Characterization of Cements from the Civil War to the Spanish American War Era in Coastal South Carolina

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Fort Sumter (1829-1861)
Repairs (1873)
Battery Huger (1898)

Naval Station Port Royal (1897)
Parris Island

Fort Fremont (1899)

We will look at equilibrium and non-equilibrium conditions faced by historic natural cement manufacturers.

PART 1: TECHNICAL INSIGHTS

Cement Technology/Equilibrium

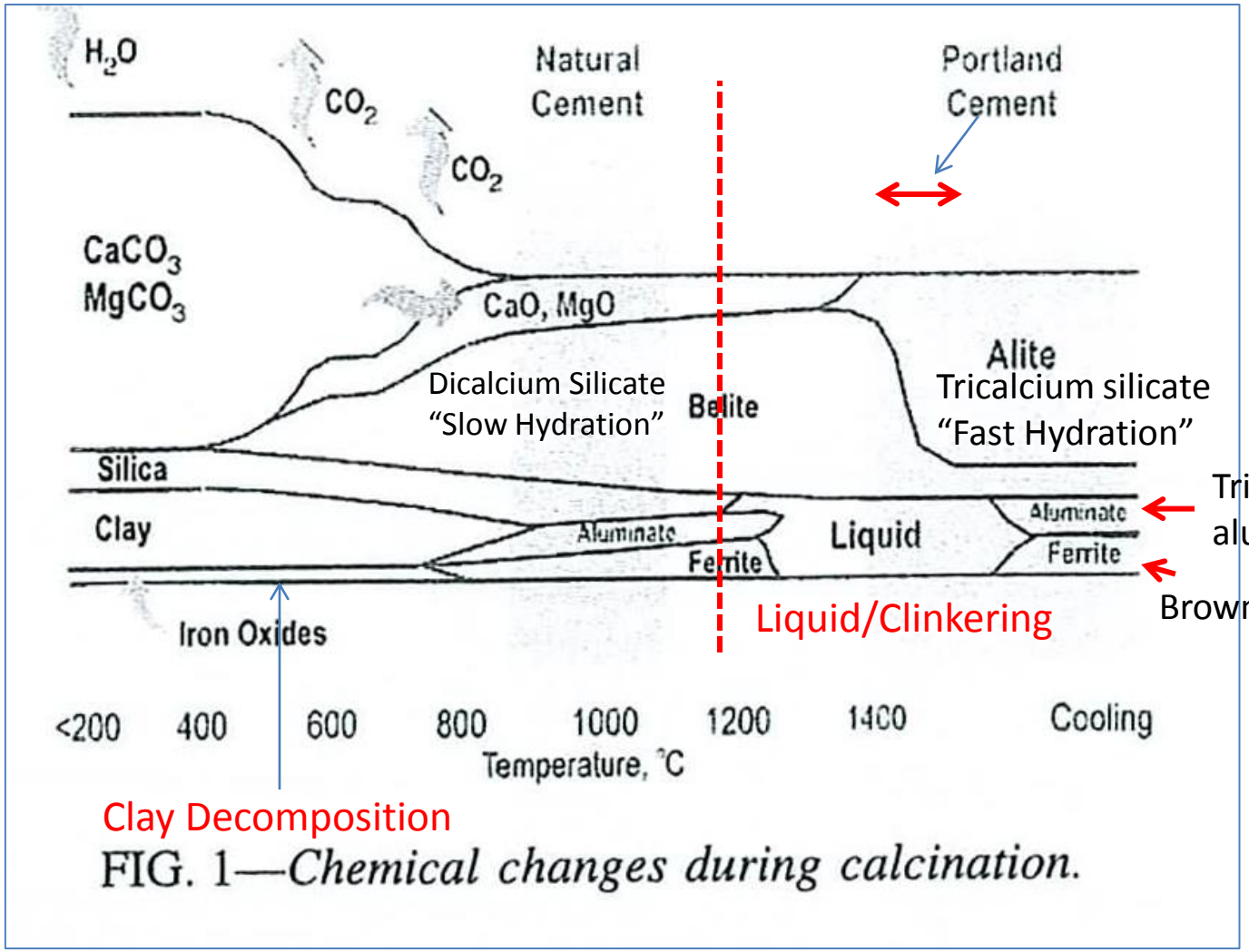
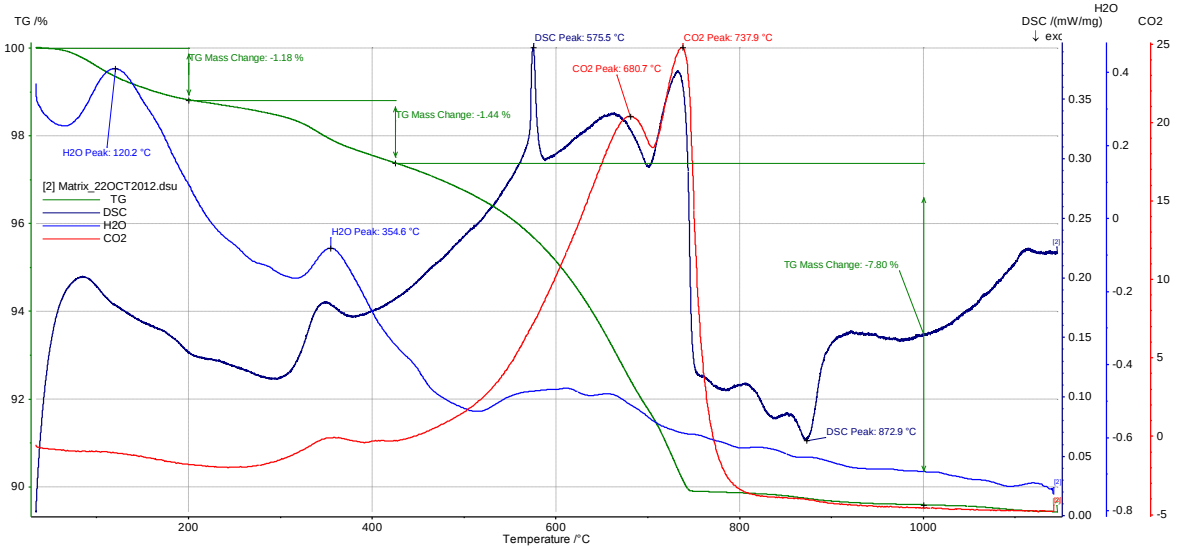


FIG. 1—*Chemical changes during calcination.*

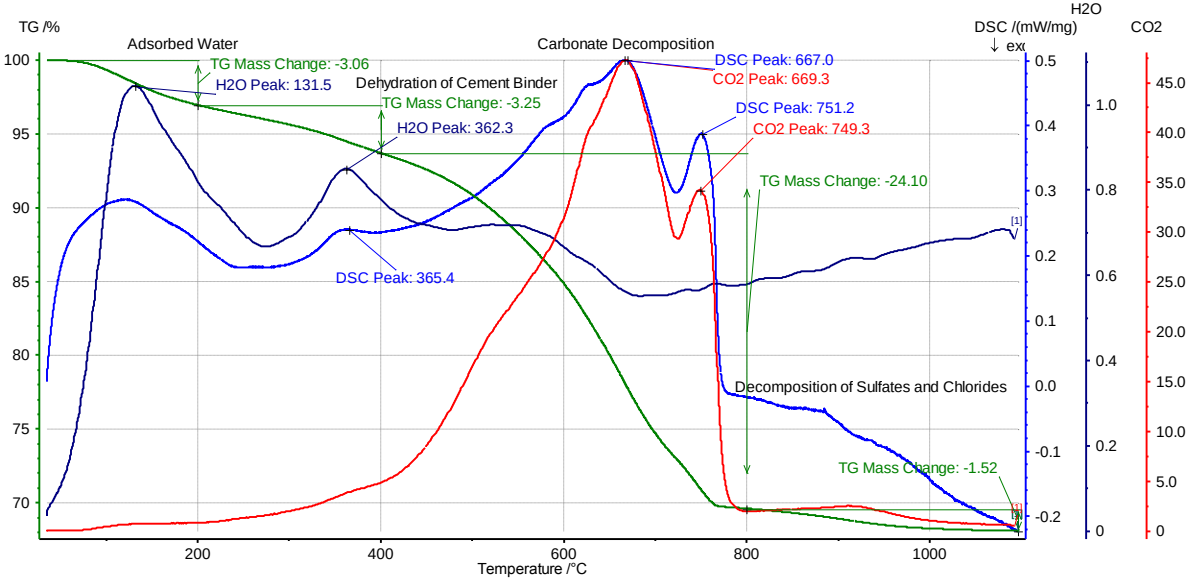
From: Natural Cement in the 21st Century, Michael P. Edison, Journal of ASTM International, JAI100676.

