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A BRIEF HISTORY OF THE USE OF ROSENDALE CEMENT IN THE U.S. (1818-1900) WITH A PRELIMINARY CASE STUDY OF FORT JEFFERSON, FLORIDA*

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Abstract

A significant masonry binder used in the United States from 1818 to 1900 was natural cement also known as Rosendale Cement. Hydraulic limestone, also known as cement rock, quarried primarily in the region of Rosendale, NY, is a stone of variable content. Depending from which strata of the formation the stone is extracted, the stone may be high in carbonates, or may have an elevated clay and silicate content. Through trial and error, the manufacturers of natural cement created a variety of products that involved the proportional mixing of stone from varying strata. The presenters will discuss the history and use of Rosendale natural cement, particularly its use in civilian and military construction in the United States.

Keywords
Natural cement, General Joseph Totten, United States military fortifications, Rosendale cement

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1 Early Mortars

Throughout the history of masonry there are references to the search for a mortar with hydraulic properties that can perform in wet conditions. An early reference is found in Vitruvius circa 25 B.C. (1960) when he comments on the conventional wisdom that, “Hard durable mortars come from lime prepared from the hardest limestone and preferably from moist shady quarries. Soft stones, such as chalk, should produce only soft mortars.” The comment belies a search for durability and the understanding that the performance of the mortar is heavily influenced by the composition of the limestone. Palladio (1965) references the existence of hydraulic limes during the Renaissance era and speaks of pozzolanic additives of volcanic ash and brick dust in order to achieve a set in wet conditions.

2 The Search for Hydraulic Mortars in Europe

Prior to the construction of the Eddystone Lighthouse in 1756, John Smeaton (1791) of England performed the “kitchen sink experiments”, informal studies on mortars with hydraulic properties. As a result of his investigations and the construction of the Lighthouse he determines that “limes which worked well for ‘water building’ were those made from limestones or chalks which contained a suitable proportion of clay.”

In the same period, L.J. Vicat (1818), a French engineer during the time of the Napoleonic wars, began his research into the nature of hydraulic limes. Vicat’s and Smeaton’s investigations were widely followed and did not escape the notice of the fledgling U.S. military that established their engineering school at West Point when Vicat was beginning his investigations.

While the Europeans were pursuing a means of identifying the methods for producing a binder with hydraulic properties, several parties in the United States were pursuing a similar course.

3 The Development of Hydraulic Mortars in the United States

3.1 The Bernard Commission and U.S. Seacoast Fortifications

Following the Revolutionary War, the U.S. Military began lobbying Congress for increased funding to establish a strong defense system. In an effort to establish a domestic corps of military engineers and end the dependence on European engineering, particularly defense and fortification engineering, the then named Department of War established the engineering academy of West Point in 1802 in West Point, NY. For the ensuing ten years, the Department of War continued to pressure the U.S. Congress for funding increases in order to build defence systems for the new country. The military did not receive the level of funding they deemed their due until the events of the War of 1812, notably the burning of the White House by the British. Their pleas regarding the lack of security of an attack from the Atlantic were borne out by this emphatic gesture (Lewis, 1979)

