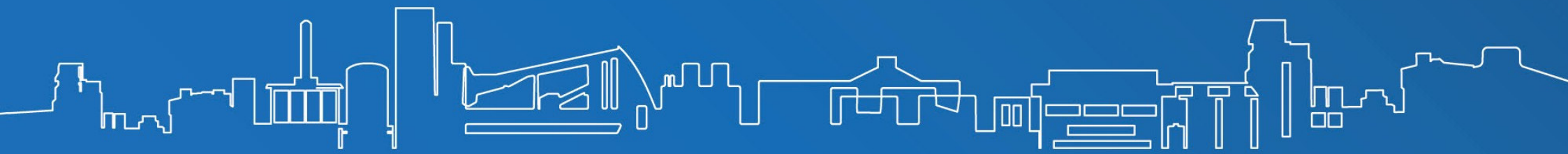
F&E at Dyckerhoff

09.11.2023, Edelputztagung , Europa Park

Fulvio Canonico



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R&D organisation

Buzzi Unicem Innovation Lab. and Technology

Vercelli – Italy

Accreditated laboratory

according to ISO/IEC 17025

Wilhelm Dyckerhoff Institute

Wiesbaden - Germany

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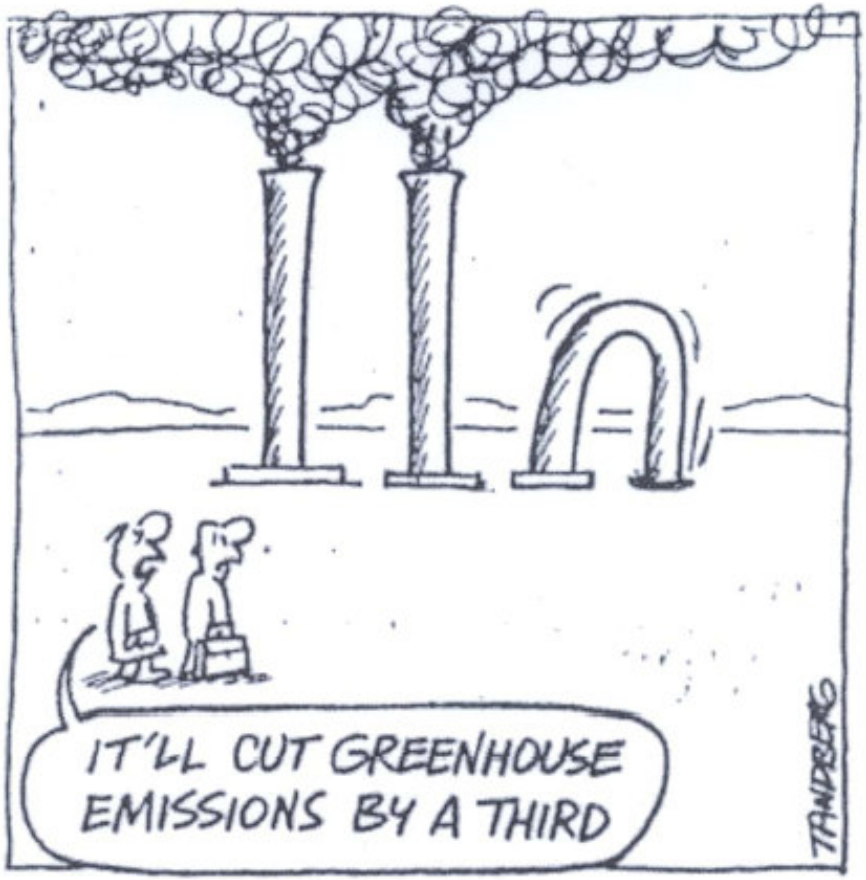
R&D strategies



Innovative CO_2 capture and use

Low carbon cement and concrete technologies

Open innovation

Dyckerhoff

ROADMAP 2030 DYCKERHOFF

EXECUTIVE SUMMARY

PRODUCT INNOVATION – CEDUR AND ECO COMFORT

CEDUR and ECO-COMFORT (CEM II/C) crucial to reduce CO_2 emission in the construction.

Dyckerhoff 1st cement producer to receive technical greenlight for the production of CEM II/C in Germany.

AMBITIOUS CAPEX PROGRAM TO FUEL THE TRANSITION

Dyckerhoff is planning to invest ~256 million euros over the period, having more than 50 initiatives.