The Problem of Variable Calcination Temperatures in Historic Rosendale Cement

Fort Fremont (1899) ; Twin Dolomite Peaks of an Intensity in Natural Stone



Fort Sumter (ca. 1845), Reverse intensity of carbonate peaks.



THE PASSING OF NATURAL-ROCK CEMENT.

PERHAPS there is nothing in commercial history more pathetic than the circumstances attending the passing away of a once great industry. The resultant loss to employés and investors, the inevitable paralysis stealthily creeping in where all was once cheerful activity, the sharp contrast of an inaction which hints unmistakably of a destiny of silence and desolation, which no man's hand can stay, all this combines to suggest something humanly tragic, something like the death-struggle of a beneficent giant.

For more than half a century the Empire State could boast of no prouder industry than the manufacture of natural-rock cement. The enterprise has made of comparatively unproductive Ulster one of the foremost counties in the State. To-day, the business interests of a large area, including the Rosendale cement district, are ruined, or hopelessly injured, and half a score of once prosperous villages are partially deserted. The Louisville cement belt is, also, undergoing a like exodus of laborers to new fields of work. Curiously enough, the great shortage in Portland-cement of last year, amounting, as it did, to a veritable cement famine, and causing the postponement of many important building-operations, failed to check the rapid decrease in the demand for natural cement. The casual observer, aware of the fact that we have never been engaged in such gigantic feats of engineering and architecture as at the present time, is naturally puzzled to account for the abandonment of this long stable commodity. The reasons are many and interesting; but, doubtless, the primal factor to blame has been the heterogeneous character of all natural cements.

The American Architect (1903)

Howard Cement Kiln Remains
Near Adairsville, GA (2011)

Was quality control simply testing the time to initial set to differentiate "lime" and "cement"?

Mining Tunnel

Fort Sumter (1829-1861)
Fort Sumter Repairs (1874)
Building 11, Naval Station Port Royal (1897) – Now Parris Island
Battery Huger, Fort Sumter (1898)
Fort Fremont (1899)

PART 2: CASE STUDIES ALONG THE COAST OF SOUTH CAROLINA

Mortar – Fort Sumter (1840's)

Right Flank Wall

Original Rosendale-Lime-Sand Mortar after Wearing Away of Portland Pointing Mortar Installed In the 1960's

Mortar Characterization

- Bulk density: 1.23-1.81 g/cm^3
- Porosity: 22.7-44.1%
- Rosendale cement
- Composition:

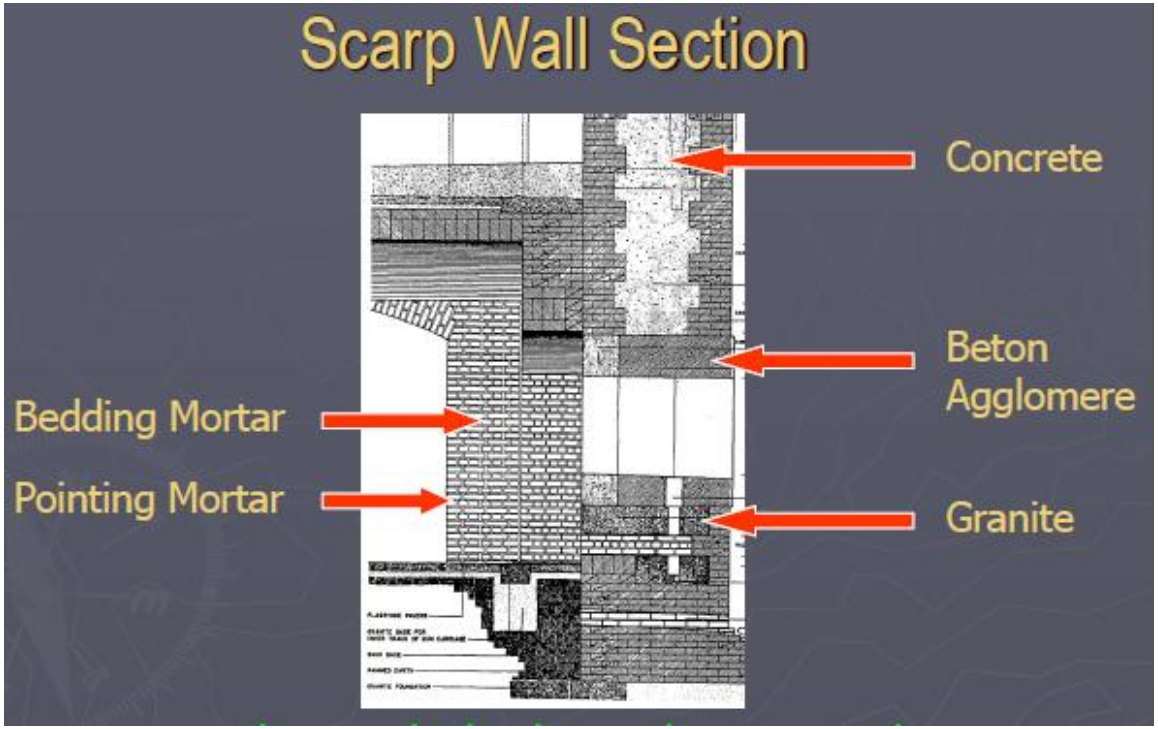
  Cement: Lime : Sand

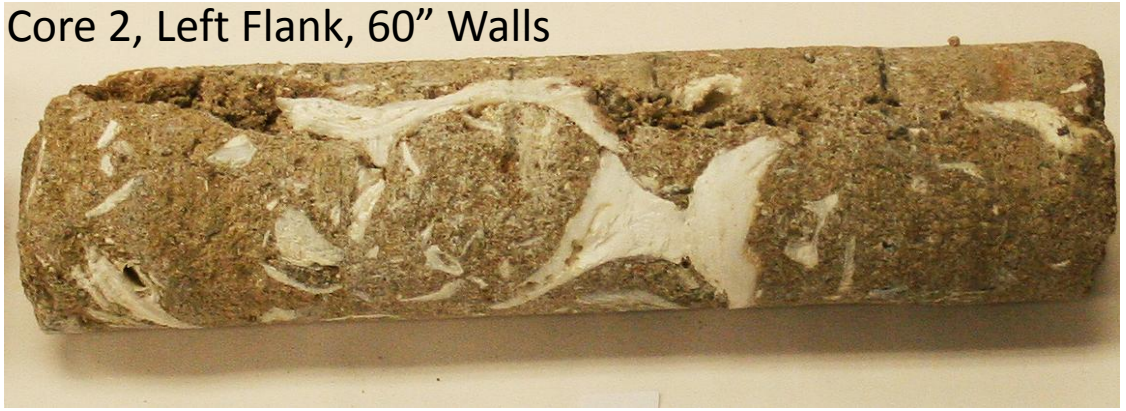
  Range 1:$\frac{1}{2}$:2 to 1:4:9

  Or, 1 (cement + lime) : 2 (sand)

