APT Mortar Workshop – October 2017

Field Prepared Mortar Performance – Test Notes

Introduction

As part of the 2017 APT annual conference in Ottawa, a workshop on masonry mortars was held at the Fairmont Chateau Montebello hotel in Montebello, Quebec. The workshop was held October 10th and 11th, 2017, and consisted of classroom sessions and practical hands on elements. The nearby Papineau Funeral Chapel (Figure 1) was used as a facility for hands on demonstrations of masonry techniques, inspection, testing, chipping out mortars, preparing mortar mixes and installation of front pointing mortars. The course covered many different aspects of masonry repair as well as materials to be considered for use on older masonry structures.

Figure 1 – Papineau family funeral chapel

The Papineau funeral chapel is a small masonry building constructed by Louis Joseph Papineau in the 1850's. It is constructed primarily of Papineauville sandstone which shares qualities with the

Potsdam/Beekmantown sandstones. It is dense, quarzitic sandstone that is predominantly white with some oxide staining yielding shades of yellow and red (Figure 2).

Figure 2 - A sample location where the existing mortar has been removed. It shows a dense, thin Portland cement front pointing mortar and a more porous back pointing mortar.

Workshop Mortars

As part of the workshop, a total of 7 mortars were mixed. Two mortars were mixed by Keith and Alex Blades, Marc Cote and Ken Trischuk in the NRC laboratories prior to the workshop (labelled P1 and P2) while a further 5 mortars were mixed on site at the chapel (labeled W1-W4). All mortars were mixed by hand in small batches (approx. 5 liters or slightly less than ¼ ft^3). A list of the key ingredients is given below while the mortar mix designs are in Table 1

- Quick lime - Provided by Graymont from the Eastern Townships of Quebec. It was used in both powder and lump form
- Slaked lime fired in Montebello – Indiana limestone fired in the kiln as part of the workshop
- Natural cement – Rosendale natural cement
- Wood ash - from the Montebello fireplace
- Nesbitt sand – siliceous sand from the area

Figure 3 shows a sieve analysis of the Nesbitt sand while figure 4 shows the percentage of the Nesbitt sand retained on the various sieves.

Table 1 Workshop Mortar Mix Designs

Mortar Mix	Lime	Additional binders	Sand	Additive/pozzolan
P1	1 - quicklime (powder)		3	
P2	1 - quicklime (lumped)		3	
W1	1 - quick lime		3	
W2	1 - quick lime		1.5	5% wood ash - added post slake
W3	1 – Montebello slaked lime		3	
W4 – X	2 – Montebello slaked lime	1 natural cement "premix"	6	
W4	1 quick lime	1 natural cement	6	

Mix 4-X – while tested on site and strength cubes made -was discarded on site as the incorrect bag of material was selected and noticed only after mixing had occurred. It was not put in the wall