Significant focus on product mix.

CCU/S INSTALLATION AT INDUSTRIAL SCALE IN GERMANY

Initial capture at Deuna cement plant to start in 2027 (first pick of CO_2).

Scaled up to 0,28 mt CO_2 p.a. by 2030.

SCOPE 1 NET CO_2 EMISSIONS

Dyckerhoff countries to reduce CO_2 net emissions to <450 kg CO_2/t cementitious product.

Dyckerhoff ETS countries to perform even better: <400 kg CO_2/t cementitious product.

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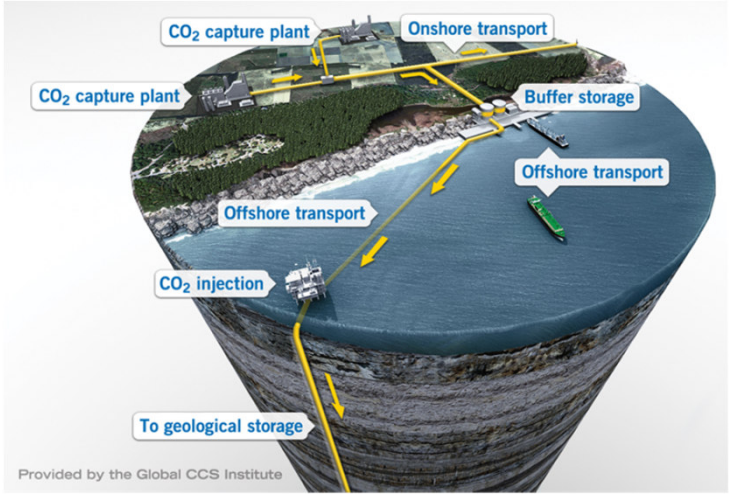
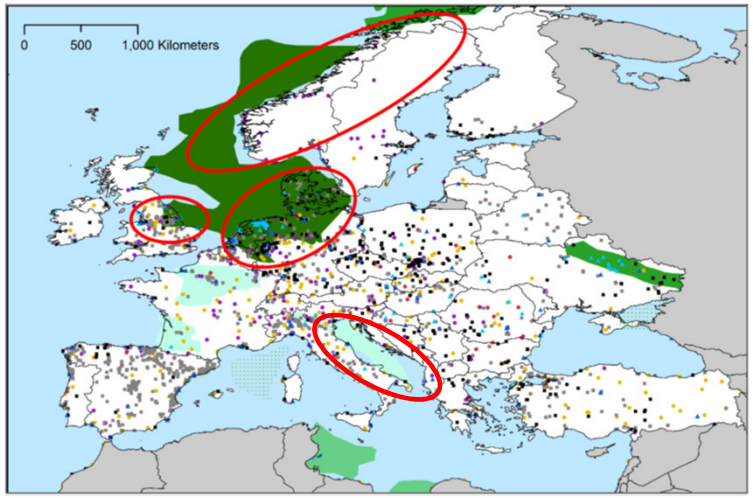
CO_2 Capture, Storage and Use

How it's work?





Ref. Prof. Matteo Romano

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Technology for CO_2 capture (CO_2 separation)

Target: separate CO_2 from flue gas and reach > 95 vol.%

Post Combustion Technologies:

CO_2 is separated from flue gas by absorption using a liquid or solid sorbent (ammine, zeolite)

- Chemical process: ammine solvent (market solutions), Ca-Looping
- Physical Process: Adsorption process (TSA, PSA), (market solutions) Membrane, MOF, cryogenic separation

Integrated process:

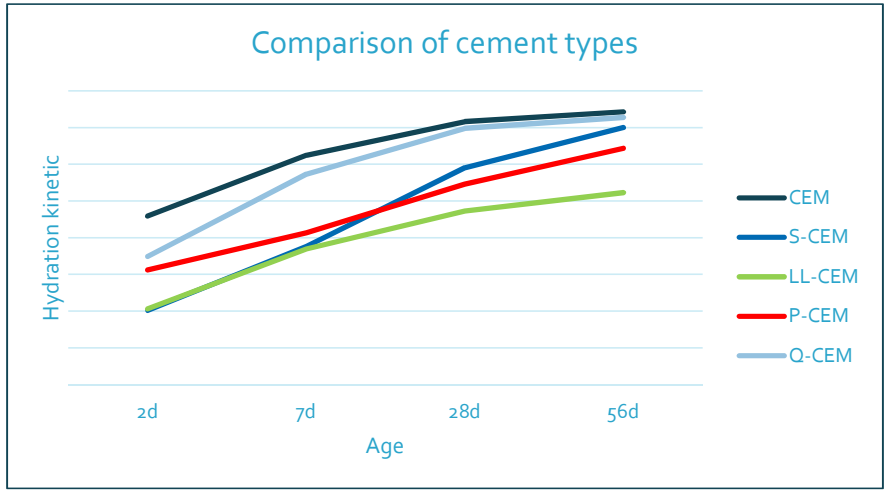
CO_2 separation is obtained in an integrated process

- Oxyfuel, indirect calcination, Ca-Looping integrated (high TRL)
- H_2 as fuel (market solutions but not applicable at full scale, high costs and energy intensive)
- Electrification (research)

Catch4climate Project	Cleanker project	Herccules project	Deuna CO2 capture project
OXYFUEL: combustion of fuel by replacing air (ca. 21% O2 + 79% inert components: N2, Ar) with pure oxygen as oxidizer	Calcium-Looping (CaL) process for CO2 capture in cement plants	CO2 capture and Storage in Mediterranean	CO2 capture in Deuna aimed at using the CO2 hub in Wilhelmshaven
First application of so-called "Pure Oxyfuel" technology in the cement production process	First application of Ca-Looping in cement plants	First application of CO2 Storage from cement plant and incinerator plant in south-Europe	The project target is to do a comprehensive feasibility study, cost calculation and timetable aimed at capturing CO2 at Deuna plant
Engineering contract for a 450 ton/day plant operating in Mergelstetten signed	CO2 capture Pilot plant (1 t/days) already operating in Buzzi Unicem plant Vernasca Italy. 75% CO2 capture rate achieved	Project started in January 2023, CO2 storage is planned in 2026-2027	CO2 capture should start in 2027 - 2028

Low carbon supplementary cementitious materials

- Natural pozzolan
- Artificial pozzolan
- Slag
- Limestone



S= Slag
LL= Limestone
P= Natural Pozzolan
Q= Artificial pozzolan

$Ca(OH)_2$ from C_3S hydration is consumed during the pozzolanic reaction

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Why a talk about pozzolanic cement?

Why Roman concrete still stands strong while modern version decays

Scientists have cracked the secret to Roman water-based structures' strength – and findings could help today's builders

Scientist Marie Jackson has said Swansea lagoon's seawall should be built using Roman concrete. Photograph: Tidal Lagoon Power/PA

Their structures are still standing more than 1,500 years after the last centurion snuffed it: now the Romans' secret of durable marine concrete has finally been cracked.

The Roman recipe - a mix of volcanic ash, lime (calcium oxide), seawater and lumps of volcanic rock - held together piers, breakwaters and harbours. Moreover, in contrast to modern materials, the ancient water-based structures became stronger over time.

Why Roman concrete still stands strong while modern version decays | Science | The Guardian

'Self-healing' Roman concrete could aid modern construction, study suggests

Research finds secret of durability of buildings such as the Pantheon could be in the techniques used at the time

'The Pantheon would not exist without the concrete as it was in the Roman time,' said Prof Admir Masic, lead author of the study. Photograph: Andreas Solaro/AFP/Getty Images

They have stood through the fall of an empire, the carnage of great wars and the foundation of a new country. But quite why structures made using Roman concrete are so durable has remained something of a mystery.

'Self-healing' Roman concrete could aid modern construction, study suggests | Science | The Guardian

Architettura Perché il cemento romano è più resistente del nostro

La ricetta del cemento dei romani: conosciamo gli ingredienti, ma non le dosi, di quel calcestruzzo così tanto più resistente di quello che facciamo oggi...