- Mineral alteration by seawater as:
  Magnesium uptake
  Leaching of lime (CaO)

Concrete Infill – Ft. Sumter (1840's)



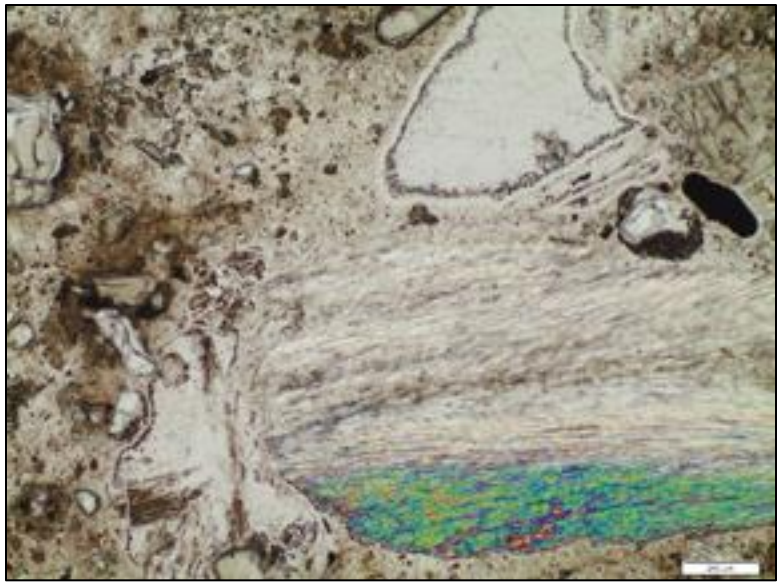


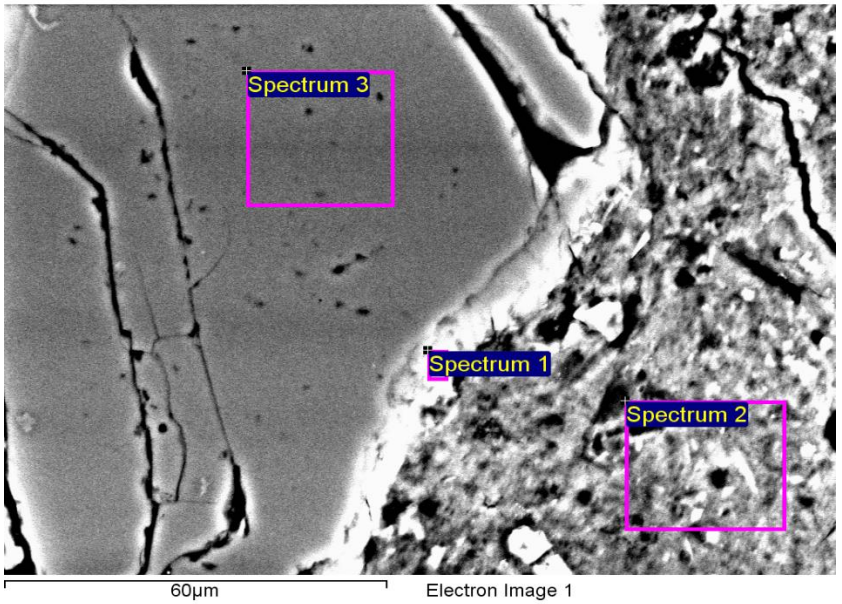
Concrete Infill (Original)

Composition:

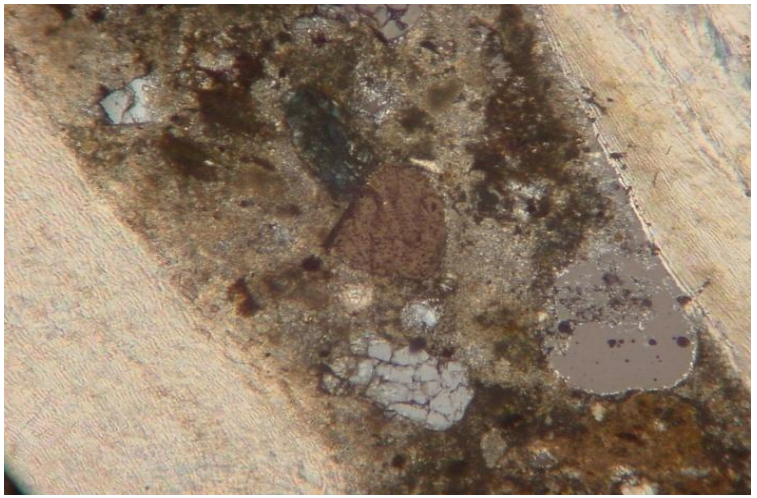
Component	Volume %
Lime as $Ca(OH)_2$	1
Sand	½-1
Shell with variable rubble	½-¾+

Evidence of ASR (The oldest observed in the USA?)





Rubble Concrete (Original, Left Face)



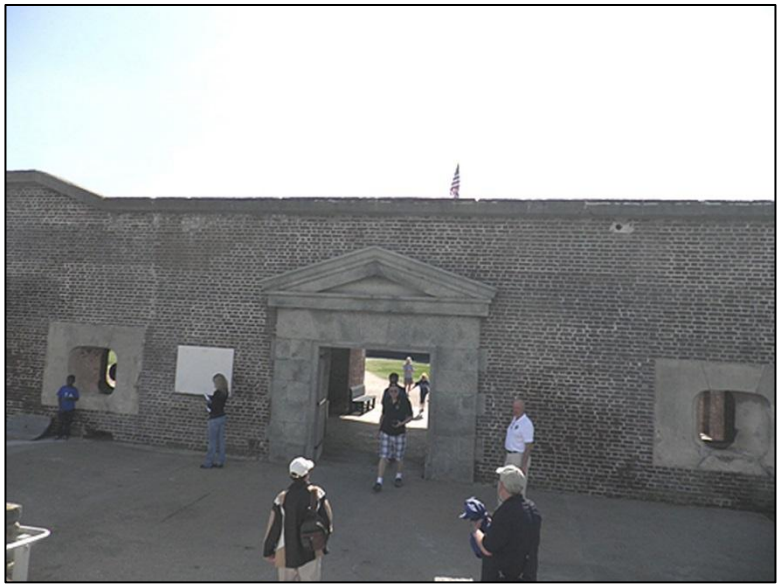
Repair Concrete (1896)

Corps of Engineers Report (1896) on Wall Repairs:

- Brooklyn Bridge Brand of Rosendale Cement
- Tested beach versus river sand finding no difference.
- Obtained granite from Edgefield, SC (111 miles from Charleston)
- Granite was -2.5” in two sizes.

The concrete was: Cement : Sand : Aggregate (brick) of 1:2:3

1873 Concrete Coping Blocks



The composition of concrete used in casting of magazines at Ft. Moultrie is given in the *Charleston Daily News*, March 4, 1873, as:

½ part of "English Cement": to 3 parts of sand (by volume)

The coping block's nominal composition at Ft. Sumter was determined as:

½ part of Portland cement to 1 parts of lime to 5 parts of sand (by volume)

Report of Operations, Ft. Sumter, February 1874, states "Portland cement and lime expended in making artificial stones".

