Addendum No.	01
Date:	February 8, 2021
Project:	City of Great Falls Envelope Renovation
Architect:	Cushing Terrell 219 2nd Avenue South Great Falls, MT 59405
To:	All Plan Holders of Record
Pages:	(50) total pages (If you did not receive correct # of pages, please notify us immediately)

Acknowledge receipt of this Addendum by inserting its number and date in the Proposal Form. Failure to do so may subject Bidder to disqualification. This Addendum forms a part of the Contract Documents. It modifies them as follows:

GENERAL

1. See attached for Test Reports performed on the exterior envelope of the building.
2. See attached for Pre-Bid Walkthrough Attendee List
3. See attached for revised Bid Form.

CLARIFICATIONS

1. During the pre-bid walkthrough, the following questions were raised and require clarification :
   a. The paint on the portions of the exterior of the building is Lead-Containing Paint. This can be disposed of without prior abatement and can be handled in the field as long as it is not pulverized, ground, or saw-cut.
   b. Details 2,3, and 4 on A212 indicate that all panels in the recess are to be removed and replaced. This is confirmed and remains as indicated in the drawings.
   c. The performance period is indicated in the contract documents. As mentioned on site, this is subject to contractor input, but it should be clarified that completion date is not a criteria for contractor selection.
   d. Staging Area for bidding purposes shall be the NW parking lot, between the Civic Center and the Children's Museum. Parking and drive access to the building immediately west of the Civic Center and the Children's museum shall be maintained.
   e. Soffit Panels are to remain in place and are not scheduled for removal.
   f. Panel composition and construction shall be per specification. Some alternate methods were presented on site and per the State Historic Preservation Office, those methods can not be entertained that this time. Dry-tamp concrete panels, per spec, are the required panel construction.

SPECIFICATIONS

SECTION 015000 Section 3.3 C

1. CLARIFICATIONS :
   a. Delete in its entirety 3.3C1. Interior existing restrooms are not available to the contractor or subcontractors and are for public use of the Civic Center only. Contractor to provide and maintain facilities of their own for the duration of the project.

DRAWINGS

1. Cast Granite Panels (CG) at the East Steps
   a. Existing panels are a cast product and the panels indicated on the drawings to be removed are to be removed and then replaced with new panels to match the existing.

END OF ADDENDUM #1

GREAT FALLS CIVIC CENTER FRIEZE VENEER REPORT

MALISANI INC.

Tony Malisani
1101 8th Avenue North
P.O. Box 1195
Great Falls, MT. 59403
Phone : (406) 761-0108
E-mail : info@malisaniinc.com

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Malisani Inc. Installation Report

MALISANI INC.
1101 8TH AVE NO
GREAT FALLS, MT 59403
(406) 761-0108

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

Timothy B. Murphy

Mineralogy, Inc.
3321 East 27th Street
Tulsa, Oklahoma 74114
USA +1 (918) 744.8284

www.mineralogy-inc.com

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Section I

Section II

Appendix I

Macroscopic, Microscopic, & Thin Section Images

Sample 1; MI#16296-01

CONDITIONS AND QUALIFICATIONS*Mineralogy, Inc. will endeavor to provide accurate and reliable laboratory measurements of the samples provided by the client. The results of any x-ray diffraction, petrographic or core analysis test are necessarily influenced by the condition and selection of the samples to be analyzed. It should be recognized that geological samples are commonly heterogeneous and lack uniform properties. Mineralogical, geochemical and/or petrographic data obtained for a specific sample provides compositional data pertinent to that specific sampling location. Such "site-specific data" may fail to provide adequate characterization of the range of compositional variability possible within a given project area, thus the "projection" of these laboratory findings and values to adjoining, "untested" areas of the formation or project area is inherently risky, and exceeds the scope of the laboratory work request. Hence, Mineralogy, Inc. shall not assume any liability risk or responsibility for any loss or potential failure associated with the application of "site or sample-specific laboratory data" to "untested" areas of the formation or project area. Unless otherwise directed, the samples selected for analysis will be chosen to reflect a visually representative portion of the bulk sample submitted for analysis. Where provided, the interpretation of x-ray diffraction, petrographic or core analysis results constitutes the best geological judgment of Mineralogy, Inc., and is subject to the sampling limitations described above, and the detection limits inherent to semi-quantitative and/or qualitative mineralogical and microscopic analysis. Mineralogy, Inc. assumes no responsibility nor offers any guarantee of the productivity, suitability or performance of any oil or gas well, hydrocarbon recovery process, dimension stone, and/or ore material based upon the data or conclusions presented in this report.*

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	$Ca_6Al_2(SO_4)_3(OH)_{12} . 25H_2O$	<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

