



Custom Mortar Matching Report

USHG Project: # 19-080

Analysis Date: 6/03/2019

Project: Pabst Mansion

Client: Pamela Williams-Lime, Pabst Mansion

2000 West Wisconsin Ave, Milwaukee, WI 53233

Client Requirements: Match Mortar / Package B

Mortar Dating: 1892

Location/Function in Building: Terra Cotta, Limestone and Face Brick Joints/Bedding Mortars

INTRODUCTION

The findings and recommendations presented in this report are premised on the results of tests performed on four mortar samples delivered to our laboratory on May 31, 2019.

The scope of testing was limited to the determination of the physical mix proportions of the major ingredients used in the mortar samples. The testing included visual examination, both with and without magnification, as well as analysis of the aggregate color, particle shape and grain size distribution.

The sample's physical characteristics, original date of construction, and guidelines from the U.S. Department of the Interior National Park Service were used to determine the proposed mortar component recommendations as well as the aggregate ratios for the replacement mix.

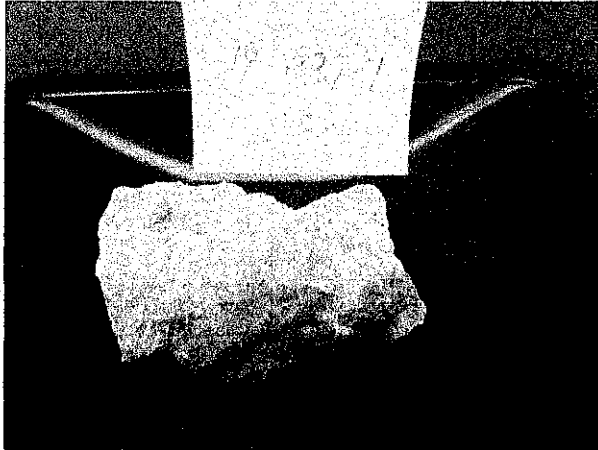
U.S. Heritage Group interpreted and adjusted the proposed mortar formulation recommendation based on the information provided to us regarding: current site conditions; present condition and type of masonry; the function of the new mortar; and the degree of weather exposure. Assuming the sample provided is representative of the original mortar, the analysis and mortar-matching diagnosis detailed in this report here will give a reliable indication of the original ingredients and allow U.S. Heritage Group to recommend a historically correct mortar formulation for your project.

SAMPLES

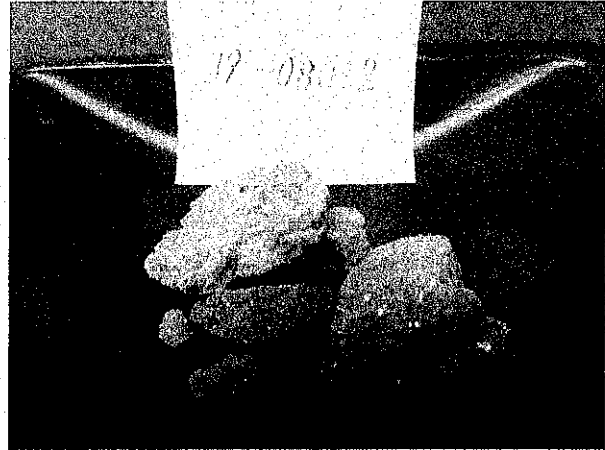
Analyzed mortar samples were dated approximately 1892.

The samples were identified in our laboratory as:

1) #19-080-1 PM Terra Cotta Bedding Mortar



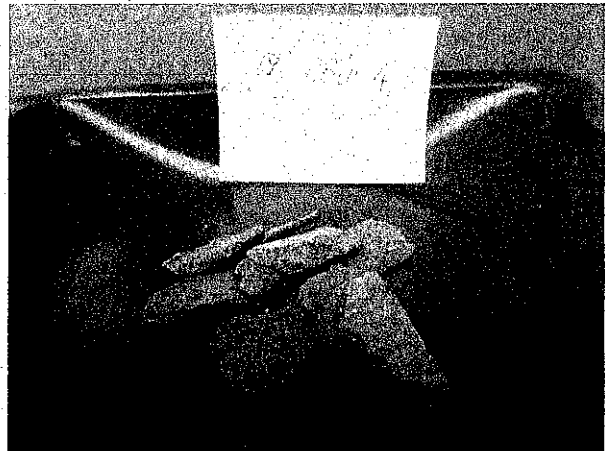
2) #19-080-2 PM Terra Cotta Joint



2133) #19-080-3 PM Limestone Ashlar Joint Profile



4) #19-080-4 PM Face Brick Mortar



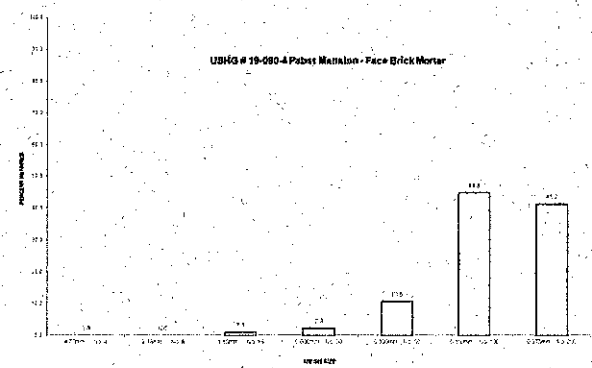
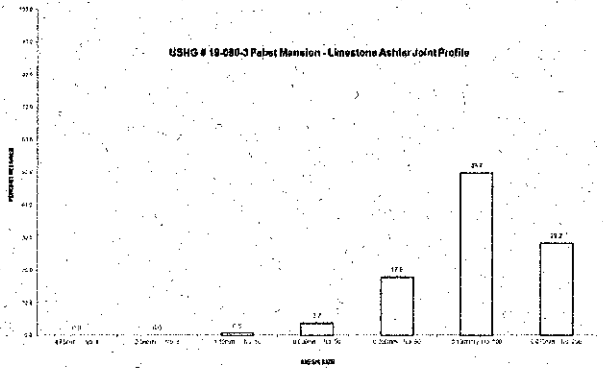
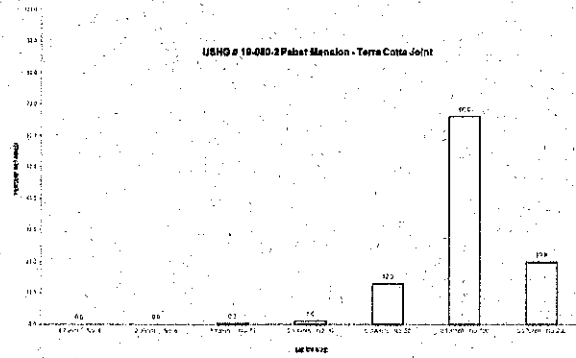
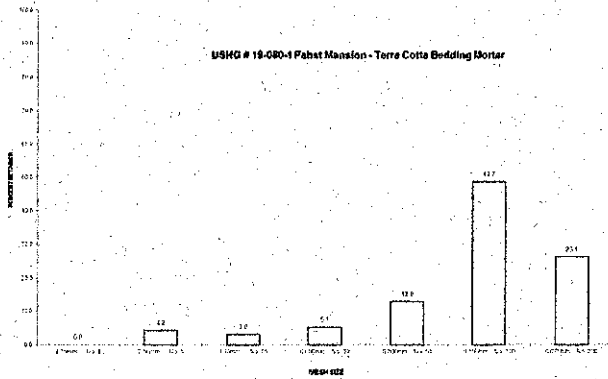
PRELIMINARY TESTING

Samples were different in color and texture which suggests they represent different mixes. Cross section of samples: #19-080-1 PM Terra Cotta Bedding Mortar, #19-080-2 PM Terra Cotta Joint and #19-080-4 Face Brick Mortar indicated the presence of small in size lime inclusions. Lime inclusions are white pieces of carbonated lime putty or quicklime that was not completely dissolved in the mortar mixture during the original application.

Next, we compared the samples against other mortars of a similar age and appearance by measuring their relative compressive strength. All samples exhibited low resistance during the direct pressure testing procedures.

AGGREGATE ANALYSIS

Next, we crushed each sample and chemically removed the binder from the aggregate using a dilute acid solution. After drying the aggregate, we viewed it under 40X magnification to determine the characteristics of the particles. A sieve separation process established the distribution of aggregate particles by a percent of total weight. We prepared a gradation charts to graphically display the color, shape and size of the aggregate particles. The aggregate sieve sizes requisite in ASTM C144 meet ASTM E11 specification requirements.



The sand weight retained on each testing sieve was as follows:

Samples:	#19-080-1 PM Terra Cotta Bedding Mortar	#19-080-2 PM Terra Cotta Joint	#19-080-3 PM Limestone Ashlar Joint Profile	#19-080-4 PM Face Brick Mortar
Testing Sieve Size	% of sand retained			
4.75mm, No. 4	0.0	0.0	0.0	0.0
2.36mm, No. 8	4.2	0.0	0.0	0.0
1.18mm, No. 16	3.0	0.3	0.6	1.1
600micro, No. 30	5.1	1.0	3.7	2.3
300micro, No. 50	12.9	12.9	17.8	10.6
150micro, No. 100	48.7	66.0	49.7	44.8
75micro, No. 200	26.1	19.8	28.2	41.2
Total sand weight	100%	100%	100%	100%

Based on the particle color and shape similarities it appears that all four mortars were likely made using sand from same area. Variation in sand gradation is normal for natural sand and suggests different time of sand extraction. Original sand extracted from mortar sample #19-080-1 PM Terra Cotta Bedding Mortar is classified as a mix of coarse-size and medium-sized aggregate and sands extracted from mortars sample: #19-080-2 PM Terra Cotta Joint, #19-080-3 PM Limestone Ashlar Joint Profile and #19-080-4 Face Brick Mortar are classified as fine-sized aggregate.