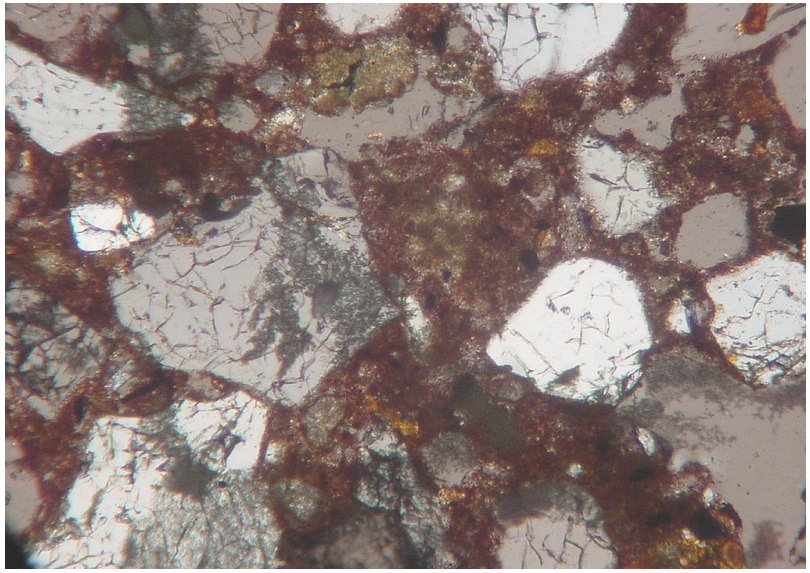
The coating composition was determined as:

1 part of lime to 2 parts of sand (by volume)

Property	Concrete	Coating
Bulk density, g/cm^3 (pcf)	1.94 (121)	1.72 (107)
Apparent Porosity, %	24.5	30.9

Mortar – Parris Island Building 11 (1897)

		Oxidized Mortar	Oxidized Sand
SiO2	%	83.16	95.72
Al2O3	%	1.87	1.757
Na2O	%	0.3	0.3
K2O	%	0.2582	0.2677
MgO	%	3.572	0.1
CaO	%	7.498	0
Fe2O3	%	2.5824	1.5491
MnO	%	0.1207	0.0388
TiO2	%	0.1616	0.1562
P2O5	%	0.107	0.05

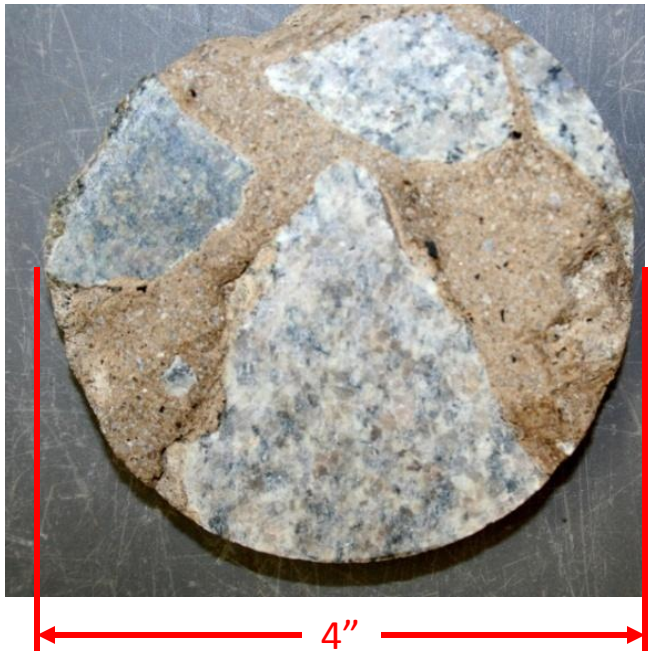


XPL

Mortar Composition: Rosendale cement, lime, and sand.

Proportions of C : L : S = 1:2:6

Concrete – Battery Huger (1898)



XRF	
Al_2O_3	10.03
SiO_2	62.69
Fe_2O_3	2.47
TiO_2	0.20
MgO	2.29
CaO	8.90
Na_2O	2.87
K_2O	6.71
LOI	3.56
Other	MnO 0.10
Sum of Major Constituents	96.45
LOI	3.56
XRD	Annite, Biotite, Sodalite, Anorthite, Q, Albite + Calcite

Cement (Major Rosendale + Portland) : Lime : Sand : Aggregate of 1:2:11:5
Aggregate: Edgefield (SC) granite of quartz, mica, and feldspar minerals.

Property	Value
Bulk density, g/cm^3	1.45 (90 pcf)
Apparent Porosity, %	39.9
Compressive strength, $lb./in^2$	2628

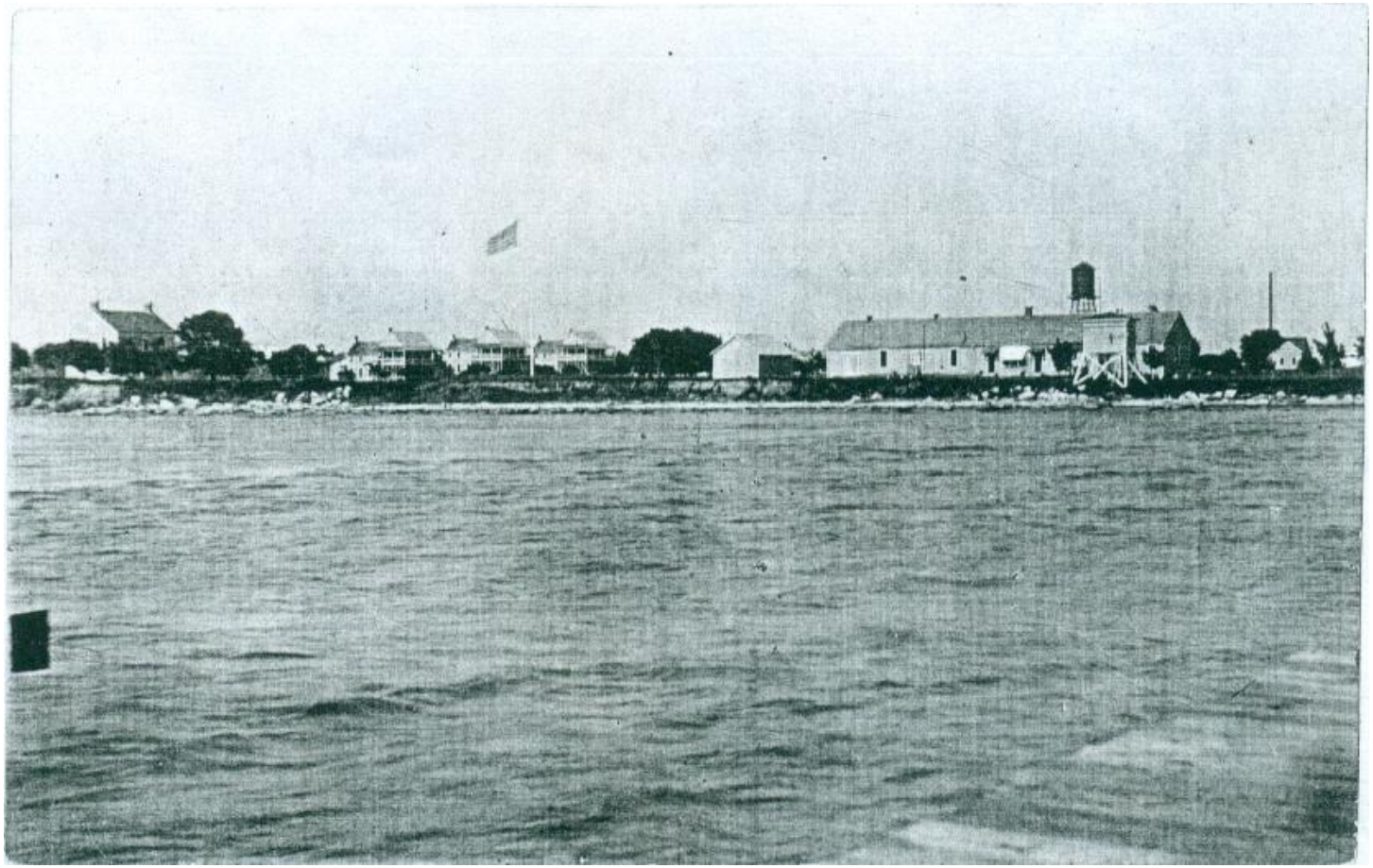
Concrete – Ft. Fremont (1899)

