The American Natural Cement Revival

REINTRODUCING A HISTORIC MASONRY MATERIAL AND ONE OF ASTM'S OLDEST STANDARDS

BY MICHAEL P. EDISON

Though few of today's construction professionals have seen or heard of natural cement, it was once the most widely used hydraulic binder for concrete, masonry mortar, stucco and grout. In 1899, 76 natural cement producers in 16 states employed thousands of workers for mining and production of nearly 3 billion pounds of natural cement.[1] One account from that time states that natural cement was used for "fully 95% of the great engineering and architectural works of this country."[2] (See sidebar on next page.)

In 1904 ASTM Committee C adopted the first ASTM standard for hydraulic cements, including separate requirements for natural and portland types. The former became the eventual basis of ASTM C 10, Specification for Natural Cement, one of ASTM's oldest standards. Ironically, natural cement use was already declining by the time these first standards were written. Portland cement became the dominant technology, and has remained so, but natural cement production continued until 1970, when the Century

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Where Was Natural Cement Used?

Natural cement was used in the construction of thousands of historic architectural and engineering structures. The following are just a few better-known American examples.

Canals

Over 150 canal systems, including the Erie, Chesapeake and Ohio, Delaware and Hudson, and the Ohio River

Water Systems

New York City, Philadelphia, Boston and Washington, D.C.

Military Fortifications

51 Third System forts, including:

- Fort Sumter, S.C.
- Fort Adams, Newport, R.I.
- Fort Warren, Boston Harbor
- Fort Hamilton, New York Harbor
- Fort Trumbull, New London, Conn.
- Fort Washington, Md.
- Fort Jefferson, Gulf of Mexico
- Fort Taylor, Key West, Fla.
- Fort Gaines, Mobile, Ala.
- Fort Point and Fortress Alcatraz, San Francisco, Calif.

Monuments

- Washington Monument (lower 150 feet)
- Statue of Liberty Pedestal
- Confederate Monument, Savannah, Ga.

Bridges

- Brooklyn Bridge
- Roebling Suspension Bridge, Cincinnati, Ohio
- Smithfield Street Bridge, Pittsburgh, Pa.
- High Bridge, New York, N.Y.
- Stone Arch Bridge, Minneapolis, Minn.
- Eads Bridge, St. Louis, Mo.

Capitols

- California
- Colorado
- Georgia
- Iowa
- Illinois
- Indiana
- Kansas
- Massachusetts
- Michigan
- Minnesota
- New York
- Texas
- U.S. Capitol

Museums

- Smithsonian Institution National Portrait Gallery
- Smithsonian Castle
- American Museum of Natural History
- National Building Museum

Other Government Buildings

- Baltimore, Md., City Hall
- Richmond, Va., Old City Hall
- Milwaukee, Wis., City Hall
- U.S. Treasury Dept.
- Eisenhower Executive Office Building, Washington, D.C.
- Buffalo, N.Y,. County Building
- Fort Worth, Texas, Courthouse
- Dallas, Texas, Old Red Courthouse
- St. Louis, Mo., Old Post Office
- Milwaukee, Wis., Library

Cement Company in Rosendale, N.Y., closed its doors. This ended a 145-year run of natural cement production in Rosendale, the Hudson Valley village whose name, in popular usage, became synonymous with the cement produced there. ASTM C 10 was withdrawn in 1979.

In 2004, commercial production of Rosendale natural cement was restarted as a means of providing the restoration industry with compatible repair and maintenance materials for historic buildings and structures. With this reintroduction has come an effort to reinstate ASTM C 10.

WHAT IS NATURAL CEMENT?

Natural cement is defined in ASTM C 219, Terminology Relating to Hydraulic Cement, as "a hydraulic cement produced by calcining a naturally occurring argillaceous [clayey] limestone at a temperature below the sintering point and then grinding to a fine powder." Portland cement, by comparison, is produced by blending and firing mixtures of limestone and clay at higher temperatures. Due to their respective firing temperatures, natural cement's hydraulic species are primarily dicalcium silicate and dicalcium aluminate (C2S, C2A), and the tricalcium silicate and tricalcium aluminate (C3S, C3A) typically formed in Portland cement production are absent.

As a result of these compositional differences, natural cement develops lower compressive strength than Portland cements, and although it sets faster, it achieves ultimate strength more slowly. These were key factors leading to the eventual market dominance of Portland cement.