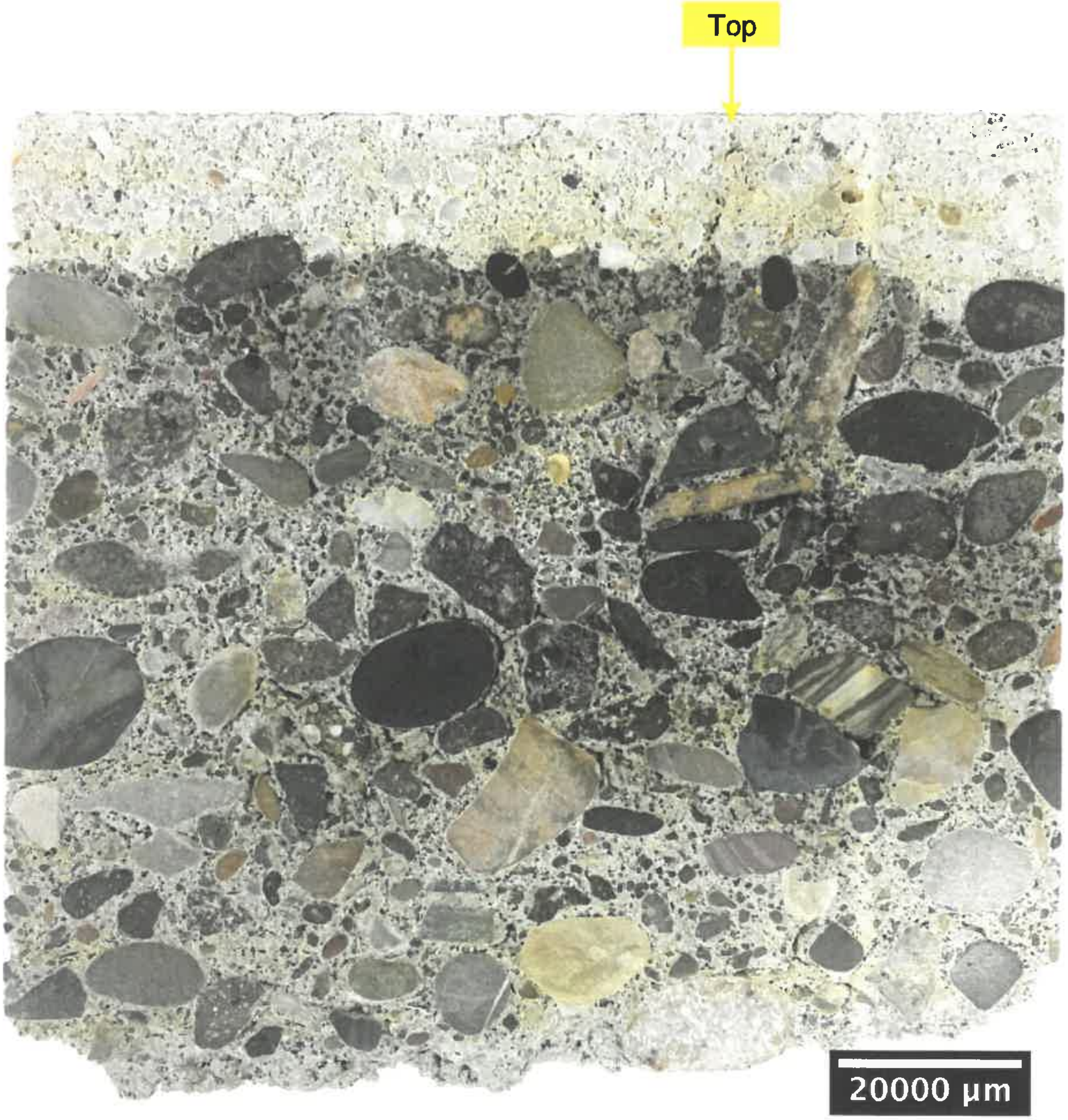
The topping cement materials exhibit an aggregate fraction that accounts for ~65-67% of the bulk volume and is dominated by marble and limestone RFs coupled with minor amounts of chert and granite RFs. The sand fraction (within the topping cement) includes quartz, marble, chert, and feldspar. In contrast, 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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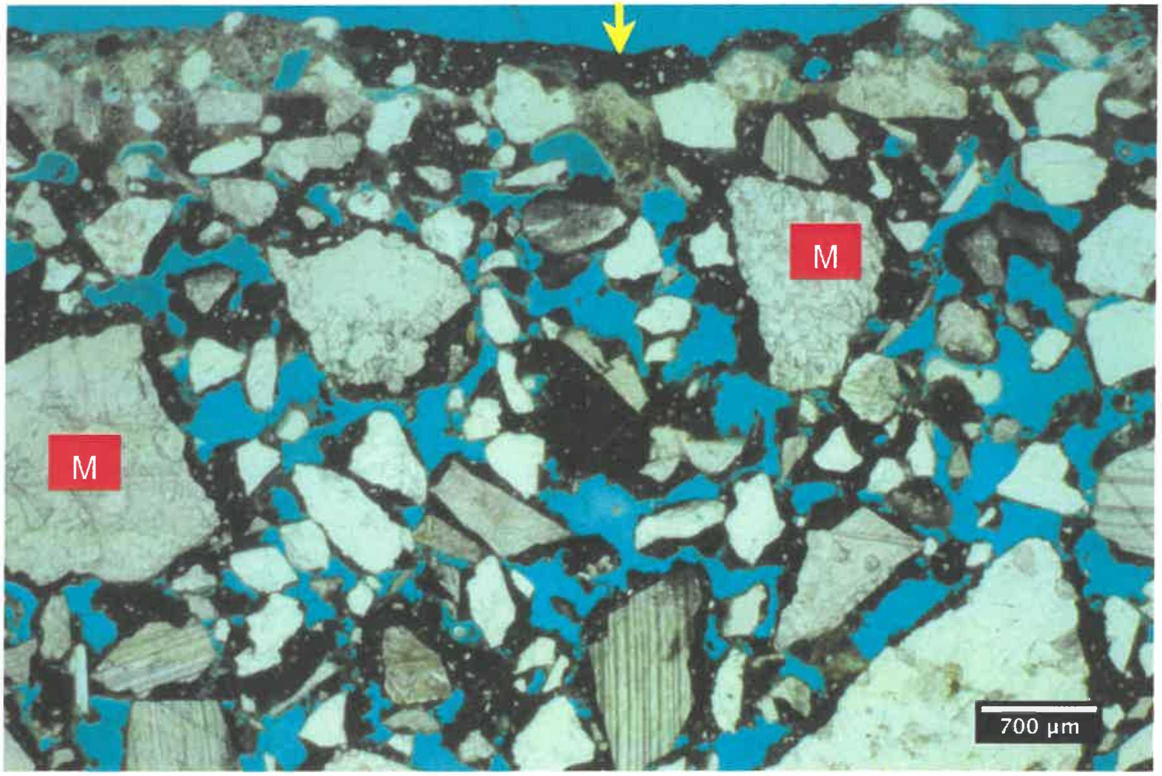
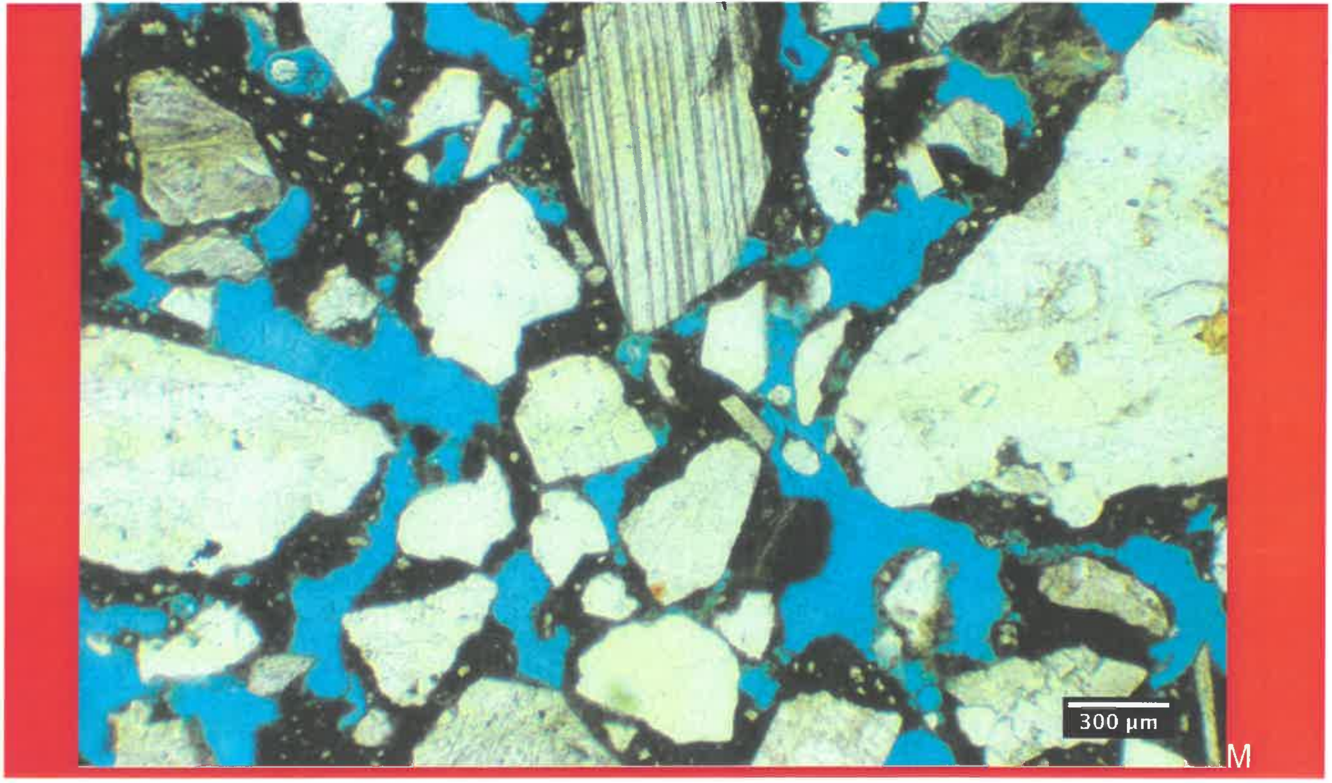
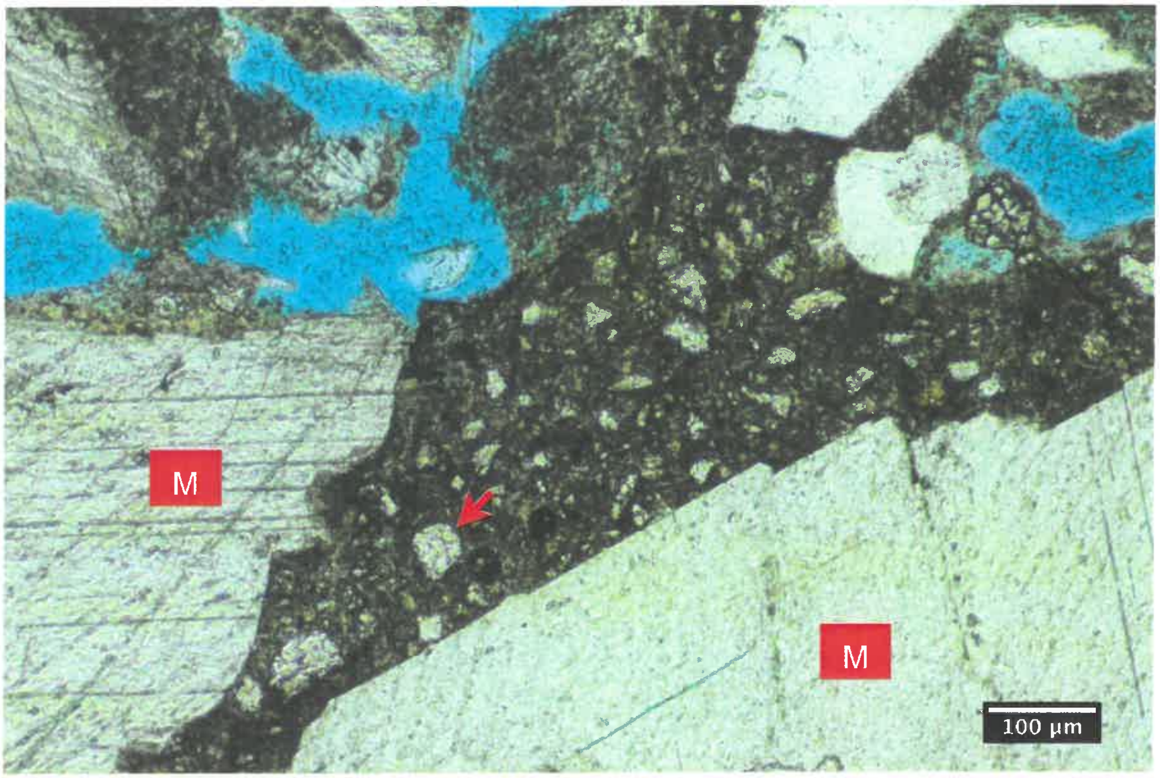
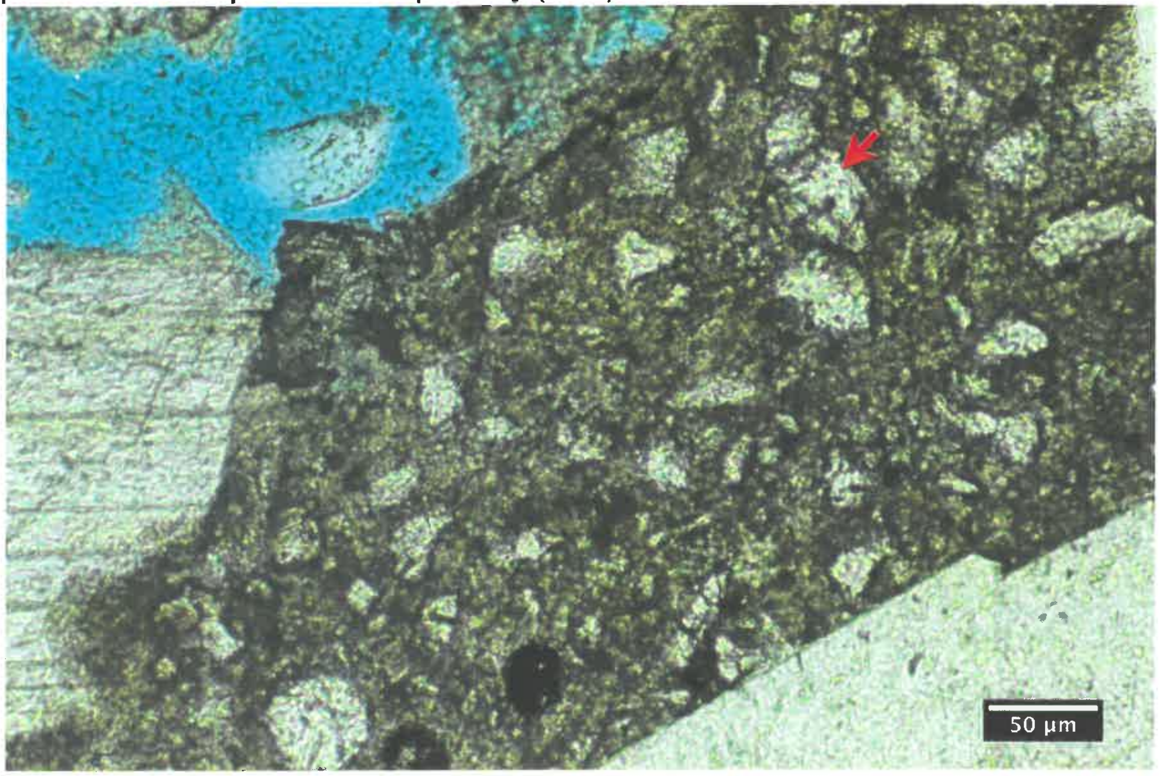