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NEWS | ARCHAEOLOGY

Scientists may have found magic ingredient behind ancient Rome's self-healing concrete

Quicklime may have made material more durable than its modern counterparts

6 JAN 2023 · 3:00 PM ET · BY JACKLIN KWAN

Scientists may have found magic ingredient behind ancient Rome's self-healing concrete | Science | AAAS

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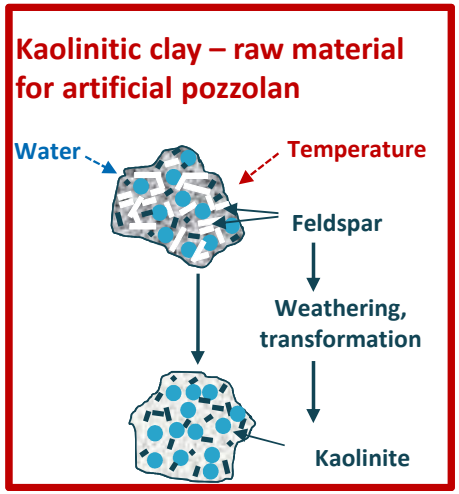
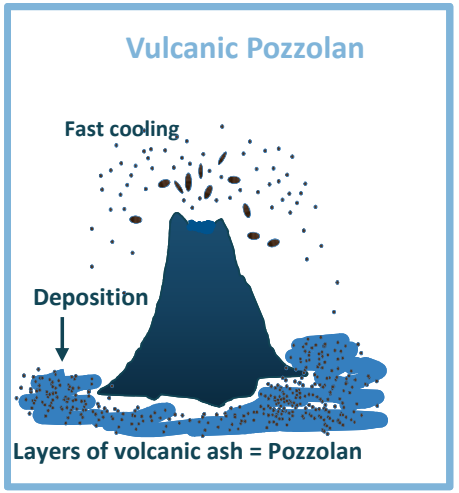
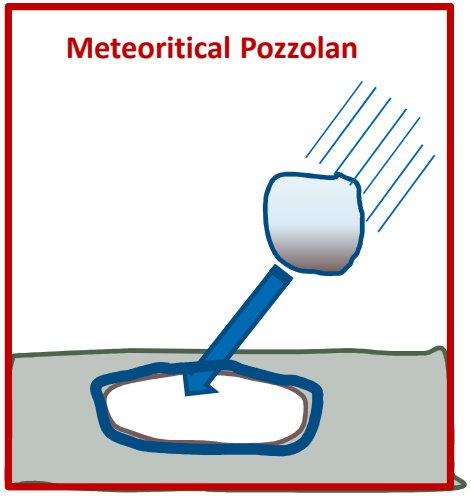
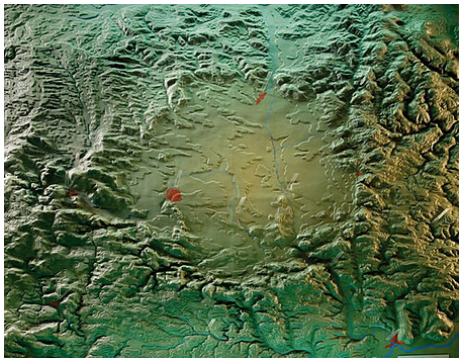
Natural or artificial pozzolan







Industrial calcination at 800 °C	Italian pozzolan (Lazio/Campania)	Ries Crater (Germany)
		
FLS Smidt	Vesuvio	Museum "Ries Crater"

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Overview

The term "natural pozzolan" embraces many inorganic materials that originate from different processes

	Origin	Structure	Characteristics
Pyroclastic rocks	Volcanic eruption	Porous structure due to gas released during eruption	Glassy structure due to rapid quenching of the magma
Zeolitized materials	Volcan eruption and altering	The altering (water, pressure, atmosphere, geothermal treatment) modifies the mineralogy of this type of materials	
Clastic sediments	Deposition process (lake or marine sediments) or clay	Biogenic sediments from siliceous skeleton of sediments are typically found	Often mixed with clay and limestone Thermal process improve the reactivity of clay based
Meteoritic materials	Impact of meteorite		

Use of natural and artificial pozzolans in Europe

Current standard situation

Norm	Cement	Clinker	Slag (S)	Silica fume	Pozzolana		Fly-ash (V)	Limestone (LL)	Minor	Requirement
					Natural (P)	Calcined (Q)				
EN 197-1	CEM II/A-Q	80-94				6-20			0-5	
	CEM II/B-Q	65-79				21-35			0-5	
	CEM II/A-P	80-94			6-20				0-5	
	CEM II/B-P	65-79			21-35				0-5	
	CEM II/A-M	80-88	12-20						0-5	
	CEM II/B-M	65-79	21-35						0-5	
	CEM IV/A	65-89		11-35					0-5	Satisfy Pozzolanic test EN 196-5
	CEM IV/B	45-64		36-**55**					0-5	
	CEM V/A	40-64	18-30	18-30					0-5	
	CEM V/B	20-38	31-49	31-49					0-5	
EN 197-5	CEM II/C-M	50-64	36 – 50 *(Limestone 6 – 20 if used)						0-5	
	CEM VI (S-P)	35-49	31 - 59		6 - 20				0-5	