Corps of Engineers Report, Port Royal SC (1898):
1 part Rosendale + Portland, 2 parts sand, and 4½ pasts granite.
Usage of 718 barrels Rosendale (97.8%) and 16 barrels of Portland (2.2%).
Granite: Columbia, SC. [Rapid Fire Guns] Additional granite from Greenwood, SC (for 10” Guns/disappearing carriages).

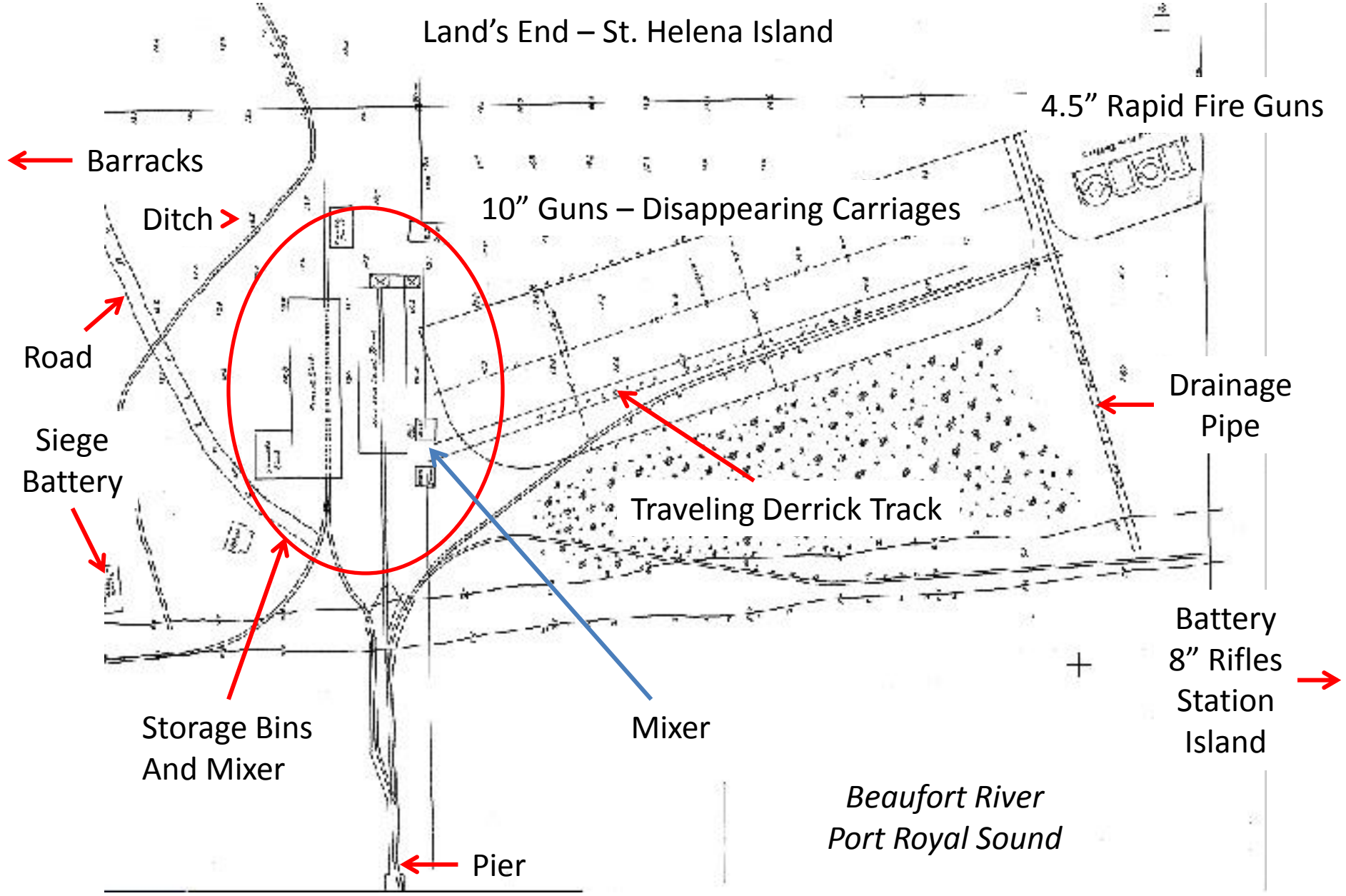
Relics of Rosendale and Portland were found in the same specimen suggesting they were used simultaneously rather than *necessarily* used by structural purpose.
Bulk density of 2.21 g/cm^3 or 138 lb./ft^3 (higher than others – reflects new technology?).

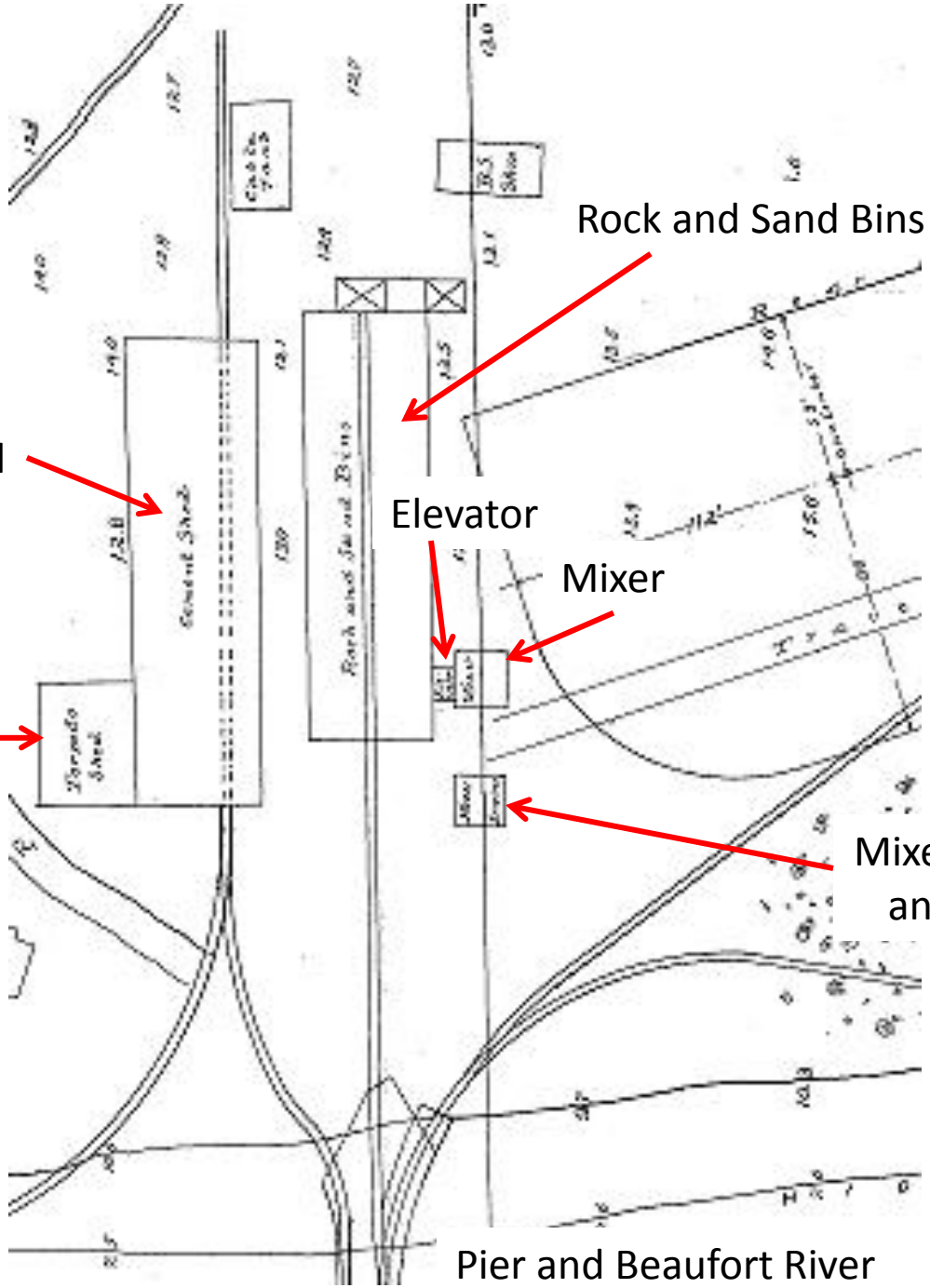
Material production was automated by 1898 using steam power. Placement involved shoveling and ramming to consolidate (density) concrete placed behind formwork. Concrete consolidation was rarely optimal.