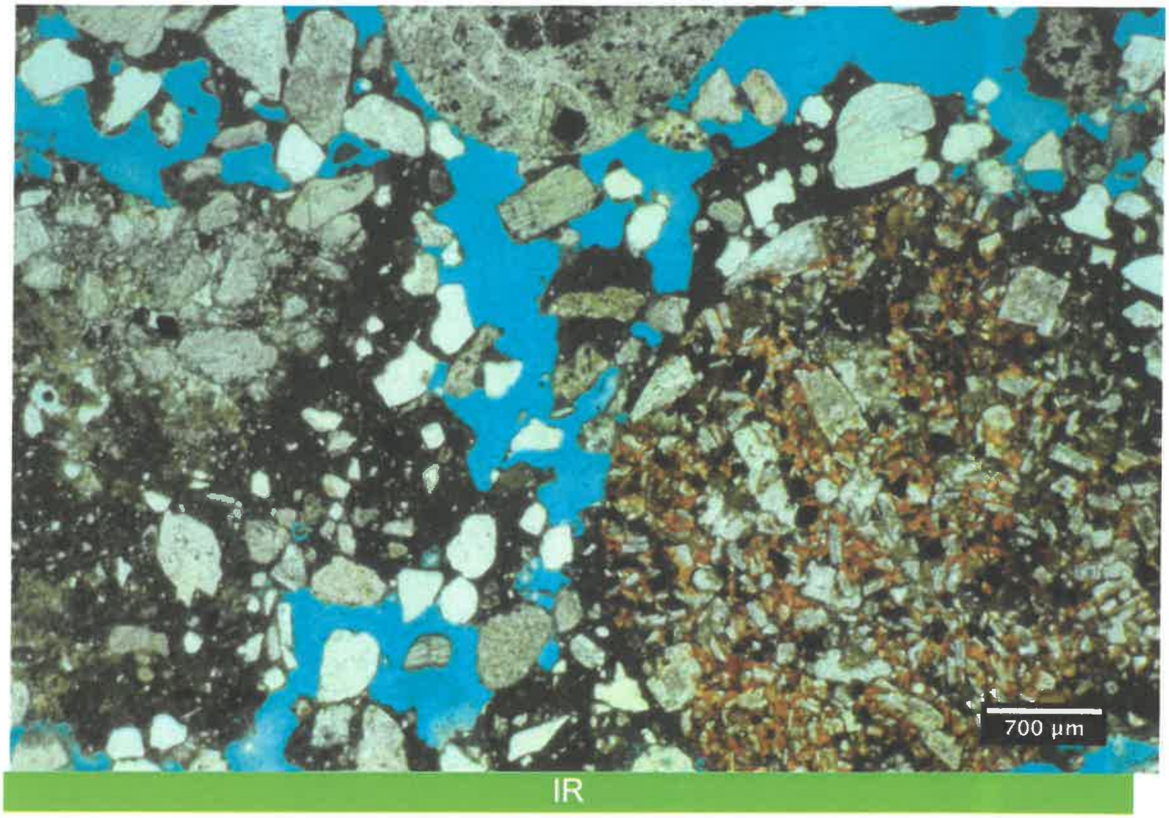
Marble RF's = 'M', ICRI CSP 5 surface profile (yellow arrow). Air-entrapment macroporosity (blue).





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

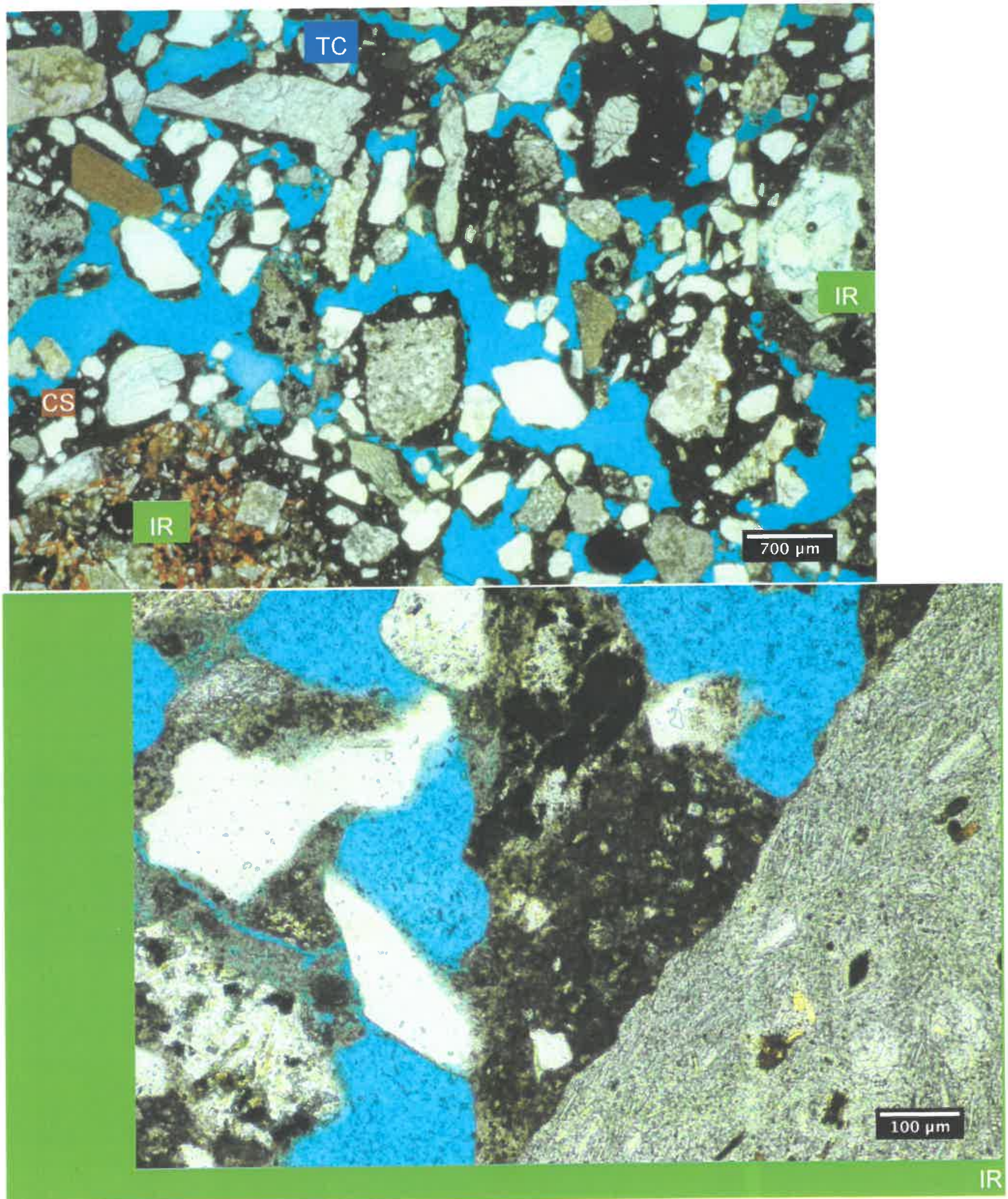




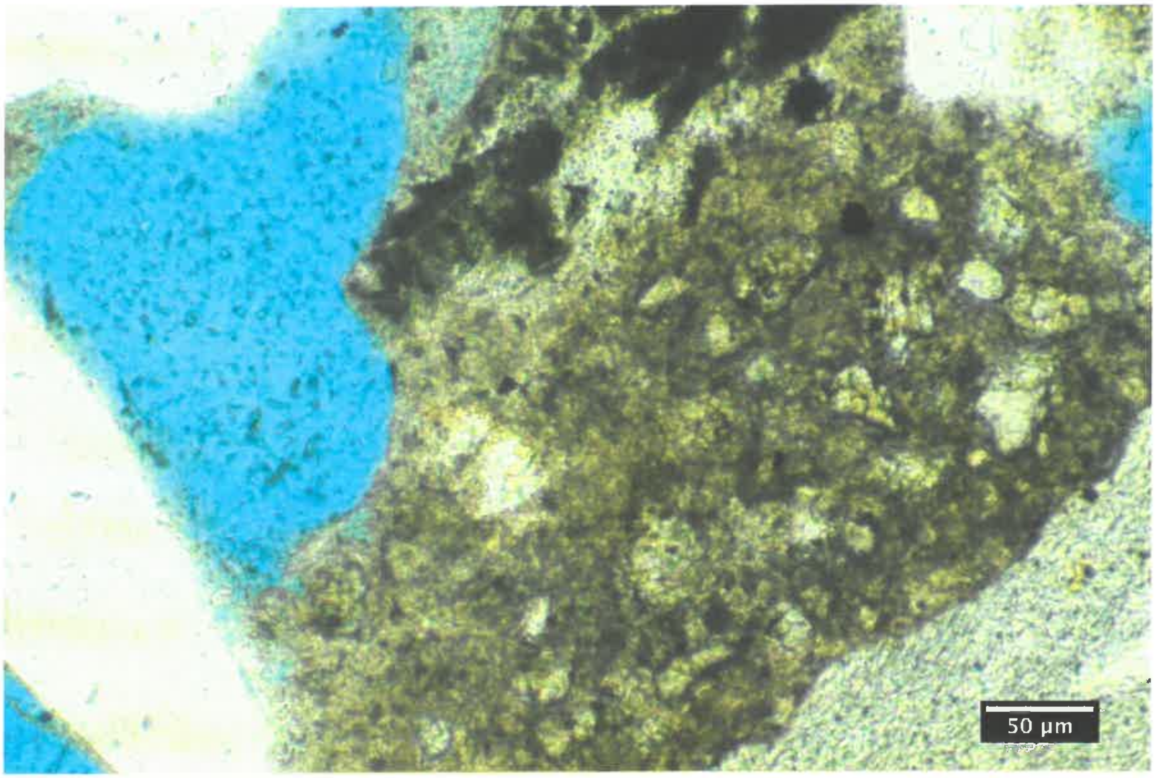
IR

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

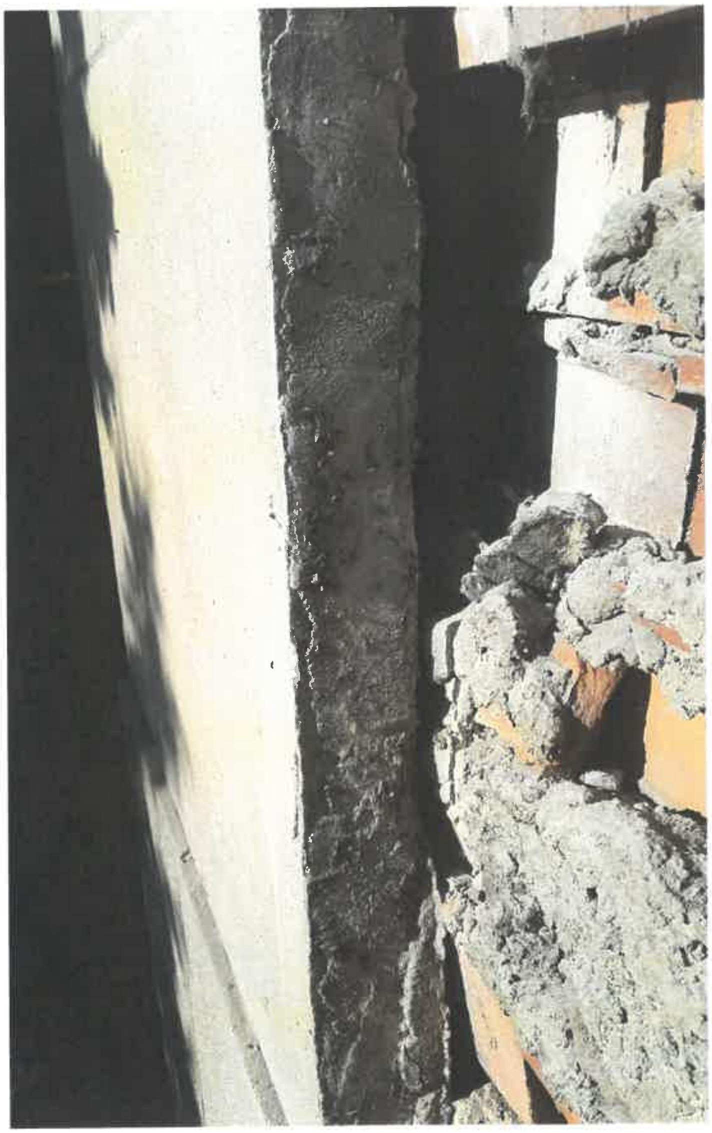


Photo 4

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
330 Pfingsten Road
Northbrook, Illinois 60062
847.272.7400 tel | 847.291.5189 fax
www.wje.com

Via Email: Munski, Ken D. <kdmunski@terracon.com>

Civic Center depicted in 1930's, Great Falls MT
http://usgwarchives.net/mt/cascade/postcards/ppcs-cascade.html

February 17, 2011

Mr. Kenneth Munski
Terracon Consultants, Inc.
1392 13th Avenue SW
Great Falls, MT 59404

Civic Center in recent years, Great Falls MT
http://www.panoramio.com/photo/2410015

Re: Civic Center Exterior Walls
Laboratory Studies of Precast Concrete
WJE No. 2011.0563

Dear Mr. Munski:

We have completed the laboratory studies of the concrete core and the deposit sample that you submitted to our laboratory for the Civic Center in Great Falls, Montana. The concrete core was examined petrographically and was tested chemically in two locations for chloride contents. The deposit sample was examined petrographically for components. The core is reported to represent the exterior facing panel of the Civic Center constructed in 1930's (pictured above). The laboratory studies were requested to determine the composition and characteristics of the concrete, and to evaluate its current condition and project its future performance.

