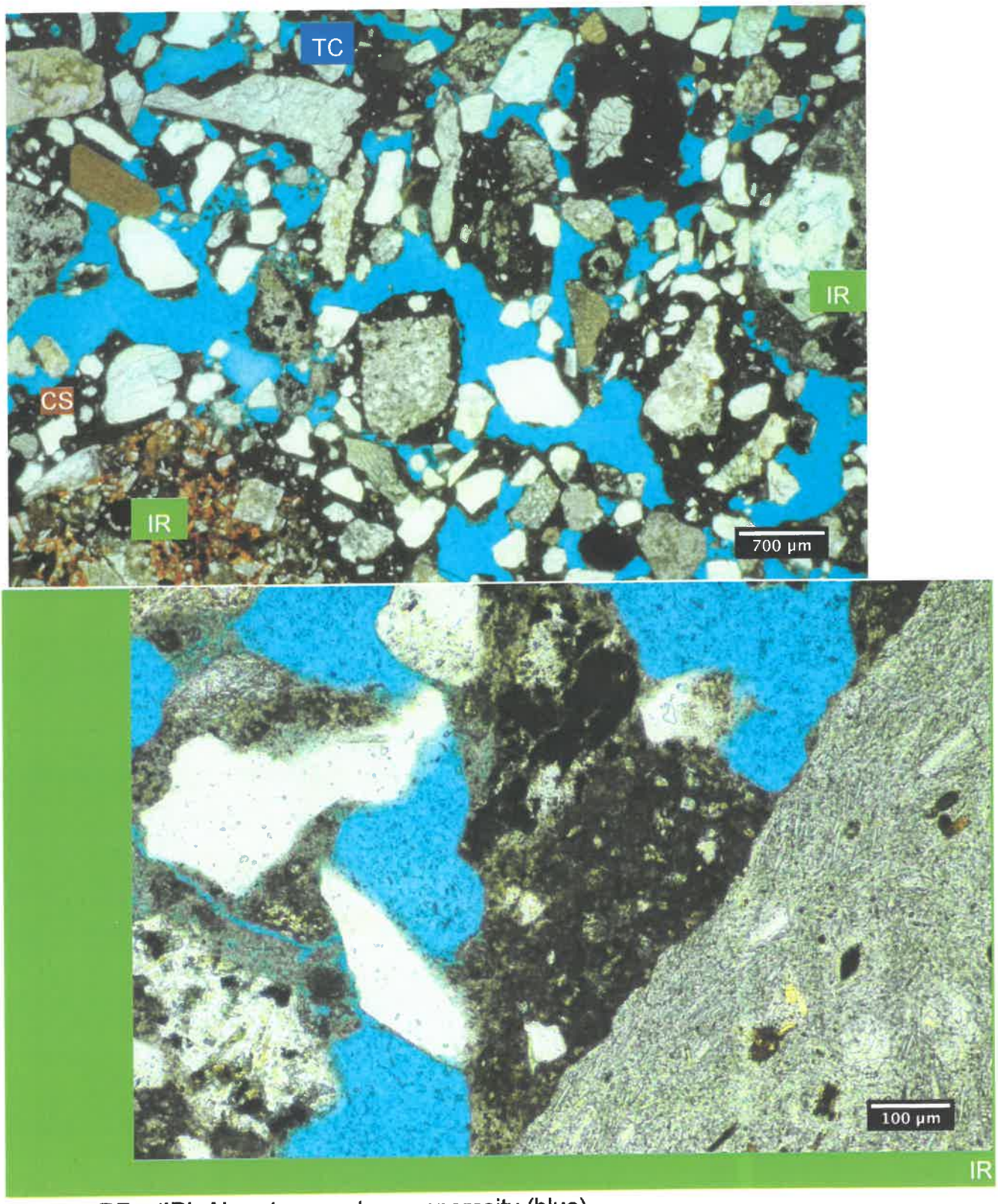
Marble RF's = 'M', Calcium aluminate crystals (red arrows) within calcite-rich cement paste. Air-entrapment macroporosity (blue).