Natural cement is significantly lower in modulus of elasticity than Portland,[3] however, allowing its successful use in large concrete and masonry structures without expansion joints. Like lime mortar, natural cement mortars deform as masonry units expand and contract with changes in temperature and moisture levels, relieving stress. In historic restoration work, avoidance of stress to the original building materials is important, as they constitute "historic fabric," the key components of historic buildings that are the objects of preservation efforts.

WHY IS NATURAL CEMENT SIGNIFICANT?

To understand the historical and technical impact of natural cement, one must look back more than 185 years. For engineers planning the construction of the Erie Canal in 1817, one of their most critical challenges was to find a cement suitable for water immersion and severe weather exposures. The 365-mile canal system's plans required construction of hundreds of masonry dams, locks, bridges, retaining walls, aqueducts and buildings. Engineer Canvass White was sent to England to study British canal structures in 1818, and returned to recommend the use of Parker's Roman Cement, a natural cement produced from argillaceous limestone. Initially concerned about the relatively high cost of this material, however, the Erie builders decided to proceed with laying up locks and walls in 1818 using

Fort Jefferson, 70 miles from Key West in the Gulf of Mexico, is one of 51 Third System seacoast fortifications built after the War of 1812. It is currently being restored using original natural cement materials.

older lime-based masonry mortar technology. The result was early failure, proving lime to be unsuitable.

White sought, and soon discovered, a similar argillaceous limestone in Fayetteville, N.Y. When burned and then ground to a fine powder, the rock yielded a hydraulic cement offering fast setting, moderate strength and excellent durability. The material was originally called "water lime" because it set when mixed with water, rather than reacting with carbon dioxide in the air. Later it became known as "natural cement" because, unlike Portland cement, which involves artificial mixtures of several ingredients, natural cement is produced directly from argillaceous limestone.

During the construction of the Delaware and Hudson Canal in 1825, a vast deposit of argillaceous limestone was discovered along its route in Rosendale, N.Y. Rosendale's proximity to the Hudson River and New York City, and the high quality of the cement produced there, quickly led to the rise of Rosendale as the premier source of natural cement in the United States. From 1817 to 1915 some 35 million tons of natural cement were produced and used in the United States, half of it originating in Rosendale. Second and third in volume, respectively, were the areas around Louisville, Ky., and along the Potomac River in Maryland, Virginia and West Virginia.

While civilian engineers were building dozens of canal systems, the U. S. Army Corps of Engineers, headquartered at West Point, was engaged in its own ambitious series of projects. Most notable was the design and construction of a series of 51 seacoast fortifications known as the "Third System." This undertaking, spanning 40 years, was intended to deter invasion by sea from Great Britain. In August 1814, British troops had landed on the Atlantic coast. After a short march inland, they attacked and captured Washington, burning the White House in the process. That was never to be allowed to happen again.

While the design of Third System fortifications is generally accredited to French engineer Simone Bernard, construction was directed by Corps of Engineers General Joseph Totten. In the 1820s, exhaustive testing of masonry materials was performed under Totten's direction, both at Fort Adams in Newport, R.I., and at West Point. Totten's conclusions led to the use of natural cement in masonry mortar, stucco and concrete in nearly all of the major military works for the next 50 to 70 years. When Totten became a member of the Lighthouse Board in 1855, natural cement was quickly incorporated into the design, construction and modification of lighthouses. As a regent of the Smithsonian Institute, he became involved in the building of the National Museum, today's Smithsonian Castle, in Washington, D.C. It, too, was constructed with natural cement. When the Washington Aqueduct system was designed and constructed, beginning in 1852, to supply the city with fresh drinking water, army engineer Montgomery Meigs designed and built the system's bridges and aqueducts with natural cement.[4] Meigs, a West Point graduate, reported directly to the chief of the Army Corps of Engineers, General Joseph Totten.

The Brooklyn Bridge, opened 1883, is perhaps the most recognized natural cement structure in the world. Natural cement concrete, mortar and grout were used in its construction.

The Erie Canal had been the training ground for America's first crop of domestically trained engineers. West Point was the nation's military engineering school. Following completion of the Erie Canal in 1825, one of its builders, Stephen van Rensselaer, founded Rensselaer

Polytechnic Institute, the nation's first civilian school of engineering, in Troy, N.Y. RPI engineers became the designers and builders of many of the 19th century's bridges, harbors, dams, railroads, lighthouses, industrial complexes, waterworks and sewer systems. Those constructions relied on the same natural cement technology used by the canal builders.