Sections of the building show large cracks in the precast concrete panels caused by corrosion of the embedded reinforcing steel. Photographs you provided to us are shown in Figures 1 and 2 show some of this distress. Other areas of the building only show fine surface cracking, as shown in Figure 3, and appear in better condition. The core provided reportedly represents this better condition and the intent of this analysis is to help assess the need to replace all panels or if some panels can be repaired.

The petrographic examination was performed using methods of ASTM C856, *Standard Practice for Petrographic Examination of Hardened Concrete*." The procedure is also applicable to other construction materials and mineral deposits. The examination was performed using stereoscopic and petrographic microscopes at magnifications ranging from 10x to 600x. Powder mounts were employed in the examination using the polarized-light microscope.

Concrete Core

The core is 4 inches long and its diameter is also 4 inches. The exposed surface of the core was formed against a finely ridged surface, and the inner surface is roughly screeded and not well densified. The outer 1/4 to 1/2 inch of the core consists of white, face mortar, and the remainder of the core consists of gray, backup concrete. The white layer is well bonded to the backup concrete. Both, mortar and concrete contain abundant, coarse size air voids that are typical of dry cast products. The air voids are common around aggregate particles, and are often interconnected.

A 3/8-inch-diameter reinforcing bar is embedded 2-1/8 from the exposed surface of the core. The surfaces of the rebar exhibit significant corrosion. Cracks radiate in all directions from the location of the rebar. The cracks appear to be caused by corrosion of the embedded reinforcing bar. The concrete is not well densified within 1 inch of the inner surface of the core. A few cracks were detected within this 1 inch zone. The cracks in this zone usually follow the areas of abundant air voids related to incomplete consolidation. There is no evidence of cracking related to any deleterious chemical reactions within the concrete or paste. (Figures 4 through 8)

Face Concrete Mix - The white facing layer is made with manufactured siliceous and calcareous sand containing quartz, limestone, and trace amounts of mica and slag. No pigment was found in the face mix. There is no indication of any problems related to the aggregate. The cement paste is white, generally hard, firm, and dense. White Portland cement was used in the mix. The water-cement ratio appears low, and it is estimated at 0.35 ± 0.03. Residual (mostly unhydrated) cement particles are frequent, and the relict (mostly hydrated) cement particles are infrequent. The paste is carbonated full depth of the face mix. Simplified, carbonation occurs due to long-term diffusion of carbon dioxide in the air into the concrete, resulting in a decrease in the pH of the concrete due to its reaction with the calcium hydroxide.

Backup Concrete Mix - The gray base concrete is made with siliceous gravel coarse aggregate having maximum nominal size of 3/8 inch. Present with the coarse aggregate are siliceous volcanic rocks and siliceous and calcareous metamorphic rocks. The particles are hard, firm, dense, rounded, and equant to elongate. Fine aggregate is natural siliceous and calcareous sand composed of the same types of rock types as those observed within the coarse aggregate and small amounts of quartz. The aggregates are uniformly distributed within the concrete. There is no evidence of any durability problems related to the aggregates.

The cement paste is generally gray, but varies from light to dark between different areas of the core. The paste is generally hard, except for lighter color areas where it is somewhat soft. The water-cement ratio appears low to moderately low, and is estimated to range from 0.30 to 0.40. The higher water-cement ratio paste is found in the light color paste in the outer half of the core. The lower water-cement ratio is prevalent in the inner half of the core. The cement paste is often scarce in the inner region of the core. The paste is fully carbonated within 3/4 inch of the outer and inner surfaces of the backup concrete and partially carbonated in the middle section of the core. Because of the great extent of the carbonation, any embedded steel is no longer protected by the concrete from possible corrosion.

Chloride Contents - The backup mix of the concrete core was analyzed chemically for acid-soluble chloride. The analyses were performed essentially according to ASTM C 1152, *Method for Acid-Soluble Chloride in Mortar and Concrete*. The results are listed in the Table below. Studies have shown that chloride contents above 0.02 to 0.03 percent by mass of concrete, depending on the cement content, can promote corrosion of embedded steel in non-carbonated concrete. Levels below this threshold can accelerate corrosion in carbonated concrete. Both chloride contents are above this threshold level and, in the presence of sufficient moisture and oxygen, may promote the corrosion of steel in the concrete.

Table—Chloride Contents

Sample	**Acid-Soluble Chloride, percent by mass of sample**
Below Face Mix (1/2 to 1 inch from exposed surface of core)	0.090
At Rebar Level (2 to 2-1/2” from exposed surface of core)	0.048

Deposit Sample

Received along with the core was a small zip lock bag labeled “Civic Center, Coating on some of the Panels” weighing approximately 9 grams. The bag contained reddish brown fines and small amounts of sand particles. The petrographic examination of the fines revealed that the major constituent of the fines are abundant particles of pigment; minor components are calcite and quartz. A cursory test for the presence of polymer was negative. The pigment appears to represent an inorganic paint or a color staining.

Discussion

The cracking in the panels is a result of corrosion of the embedded reinforcing steel. Regular carbon steel reinforcing bars (black bars) are passive in normal portland cement concrete because the concrete provides a desirable high pH (~13) medium and also acts as a physical barrier isolating the steel from the environment. However, black reinforcing bars are vulnerable to corrosion when the high pH of the concrete at the steel depth is lost or when chloride ions are present. Chloride from sea water or road deicers is known to penetrate the concrete cover and cause aggressive corrosion of the embedded reinforcing. Calcium chloride based chemical admixtures were added to reinforced concrete prior to the 1950’s as a setting time accelerator. This practice was mostly stopped when it was found that this admixture would cause corrosion of the embedded reinforcing. Chloride contamination causes corrosion because steel is active after a threshold concentration of chloride (often called chloride threshold, C_T) is reached. Though varied from case to case, the C_T of black bars is low and typically about 0.03% by weight (1.2 lb/yd^3). The concrete sample examined contained chloride above this threshold value so the corrosion is likely chloride induced. While the near surface had slightly higher chloride than the center of the sample, it is likely that the chloride was admixed into the concrete as a set accelerator when the panels were built, possibly with more chloride added to the face mix than to the backup mix.

The typical causes of embedded steel corrosion are either chloride contamination or concrete carbonation, or both. Carbon dioxide in the air slowly penetrates the concrete and this carbonation results in loss of the favored high pH. The black bars will then corrode in the low pH concrete environment; however, this corrosion is typically at a much slower rate than chloride induced corrosion. Carbonation is a process which highly depends on the concrete moisture condition. The most favorable condition for the diffusion of carbon dioxide into concrete (carbonation) is when the concrete has a moderate internal relative humidity. Water filled pores in wet, saturated concrete (relative humidity near 100%) restrict gaseous carbonate dioxide, slowing carbonation. Cracks that expose the steel reinforcement directly to water and oxygen may pose an increased risk for corrosion of the embedded steel bars. Such cracks allow oxygen and carbon dioxide access to the steel and can result in corrosion. The lack of complete consolidation of the back face likely increased the carbonation rate and reduced concrete passivation of the embedded steel. A combination of chloride contamination and concrete carbonation has resulted in corrosion of the embedded reinforcing steel.

Conclusions

Our laboratory studies of a single concrete core indicate that the cracking present within the core is due to corrosion of the embedded reinforcing bar. Several cracks radiate in different directions from the location of the corroded rebar. There are two major causes for the corrosion; (1) carbonation of the cement paste that extends virtually full depth of the concrete, and (2) high chloride levels that are two to more than four times the typical corrosion threshold for uncoated reinforcing in concrete. A source of chloride is likely the addition of chemical admixtures to the concrete to accelerate the setting of the concrete and face mix. Drift of chlorides from deicing salts spread on the streets and sidewalks in winter could also contribute to the chloride. Additional sampling and testing could determine the source of the chloride contamination. Corrosion of the embedded steel is expected to continue because the concrete paste is carbonated and the chloride contents are well above the corrosion threshold level. Surface sealing the panels is not likely to extend their service life significantly since the carbonation and chloride is within the concrete and in contact with the reinforcing. Assuming that this core sample is representative of the moderately deteriorated panels, this panel deterioration appears to be past what is practical to affect a lasting repair of the panels.

Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Lidia Uznanski

Lidia Uznanski
Senior Associate, Petrographer

Paul D Krauss

Paul D. Krauss, P.E.
Project Manager

Figure 1. View of cracking on upper part of Civic Center (NTL).

Figure 2. View of cracking caused by corrosion of embedded reinforcing steel (NTL).

Figure 3. View of the fine cracks on panels that are currently in good condition (NTL).

Figure 4. Side view of the core. Cracks radiate from the corroded reinforcing bar. One fine crack to the surface is outlined in red. The irregular cracks in the photo located to the right of the (encircled) rebar and oriented parallel to the inner surface coincide with abundant air voids that are typical of dry cast concrete.