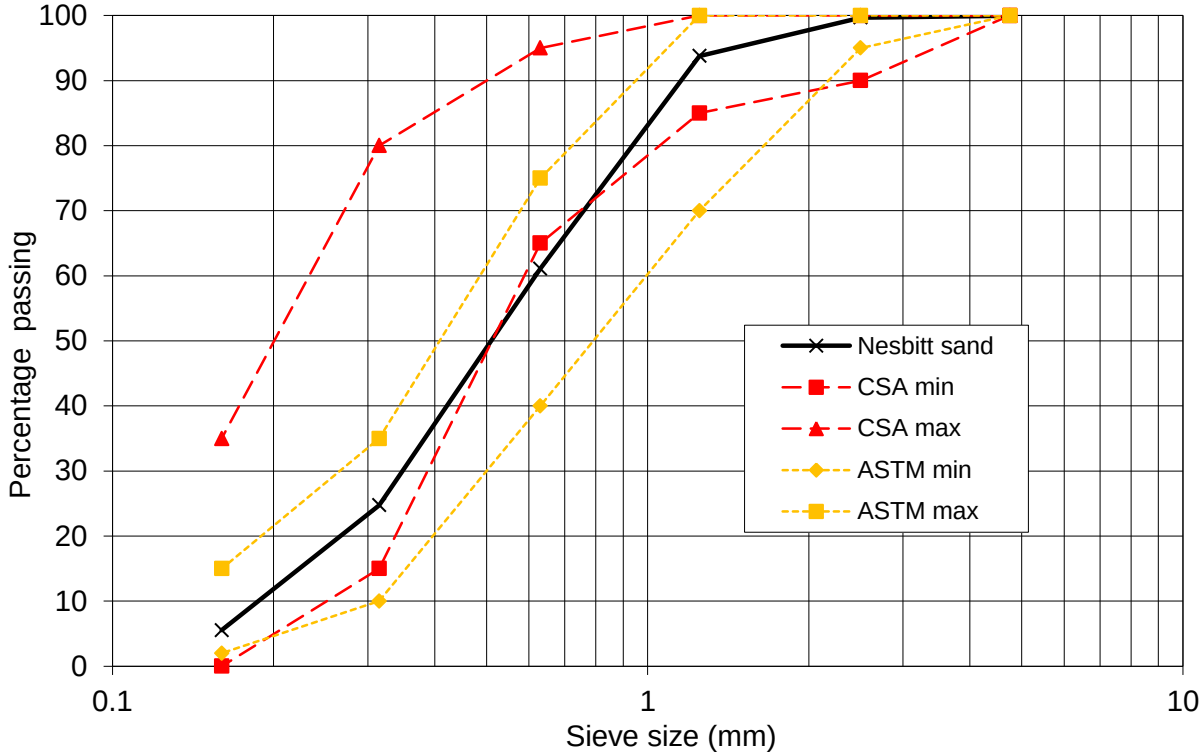

Figure 3 – Sieve analysis of Nesbitt sand with CSA and ASTM limits

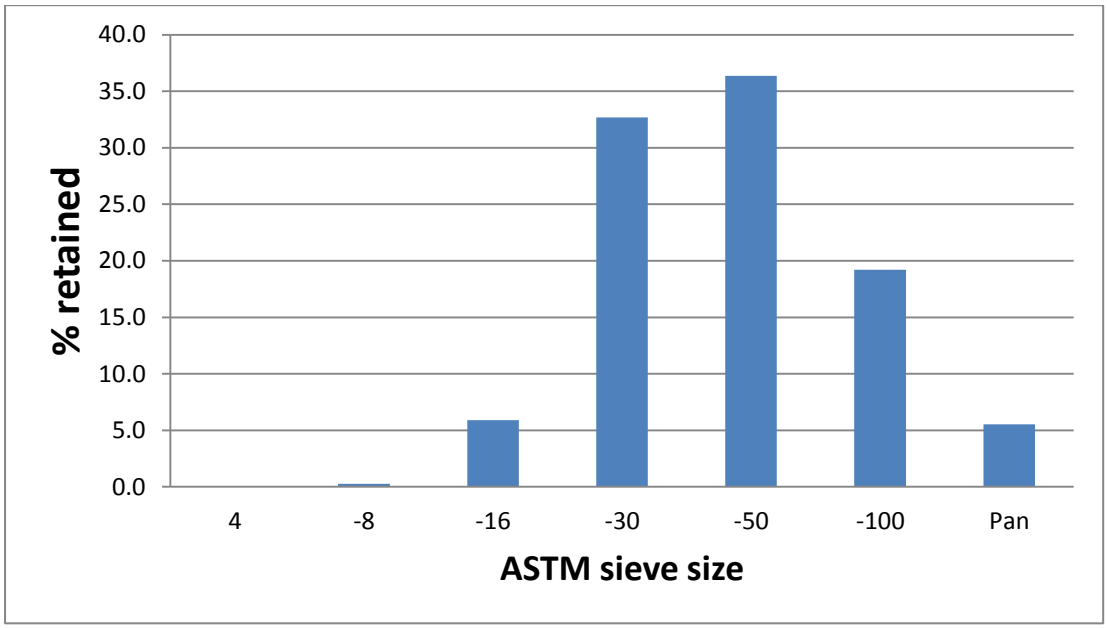

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Figure 4 Nesbitt sieve analysis - percentage retained on each sieve