PART 3: CONCRETE PLACEMENT



Fort Fremont from the Beaufort River (1899)


Land's End – St. Helena Island
4.5" Rapid Fire Guns
Barracks
Ditch
10" Guns – Disappearing Carriages
Road
Drainage Pipe
Siege Battery
Traveling Derrick Track
Battery 8" Rifles Station Island
Storage Bins And Mixer
Mixer
Beaufort River
Port Royal Sound
Pier


Rock and Sand Bins
Cement Shed
Elevator
Mixer
Traveling Derrick
Torpedo Shed
Mixer Engine for Mixer and Batch Car Hoist
Pier and Beaufort River

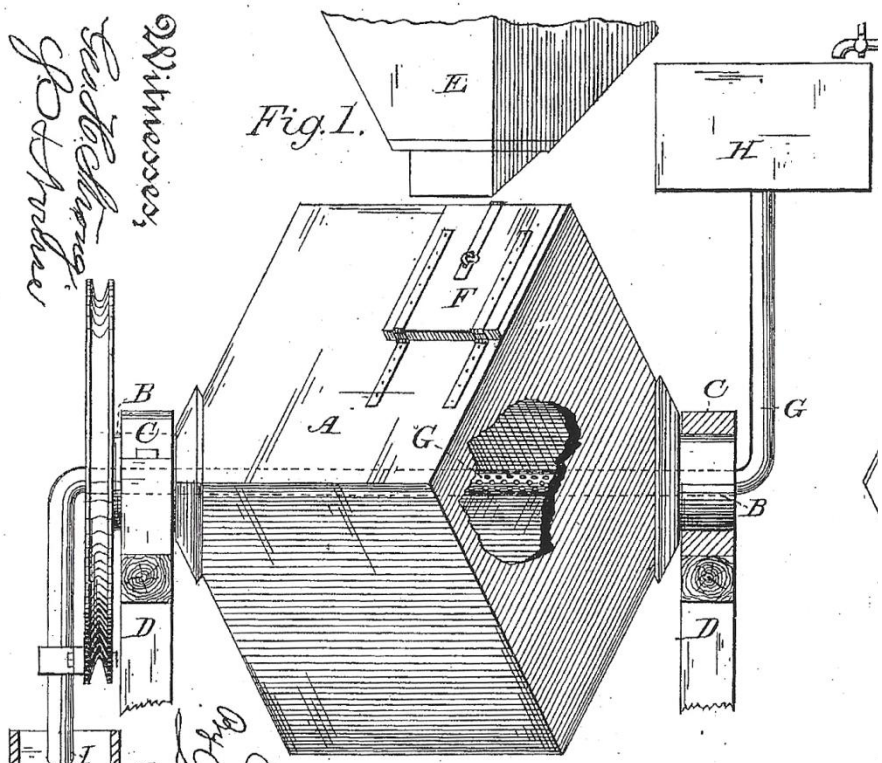
(No Model.)

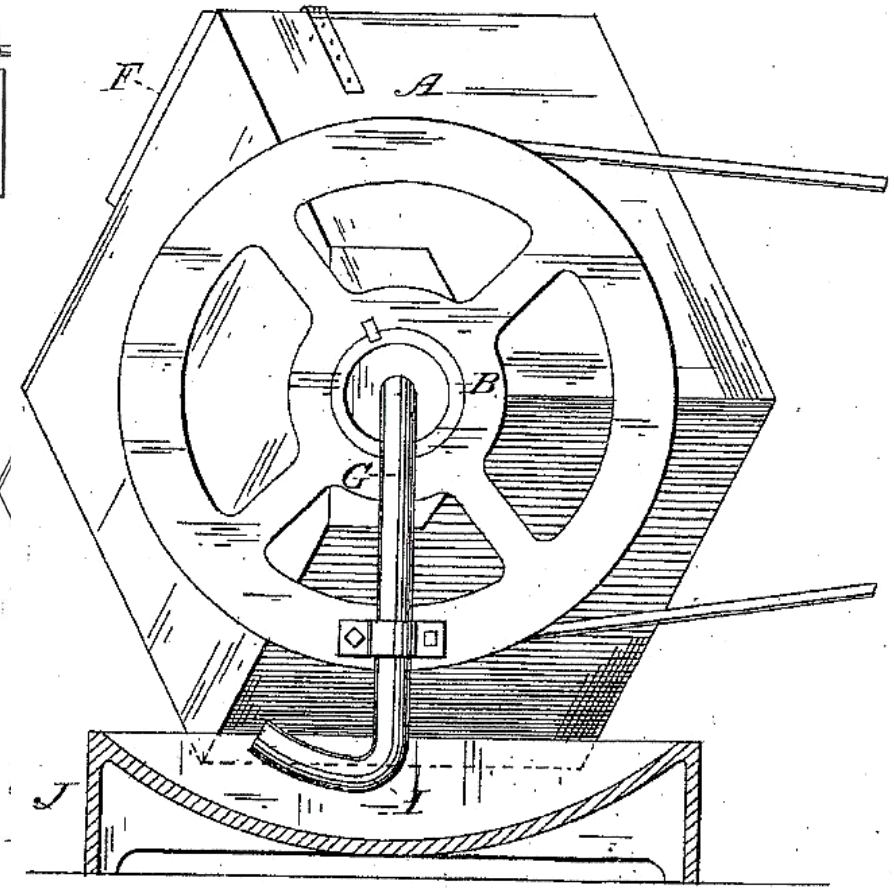
E. L. RANSOME.

MANUFACTURE OF CONCRETE.

No. 306,522. Patented Oct. 14, 1884.

Fig. 1.

