Production of European Roman cements: history and the situation today /

Production de ciments romains européens: histoire et situation actuelle

Wolfgang SCHWARZ

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COMPOSITE - ANODE - SYSTEMS GMBH

Natural cements in European cultural heritage: history, properties, applications and conservation»
ICOMOS 26 – 27 April, 2012, Paris, France

History of Hydraulic Cements

1824 AD	J. Aspdin “Portlandcement”	
1796 AD	J. Parker “romancement”	
1756 AD	J. Smeaton “hydraulic lime” (Eddystone lighthouse)	
1300	Rediscovery of the hydraulic lime in Europe?	
300 AC - 500 AD	Roman Cement Aequaducts, Viaducts e.g. Pantheon 29 AC	Lime, Puzzolanes, Potash Vetruvius “10 Books about Architecture” 25 AC
1500 AC	Palace of Phaistos, Crete Cyprus, Mykonos, Minoic - Crete Culture	air hardening lime, hydraulic limes ? “Higher strength then the later Roman Cements”
7000 - 9000 AC	Egypt : HUMRA India: SURKHI Mesopotamia, Galiläa	calcined clay mixed with lime air hardening lime, hydraulic limes Calcined clay as refractory materiall

R. Malinowski, Y. Garfinkel,
Concrete International, März 1991

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ROMAN CEMENT - 1st CEMENT AS CONSTRUCTION MATERIAL PRODUCED ON AN INDUSTRIAL SCALE

WHY HYDRAULIC CEMENTS ?

Industrialization was accompanied by:

Industrial production of goods	**required infrastructure for transport of raw materials (wood, coal, steel) and manufactured goods**
Need for Infrastructure	**Requirement for Channels, Bridges, Civil Structures in Harbours**
Rapid Growth of Population and Urbanization	**Requirement for Sewer Systems**

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ROMAN CEMENT - for Civil Structures in the 19th Century