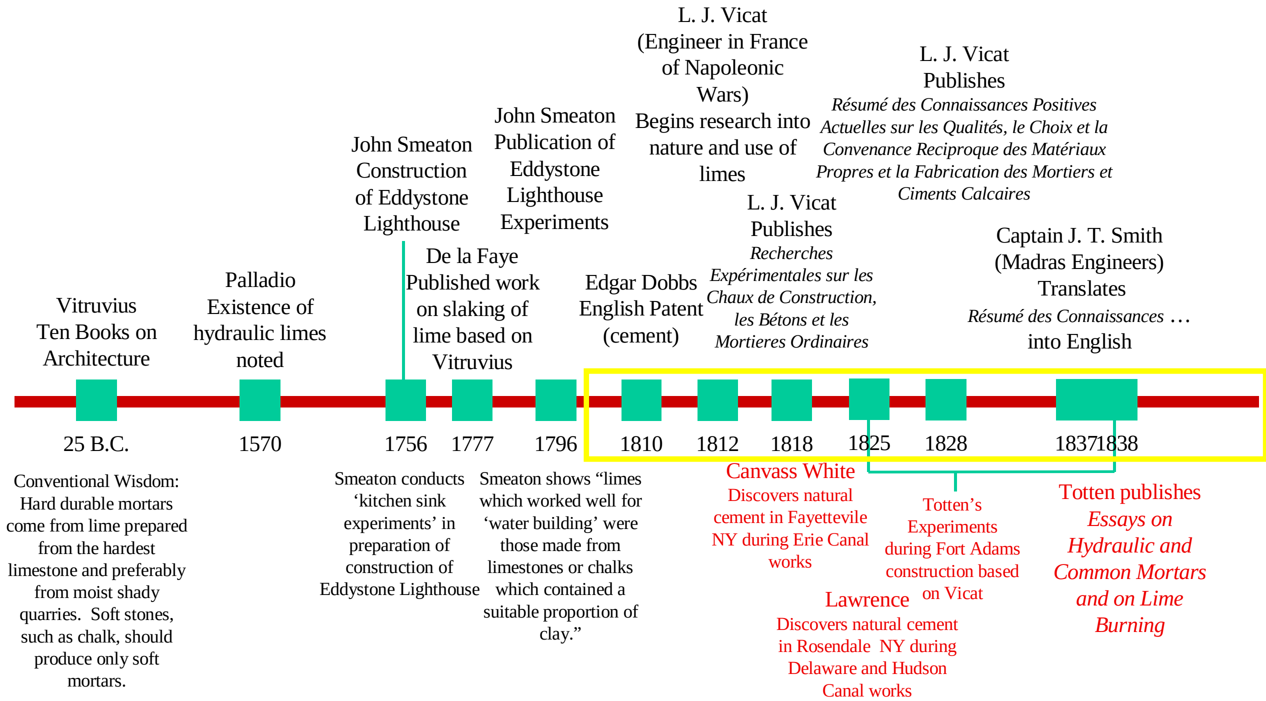


Figure 1 Time line of the search for hydraulic properties (Martin, 2003).

In 1816, Congress approved and funded the Bernard Commission whose goal was to assess the fortification system along the eastern seaboard of the United States. Appointed to the head of the Commission was Simon Bernard, a French general of Napoleon. Also appointed were U.S. Military Officers Swift, McCree, and Totten. As senior officers instrumental in the establishment of West Point, Swift and McCree were affronted by the appointment of a foreign head to the board and resigned their positions on the board and their commissions. Joseph G. Totten remained on the board and following Bernard's departure, became the principal engineer of the fortifications of the Third System (Lewis, 1979).

General Joseph Totten is a central figure in the development of hydraulic mortars in the United States. Driven by the goal of constructing a vast system of masonry fortifications along the eastern seaboard in hostile climates, Totten needed a binder that would set under water and more quickly than a lime and could withstand the wet coastal conditions. Totten was well versed in the work on mortars and betons being executed by the Europeans and went on to create his own body of research. The masonry technologies he developed, and especially his mortars, heralded a significant impact on the building practices in the United States in the 19th century.

3.2 The Canals

During this same time period, a young American engineer by the name of Canvass White was hired to work on the construction of the Erie Canal from 1816 to 1824. In 1817 he was sent to England by Chief Engineer Benjamin Wright to examine and study the material and design of the canals of that country. White's highest priority was to find a material to replace wooden locks used in the United States. English canals used a limestone mix that intrigued the young engineer. White took the data on limestone that he gathered on his trip and began experimenting with local limestone. While working on the canal in 1818, White observed a formation of limestone in Fayetteville, NY that, when fired, produced a binder with hydraulic properties. White experimented with the stone and was successful in achieving a hydraulic set that was used throughout the construction of the Erie Canal (Whitford, 1906).