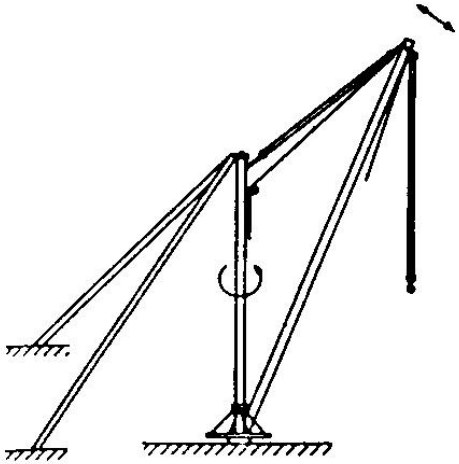




Witnesses,
Edw. C. Clarke
J. D. Archer

Inventor,
E. L. Ransome
By Dewey & Co.
Attorneys

N. PETERS, Photo-Lithographer, Washington, D. C.



Derrick

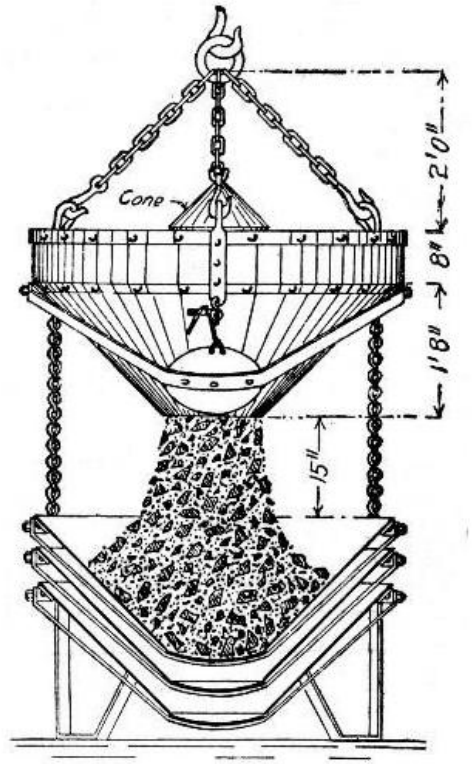
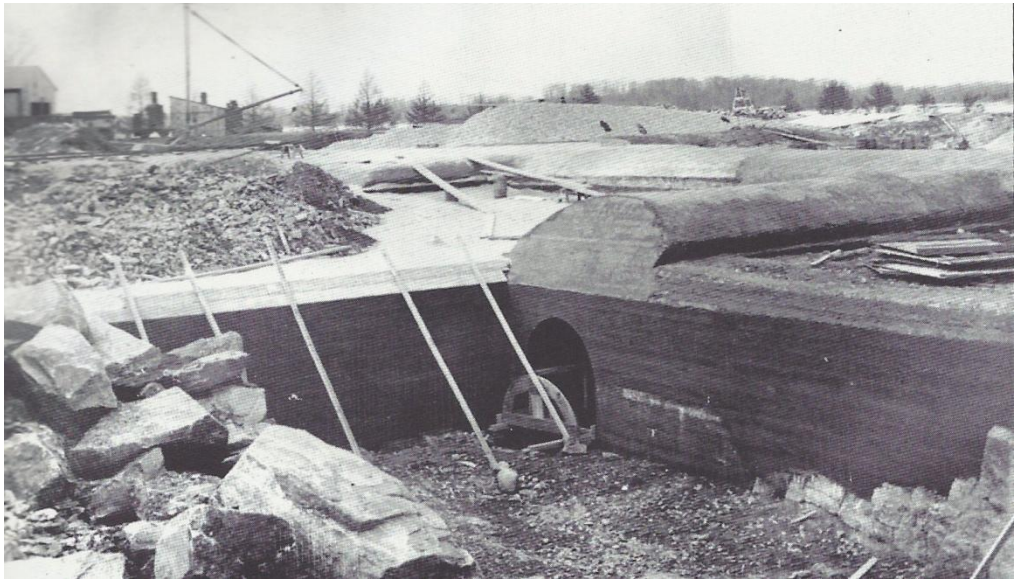


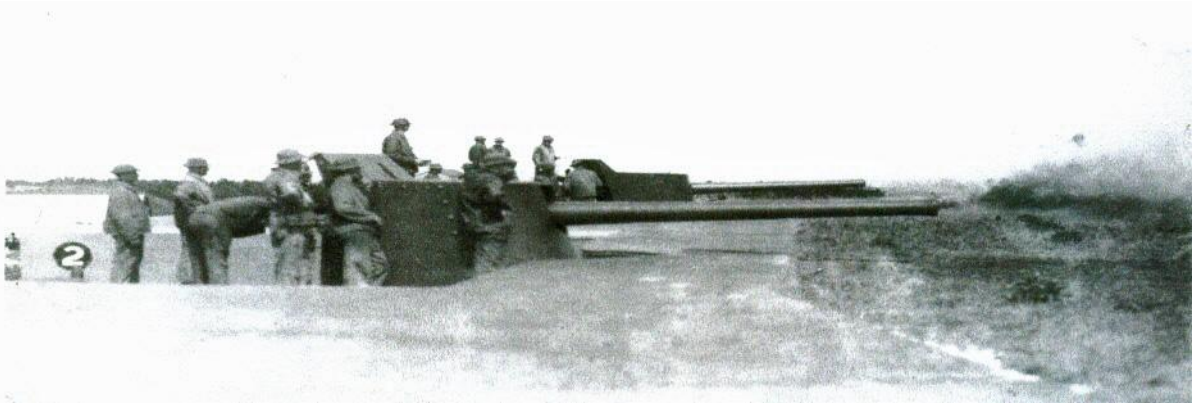
Fig. 25.—Hains Gravity Mixer, Telescoping Hopper Form.

Ramming

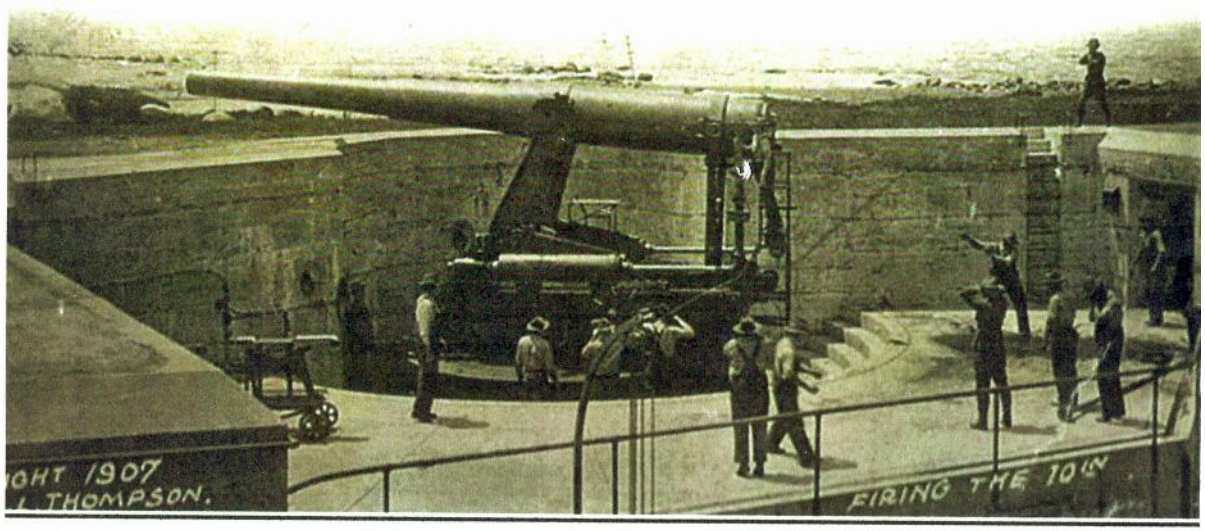
From : Concrete Construction Methods and Cost, Halbert P. Gillette and Charles S. Hill, Myron C. Clark Publishing Co. (1908).