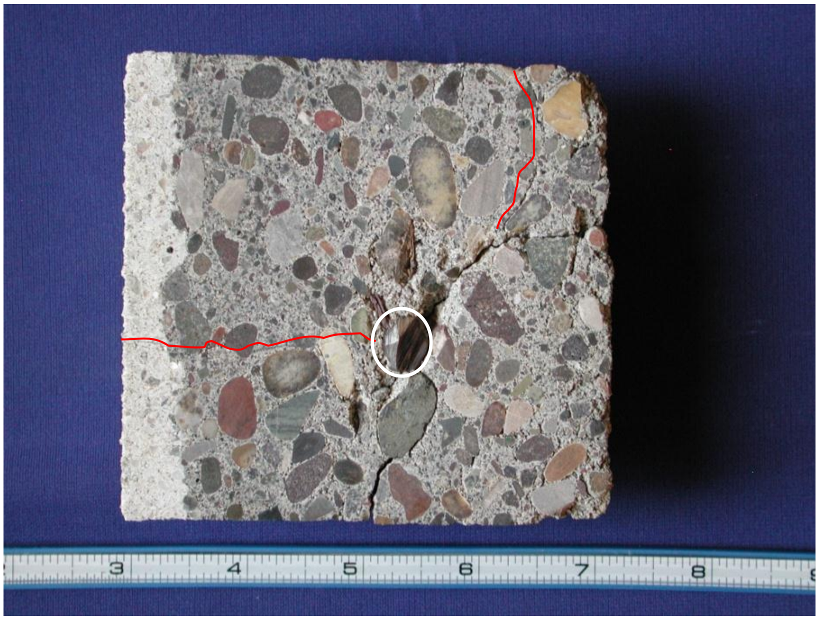


Figure 5. Lapped section of the core. Cracks radiate in all directions from the corroded reinforcing bar (encircled). The finer cracks are outlined in red.

Figure 6. View of the finely ridged, exposed surface of the face mix.

Figure 7. View of the inner, poorly densified surface of the backup concrete.

Figure 8. Section of the corroded reinforcing bar.

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

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www.wje.com

Via E-mail

August 16, 2018

Mr. Tony Houtz
CTA Architects Engineers
219 2nd Avenue South
Great Falls, Montana 59405

Re: Concrete Testing for Great Falls Civic Center, Great Falls, Montana
WJE No. 2018.3742

Dear Mr. Houtz:

Laboratory studies were completed on seven concrete core samples removed from Great Falls Civic Center, in Great Falls, Montana. Core samples were removed from the building exterior walls by others and shipped to WJE laboratories for analysis. The building was built in the 1930's and exterior walls are experiencing varying degrees of cracking and spalling due to corrosion of embedded reinforcing steel. Sections of the building show large cracks in the precast concrete panels caused by corrosion of the embedded reinforcing steel while other areas have much less distress. This analysis was requested to help assess the need to replace all panels or if some panels can be maintained.

Laboratory studies included petrographic evaluation of the concrete focusing on characterization of the concrete, including determination of the depth of carbonation in each sample. Chloride ion content testing was also performed to quantify any chlorides present near the surface of the concrete and at the depth of the embedded reinforcing steel.

SAMPLES

The samples represent full and partial depth cores removed from Great Falls Civic Center. The cores represent cast stone concrete that contain a face mix that is visible on the exposed surface and a backup concrete mix. Images of the samples, as-received in the laboratory are shown in Figure 1 through Figure 14.

The cores can be separated into two groupings: Cores 4A-E and 4B-E exhibit a face mix that contains a white paste with white and black aggregate particles. The remaining five cores, Cores 1A-S, 1B-S, 1C-S, 2A-W, 3A-N, exhibit a face mix with a white paste with white aggregate particles.

Table 1 provides information on the nominal 2.9 inch diameter cores:

Table 1. Sample Information

Sample ID	Total Length (inches)	Face Mix Description	Face Mix Thickness
1A-S	3.9	White/beige aggregate	Variable from 3/8 to 3/4
1B-S	3.5	White/beige aggregate	Variable from 3/8 to 1/2
1C-S	3.7	White/beige aggregate	Nominal 1 inch
2A-W	4.0	White/beige aggregate	Variable from 1/2 to 3/4 inch
3A-N	2.6	White/beige aggregate	Nominal 3/8 inch
4A-E	3.8	Contains black and white aggregate	Variable from 3/8 to 3 inches
4B-E	4.0	Contains black and white aggregate	Nominal 1/2 inch

LABORATORY STUDIES

Petrographic Studies

Methods

The petrographic studies were conducted in accordance with the procedures described in ASTM C856, *Standard Practice for Petrographic Examination of Hardened Concrete*. Microscope examination and various tests conducted during the petrographic examination are designed to elicit specific information about the composition and condition of the concrete. The observations are interpreted to derive conclusions about quality, performance, and probable cause of various types of distress.

Each core was cut in half perpendicular to the top surface using a water-cooled, continuous-rim, diamond saw blade. One planar saw-cut surface of each core was lapped using progressively finer silicon carbide abrasives to achieve a fine, matte finish suitable for examination with a stereomicroscope. Lapping exposes textural features such that the edges of air voids, cracks, and aggregate constituents can be more easily observed. Lapped sections of the cores are shown in Figure 15 through Figure 21. Lapped and fracture surfaces were examined at magnifications up to 40X using a Leica S6D stereomicroscope. Core 3A North was chosen for detailed petrographic studies, and a thin section was prepared through the face mix and base mix of the core assess paste characteristics. The thin sections were examined at magnifications ranging from 50X to 500X using a Leica DM2700P petrographic (polarized-light) microscope.

Findings

General Description of the Seven Cores

The cores each contain a variable thickness face mix that resembles natural stone (Figure 22 and Figure 23), and a backup mix that looks more like traditional concrete. The interface between the face mix and the backup mix is intimate, with the two mixes often intermixed. Portions of the face mix are visible within the backup mix, which is especially apparent in Core 4A East (Figure 20).

The exterior (or exposed) cast stone surface is generally flat and smooth with abundant exposed aggregate particles. The surfaces appear slightly weathered, with some loss of paste. Press lines, or oriented voids, are observed parallel to the exposed surfaces, likely from a dry tamping consolidation processes.

The cast stone is non-air entrained, and the air content varies between samples. Non-spherical and irregularly shaped entrapped air voids are generally abundant in each sample. Few to no spherical air voids are present. These observations are consistent with a dry tamp production method of cast stone that uses a zero-slump mixture (and no air entraining admixtures). The cores exhibit paste coated aggregate particles that are often observed in point to point contact.

Core 3A North

Core 3A North contains a white to beige surface mix with exposed aggregate particles. The cast stone is composed of coarse sand-sized crushed limestone and siliceous sand dispersed with white portland cement matrix (Figure 24). No supplementary cementitious materials such as slag cement, fly ash or silica fume were observed. No pigment was apparent. The aggregate appears hard and sound, and no evidence of material-related distress, such as alkali-aggregate reactivity it observed.

The backup mix is a traditional concrete, with nominal maximum-sized 3/8 inch pea gravel aggregate dispersed in non-air entrained portland cement paste (Figure 25). The backup mix also represent a dry tamp material, with non-spherical and irregularly shaped entrapped air voids generally abundant in each sample, and few to no spherical air voids.

The extent of cement hydration in both the face mix and backup mix is moderately advanced, which is considered normal. No evidence of restricted hydration was observed and cement particles frequently exhibit hydration rims. Both the face mix and backup mix are generally uniformly mixed, with no areas of aggregate segregation or large paste-rich areas observed.

Cracking

Cracking is limited within the samples, and cracking is not apparent on the exterior surfaces of the cores. Core 3A North contains a longitudinal crack that begins along the exterior face of the sample (Figure 26); however, the crack was not visible before the core was cut in half because the large volume of entrapped air voids within the mix camouflages the crack along the exposed surface. The crack in Core 3A North is widest at the exterior surface and tapers with depth. The crack breaks aggregates beginning approximately 6 mm from the exterior surface, indicating that the crack propagated through the cast stone after it had gained appreciable strength. The crack is likely early-age shrinkage induced, however the small aggregate size, low matrix volume, and high volume of irregularly shaped voids contribute to poorly-defined crack surfaces (there are no sharp, well-defined crack boundaries observed), which limits the interpretation of cause and relative age of the cracks. However, the petrographic studies have definitively established that cracking was not caused by alkali-aggregate reactions or cyclic freeze/thaw distress.

Within Core 3A North, transverse elongate voids appear similar to cracks, but are caused by the compaction of the dry tamp product. The elongate voids occur primarily in the transverse direction, but also occur longitudinally to a lesser degree, around aggregate particles (Figure 27 and Figure 28). In Core 3A North, these elongated void spaces are visible within the backup mix, and are not observed in the face mix.

Carbonation

Carbonation measurements were taken after application of phenolphthalein, a pH indicator, was applied to fractured surfaces of each sample. The depth of carbonation in each core, measured from the exterior surface, is summarized in Table 2:

Table 2. Carbonation Depth Measurements

Sample ID	**Carbonation Depth, mm (inches)**	**Notes**
1A-S	1 mm (0.04 in.)	Fully carbonated to 1 mm (0.04 in.), partially carbonated to 5 mm[1] (0.20 in.)
1B-S	1 mm (0.04 in.)	Fully carbonated to 1 mm (0.04 in.), partially carbonated to 5 mm (0.20 in.)
1C-S	2 mm (0.08 in.)	Fully carbonated to 2 mm (0.08 in.), partially carbonated to 5 mm (0.20 in.)
2A-W	5 mm (0.20 in.)	
3A-N	2 mm (0.08 in.)	
4A-E	1 mm (0.04 in.)	
4B-E	1 mm (0.04 in.)	

WJE tested a single concrete sample from the Civic Center building in 2011 for Terracon (report dated February 17, 2011) and found that the paste was fully carbonated within 3/4 inch of the outer and inner surfaces of the backup concrete and partially carbonated in the middle section of the core.

Chloride Ion Content Testing

The acid-soluble chloride contents were determined at two depths in four cores. Cores 1A South, 2A West, 3A North and 4B East were chosen for studies in order to space the chloride ion content testing around the building, based on the sample IDs. Each core was tested in the near surface, at a depth of 1/4 inch to 3/4 inches and deeper in the concrete, from a depth of 1-7/8 inch to 2-3/8 inches.

The acid-soluble chloride analysis was performed essentially according to ASTM C1152, *Method for Acid-Soluble Chloride in Mortar and Concrete*. The results are listed in Table 3. WJE tested a single concrete sample from the Civic Center building in 2011 for Terracon (report dated February 17, 2011) and found acid-soluble chloride levels of 0.090 at 1/2- 1 inch depth and 0.048 at 2 to 2-1/2 inch depth.

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[1] Partial carbonation refers to areas where the paste does not appear fully carbonated, but patches of carbonated and uncarbonated paste are present.

Table 3. Chloride Contents

Sample	Depth (inches)	Acid-Soluble Chloride, percent by mass of sample
1A South	¼ - ¾	0.092
	$1\,^{7}/_{8}$ - $2\,^{3}/_{8}$	0.041
2A West	¼ - ¾	0.148
	$1\,^{7}/_{8}$ - $2\,^{3}/_{8}$	0.060
3A North	¼ - ¾	0.076
	$1\,^{7}/_{8}$ - $2\,^{3}/_{8}$	0.046
4B East	¼ - ¾	0.008
	$1\,^{7}/_{8}$ - $2\,^{3}/_{8}$	0.005

SUMMARY AND DISCUSSION

Laboratory studies were conducted on seven samples of cast stone. Petrographic studies were performed to characterize the concrete, including determining the carbonation depth of each sample. Chloride ion content testing was performed to quantify any chlorides present near the surface of the concrete and at the depth of the reinforcing steel.