CEM IV/A and CEM IV/B are also parte of the family of sulfate resistent cement, if the C_3A of the clinker < 9%

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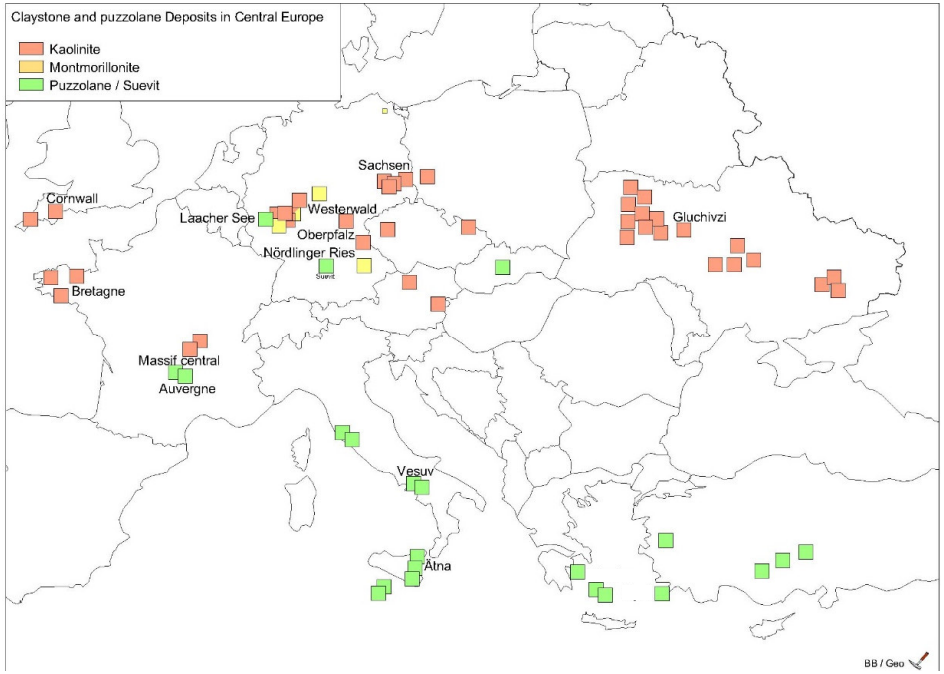
Where are they both located? Overview in central Europe

Natural pozzolans: Present in volcanic regions: e.g. south of Europe, in particularly in Italy

Kaolinitic clays: Many deposits worldwide: mostly widespread in East Europe, India, Brasil, Cuba, Cameroon…

Natural pozzolans and clays are a relatively cheap material, transport strongly affect the final costs.



Buzzi Unicem

Reaction product of Pozzolanic hydration

	Reaction product
Portland cement Hydration	C-S-H Ettringite Ca(OH)2
Pozzolanic reaction (Pozzolan + Lime)	C-S-H and C-A-S-H C4AH13 Carboaluminate
Pozzolanic cement	C-S-H and C-A-S-H Ettringite C4AH13 Carboaluminate
Slag cement	C-S-H and C-A-S-H Ettringite Ca(OH)2 Hydrotalcite

