Rosendale Natural Cement: Reintroduction of an Authentic North American Historic Binder

Michael P. Edison

Abstract Natural cement was the predominant hydraulic binder used in engineering and architectural construction in the United States in the 19th Century. Produced from argillaceous limestone, typically high in magnesium content, calcined at temperatures below the sintering point, American natural cements were used in the construction of tens of thousands of structures of various types. The town of Rosendale, New York was the most prolific centre for production of natural cements, and its name became synonymous with American natural cements in general. Rosendale cement production was restarted in 2004, to provide authentic in-kind material for use in restoration of historic structures. ASTM Standard C10, Specification for Natural Cement, was reinstated in 2006, and aimed to maintain authenticity of the traditional material. From 2004 to 2009, Rosendale cement was used successfully in more than 100 historic restoration projects in the United States and Canada. Two case studies are used to illustrate the challenges of the material selection process and the ultimate performance of Rosendale natural cement in major historic restorations: The repointing of the south range of the American Museum of Natural History in New York City and the partial reconstruction and repointing of Fort Jefferson, Dry Tortugas National Park in Florida. Testing, analysis and mix designs are reviewed.

1 Historical Uses

The historical production and uses of natural cement in the United States are well-documented. In 1899 alone, 76 natural cement manufacturers in 16 American states engaged thousands of workers in the production of some 3 billion pounds (1.36 million metric tons) of natural cement [1]. In 1898, Uriah Cummings wrote that natural cement was used in "fully 95% of the great engineering and architectural works of this country" and listed several hundred prominent examples of same, along with the sources of the natural cement used in their
construction [2]. Modern petrographic analyses performed to date have invariably confirmed Cummings' representations. Although natural cement production waned in the early 20th Century, overshadowed by the explosive growth of the portland cement industry, two manufacturers remained in operation until the early 1970's. The use of natural cement in Canada is not well-documented, but at least two production sites were known to have been operating during the same period [2].

2 The American Natural Cement Revival

A portion of the American restoration industry has embraced the concept of in-kind repair and replacement for historic mortars, and a variety of traditional limes and imported hydraulic limes have been marketed for such purposes. Hydraulic lime was never intentionally manufactured in significant quantities in the United States, however, as it was deemed less valuable than natural cement [2, 3, 4]. In the absence of a commercial source for American natural cement, however, utilization this of historic hydraulic binder was not an option. To overcome this limitation, mining of natural cement rock was restarted in Rosendale, New York, and small scale production of natural cement for use in historic restoration work was begun in Plainville, Connecticut in 2004. From 2004 to 2009, more than one hundred historic restoration projects in the United States were completed utilizing authentic Rosendale natural cement. The challenges associated with the reintroduction of this historic technology were considerable, and may be best illustrated by two significant projects: Repointing of the south range of the American Museum of Natural History in New York City, and repointing and partial rebuilding of Fort Jefferson, on Garden Key in the Gulf of Mexico.

![Fig. 1 1994 aerial photograph of Fort Jefferson, Garden Key, Florida. Demonstration phase installation of natural cement-lime mortar was in progress at that time.](image-url)
3 Challenges to Natural Cement Acceptance

Despite its 180 year history of positive performance, natural cement was not immediately embraced for use as a restoration material for either project. Obstacles included inaccurate analyses of original materials at Fort Jefferson, and procedural problems in preconstruction testing of mortars for the American Museum of Natural History.

3.1 Fort Jefferson

The mortar used at Fort Jefferson was historically documented to have been composed of a mixture of natural cement from Rosendale, New York and calcareous beach sand, ground in a roller pan mortar mill [2, 3].

In June, 2004, water vapour transmission testing was performed, comparing 150-year-old Fort Jefferson mortars with two proposed natural cement mortars for the then-pending restoration project [5]. The proposed restoration mortars both utilized natural cement and differed only in their aggregate: binder ratios. The aggregate utilized was calcareous beach sand from Garden Key, as was used in the original construction. The laboratory report concluded that both of the proposed mortars were higher in permeability than the 150-year old mortar, noting that with increasing age the proposed mortars may also become less permeable. Results are summarized in Table 1. It was further concluded that all three mortars were compatible with the harder, pre-civil war Maine brick, but only mortar #2 would be expected to be compatible with the softer, Civil War-era Pensacola, Florida brick. The lower permeability of the original mortar notwithstanding, consequential distress to the Pensacola brick was not evident.

Table 1 Water Vapor Transmission test results at 28 days for original and proposed mortars at Fort Jefferson, ASTM E96. Results are averages of 3 cubes each.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Water Vapor Transmission, grams/hr m²</th>
<th>Water Vapor Transmission, grains/hr m²</th>
<th>Permeance, perms</th>
<th>Permeability, perm-in.</th>
<th>Aggregate - Binder Ratio by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed #1</td>
<td>10.9</td>
<td>15.6</td>
<td>21.8</td>
<td>12.2</td>
<td>2:1</td>
</tr>
<tr>
<td>Proposed #2</td>
<td>13.5</td>
<td>19.3</td>
<td>27.1</td>
<td>13.5</td>
<td>2.5:1</td>
</tr>
<tr>
<td>Original*</td>
<td>8.8</td>
<td>12.5</td>
<td>17.5</td>
<td>11.1</td>
<td>1-1.5:1 [7]</td>
</tr>
</tbody>
</table>

*Mortar samples removed intact from 1850's brick

Mortar analyses of various samples of Fort Jefferson mortar were performed using XRD as the primary means of binder identification. This method has been criticized as unsuitable for primary identification of historic binders, however, because although it is an excellent method for determining mineral phases, it cannot image the binder residuals that are the key to identification [6].
laboratory hence erroneously concluded that the binder was a form of lime with clinkered impurities. The project conservator subsequently designed a mortar mix based on high calcium lime putty and beach sand, mixed and ground in a roller pan mill. Natural cement was added as a minor constituent only. Phase 1 construction proceeded with this mixture in 2005. The high lime mortar proved a poor visual match to original materials (Fig. 2) and it performed poorly in the salt-contaminated masonry structure. It was soon damaged by severe exposures that included direct hits by two hurricanes in 2006.