Figure 5 Mixing of fresh mortar on site

Figure 6 Installation of mortar in the buttress – including resetting a stone

Curing

Mortar cubes constructed during the workshop were immediately transported from site back to the NRC laboratories where they were cured 14 days damp cure (100% R.H.). At 14 days the cubes were removed from their moulds. They were extremely soft and great care was taken to remove them from the molds. While the intent had been to damp cure until testing (as per CSA A179 for compressive strength cubes) it was decided to dry cure them if there was any hope of them gaining enough strength to be reasonably tested. After 14 days, the cubes were kept in laboratory conditions at 22°C and 50% R.H. until testing.

All of the mortars installed in the walls of the chapel were cured "as is". No special damp curing was applied after installation; they were just left to cure in local ambient conditions.

Test Results

Compressive Strength

On site, the air content and workability (using the Vicat Cone (ASTM C780)) were measured as well as a set of mortar cubes constructed for measuring compressive strength for each mortar mix.

Cubes were tested at various ages (typically 3 cubes per age) using a Tinius Olsen 60, 000 lb universal testing machine to determine compressive strength development over time. The results of the compressive strength along with the Vicat cone and air measurements of the fresh mortar are presented in Table 2.

Table 2 Compressive Strength Development

Mortar Mix	Vicat Cone (mm)	Air (%)	Compressive Strength(MPa)			
			28d	56d	90d	6 months
P1	32	3.5	-	0.75	1.01	1.55
P2	22	3.75	-	0.80	1.20	1.94
W1	12	-	0.90	1.28	2.02	-
W2	24	4	0.82	1.53	1.98	-
W3	18	5.25	0.80	1.48	2.05	-
W4-X	19	7.5	0.22	1.22	1.27	-
W4	31	5.5	-	1.21	1.21	-

Note: 1MPa = 145 psi

Figure 7 shows field testing of the mortars and preparation of cubes while figure 8 shows the strength development over 6 months for mortars P1 and P2. There still remain 3 cubes for mixes P1 and P2 which will be tested at 1 year.