Among RPI's graduates was Washington Roebling, son of John Roebling, one of the D & H Canal engineers and designer of a number of natural cement bridges that survive today. Washington Roebling used natural cement concrete, grout and mortar in the completion of his father's master design, undoubtedly the best-known natural cement structure in the world, the Brooklyn Bridge. The bridge opened in 1883 and, in 2004, it carried an average of 137,563 vehicles per day.[5]

Until the turn of the 20th century, natural cement remained the predominant hydraulic binder used in the United States for both military and civilian construction. Only in 1897 did domestic production levels of portland cement begin to exceed imports, marking the beginning of portland's rapid rise in use in the United States. By 1903, its use levels had permanently overtaken natural cement. Portland cement use levels grew twentyfold in the first decade of the 20th century and reached more than four times that level in the 1920s. Its higher strength and faster cure permitted economies in design and overall construction costs, while problems with the sometimes inconsistent quality of natural cements could be overcome by careful manipulation of Portland cement ingredients.

Milwaukee City Hall, 1896, is a prime example of the architectural use of natural cement, which boomed in the 1880s and 1890s.

Yet natural cement did not disappear. It even enjoyed some growth in the 1920s and 30s, though never coming close to recapturing its earlier market share. In the 50s and 60s, it was used as an addition to Portland cement and that is how ASTM C 10 described its scope of use in its last revision (1976).

THE NATURAL CEMENT REVIVAL

In the 1980s, historic restoration in the United States reached a critical mass. The adaptive reuse of historic structures, rather than their destruction and replacement with modern buildings, was fueled by a growing sensibility that historic buildings and structures are cultural treasures to be preserved in the public interest. Tangible support was provided by the enactment of investment tax credits for historic buildings restored in accordance with the Secretary of the Interior's guidelines. As the guidelines favor use of original materials to the greatest extent feasible, this led to a resurgence in the commercial production of traditional masonry materials.

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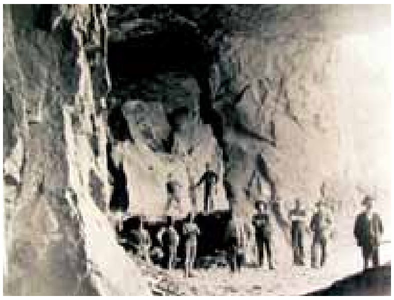
In the absence of commercial sources of natural cement, the importance of its technical and historical role was temporarily obscured. The use of lime-based materials has enjoyed a revival, but they do not accurately represent mainstream, large-scale, 19th century building practices. Indeed, many of the advances achieved during that period were only made possible by the replacement of lime-based technology with natural cement. To fulfill the growing need for authentic 19th century masonry materials, natural cement was reintroduced in 2004.

The lack of a current ASTM standard specification for natural cement is an obstacle to the full realization of historically accurate and appropriate restoration work. Natural cement was used as a structural material, and will be required to fulfill structural performance requirements in the course of some of its applications in historic repair and rebuilding. To protect the public, it is essential that materials marketed today as natural cement meet the same requirements that governed performance historically. In addition, ASTM Task Group C12.03.03 on Historic Mortars, working to develop a new standard for historic mortars, must be able to reference an ASTM standard specification for natural cement if they are to include it in an eventual standard. To exclude natural cement from any eventual ASTM standard for historic mortars would be to forsake history.

As the restoration industry rediscovers natural cement technology and its importance in our engineering and architectural heritage, there is also a danger that inauthentic materials will be promoted and labeled as natural cement. Natural portland cements produced in Europe by high-temperature firing of impure limestone are already being promoted as natural cements, although they would not have qualified under the former ASTM C 10 standard and do not meet the cur-

rent ASTM C 219 definition. Their confusion with the traditional materials used in the United States may lead to incompatible and inappropriate repairs, potentially damaging the very structures that are the objects of the preservation efforts employing them.

ASTM C 10 replaced a broad series of inconsistent and sometimes arbitrary specifications at the beginning of the 20th century. It provided a means of protecting public safety and purchaser's interests, while establishing uniform performance requirements as a fair basis on which cement producers could compete. Today's natural cement industry will never regain the market dominance it once enjoyed, and that is not its objective. But a reinstated ASTM C 10 standard is as essential to performance reliability, consistency and protection of the public's safety and interests in the 21st century as it was when it became one of ASTM's first standards, more than a century ago. //



Natural Cement Mine, circa 1890. Room and pillar mining techniques were most commonly used in natural cement rock mining.

References

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3 Report of tests of metals, etc., made at Watertown Arsenal, for 1902, pp. 501-505

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5 New York City Bridge Traffic Volumes 2004, NYC Dept. of Transportation

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