Concrete

The seven samples are composed of generally well-consolidated dry tamp cast stone, a concrete masonry product produced by mechanical consolidation of a zero-slump concrete mixture. The samples contain face mixes that appear similar to sandstone/limestone and granite natural stone, and traditional concrete backup mix. The two mixes in each sample are in intimate contact, with occasional patches of the face mix visible within the backup mix. Based on detailed petrographic examination of Core 3A North, the face mix is composed of coarse sand-sized crushed limestone and siliceous sand dispersed with white portland cement matrix. No coloring pigments were observed in the mix. Based on brief petrographic studies with the other six samples, the face mix in each sample appears to be similar (except for a different aggregate composition in Cores 4A/B) and composed of white portland cement with no coloring pigments.

The samples contain abundant entrapped air voids, a relic of the consolidation process for dry tamp cast stone. Some sand grains were observed to have little paste surrounding them, and were in point to point contact. Partly due to the nature of the material and the presence of voids, no cracking was observed on the exterior surface of the cores. Only when Core 3A North was cut in half longitudinally was a longitudinal crack observed in the face mix of the core. The crack begins along the exterior surface, is widest at the point, and tapers with depth. The crack breaks an aggregate particles beginning approximately 6 mm from the exterior surface. The crack is likely related to early-age shrinkage, and does not represent a material distress mechanism such as alkali aggregate reactivity or deterioration due to cyclic freezing and thawing. Transverse and occasional longitudinal elongate voids are present within Core 3A North, which represent an artifact of sample consolidation. The voids appear similar to cracks, but are the result of elongated air voids entrapped in the mix. Overall, the concrete appears sound and has not experienced concrete materials-related distress.

Corrosion

Regular carbon steel reinforcing bars (black bars) are passive in normal portland cement concrete because the concrete provides a desirable high pH (~13) medium and also acts as a physical barrier isolating the steel from the environment. However, black reinforcing bars are vulnerable to corrosion when the high pH of the concrete at the steel depth is lost or when chloride ions are present. Most commonly, chloride from sea water or road deicers is known to cause aggressive corrosion of the embedded reinforcing. Calcium chloride based chemical admixtures were added to reinforced concrete prior to the 1950's as a setting time accelerator. When mixed with concrete in solution form, calcium chloride accelerates cement hydration (the chemical reaction that cause concrete to harden and gain strength) resulting in more rapid strength development. This practice was mostly stopped when it was found that this admixture would cause corrosion of the embedded reinforcing. Chloride causes corrosion because steel is active after a threshold concentration of chloride (often called chloride threshold) is reached. Though varied from case to case, the chloride threshold of black bars is typically about 0.03% by weight of concrete (1.2 lb/cu. yd).

Carbonation of concrete occurs due to long-term diffusion of carbon dioxide in the air into the concrete, resulting in a decrease in the pH of the concrete due to its reaction with the calcium hydroxide. This decrease in the pH can result in depassivation of the embedded reinforcing steel and corrosion. The cast stone exhibits limited carbonation, extending between 1 mm to 5 mm (0.04 to 0.20 inches) from the exterior surface. Areas of partial carbonation are observed, where patches of carbonated and uncarbonated paste are present. These areas of partial carbonation are likely due to the presence of the large amount of entrapped air, where interconnected voids allow for atmospheric carbon dioxide to penetrate deeper into the concrete than in areas where the voids are not interconnected. The cover over embedded reinforcing is reported to be slightly over 2 inches so the depth of carbonation has not progressed to the expected depth of the reinforcing steel for the cores samples tested. However, deeper carbonation was noted on the sample WJE tested from the Civic Center building in 2011 for Terracon (report dated February 17, 2011) and found that the paste was fully carbonated within 3/4 inch of the outer and inner surfaces of the backup concrete and partially carbonated in the middle section of the core. We do not know where on the building the 2011 sample was taken from. Based on our testing, concrete carbonation is not likely a primary cause of the corrosion but may be a secondary contributing factor in local areas where cracking or high porosity in the precast panels exist.

Chloride ion content testing show that there are elevated levels of chlorides within both the face mix and the backup concrete that is consistent with an intention addition of calcium chloride accelerator during manufacturing. The face mix has chloride levels of between 0.076 to 0.148 percent by mass that correlate to an approximate 1 to 1.5 percent addition of calcium chloride (%$CaCl_2 \cdot 2H_2O$ by mass of cement). The backup concrete has chloride levels between 0.041 to 0.060 percent by mass that correlate to a 0.5 percent addition of calcium chloride (%$CaCl_2 \cdot 2H_2O$ by mass of cement). These are typical levels of admixed calcium chloride used to accelerate the setting of concrete and it makes sense that higher levels might have been used in the face mix to accelerate the manufacturing process.

The exception is Core 4B East that does not contain admixed chloride and measured values were very low in both the face mix and backup concrete. This core contains a different aggregate in the face mix than the other cores; the face mix contains white and black aggregate particles. Corrosion of the embedded reinforcing within the concrete represented by Core 4B is not expected.

Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Daniela Mauro
Associate III, Petrographer

Paul Krauss
Principal

Figure 1. Exterior surface of Core 1A South, as-received.

Figure 2. Side view of Core 1A South, as-received. Exterior of the core is on the left side of the image.

Figure 3. Exterior surface of Core 1A South, as-received.

Figure 4. Side view of Core 1B South, as-received. Exterior of the core is on the left side of the image.

Figure 5. Exterior surface of Core 1A South, as-received.

Figure 6. Side view of Core 1A South, as-received. Exterior of the core is on the left side of the image.

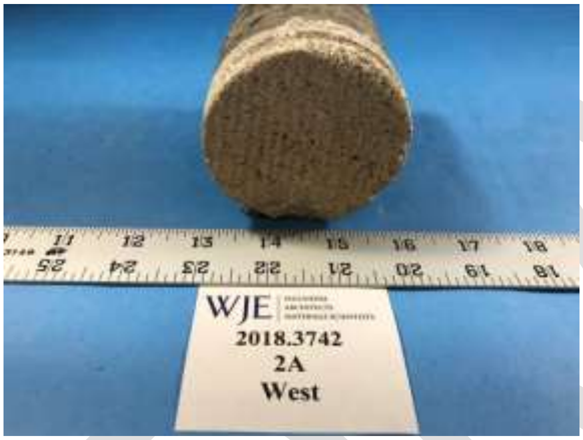

Figure 7. Exterior surface of Core 1A South, as-received.

Figure 8. Side view of Core 2A West, as-received. Exterior of the core is on the left side of the image.

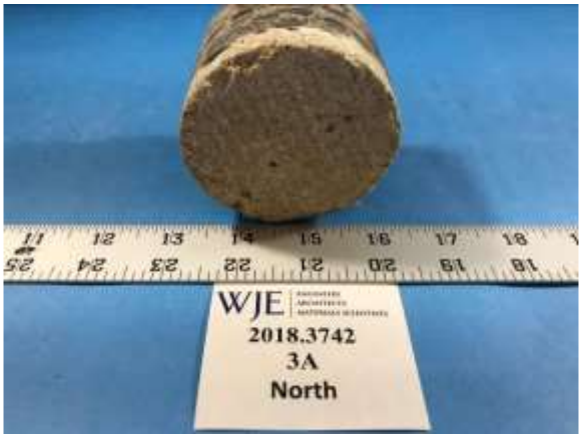

Figure 9. Exterior surface of Core 1A South, as-received.

Figure 10. Side view of Core 3A North, as-received. Exterior of the core is on the left side of the image.

Figure 11. Exterior surface of Core 1A South, as-received.

Figure 12. Side view of Core 4A East, as-received. Exterior of the core is on the left side of the image.

Figure 13. Exterior surface of Core 1A South, as-received.

Figure 14. Side view of Core 4B East, as-received. Exterior of the core is on the left side of the image.

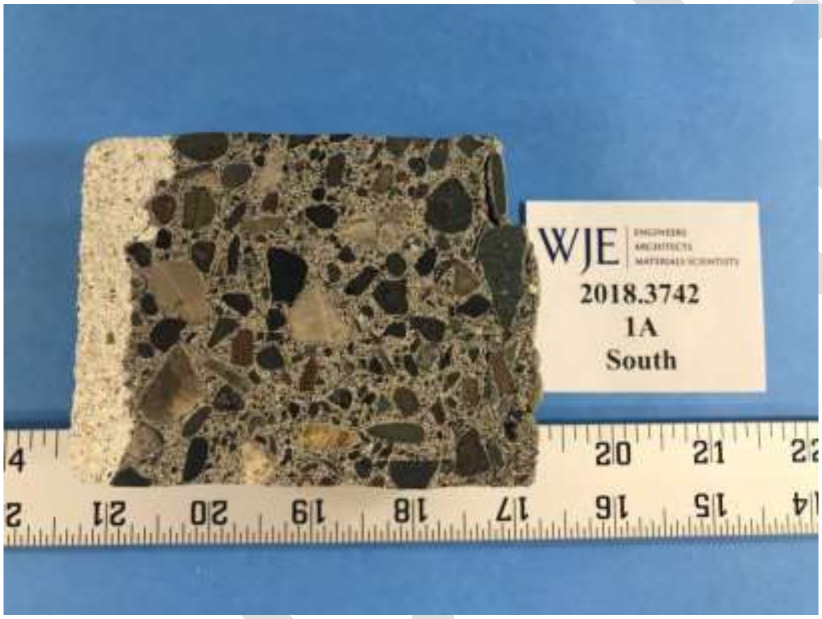

Figure 15. Lapped cross section of Core 1A. Exterior surface is on the left side of the image.

Figure 16. Lapped cross section of Core 1B. Exterior surface is on the left side of the image.

Figure 17. Lapped cross section of Core 1C. Exterior surface is on the left side of the image.

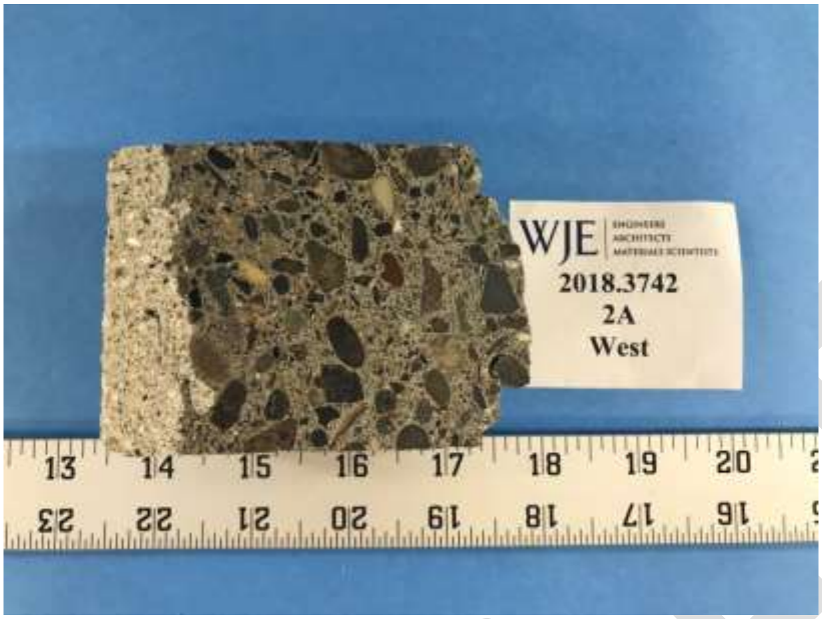

Figure 18. Lapped cross section of Core 2A. Exterior surface is on the left side of the image.