Fig. 2 High lime content, Phase 1 mortars (embrasure openings, at right) were a poor visual match to original materials, which contained no lime. Demonstration phase mortars (left), containing more natural cement, performed and matched better.

Early in Phase 2, new mortar analyses were performed. Utilizing ASTM C1324 petrographic procedures, ASTM C457 Procedure B Modified Point Count method, and ASTM C114 Chemical Analysis, the geologist/petrographer concluded that mortars and coral concrete at Fort Jefferson contained no lime, the binder being composed entirely of natural cement [7]. After protracted conflict, the restoration mortar binder was changed to natural cement. Repairs now blend seamlessly with original materials (Fig. 3).

The restoration of Fort Jefferson remains ongoing as of this writing, and to date, more than 35 tons of natural cement have been installed at the site in various locations.
Fig. 3 Phase 2 work fully implemented use of natural cement, providing a "remarkable improvement in the overall aesthetics and virtual seamlessness of the new work abutting to existing work" [8].

3.2 The American Museum of Natural History

The historic south range of the American Museum of Natural History was constructed from 1888 to 1899 using red granite from northern New York State and Rosendale natural cement mortar. Petrographic analyses of multiple samples of the building's red mortar confirmed the presence of natural cement, and despite some problem areas, the overall condition of the mortar was determined by the project architects to be remarkably good. The museum was committed to the highest standards of authenticity in the restoration work. Original wood windows were retained and restored, rather than replaced. The original granite quarry was reopened to obtain matching replacement stone. The use of historically accurate natural cement mortar for repointing was also favoured, but it was not a foregone conclusion.

Concerns over the use of natural cement centred around workability, shrinkage and bond strength to the building's dense granite building stone. Laboratory testing was undertaken in 2005 by the project consultants and problems developed early on. In attempting to utilize testing protocols more suitable to other masonry materials, the laboratory prehydrated the specimen natural cement mortars for 30 minutes before readjusting with water to standard flow and casting 50 mm cubes. The time of initial setting for the natural cement being evaluated was somewhat less than 30 minutes, however, much shorter than is typical of portland cement-lime mortars. Attempts to adjust mortar consistency with additional water after 30
minutes therefore resulted in disruption, producing erroneous reports of low strength, high shrinkage and negligible bond strength. As a consequence, the project's specifications went forward calling for use of portland cement-lime mortar, but the consultants left the door open to reconsideration of natural cement, pending development of further data and supporting information.

In 2006, a number of efforts were undertaken, all of which contributed to the reversal of the decision to use portland cement-lime mortars for the project. ASTM C10, Standard Specification for Natural Cement was reinstated. Among the requirements of the standard was a minimum time of initial setting of 30 minutes. Natural cement processing had already been altered in anticipation of this requirement, earlier the same year. A year-long study of natural cement curing rates and performance was also initiated at that time, and new bond strength and shrinkage testing were undertaken.

In 2007, the first phase of masonry repointing was begun at the American Museum of Natural History in New York. The decision to use natural cement mortar was not reached until shortly before work commenced.

In early 2007 the laboratory studies were completed. Results showed that the proposed natural cement mortar developed approximately twice the bond strength to granite of a 1:1:6 portland cement-lime-sand mortar after 28 days. Shrinkages were found to be equivalent for both types of mortar, at approximately 0.05%. Strength development for Rosendale natural cement was found to be most dynamic in the period from 30 to 90 days after casting (Fig. 5), in contrast to
Portland cement, which typically develops the majority of its strength in the first 7 days.

**Fig. 5** Rosendale natural cement's strength development is most dynamic between 28 and 90 days' cure [9]

The final testing was a workability evaluation, performed on site in the Spring of 2007 (Fig. 6). Candidate mortars in several colours, including both portland-lime and natural cement formulations, were installed on the building in a mock-up area. The masons installing the various mortars agreed that they found the natural cement mortar to be more workable. The Museum accepted the subsequent recommendations from the project consultants and reaffirmed its commitment to preserving the building's integrity by using historically accurate materials. Some 20 tons of natural cement mortar were installed over the course of the next 2 years.
Masons preferred the workability of natural cement mortars to portland-lime, when both types were installed in mock-up areas.

4 Conclusions

Natural cement has been able to overcome significant technical scepticism and perceptual concerns to re-emerge as a mainstream 21st Century restoration material in the United States. As performance data for natural cement based on modern testing protocols continues to be developed, its capacity to provide permeable, compatible, low shrinkage structural restoration mortars is confirmed. As the experience of restoration tradespersons has expanded, utilizing natural cement in a wide variety of situations and recipes, their confidence in its workability and reliability has grown accordingly.

The demonstrated successes at Fort Jefferson and at the American Museum of Natural History serve as examples of the potential to maintain historic integrity and authenticity, while restoring and preserving America’s great engineering and architectural works of the 19th and early 20th Centuries. With competent analysis of original materials and knowledgeable mix design of natural cement-based restoration mortars, the caretakers of natural cement buildings and structures are able to preserve the standing examples of a major historic building technology unique to its time period.
5 References

2. Cummings U (1898) American Cements. Rogers and Manson, Boston