Brooklyn Bridge 1870 - 1883

Washington Life Insurance Building, NYC (85 m, 18 Stories) 1898

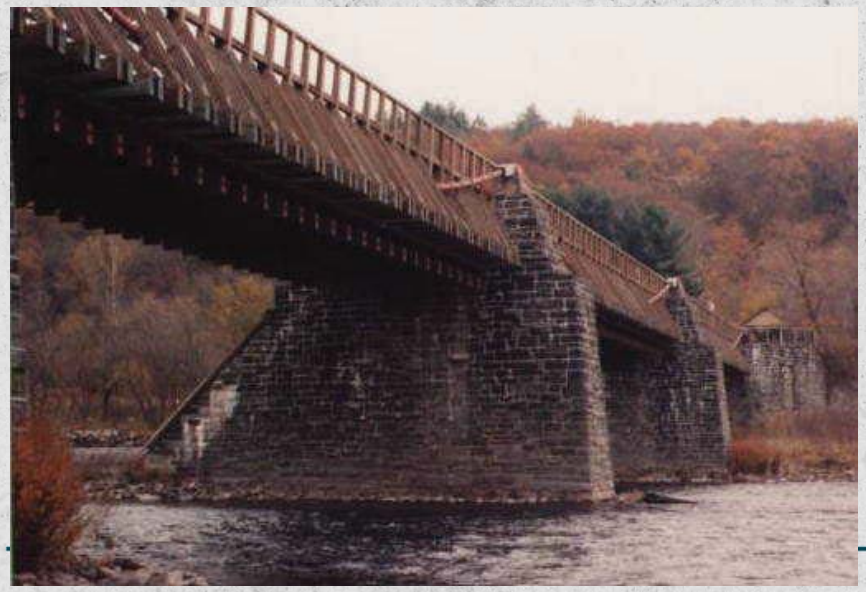


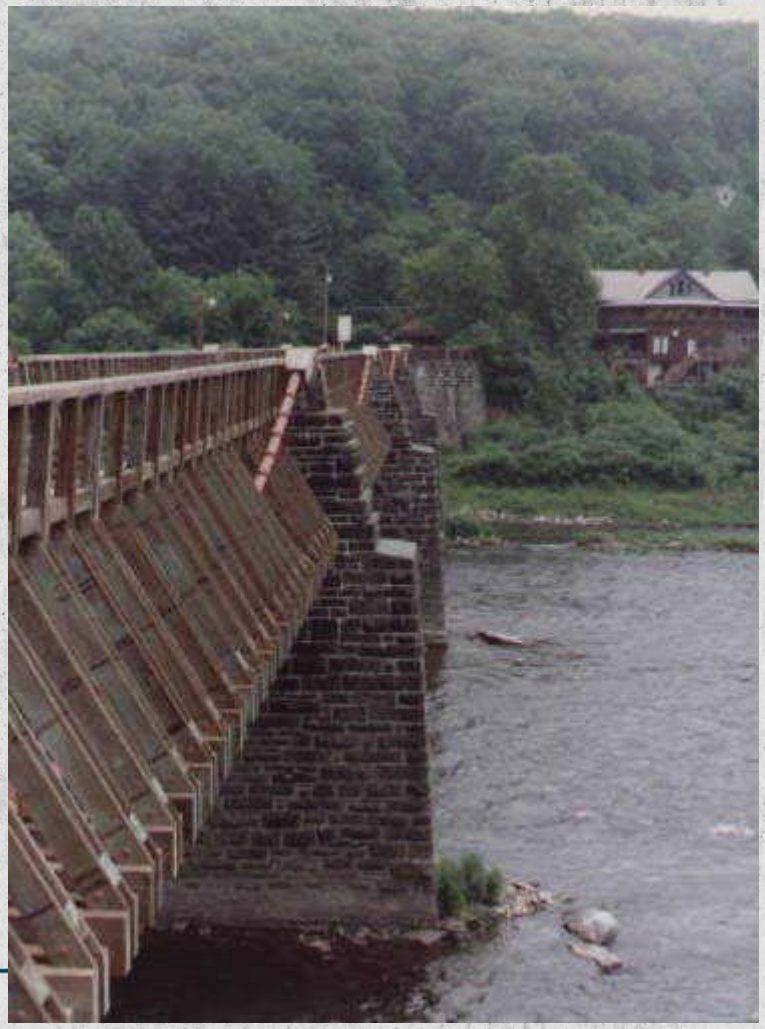


Delaware – Hudson – Canal 1848,

Delaware Aqueduct (Roebling Aqueduct) - Lackawaxen, Pennsylvania and Minisink Ford, New York

Load: 2000 tons of water





What is Roman Cement?

L. Tettmayer, Zürich (1893):

Roman Cements are products, that are obtained by calcining clay rich marls below sintering temperature and that do not "slake" if sprinkled with water, therefore have to be pulverized mechanically.

ROCEM (FP6 2003 - 2006):

Reactive phases are non-crystalline aluminate- (early strength) and α'-belite phases 14 - 90 day strength) that form below 950°C.

ROMAN CEMENT - Definition

L. Tettmayer, Zürich (1893):

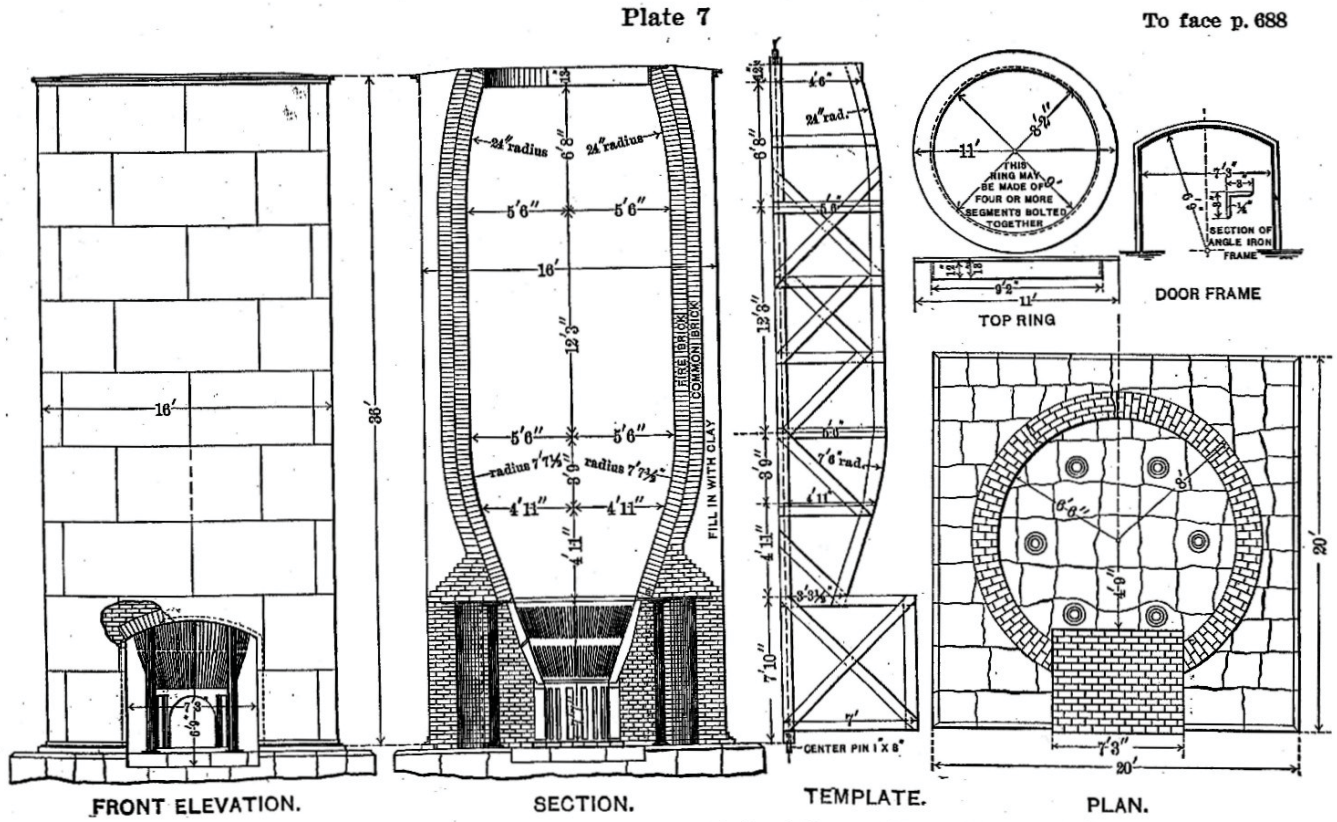
Mixed with water, Roman Cements warm up, depending from the raw material, treatment of the calcined stones, duration of storage, etc., very differently.

Roman Cements are used for sealing, to dry up and for rapid casting, in second degree for their strength.