Shortly afterwards, in 1828, while working on the Delaware and Hudson Canal, Cement rock was discovered on the property of Watson E. Lawrence in Rosendale, NY that yielded a binder with hydraulic properties (Sylvester, 1880).

3.3 The Experiments of General Joseph Totten and Quincy Adams Gillmore

From 1825 until 1838, General Joseph Totten engaged in the construction of Fort Adams, Newport, R.I. (Figure 2). Throughout the construction period, Totten experimented with three different hydraulic cements: "Cement A – New York," "Cement B – New York," and "Cement C – Parker's Cement of England." Over the thirteen-year construction period, Totten tested a wide variety of mortar formulas and masonry techniques. At the conclusion of these tests Totten (1842) published,

> *Essays on Hydraulic and Common Mortars and on Lime Burning Translated from the French of Gen. Treussart, M. Petot, and M. Courtois With Brief Observations on Common Mortars, Hydraulic Mortars, and Concretes and an Account of Some Experiments Made Therewith at Fort Adams, Newport Harbor, R. I., from 1823 to 1838*.

Totten's thirst for experimentation was seemingly boundless, and, due to his position, he took full advantage of his access to military resources and the facilities at West Point. At the conclusion of these experiments and the construction of Fort Adams, Totten settled exclusively on the use of Rosendale cement in his mortars and concretes (Totten, 1842).

Figure 2 Fort Adams, Newport, RI, USA (photograph credit to post card Fort Adams Trust)

Prior to the construction of the casemates at Fort Jefferson, Totten directed a set of experiments at West Point to test masonry configurations and to develop a shutter apparatus for embrasure openings. In 1851, Totten directed the construction of the 1st Target (Figure 3), which emulated the construction of a scarp wall with six embrasure openings. The wall was constructed of a variety of materials including brick, granite, asphaltic concrete, lead concrete, and cement[3] concrete, with the

[3] "The term 'cement' is applied in these notes, as generally in this country, to a material possessing considerable hydraulic energy. The test applied to inspections under the Engineer Department, requires generally that a cake made of pure cement, immersed in water before hardening, shall in a few minutes, support a wire 1/25 of an inch in diameter, loaded with the weight of one pound."

intent of testing these materials for their resistance to "being fired upon." The embrasure openings have a variety of opening shapes and profiles; some are wholly of masonry while others have cast iron plate inserts. The 1st Target was destroyed by being fired upon approximately 15 months after the completion of construction. The 2nd Target was constructed in 1854 with three, more refined, embrasure openings. The second target was destroyed by being fired upon approximately 13 months after the completion of construction. Totten (1857) observed: *"The mortar in the interior of the masonry and concrete of both targets, as exposed in the breaches, was although to a certain degree solid and hard, decidedly damp, not to say wet – as was plainly shown by the darker color of the inner portions, and as was evident to the touch", p. 39.* This comment, along with the myriad of tests performed to determine factors affecting setting time, indicate that Totten concerned himself with the acceleration of the setting time of his mortars and concretes.