Figure 7 – Constructing mortar cubes on site

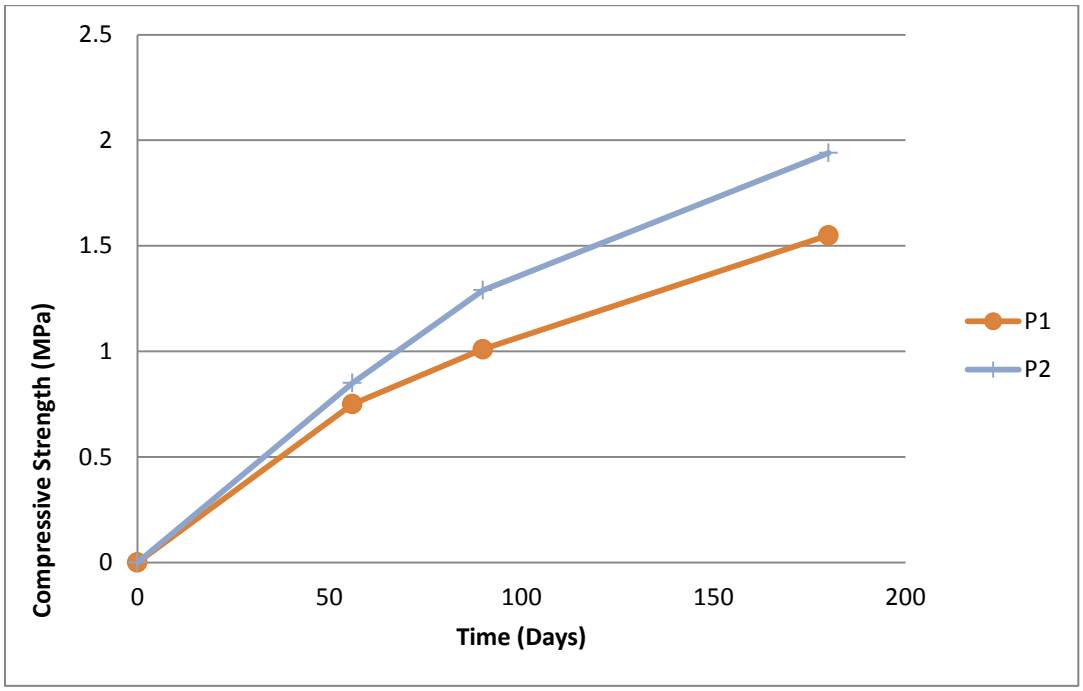

Figure 8 Strength development of two hot mixed lime mortars prepared prior to the workshop.

Site review at 5 months

On March 31, 2018 – Marc Cote and Ken Trischuk revisited the chapel to see how the mortars fared through their first winter. Four mortars were installed on the chapel site – W1 to W4. The mortars were installed as shown in figure 9 (elevation) and figure 10 (photo) as follows;

- Mix W1 – in site **#10**
- Mix W2 - in site **#9**
- Mix W3 - in site **#8** and,
- Mix W4 - in site **#11**

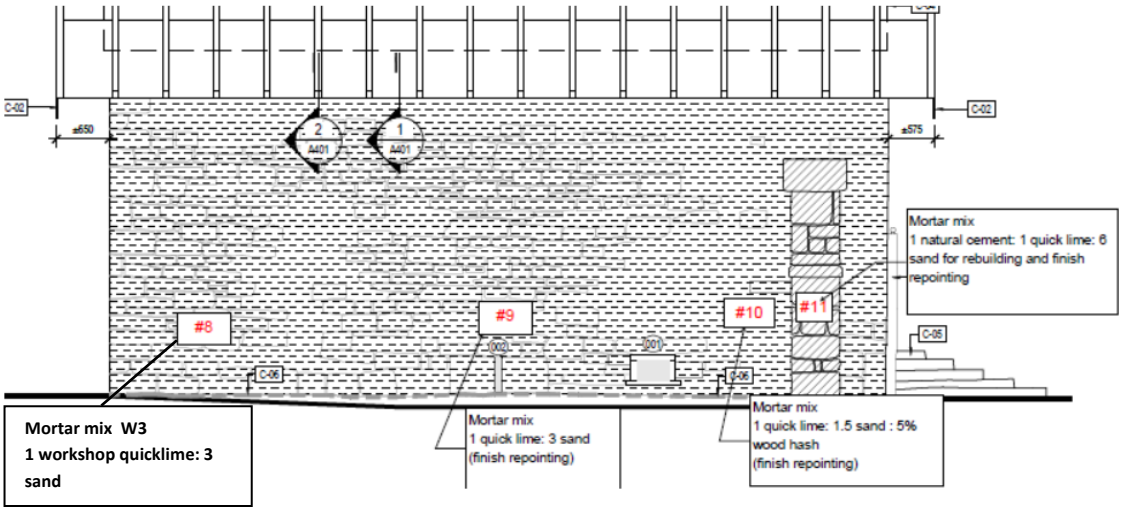

Figure 9 Site plane of south wall exposure where trial mortars were installed.