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ROMAN CEMENT - 1st CEMENT AS CONSTRUCTION MATERIAL PRODUCED ON AN INDUSTRIAL SCALE

Shaft kiln equipped with Campbell Grate for burning natural rock cement

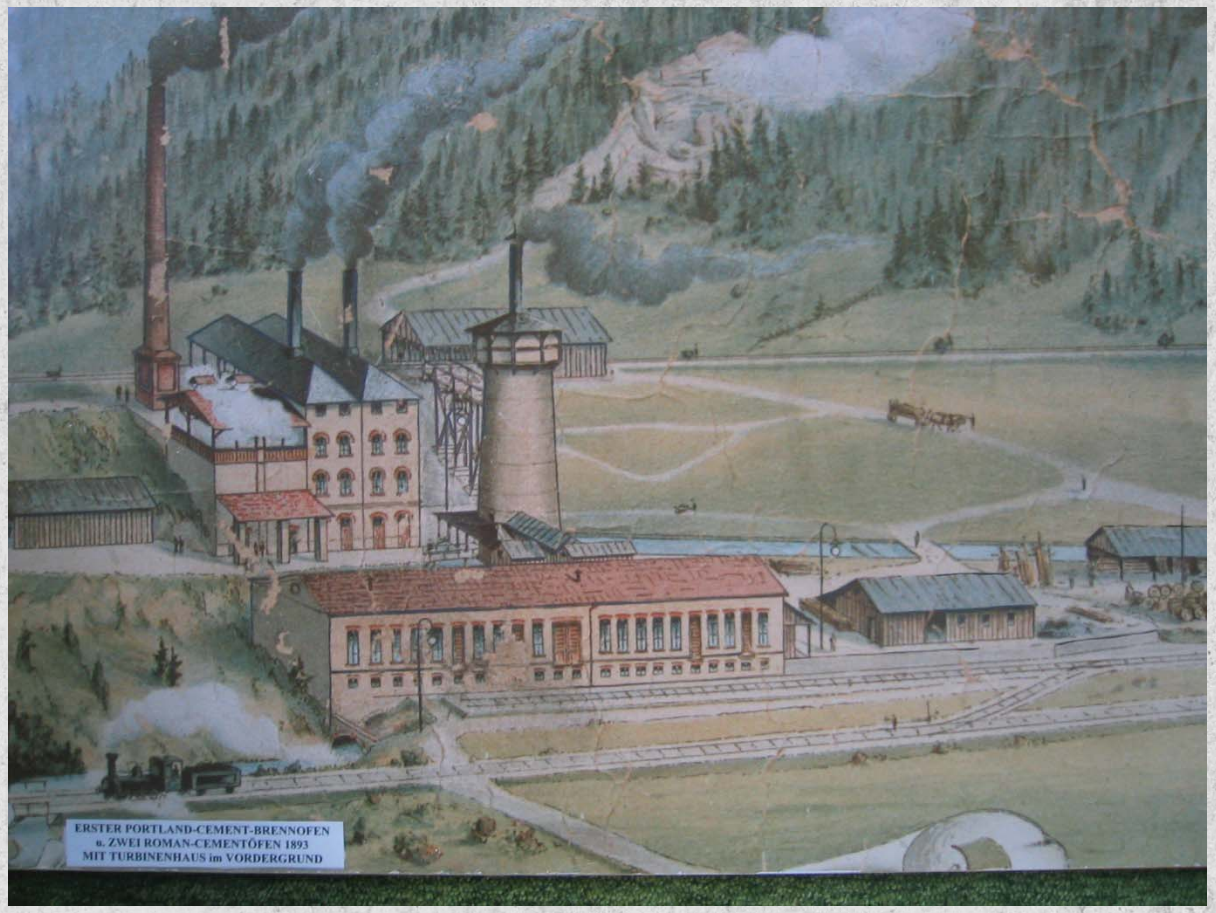


Kiln for burning natural rock cement, equipped with Campbell grate (Mineral industry, 6:106)

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ROMAN CEMENT – ROCARE PROJECT:

Wietersdorfer & Peggauer Zementwerke



- two Roman Cement Kilns

and

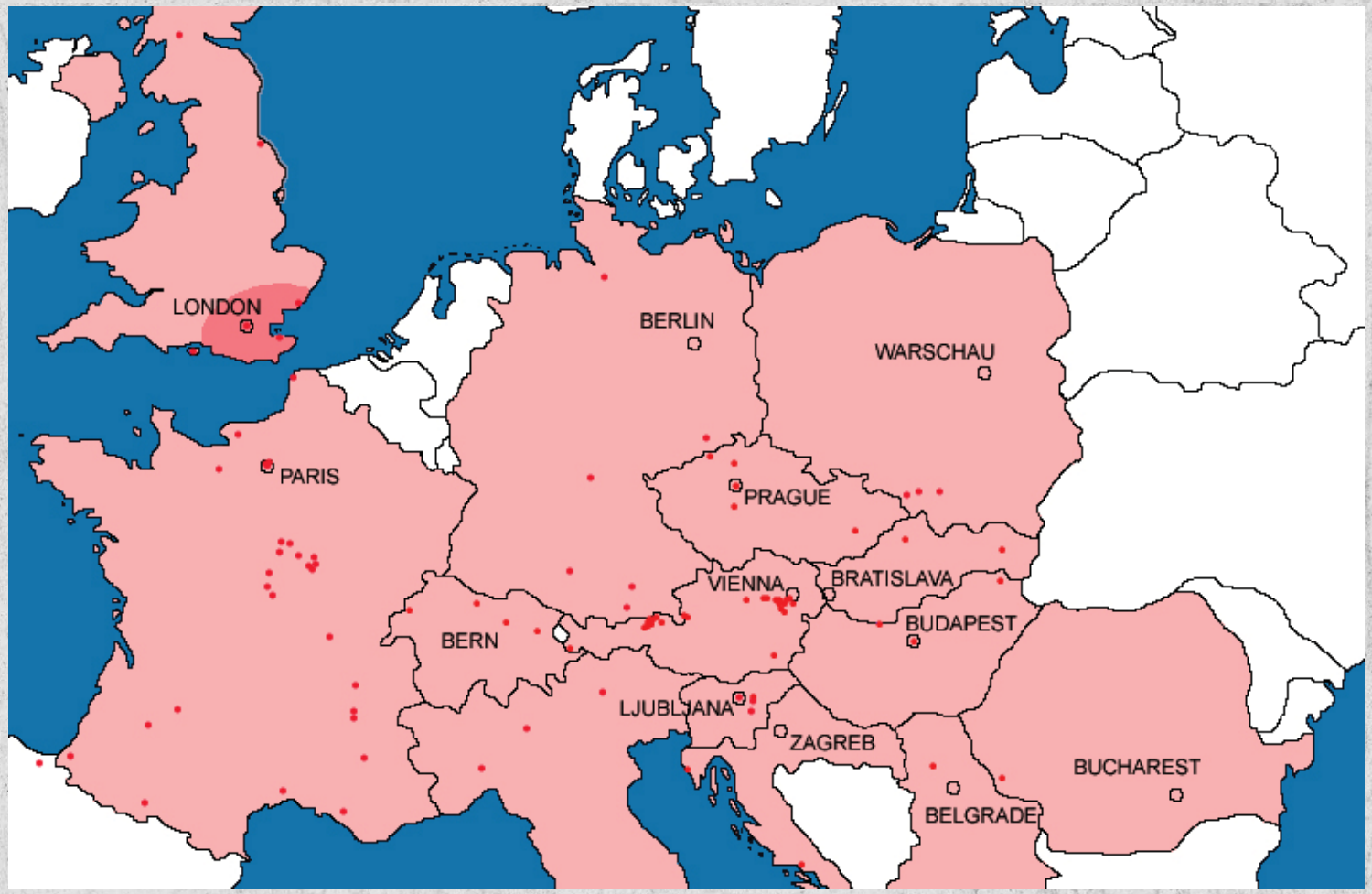
- one Portland Cement Calcination Kiln

Wietersdorf 1893

with electric generator facility in foreground

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ROMAN CEMENT – PRODUCTION in EUROPE



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WHY ROMAN CEMENTS IN THE 21st CENTURY ?

Data Available over a Period of more than 150 Years

- High Durability in Pointing Mortars (see Brooklyn Bridge)
- High Durability in Renderings and Stuccoes
- High Frost-Thaw Resistance (non saturated)
- High Resistance towards Chemical Attack (Sulfate)
- High Capillary Porosity
- Excellent Transport Properties for Humidity

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Manufacturing Partners:

Wietersdorfer & Peggauer, W&P Kalk GmbH, Peggau (A)

Facilities: - Lepolprocess with Rotary Kiln 700 t/day OPC
- Shaft - Kiln 60 - 70 t/day Limestone
- Ring-Shaft Kiln 120 t/day limestone

MBM - Institute of Ceramics and Building Materials, Krakow (PL)

Facility: - Pilot Scale Lepolprocess/Rotary Kiln 350 kg/hour

VFB - Mauerbach (Karl Stingl), (A)

Facility: - Traditional Shaft Kiln in Mauerbach- 1000 - 2000 kg/Batch
- Commercial Shaft Kiln in Satteins (A) - 8000 kg/Batch

ROMAN CEMENT – ROCARE PROJECT: Production of Roman Cement on an Industrial Scale

Roman Cement Production Capacity of ROCARE Partners

Production Capacity	W&P	MBM	VFB
Tons/h	20	0,35	--
Tons/day	480	8,40	0,6
Tons/year	100'000	2'000,--	100,--
Market	large variety of applications in the restoration, dry mortars, special renderings etc.	applications in the restoration of historic monuments	specialized applications in the restoration of monuments

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ROMAN CEMENT – ROCARE PROJECT: Production of Roman Cement on an Industrial Scale

HISTORIC PRODUCTION TECHNIQUE	AVAILABLE STATE OF THE ART PRODUCTION TECHNIQUE
SHAFT KILN (Coal or Gas Fired?)	LEPOL KILN (Semi Dry Process)
HIGHLY VARIABLE PRODUCT QUALITY	CONTROLLED PRODUCT QUALITY
HIGH LABOUR COSTS	STANDARD LABOUR COSTS
MODERATE MODIFICATION OF STANDARD PRODUCTION MODES	SMALL MODIFICATION OF STANDARD PRODUCTION MODES

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Raw material (Marl) for Roman Cement Production

Parameter	Range	Optimum Range
Hydraulic Modulus HM	1,2 – 1,7	1,3 – 1,7
Silica Modulus SM	2 – 4	2 - 3
CaO	< 40%	35 - 37%
SiO2	> 20%	>22 %
Al2O3	> 6%	> 8%
SO3	< 1%	< 0,2%
Fraction of Clays	> 13%	>15%, kaolinite, illite