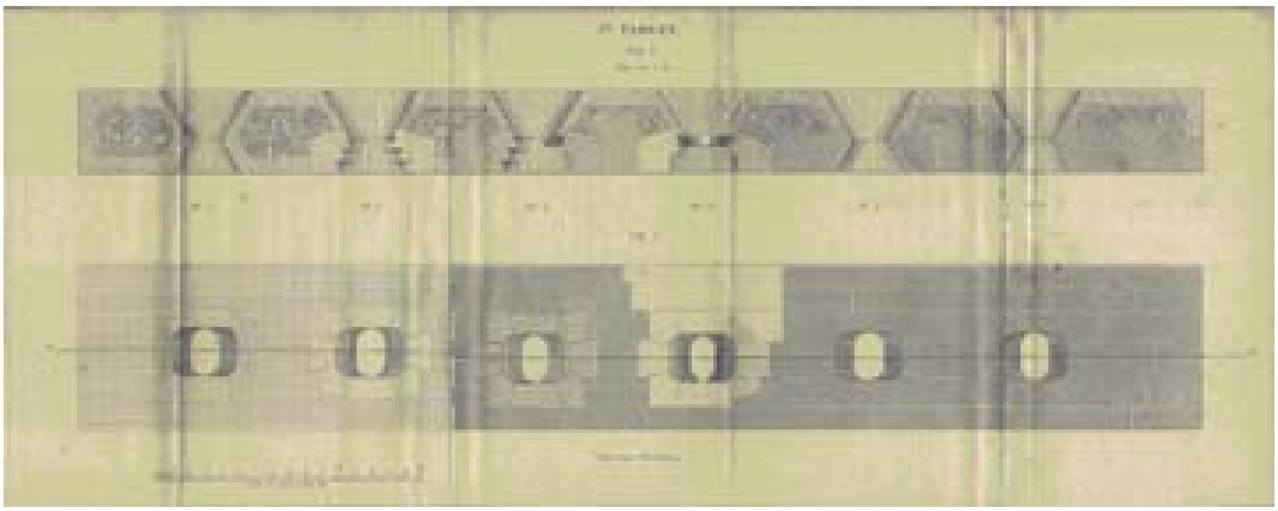
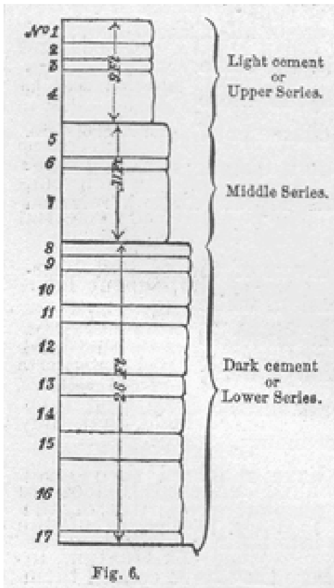


Figure 3 1st Target, Constructed 1851, Destroyed by Firing Upon 1852, West Point, NY, USA. (Totten, 1857, Plate II.)

3.4 The Production of Rosendale Cement

In his treatise, Gillmore (1872) devotes considerable effort to the description of the cement works producing Rosendale cement. He describes the stratification of the Rosendale limestone bed in some detail. The bed strata of the Rosendale deposit vary from highly silicious to highly argillaceous, with beds of pure calcareous rock between. He states that the stone suitable for hydraulic lime or cement is variable but typically contains carbonates of lime and magnesia, "silica, alumina, oxide of iron, and a small amount of alkali, and are generally comprised in the beds of passage between deposits that are purely silicious or argillaceous, and those that are purely calcareous or dolomitic."p. 16.

Gillmore records his survey of the Rosendale beds, the character of the stone found in different locations of the bed, and the numerous cement works which included the Newark Lime and Cement Manufacturing Company, Hudson River Cement Company, Ogden Rosendale Cement Company, Delafield & Baxter, Lawrence Company, Newark and Rosendale Company, Rosendale Cement Company, Maguire, Crane & Co., and The Rosendale and Kingston Cement Company. He gives detail as to the strata, or combinations of strata quarried to produce their cement (Figure 4). "No one manufacturer makes use of all of these beds, and no two of them the same beds, in the same proportions. This is due principally to those marked variations in the hydraulic character of the stone, within comparatively short distances, which constitute a characteristic feature of this deposit, already referred to in general terms."p. 37. Some operations mined from different strata and mixed the raw stock prior to firing, while some mixed afterward. Gillmore further discusses the possibility of varying performance as a result of the changing nature of the stone and laments the absence of consistency in the finished products. He recommends that preliminary trials for the character of the stone be developed to ensure confidence in the performance of the mortar.