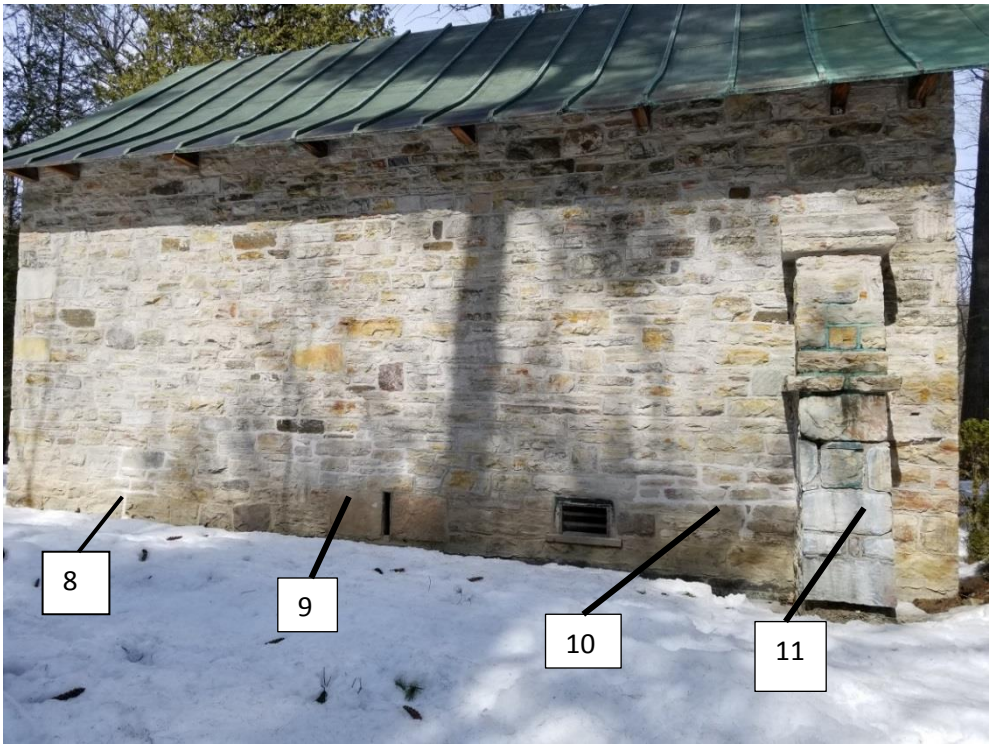

Figure 10 Photo of South elevation of Papineau Chapel indicating the test mortar locations

Figures 11-15 show close ups of the locations for the mortars in the wall along with a couple of notes on their condition. In general the three mortars W1, W2 and W3 visually appear to be in good condition. These mortars are located under a good roof overhang which would protect them to some degree from

rain and snow melt coming off the roof - thus they are exposed to lower moisture content and would be less susceptible to freeze-thaw damage.

There are a few minor shrinkage cracks in mixes W1-W3 but no erosion of the mortars. There are some problems with hollow sounding locations when one taps the mortar with a screwdriver. Whether this is a sign of erosion of the mortars or simply lower quality installation from the workshop participants[1] is unclear.

Figure 11 Close up of mix W3 in location #8 – probably the best performer of the 4 mortar mixes

[1] Of course the workshop participants themselves were of the highest quality!

