

Project: USHG #08007 and #08008



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EVALUATION OF MORTAR COMPOSITION – ASTM C1324

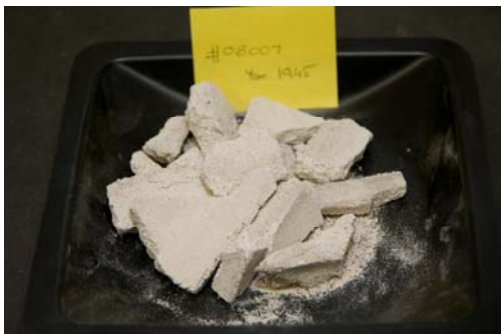
1.0 INTRODUCTION

In an effort to facilitate an accurate restoration to the building, mortar samples were taken from selected locations on the building in order to identify the composition and proportions of the original mortar ingredients. The following report summarizes the methods of testing and the results herein on the samples provided for this examination.

2.0 METHODOLOGY

The samples were analyzed according to chemical procedures and petrographic examination methods of ASTM C1324, “*Standard Test Method for Examination and Analysis of Hardened Masonry Mortars*”.

3.0 SAMPLES



Sample #1
USHG # 08007 - section built in 1945



Sample #2
USHG # 08008 – section built in 1985



4.0 RESULTS

4.1 PETROGRAPHIC EXAMINATION

Sample 1 - USHG # 08007 (section built in 1945)

Paste

The paste consists of hydrated portland cement, hydrated lime, and has a light gray color. The entire paste is carbonated. The paste has good to average hardness with good paste-aggregate bond and good firmness.

The paste contains a low number of pockets of hydrated lime measuring up to 1 mm in size. Brick fragments are not present. The degree of hydration is highly advanced. Aggregate and paste volumes appear normal.

Aggregate

The fine aggregate is finely graded natural with 1.5 mm maximum grain size and a modal (most frequent) grain size of 0.5mm. The particle grading appears to be similar to natural sand grading listed in ASTM C144. The sand consists of quartz, feldspar, ironstone, hornblende, and low amounts of pyroxene. A few soft limestone fragments, measuring in size up to 3/8-inch (10mm), were detected and may be an impurity in originally used lime or lime putty. The aggregate is chemically and physically stable.

Air Content

The mortar air content is very low, at 1.6%. The air-voids are entrapped.

Sample 2 - USHG # 08008 (section built in 1985)

Paste

The paste consists of hydrated portland cement, hydrated lime, and red pigment. The entire paste is carbonated. The paste has very good hardness with good paste-aggregate bond and good firmness.

The paste contains a very low number of pockets of hydrated lime. Brick fragments are not present. The degree of hydration is highly advanced. Aggregate and paste volumes appear normal.

Aggregate

The fine aggregate is natural sand with 1.5 mm maximum grain size and a modal (most frequent) grain size of 0.58mm. The particle grading appears to be similar to natural sand grading listed in ASTM C144. The sand consists of quartz, feldspar, hornblende, and low amounts of claystone, pyroxene, augite and siltstone. A few coarse fragments of limestone fragments, measuring in size up to 3/8-inch (10mm), were detected and may be an impurity in originally used lime or lime putty. The aggregate is chemically and physically stable.

Air Content

The entrapped air content is 2.5%. The air-voids are entrapped



4.2 CHEMICAL ANALYSIS

Both samples were chemically analyzed for portland cement content according to the soluble silica method in ASTM C1324, "Standard Test Method For Examination and Analysis of Hardened Masonry Mortars".

The Portland cement was assumed to contain 63.5% calcium oxide (CaO) and 21.0% silicon dioxide (SiO₂). The hydrated lime was estimated to contain 71.0% calcium oxide (CaO) and 3.5% magnesium oxide (MgO).

The densities (loose volume basis) of the mortar ingredients were assumed to be those listed in ASTM C270. Eighty lbs. of oven-dry sand was assumed to be equal to one cubic foot of damp loose sand.

Based upon the results of the chemical analysis, the volumetric proportions appear to be:

Constituent	Sample #1 1945	Sample #2 1985
Portland cement:	1.0 ft. ³	1.0 ft. ³
Hydrated Lime:	0.8 ft. ³	0.4 ft. ³
Natural Sand:	4.9 ft. ³	3.0 ft. ³
Mortar Type	N	S / N

The results of chemical analysis are given in the Table 1.

4.3 PROPOSED REPLACEMENT MIX

In light of these findings and the intended use of the replacement material, U.S. Heritage Group recommends specifying a replication mortar formulation consisting of 1 part Portland cement, 2 part hydrated lime and 8 parts sand for both mortars.

This mix design would fall under the classification "Type O" in ASTM C270 Proportion Specification. The Portland cement must meet ASTM C150; the non-hydrated lime is required to meet ASTM C207; and the sand should match the original sand as closely as possible in terms of color, size and shape.

Adjustments to the aggregate gradation curve should be considered when a mortar joint width exceeds ½ inch. The rationale in recommending this mortar is based upon the nature of the repairs and considering the National Park Service guidelines (set-forth below) that recommend that a replacement mortar be formulated to be softer in compressive strength than that of the original to protect the adjacent masonry units.

*** "The new mortar must be as vapor permeable and as soft or softer (measured in compressive strength) than the historic mortar. (Softness or hardness is not necessarily an indication of permeability; old, hard lime mortars can still retain high permeability.)"*

** Preservation Briefs #2 Repointing Mortar Joints in Historic Masonry Buildings, Technical Preservation Services, National Park Service, 1998.



4.4 JOBSITE MOCK-UP SAMPLE

The replacement mortar sample should be field-tested through a jobsite mock-up. The mock-up sample should be installed by a qualified craftsman who understands the curing and application details of Type O mortars. Once the mock-up sample is installed, appropriate precautions should be taken to ensure that the mortar is protected from wind, sun, rain and frost to enable slow curing (i.e. carbonation) to take place.

*The sample should be allowed to **cure in the wall for a minimum of seven but preferably fourteen days** before final color match is approved.*

The sand gradation charts illustrating the sand isolated from your samples were sent by overnight mail last week. We look forward to providing you with a custom, ready-to-use, historically correct mortar for your project. When inquiring about this match please use the project number USHG#08007 /08008.

Respectfully,

U.S. Heritage Group, Inc.

Nelson Testing Laboratories

Tom Glab
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Chemist, Petrographer



Table 1. Chemical Analysis of Mortar Samples

Constituent	Percent by Mass %	
	Sample #1 USHG # 08007 "1945"	Sample #2 USHG # 08008 "1985"
Silica - SolubleSiO ₂	3.67	5.38
Calcium Oxide - CaO	16.94	19.33
Brucite – Mg(OH) ₂	< 0.3	< 0.3
Insoluble Residue	72.68	65.47
Magnesium Oxide – MgO	1.3	1.11
Loss on Ignition		
At 0-110°C	0.0	0.0
At 110-550°C	4.01	5.89
AT 550-1000°C	9.11	3.7
Calculated Constituents		
Portland Cement	18.65	25.6
Hydrated Lime	7.45	4.45
Fine Aggregate	73.5	67.0
Iron oxide (pigment)	0.4	2.95
Volumetric Proportions (according to ASTM C270) – Loose Volume Ratios		
Portland Cement : Hydrated Lime : Sand	1.0 : 0.8 : 4.9	1.0 : 0.4 : 3.0
Mortar Type	Type N	Type S/N