Figure 19. Lapped cross section of Core 3A. Exterior surface is on the left side of the image.

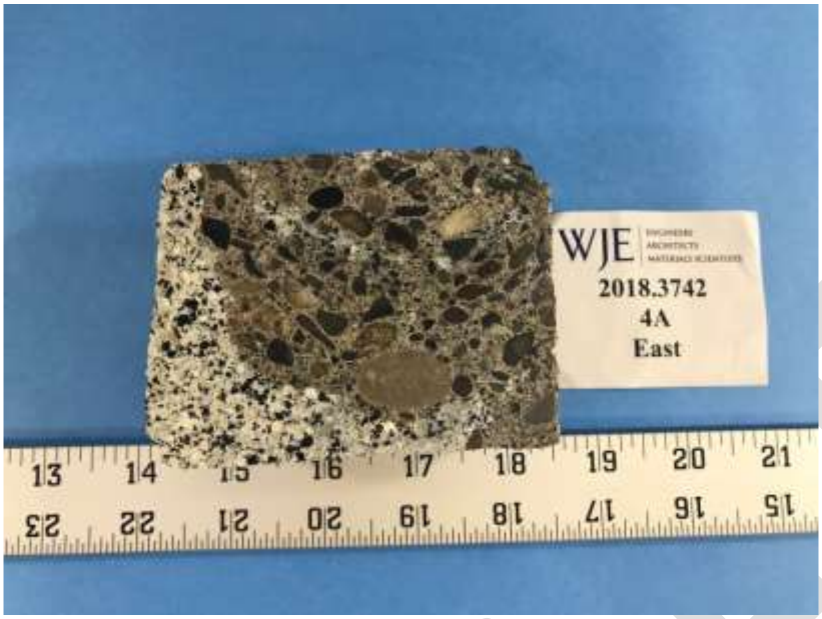

Figure 20. Lapped cross section of Core 4A. Exterior surface is on the left side of the image.

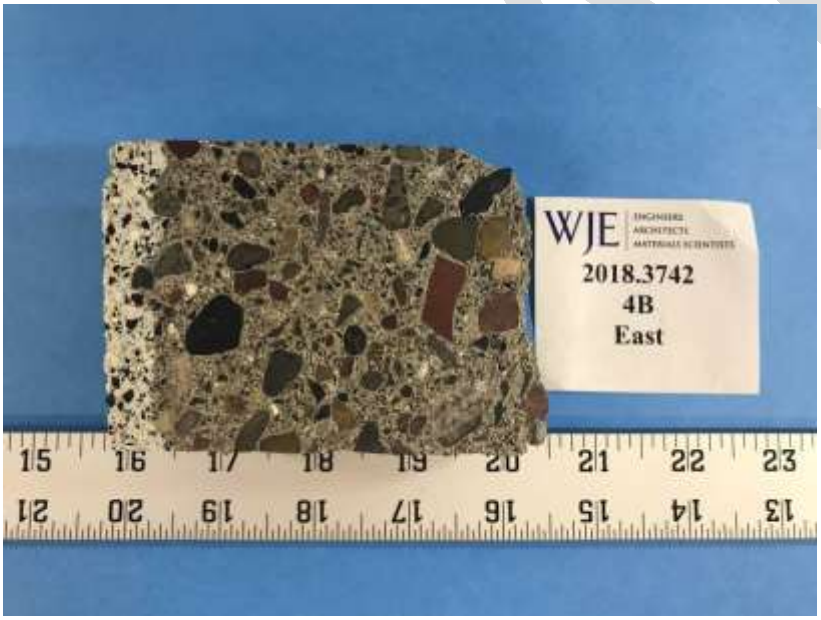

Figure 21. Lapped cross section of Core 4B. Exterior surface is on the left side of the image.

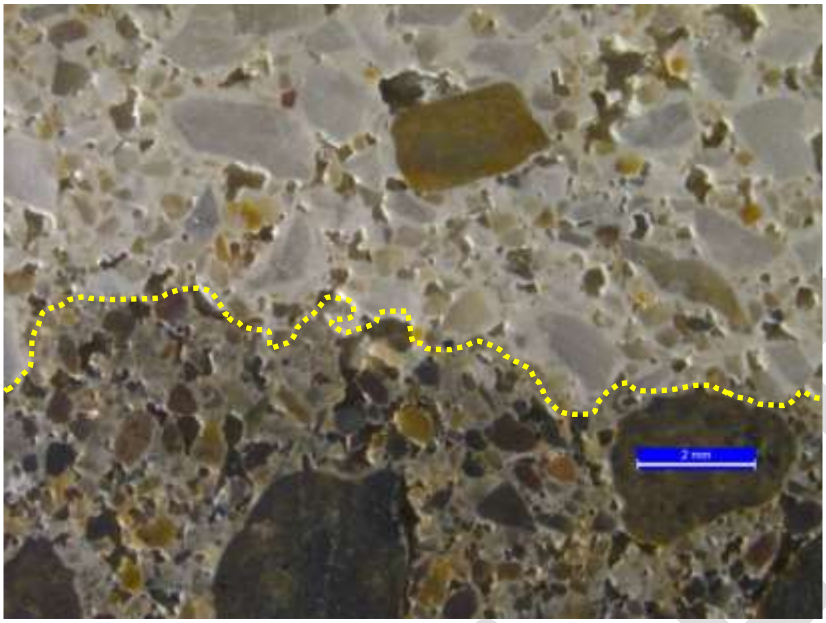

Figure 22. Boundary between the face mix (above dotted yellow line) and backup mix in Core 1A South. The face mix in this core resembles a limestone or sandstone natural stone.

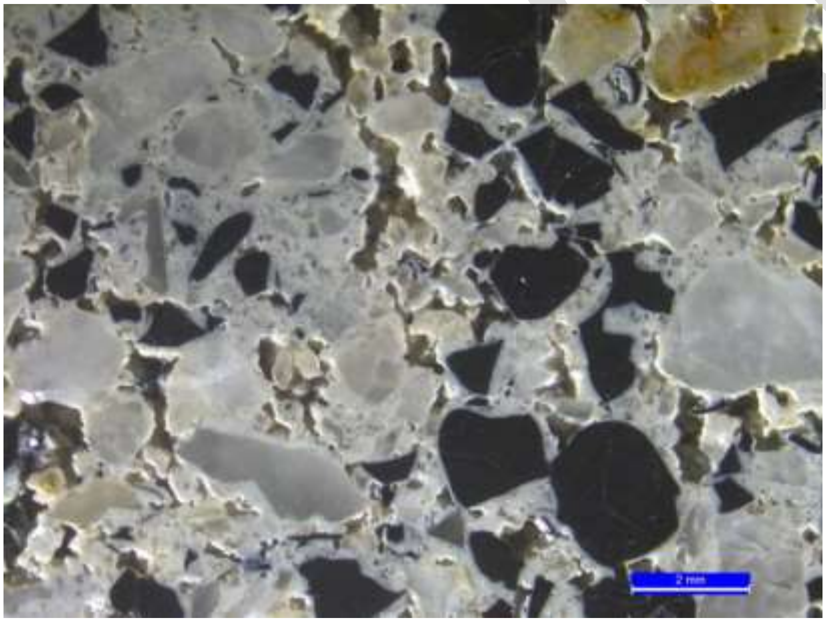

Figure 23. Image of a lapped cross section showing the face mix in Core 4A South. This face mix appears similar to a granite natural stone.

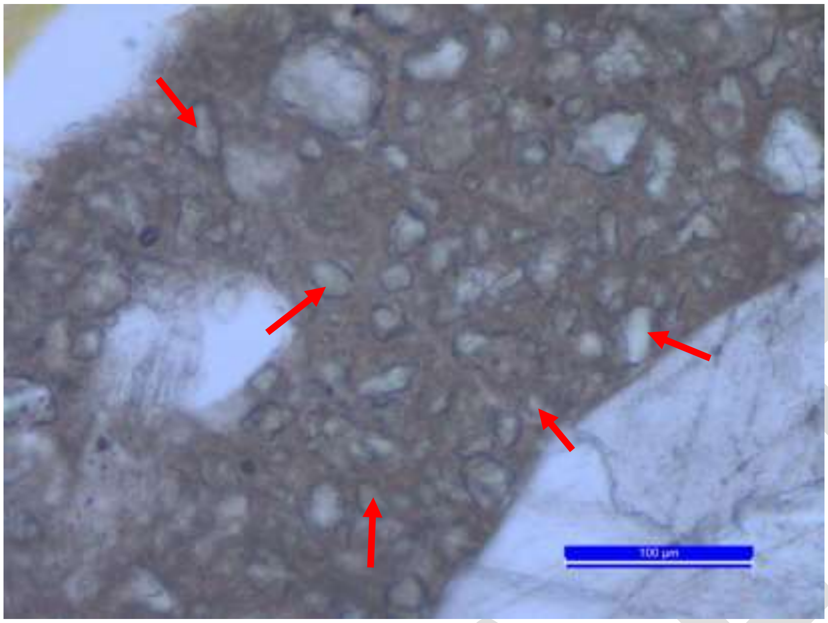

Figure 24. White portland cement (red arrows) present within the face mix of Core 3A North. Plane-polarized light image.