BINDER TO AGGREGATE RATIO

The binder percentage in the first three mortar samples was established and found to be above 50%, and for sample 19-080-4 PM Face Brick Mortar just below this value (49.9%), which would be considered a very binder rich formulation. The results of this calculation can be affected by the presence of calcium carbonate in the aggregate which would have been dissolved out during the chemical wet process. This factor was considered in the evaluation of the proposed replacement formulation.

Sample	#19-080-1 PM Terra Cotta Bedding Mortar	#19-080-2 PM Terra Cotta Joint	#19-080-3 PM Limestone Ashlar Joint Profile	#19-080-4 PM Face Brick Mortar
Binder	62.2%	60.6%	78.3%	49.9%
Aggregate	37.9%	39.4%	21.7%	50.1%

SUMMARY OF TEST RESULTS

Direct pressure testing indicates low compressive strength for all four samples. The material reaction noted during chemical wet process was quite similar for all samples, and it did not indicated presence of a hydraulic component in the three of four material. This coupled with the samples' appearance, suggests that those three mortars were originally mixed using non-hydraulic slaked lime putty and sand. However in the case of sample 19-080-1 PM Terra Cotta Bedding Mortar presence of a hydraulic component was indicated.

Since dry hydrated lime in bags was not available on a market until 1930, slaked lime putty was used in most mortar formulations dated before 1930. Moreover, the presence of lime inclusions in samples indicate that the mortar was mixed using slaked lime putty instead of hydrated lime.

PROPOSED REPLACEMENT MIX

In light of these findings and the intended use of the replacement material, U.S. Heritage Group recommends specifying the following replication mortar formulations for particular samples. For sample 19-080-1 Pabst Mansion – Terra Cotta Bedding Mortar:

1 part natural hydraulic lime and 2.5 parts sand selected from the USHG sand library.

While for samples: 19-080-2 Pabst Mansion – Terra Cotta Joint, 19-080-3 Pabst Mansion - Limestone Ashlar Joint Profile and 19-080-4 Pabst Mansion – Face Brick Mortar:

1 part slaked lime putty and 2.5 parts sand selected from the USHG sand library.

Mineral-based color pigments were used to match the original color of exterior mortar.

Above recommendation was made in accordance with Preservation Brief 2:

“The new mortar must be as vapor permeable and as soft or softer (measured in compressive strength) than the historic mortar.”

Note: Masonry work using this formulation must be completed 28 days prior to freeze thaw cycles occurring. Do not perform any masonry work unless air temperatures are between 40 degrees Fahrenheit (10 degrees Celsius) and 95 degrees Fahrenheit (32 degrees Celsius) and will remain so for at least 5 weeks after the completion of the work.

Slaked lime putty should be aged for a minimum of three months before use in a mortar mix. Building elements such a chimney or foundation wall may require addition of hydraulic component in the mortar. Type and amount of hydraulic additive used in a new mortar should be established based on the condition of the existing masonry units to make sure that new installed mortar is softer with greater rate of water absorption.

JOBSITE MOCK-UP SAMPLE

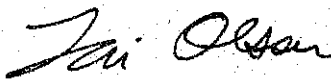
The replacement mortar sample should be field-tested through a jobsite mock-up. The mock-up sample should be installed by a qualified craftsperson who understands the curing and application details of traditional lime mortars. Once the mock-up sample is installed, appropriate precautions should be taken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

Thank you for seeking our advice and entrusting these important details to U.S. Heritage Group. We are always available to discuss these findings with you in detail. Please contact me directly at 773-286-2100 if you have any questions.

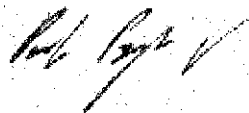
We look forward to providing you with a custom, ready-to-use, historically correct mortar for your project.

Respectfully,

U.S. Heritage Group, Inc.



Tai Olson
Laboratory Manager



Piotr Psuja PhD Eng.
Laboratory Manager

Note: This information is held in confidence and becomes a permanent record at the U.S. Heritage Group laboratories located at 3516 North Kostner Ave., Chicago, IL 60641. It can be referenced at any time in the future by the property owner named above or by an authorized mason contractor involved with the restoration work. When inquiring about this match please use the project number USHG #19-080.