Structure homogeneous, no layer structure (no calcite or quartz layers), highly bioturbated

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ROMAN CEMENT – ROCARE PROJECT:

Wietersdorfer & Peggauer Zementwerke



Evaluation of suitability of raw materials	Nov. 2009 - March 2010
Selection of suitable marl	April 2010
Pilot trials	Mai - June 2010
1st industrial scale trial Roman Cement production	August 2010
2nd industrial scale trial Roman Cement production	December 2010
Conformity tests adapted EN 196	June 2011 -

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- Marl from Wietersdorf, Carinthia (A)

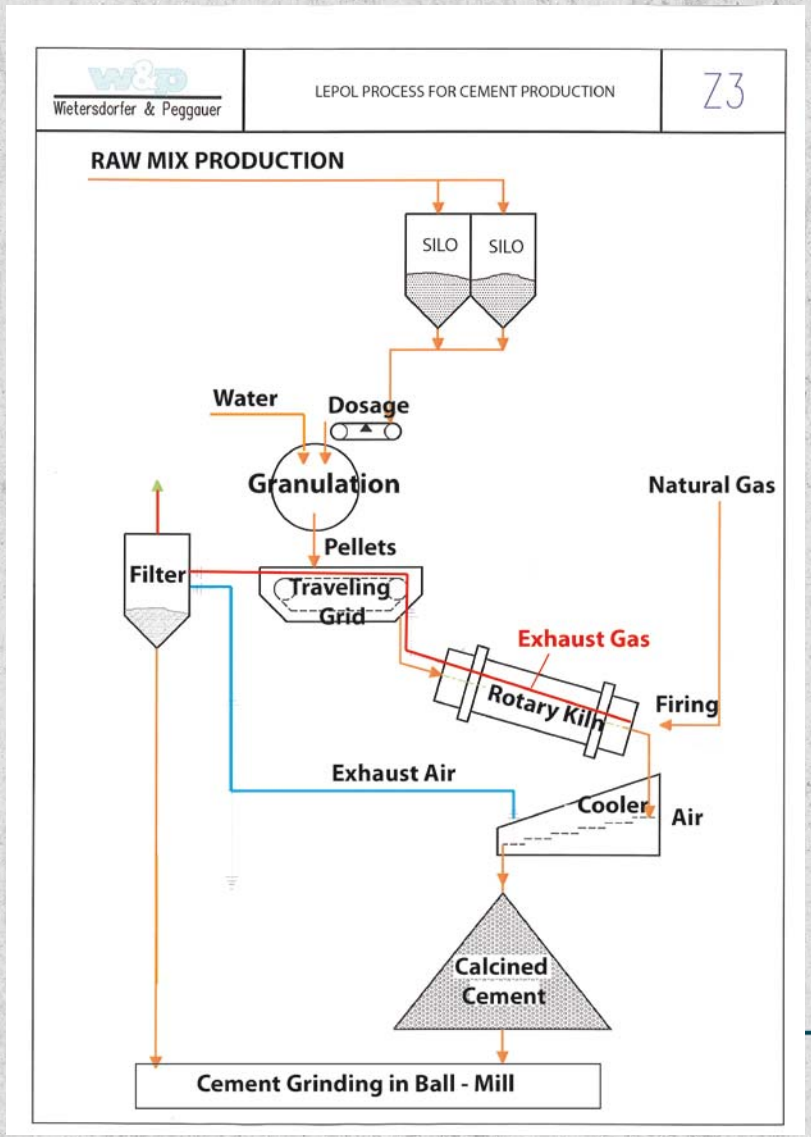


XRD by TPA

quartz	12
potassium feldspar	1
plagioklase	1
clay minerals	19
mica/illite	14
chlorite	3
kaolinite	1
expanding	1
Fe-oxides	3
calcite	64

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ROMAN CEMENT – ROCARE PROJECT:
Wietersdorfer & Peggauer Zementwerke



Wietersdorfer marl, crushed and ground, pelletized and fed to the traveling grid.
Calcination temperature: 800 - 900°C local spots up to 1000°C.