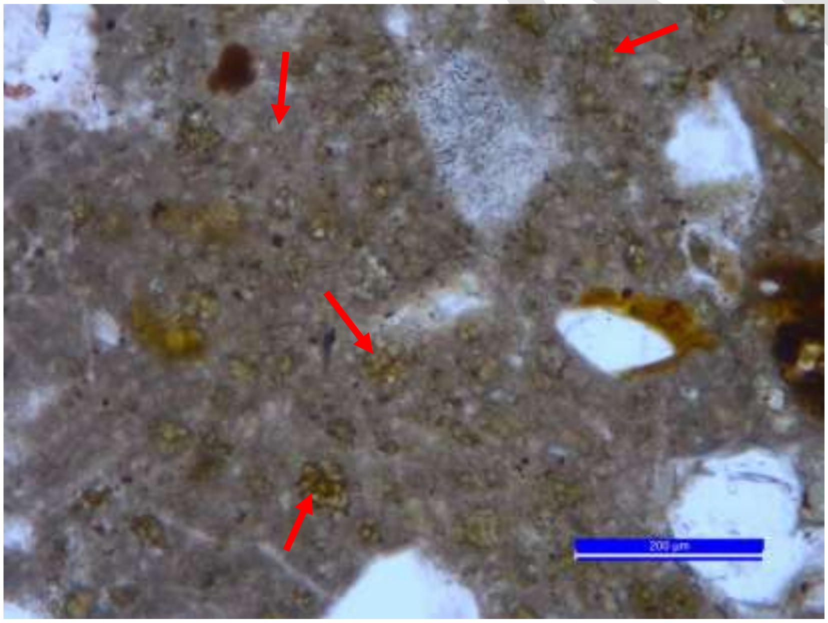

Figure 25. Ordinary grey portland cement (red arrows) present within the backup mix in Core 3A North. Plane-polarized light image.

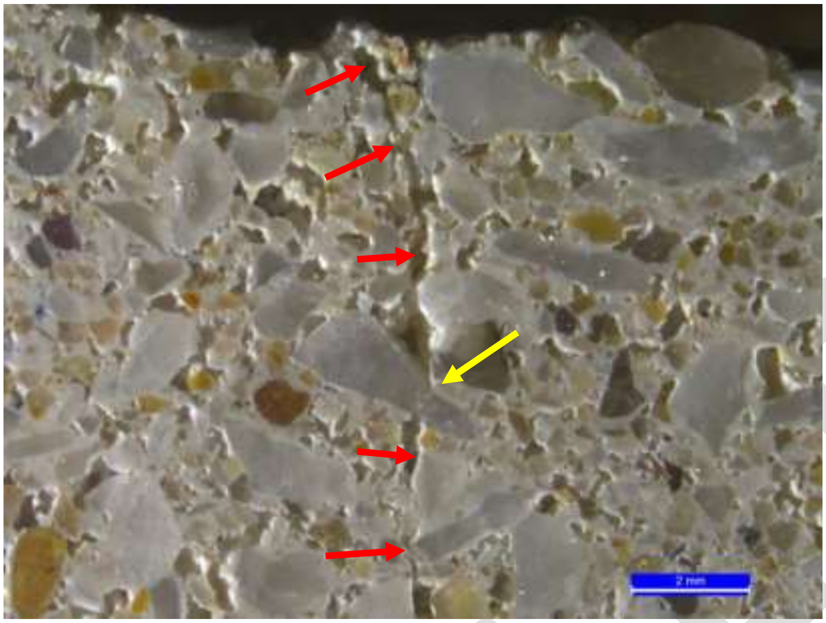

Figure 26. A crack (red arrows) that begins along the exterior surface of Core 3A North and breaks its first aggregate particle (yellow arrow) approximately 6 mm form the surface.

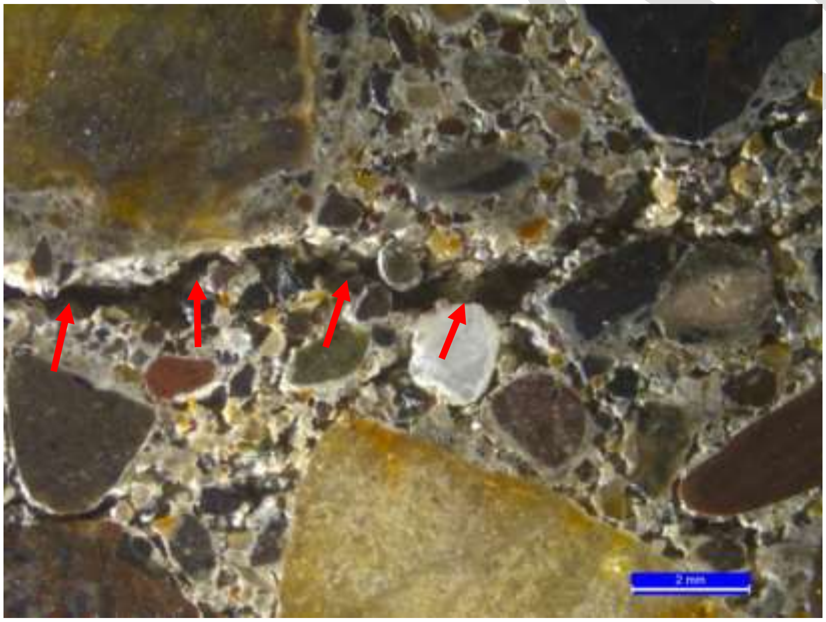

Figure 27. Elongated voids are observed within the backup mix in Core 3A North. The void in this image (red arrows) runs transverse through the core.

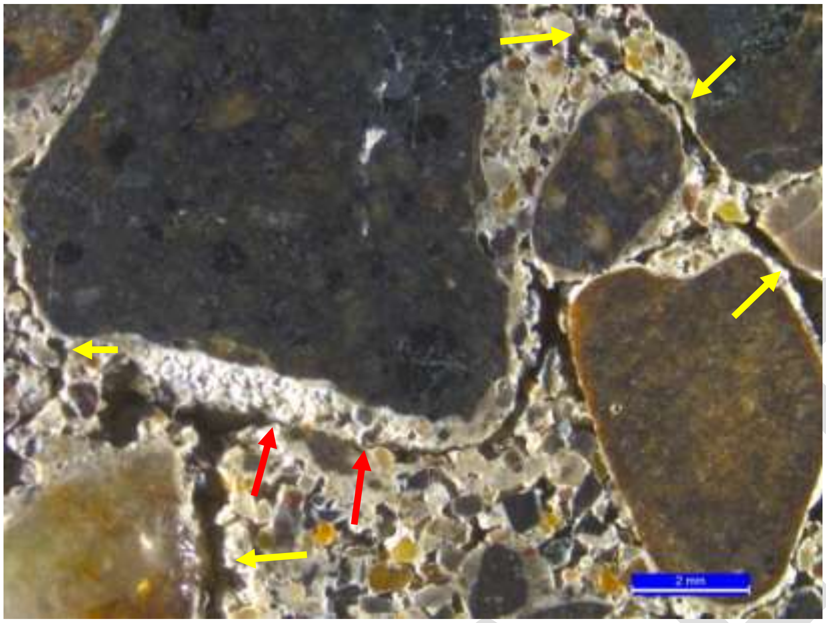

Figure 28. While most of the elongated voids run transverse (red arrows), some longitudinal voids (yellow arrows) are also observed in the backup mix.

Cushing Terrell

PRE-BID MEETING SIGN-IN SHEET

PROJECT:	Great Falls Civic Center Exterior Façade Renovation	PROJECT MANAGER:	Anthony Houtz
PROJECT REF:	CITYGFCC_ENV	DATE:	February 1, 2021

NAME	COMPANY	EMAIL ADDRESS	PHONE
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CJ Bailey	Benchmark Masonry Inc.	CJ@BenchmarkMasonryInc.Com	406-366-4223 Cell 406-366-6257-office
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Wells Hansgen	Hydro Tech	Wells@HTrestoration.com	801 372 5148
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Lee VandeBerg	Liberty Electric	lee.vandeberg@libertyelectricinc.com	406-761-6308

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Terrell

PRE-BID MEETING SIGN-IN SHEET

PROJECT: Great Falls Civic Center Exterior Façade Renovation

PROJECT MANAGER: Anthony Houtz

PROJECT REF: CITYGFCC_ENV

DATE: February 1, 2021

NAME	COMPANY	EMAIL ADDRESS	PHONE
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Wyatt Johnson	Dick Anderson Construction	wyatt.johnson@daconstruction.com	406-403-8932
BILLY BRENNAN		BILLY@BRENNANHC.COM	452-1133

BID FORM

PROJECT: City of Great Falls Civic Center
Exterior Envelope Renovation
#2 Park Drive South
Great Falls, MT 59401

CT Project No.: CITYGFCC_ENV

TO: City of Great Falls
#2 Park Drive South
Great Falls, Montana 59403

BID FROM: ____

____

I have received the Contract Documents and Project Manual for the City of Great Falls Civic Center Envelope Renovation, Great Falls.

I have also received Addenda Nos. ______________________________, and have included their provisions in my Bid. I have examined both the documents and the site and submit the following Bid:

In submitting this Bid, I agree:

1. To hold my bid open until April 14, 2021.
2. To accept the provisions of the Instructions to Bidders regarding disposition of Bid Security.
3. To enter into and execute a Contract, if awarded on the basis of this Bid and to furnish all bonds and insurance required by the bidding documents.
4. To accomplish the work in accord with the Contract Documents.
5. I certify that I am not presently working beyond the contract time including and authorized extensions of time on any previously awarded public contract in the State of Montana. (MT).
6. To complete the work outlined in the Contract Documents within _________________ calendar days.
7. <u>I have completed the qualified masonry contractor form and it is attached herein.</u>

Base Bid:

I will perform all of the Work in the base bid, for the lump sum price of:

____dollars

($__________________).

Included in the base bid total is a lump sum price of _______________________________dollars for the temporary canopy, including assembly and disassembly, as indicated in the contract documents.

Alternate Bid Item #1 (ADD):

Provide and install all work for Roof Section ‘D’ as outlined on sheet A106.

ADD____dollars

($_________________________).

Alternate Bid Item #2 (ADD):

Provide and install all work for Roof Section ‘E’ as outlined on sheet A106.

ADD____dollars

($_________________________).

Alternate Bid Item #3 (ADD):

Provide and install all work for Roof Section ‘F’ as outlined on sheet A106.

ADD____dollars

($_________________________).

Alternate Bid Item #4 (N/A):

Not Used.

Alternate Bid Item #5 (ADD):

Provide and install lead caming in all skyward facing joints as indicated on sheets A107 and A701.

ADD____dollars

($_________________________).

Unit Pricing – All unit prices shall include costs for labor and materials necessary for complete removal and replacement :

A. Unit Price 1: Removal and Replacement of Cast Stone panel size 5’x5’. $____________

B. Unit Price 2: Removal and Replacement of Cast Stone panel size 4’x5’ $____________

C. Unit Price 3: Removal and Replacement of Banding panel size 1’x5’. $____________

D. Unit Price 4: Removal and Replacement of Ornamental Cast Stone Dentil panel size 2’x5’. $____________

E. Unit Price 5: Removal and Replacement of Cast Stone Coping size 6’x5’. $____________

F. Unit Price 6: Removal and Replacement of Ornamental Cast Stone Entablature unit. $____________

G. Unit Price 7: Removal and Replacement of Cast Stone Panel size 6’4”x4’ as indicated. $____________

I have attached the required Bid Security to this Bid. I understand that if I do not answer the above questions and complete all blank spaces provided, my bid may be rejected as an incomplete bid.

Respectfully Submitted:

Date: ____________________________ By: ____________________________

Contractor

____

Signature

____

Title

____

Business Address

(Seal - if by a Corporation) ____________________________

Montana Public Contractor’s License No.