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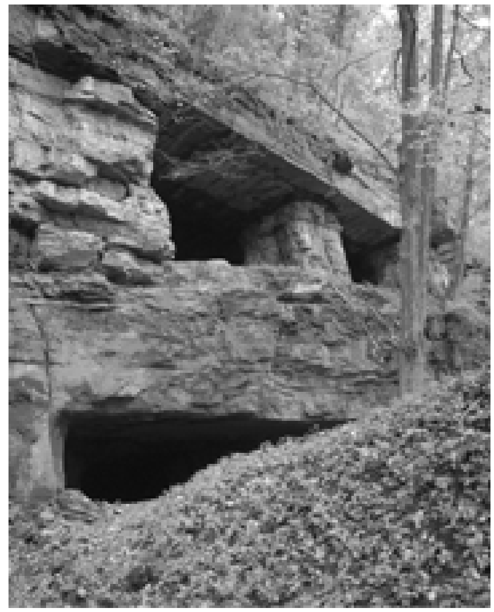

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Figure 4 a) Bedding Planes of the Rosendale Deposit (Gilmore 1863, p. 38) b) Rosendale Mine (photo credit to Ken Uracius, 2003)

During the time of the early canal works and Totten's work at Fort Adams, the production of Rosendale cement was less than a million barrels per decade. At the time of Gilmore's first edition of his treatise (Gilmore, 1863) the production of Rosendale had increased to 11 million barrels per decade.

The onset of the US Civil War triggered the abandonment of the masonry fortifications effort, but there was no decrease in the demand for Rosendale cement. The production of Rosendale continues to rise throughout the remainder of the 19th century. Uses included military and civilian applications including railroads, bridges, civil works, and buildings. The production and delivery of Rosendale cement rose to over 53 million barrels in the last decade of the nineteenth century (Cummings, 1898, p. 288) (figure 5).