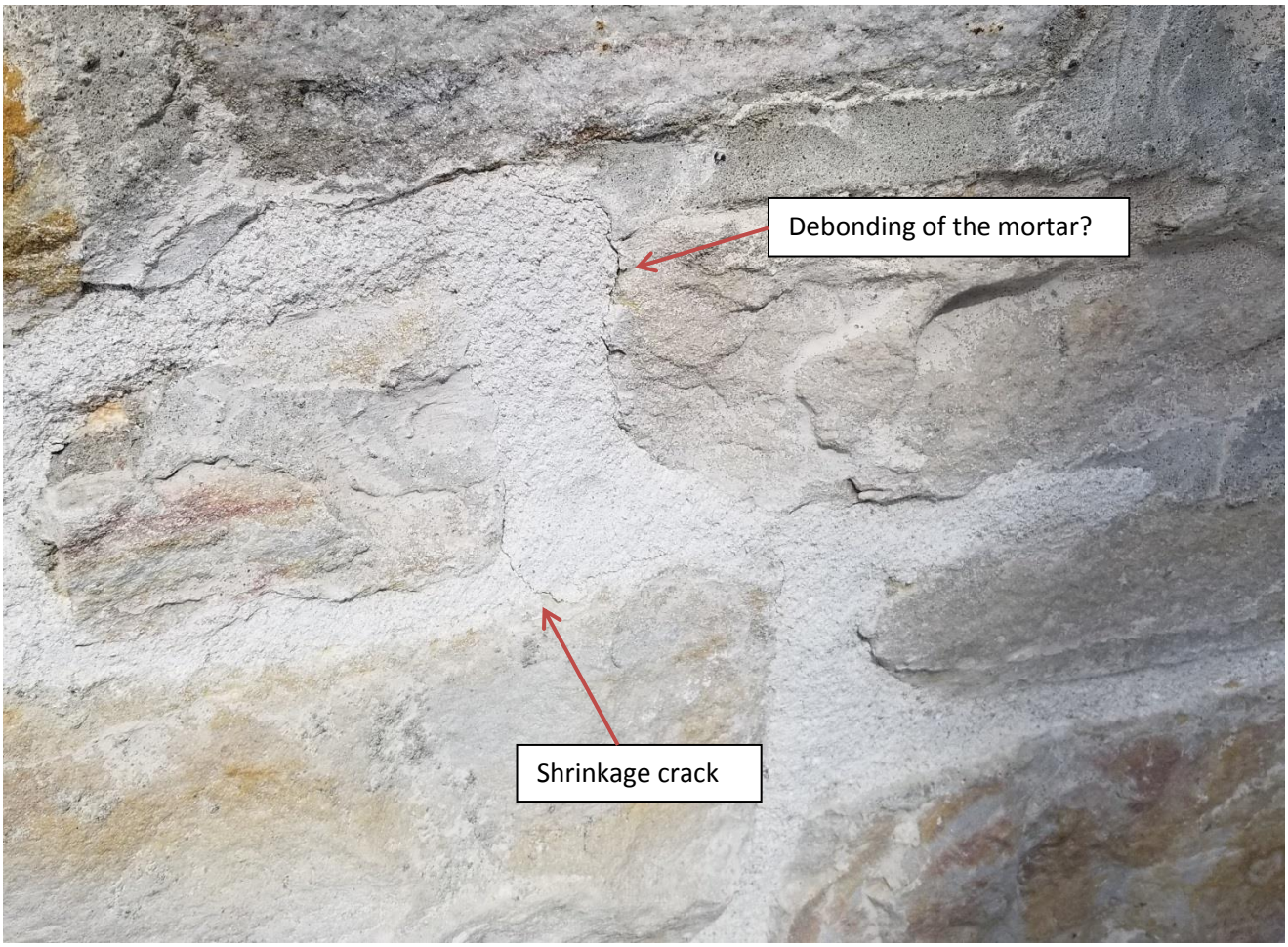

Figure 12 Close up of mix W2 in location #9 – some shrinkage cracks and perhaps some debonding from the stone