Formwork, Fort Totten, 1890's, from Richard Lowery (2013)
"In Defense of Natural Cement: A Critical Examination of the Evolution of Concrete Technology" (Photo: Bayside Historical Society Collection)



10” Battery – Then and Now



Identifying Historic Rosendale and Portland Cements

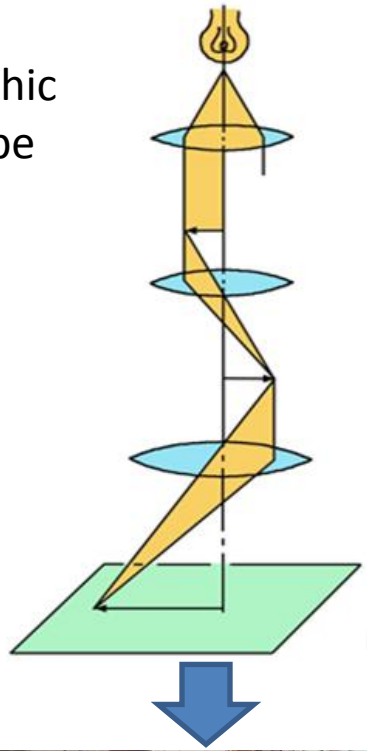
- Practical –color

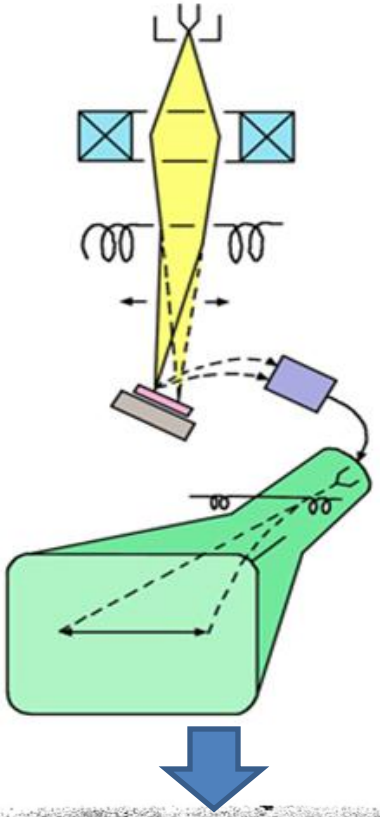
- Microscopy
    1. Petrography – See “Petrography: Distinguishing Natural Cement from Other Binders in Historical Masonry Construction Using Forensic Microscopy Techniques”, John J. Walsh, Journal of ASTM International (2007).
    2. SEM/EDAX

- Laboratory – “Black Box” as confirmation
    1. XRF (chemical analysis) – MgO content.
    2. Thermogravimetric analysis – double carbonate peaks for $MgCO_3$ and $CaCO_3$ decompositions.
    3. Soluble salts – [Mg] concentrations.

Further characterization by MIP (porosimetry) and XRD.

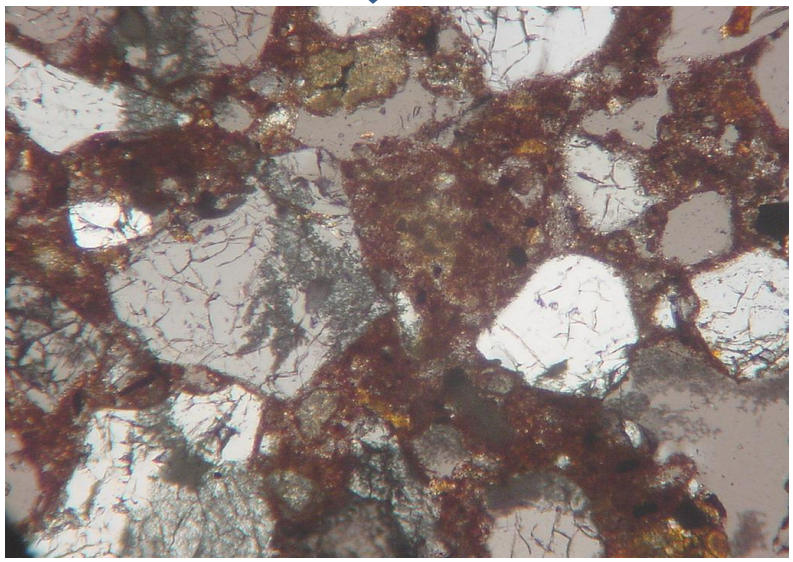
Petrographic Microscope (Optical)

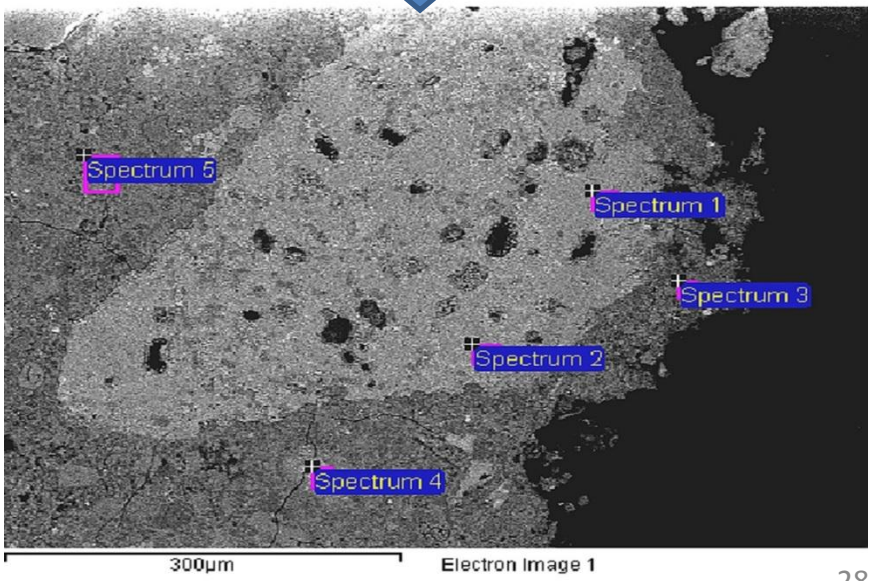




SEM (EDAX)

Ft. Fremont





EDAX Analysis of Cement Particles Compared to Reference Chemistries Fort Fremont

Analysis as oxides, ignited basis

Spectrum	1	2	3	4	5	Average of relics	For comparison	For comparison
ID	Cement relic	Cement relic	Cement relic (matrix)	Cement relic (matrix)	Cement relic (matrix)		Historic natural cement	Portland Cement (historic)
MgO	7.55	12.03	22.78	4.06	12.37	11.76	4.0-18.0	1.2
Al_2O_3	15.70	7.88	3.86	0	2.19	5.97	3.4-6.3	5.9
SiO2	42.46	40.89	35.50	30.29	21.43	34.11	22.6-29.9	21.9
K_2O	12.36	2.63	2.17	0	2.15	3.86		
CaO	19.64	32.21	28.65	65.65	61.85	41.48	36.0-48.2	63.1
Fe_2O_3	2.29	4.37	7.04	0	0	2.74	1.8-7.2	1.0
Basicity Index*	0.61	0.83	0.89	1.7	3.14		1.05-1.90	2.13

* $(CaO+MgO)/(Al_2O_3+Fe_2O_3+SiO_2)$

Summary

- Timeline

- Mortar Identification

  Petrographic Microscopy and Analytical Tools
- Construction

  Semi-automated by 1898. Incomplete consolidation is frequently noted.