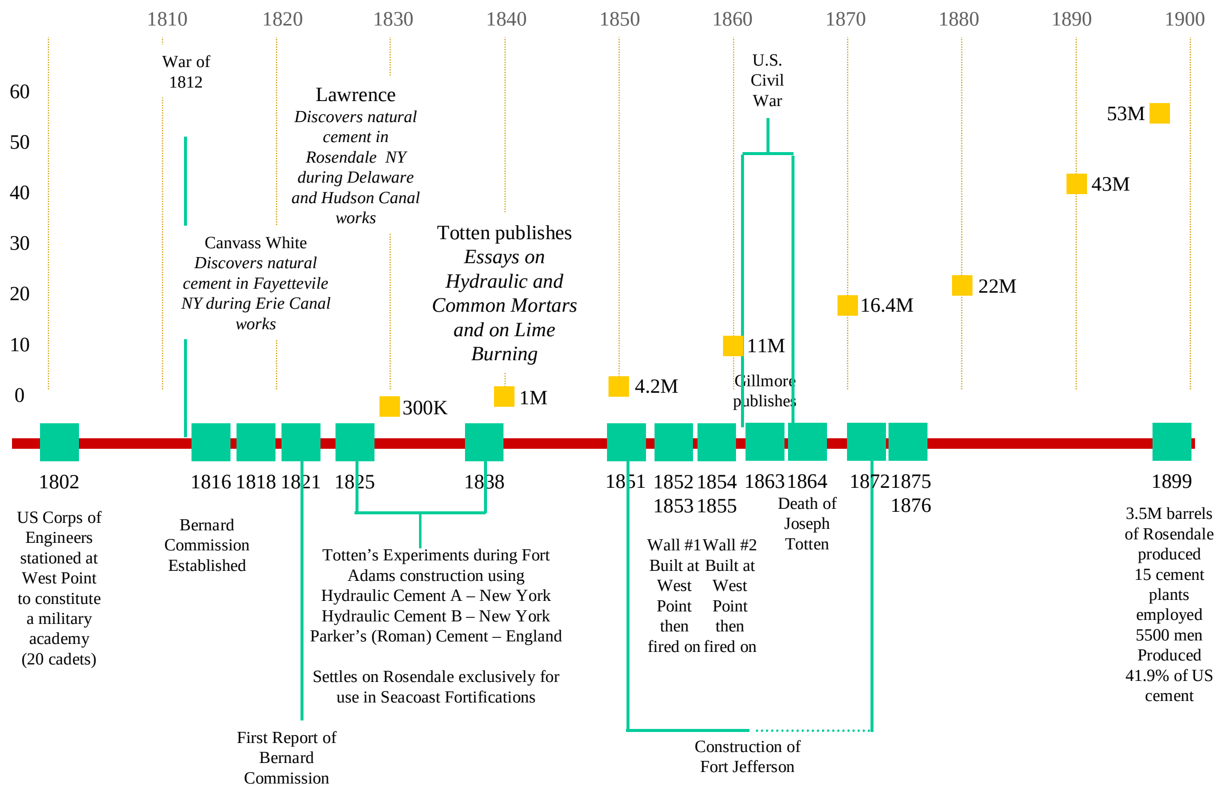

Figure 5 Comparison of Production of Rosendale Cement in Millions of Barrels with Masonry Activities (Martin, 2004)

3.5 The Masonry of Fort Jefferson

Many of the technologies that Totten began to develop at Fort Adams came to full fruition in the construction of Fort Jefferson (Figure 6), which was constructed from 1851 to 1872. The technologies used at Fort Jefferson were informed by the technologies developed at Fort Adams, the later investigations performed at West Point, and the testing documented by Q.A. Gillmore. The technological developments were not restricted to the masonry arts, but included the development of fort configurations with particular attention given to the casemate and the embrasure opening. In the correspondence throughout the construction period, Totten consistently monitored the mix formulas of the mortars and concretes.

Fort Jefferson is located in a remote marine environment. Construction on the fort proper commenced in 1851 and ceased in 1872, though the fort was never actually completed. Prior to the commencement of construction, Totten completed his experimentation at Fort Adams. During the construction of the Fort, the experimental targets were developed at West Point, and Gillmore was conducting the testing and surveys of Rosendale cement documented in his Treatise on Limes.

Figure 6 Fort Jefferson, Dry Tortugas, FL, USA (photo credit to U.S. National Park Service, 2002)

The mortars and concretes used throughout Fort Jefferson were petrographically examined.

> "All samples are composed of a mixture of carbonate natural sand and a hydraulic cement. No Portland cement nor hydraulic lime is detected in the sample. The historic nature of the material defies classification as provided by ASTM C270 and no attempt is made to categorize the mortar by the modern specification. The cement appears as moderately dark brown fine lumps (in one case one centimeter in diameter). The cement is identified as the product of low temperature calcination of a siliceous-dolomitic limestone. Relict rhombic dolomite structures are common within the residual cement grains as well as dispersed, fine quartz sand and uncalcined calcite in lower abundance. Microscopic ferruginous rims are common along calcined phases. In many cases, the residual cement grains are largely isotropic in cross polarized light. The nature of the product is consistent with the Rosendale Cement produced in upstate New York in the 19th and early 20th century. The toasted brown coloration of the hydrated paste is also characteristic of the Rosendale Cement [4]."

A study by Manucy (1961) identifies the strata related to the sequential construction seasons at Fort Jefferson. The different mixes and qualities appear to correspond primarily to construction seasons. Both brick quality and mortar and concrete mixes are visibly different from one construction period to the next. The mortars and concretes have performed remarkably well in light of their age of 150 years. Failures have occurred as erosion of joints and brick, delaminating of surface brick (Figure 7).

4 Conclusions

Rosendale natural cement was a widely used hydraulic binder in the United States in the nineteenth century. The use of hydraulic cements is the result of a long term quest to develop a binder for mortars and concretes that will achieve a set quickly and in wet environments. The activities of the U.S. military in the development of the Third System Fortifications included extensive testing of masonry and mortars, which ultimately determined that Rosendale was the preferred domestic natural cement. The Rosendale natural cement mortars used in Fort Jefferson have performed exceptionally well in a harsh environment.

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[4] Testwell Laboratories, 2004, *Petrographic Examination and Chemical Analysis of Hardened Mortar, Fort Jefferson, Florida,* Ossining, NY, U.S.A.

a) b)

Figure 7 View of Varying Masonry Condition at Fort Jefferson, Dry Tortugas, FL, USA (photograph credit to Martin, 2003)

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