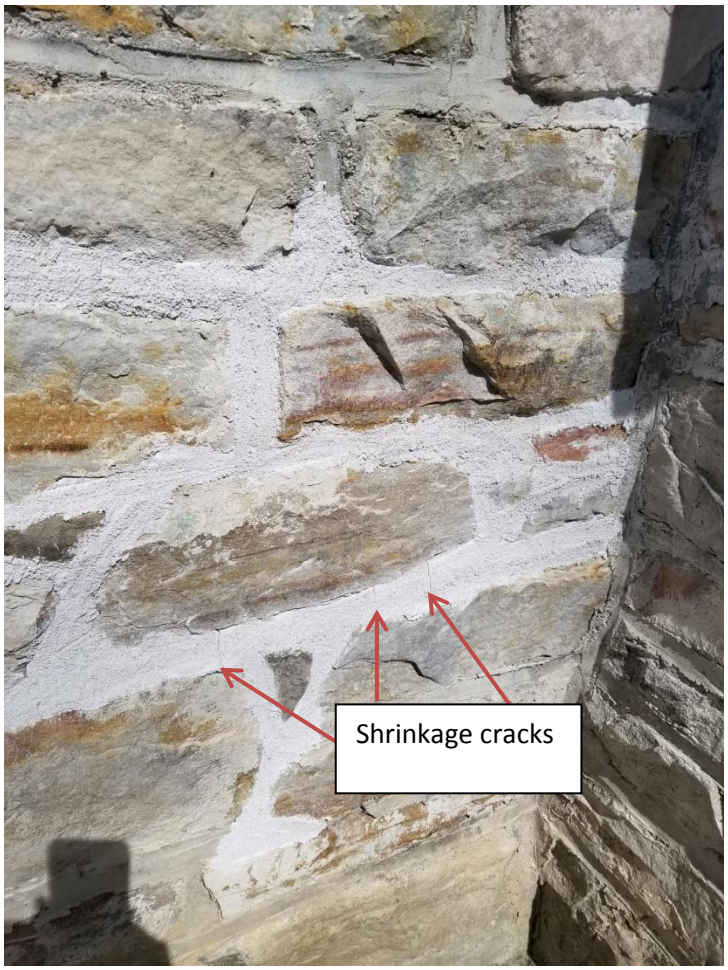

Figure 13 Close up of mix W1 in location #10 - more shrinkage cracks

Mortar W4 in location 11 was a different story. The mortar here was all very soft and could easily be removed with your fingers. Whether this is a result of the mix design or the increased exposure is unclear. The location on the buttress would be exposed to higher moisture content as is evidenced by water staining coming down the face of the buttress. Higher moisture content would make it susceptible to freeze-thaw deterioration. Mix W4 also had a slightly lower compressive strength at 90 days than mixesW1 – 3.

Figure 14 Close up of mix W4 in location # 11 – Marc's awl (~ 70mm long) slid easily in to the soft mortar - essentially reduced to the consistency of a soft mud in the mortar joints.

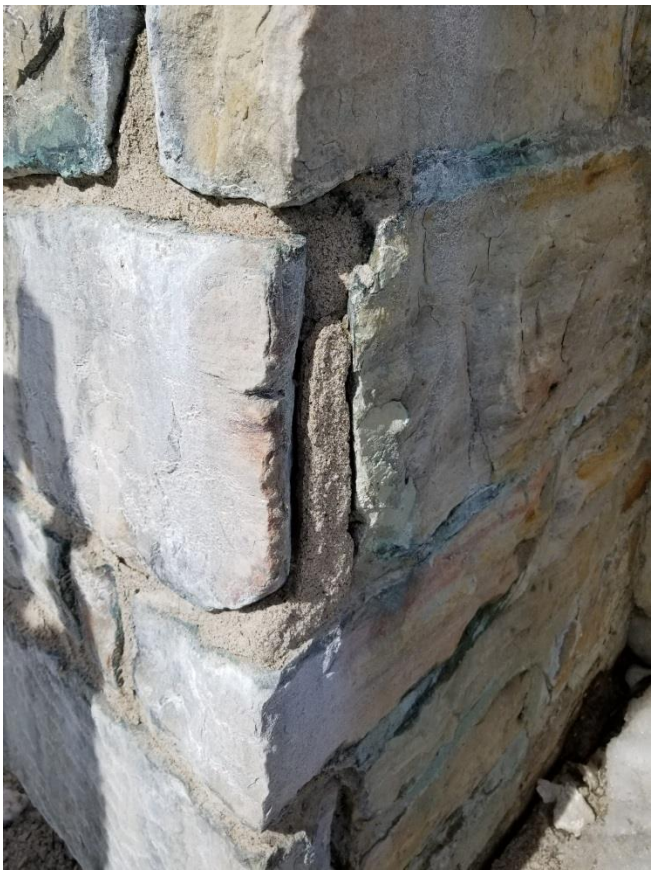

Figure 15 Another close up of mix 4 in location #11 – erosion of the mortar away from the stone

Acknowledgements

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