ROMAN CEMENT – ROCARE PROJECT:
Wietersdorfer & Peggauer Zementwerke





Calcination at 800 – 900°C

– mineralogical

thermometer

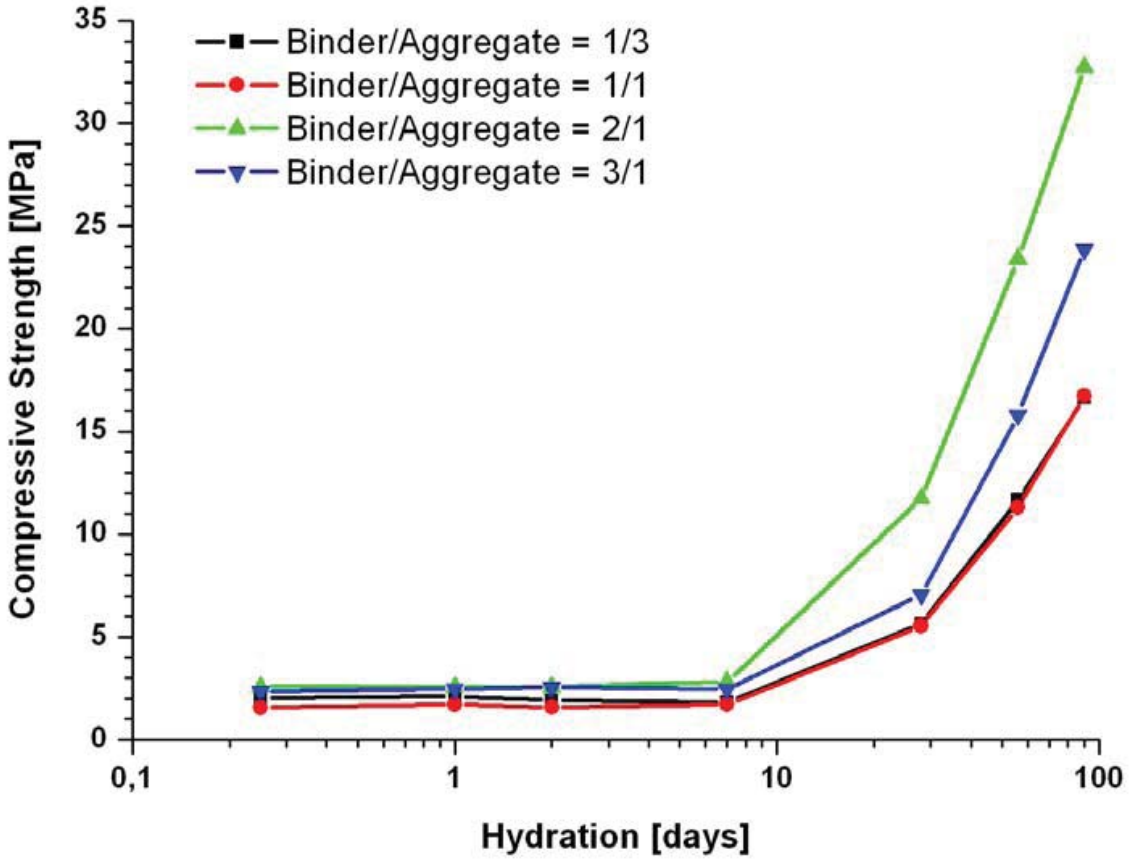
calcined cement pellets

after cooler



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Strength development in Roman Cement mortar (adapted EN 196)



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ROMAN CEMENT – ROCARE PROJECT:
Wietersdorfer & Peggauer Zementwerke