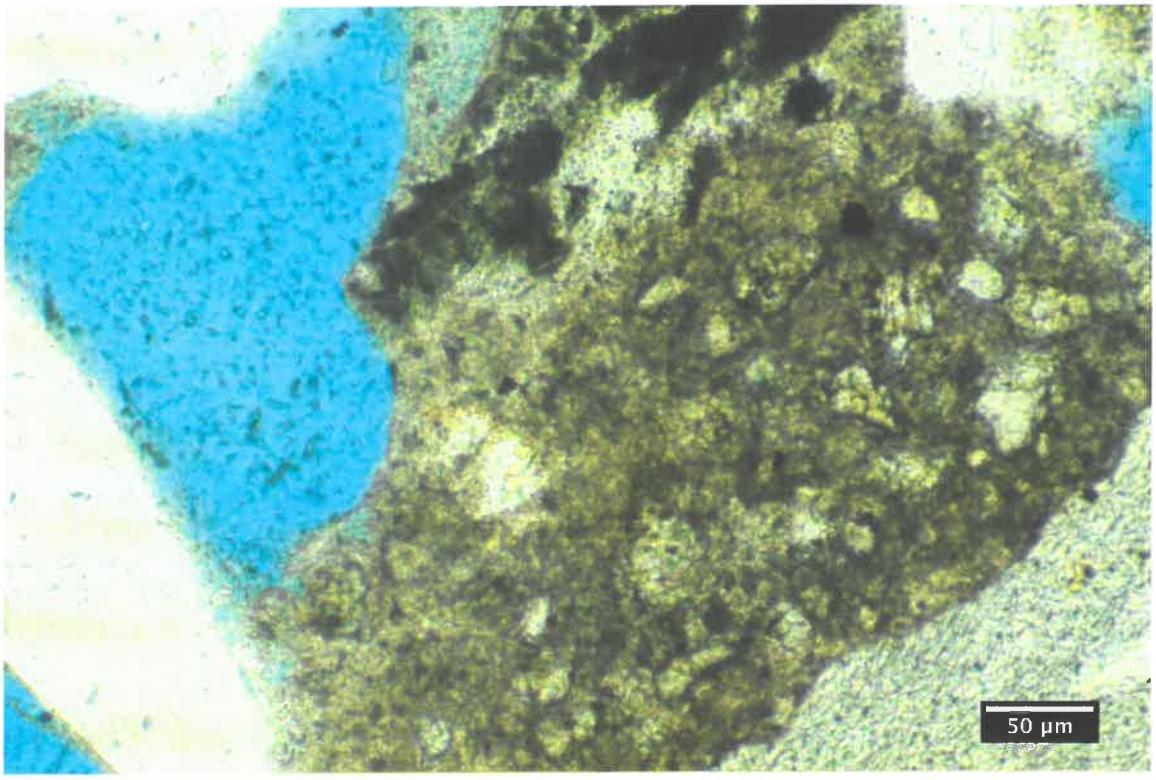


IR

Concrete substrate ('CS'), Igneous RF's = 'IR', Topping cement ('TC'). Airentrapment macroporosity (blue).



Igneous RF = 'IR', Air-entrapment macroporosity (blue).



Methods of Test

Petrographic examination of the concrete cores was performed in general accordance with ASTM C 856, "Standard Practice for Petrographic Examination of Hardened Concrete."

The x-ray diffraction test method evaluates the mineralogy of the 0-3 mm BTC profile slice of the concrete to assess the composition of aggregate materials, cement paste components, and authigenic (i.e., secondary) mineral phases. Bulk powder samples are scanned from 2-50 degrees 2-Theta, and the resulting XRD patterns are interpreted using reference data available within the JCPDS diffraction data base.

Site Photos

Photo 1

Photo 2

Photo 3

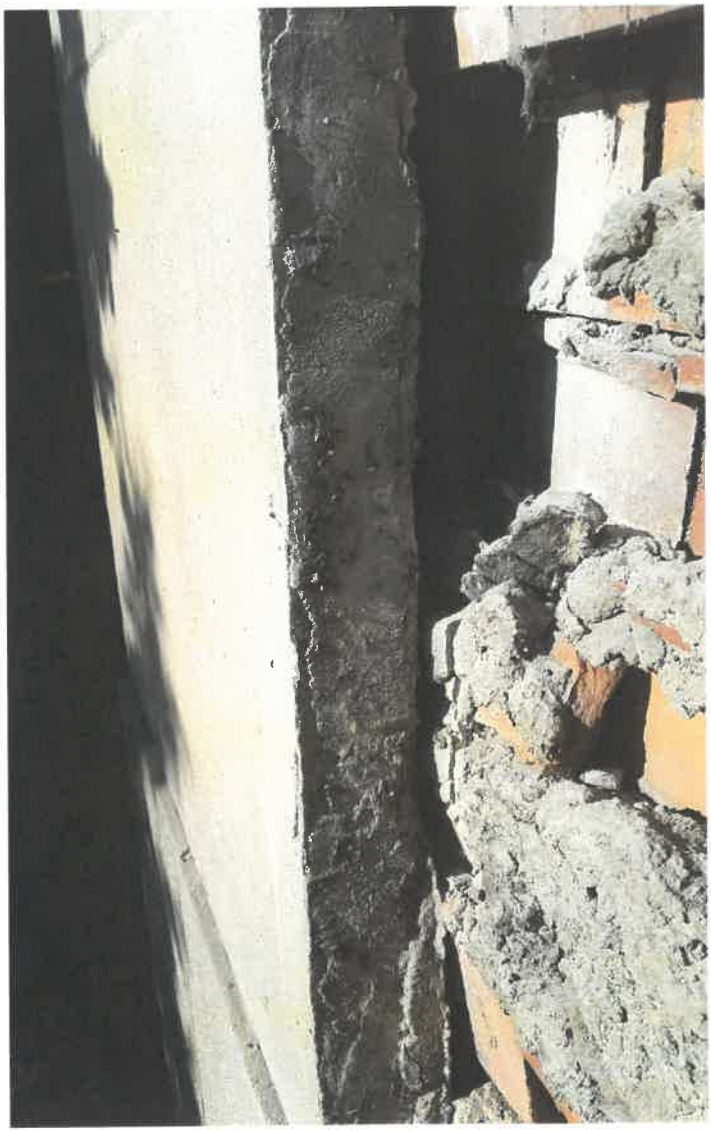


Photo 4