OUTLOOK & PERSPECTIVES

- 1st industrial Roman Cement production was successful but not optimum

- Completion of conformity tests according to adapted EN 196

- Optimization of Roman Cement production

- Commercial Production starting in 2013

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ROMAN CEMENT –

Production on Semi-Industrial Scale

open rotary kiln with open rotary cooler



dimensions: 1,25 x 16 m

capacity: 500 kg/h

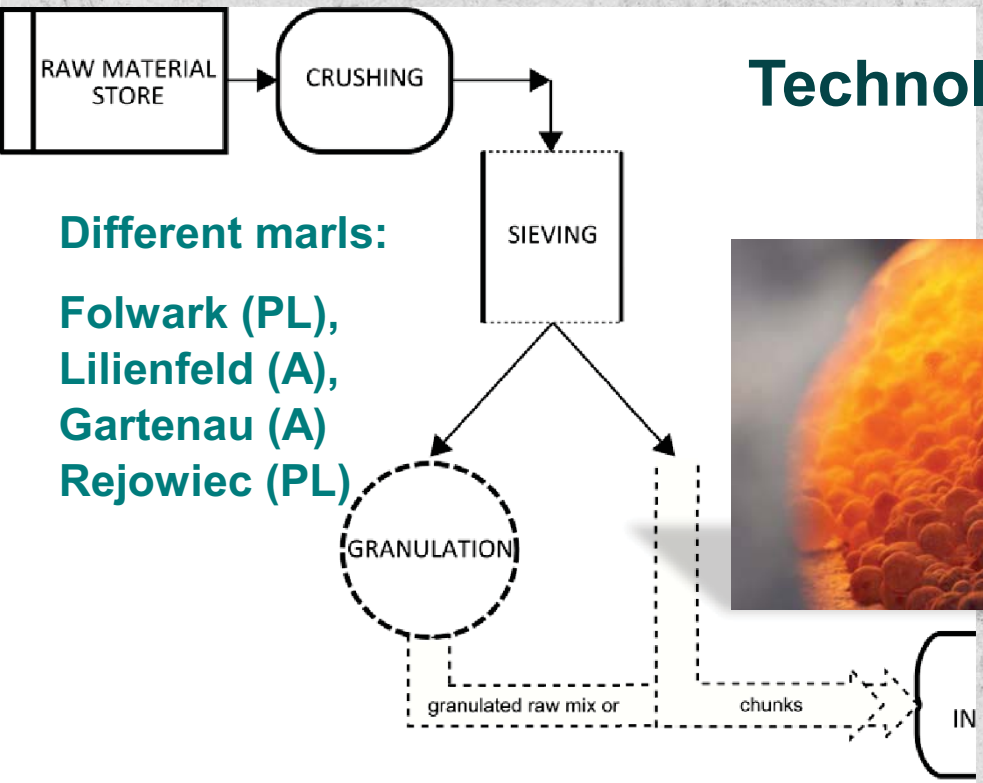
kiln speed: 0.5-3.0 rpm

fuel: heavy oil

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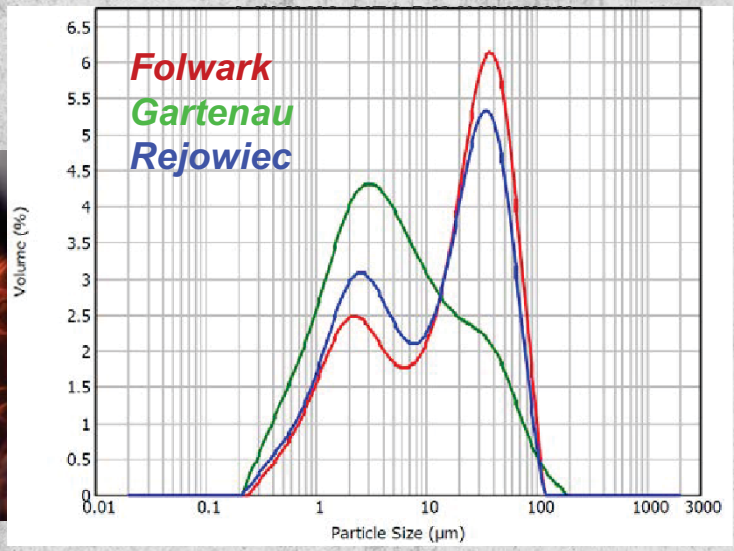
Production on Semi-Industrial Scale

Technology



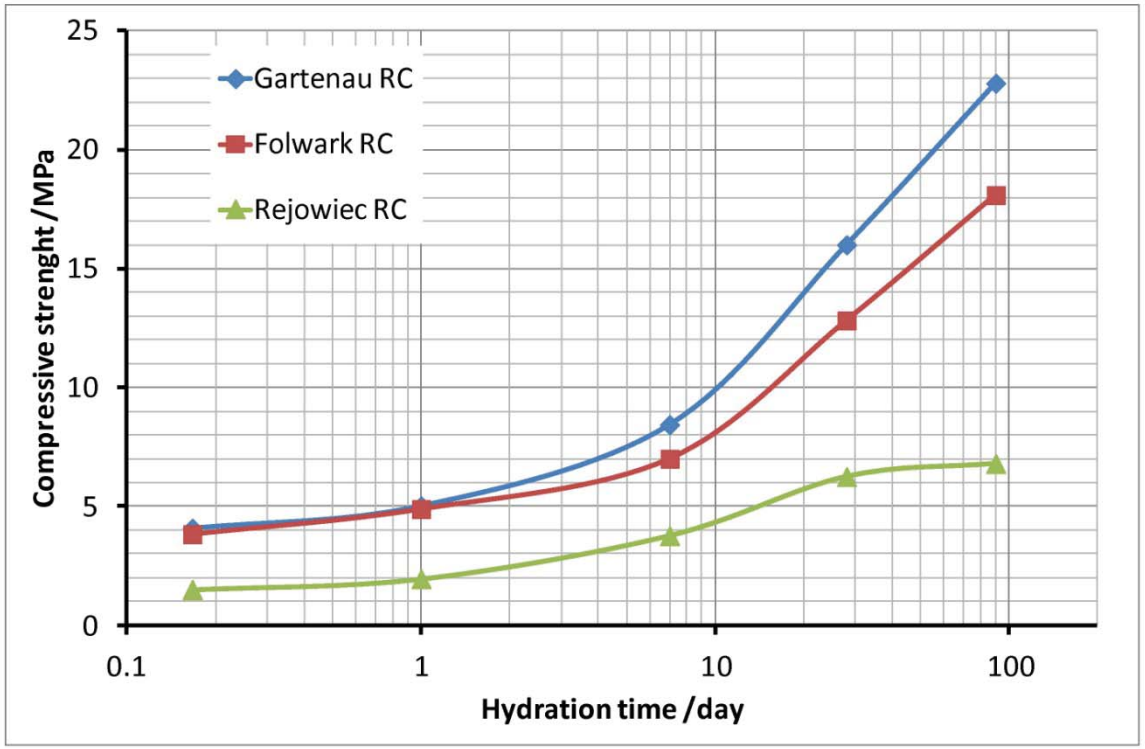
Different marls:

Folwark (PL),
Lilienfeld (A),
Gartenau (A)
Rejowiec (PL)



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Strength development in MBM Roman Cement mortar (adapted EN 196)



rocare ROMAN CEMENT

COOPERATION

Institute of Ceramics and Building Materials

Ready Made Products from Roman Cement

Coarse-grained mortar on the basis of Roman cement

Product: Industrially prepared, dry mortar for the renovation of historical buildings' elevations.

Fine-grained mortar on the basis of Roman Cement

Product: Universal, industrially prepared, dry mortar for the renovation of historical buildings' elevations.

Paint on the basis of Roman cement

Product: Cement paint, industrially prepared, for applying on historical surfaces.

Casting mortar on the basis of Roman cement

Product: Industrially prepared dry mixture for creating stucco elements and run elements.

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ROMAN CEMENT –

Institute of Ceramics and Building Materials

Production on Semi-Industrial Scale





Highly successful applications of

MBM Roman Cements

in the Restoration of Monuments

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Apartment house (M. Skłodowska-Curie Street 7, Krakow) – 2010





Apartment house (Starowislna Street 10, Krakow) – 2011





ROMAN CEMENT –
Restoration of Monuments

Institute of Ceramics and Building Materials

Building of former Trade Academy (KapucyDska/F.Straszewski Street, Krakow) – 2005/2006

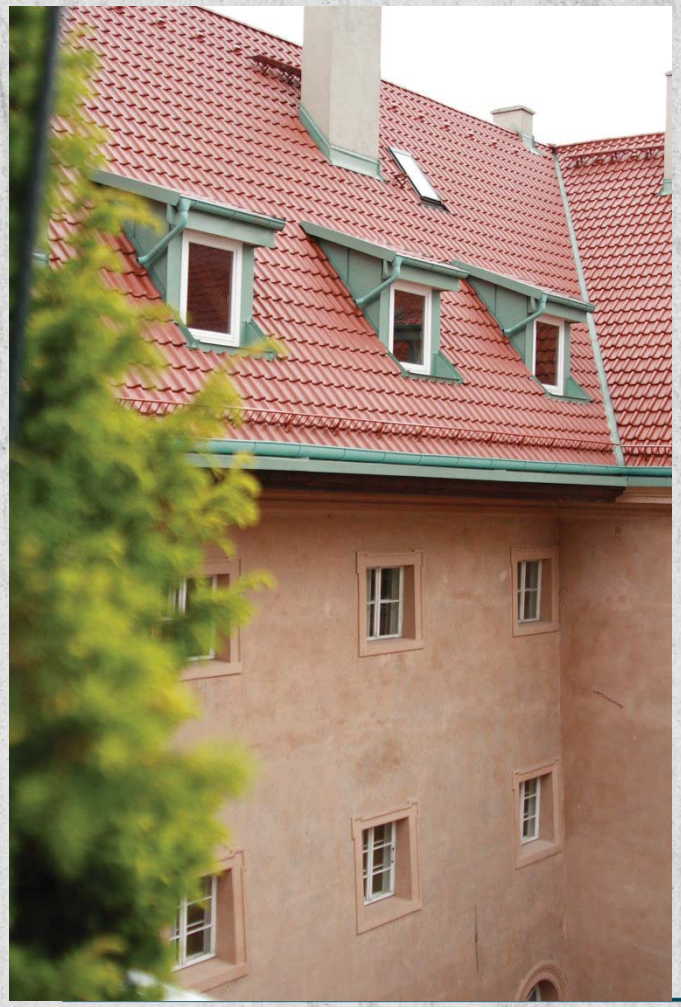




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Restoration of Monuments

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Cloister of Society of Jesus (Mały Rynek 8, Krakow) - 2009



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Restoration of Decorative Elements



Decorative Elements of the Apartment house (M. Skłodowska-Curie Street 7, Krakow) – 2010

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Restoration of Monuments

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Apartment house (Jozefinska Street, Krakow) - 2008







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ROMAN CEMENT – VFB Roman Cement
Production on Industrial Art Scale



Discontinous Shaft Kiln: Production Capacity 600 kg/Batch, Optimum Calcination Temperature > 900°C



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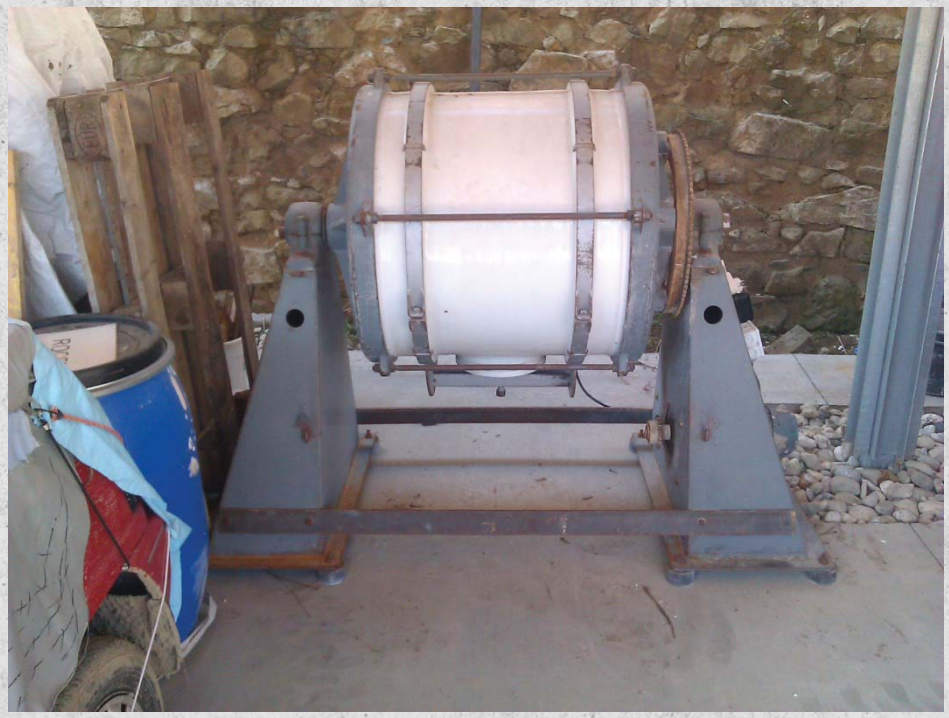
Calcination in the shaft kiln (Gartenau marl)



ROMAN CEMENT – VFB Roman Cement
Production on Industrial Art Scale



Grinding of Roman Cement in a Hammer Mill (left) or in a Ball Mill (bottom)



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Merci pour votre attention