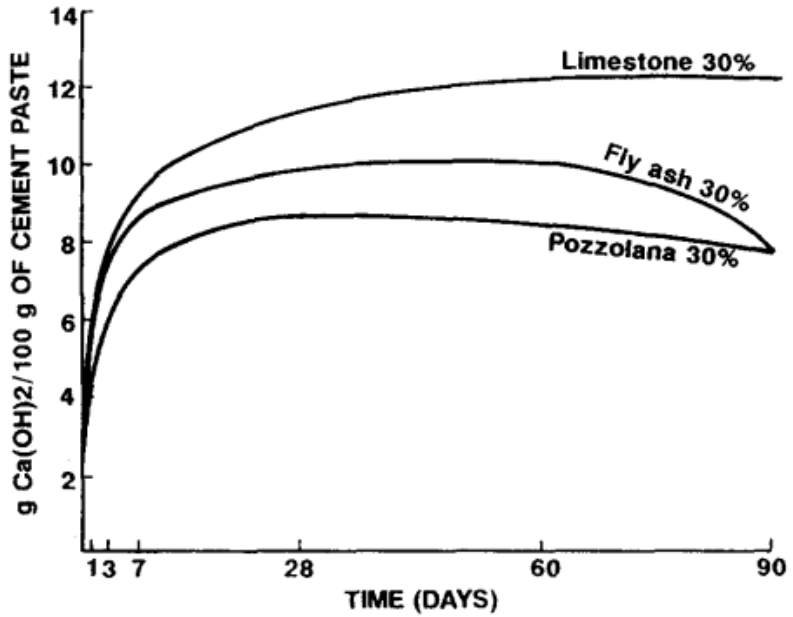


Fig. 7. Free portlandite in blended cement pastes.[20]

Cement and Concrete Composites Volume 15, Issue 4, 1993, Pages 185-214

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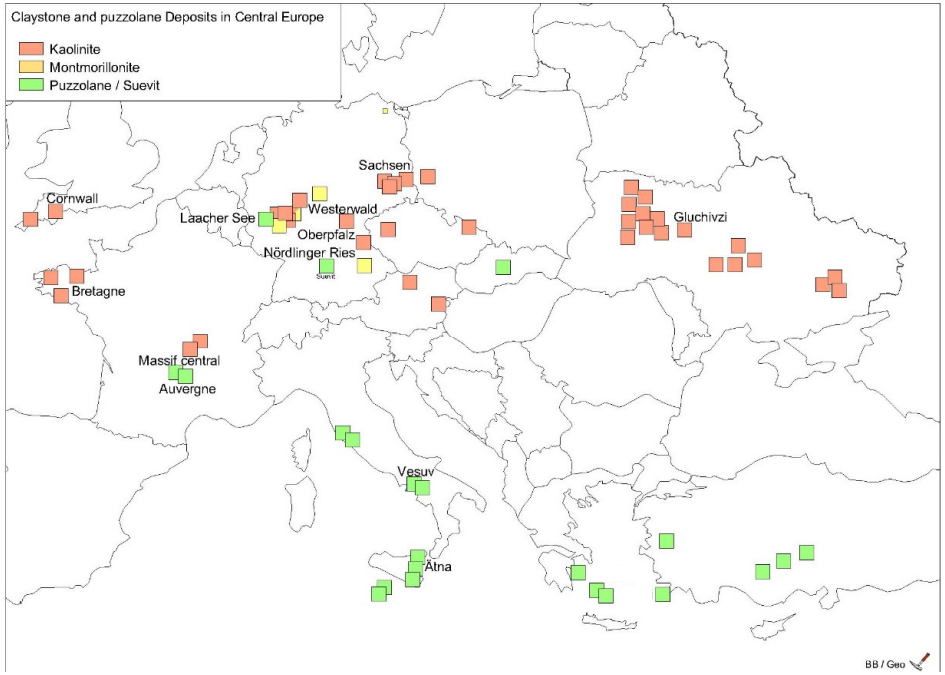
Some numbers of cements containing pozzolana

In Italy more than 2.2 M tons of pozzolanic cement (CEM IV) are produced yearly (about 10% of the Italian production). Pozzolanic cement are in Italy frequently recommended for works in aggressive environment (sea water, high sulphate).

VDZ reports in 2021 0.5 M tons of CEM IV and CEM V cement in Germany (about 2% of German production).

The report of the Turkcimento association states more than 4.4 M tons of pozzolanic cement was produced in Turkey in 2021, about 8% of the yearly cement production.



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Pozzolan mortars

An ancient material

DOI: 10.1111/jace.18133

RESEARCH ARTICLE

Journal of the American Ceramic Society

Reactive binder and aggregate interfacial zones in the mortar of Tomb of Caecilia Metella concrete, 1C BCE, Rome

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Abstract

Integrated spectroscopic analyses and synchrotron X-ray microdiffraction investigations provide insights into the long-term reactivity of volcanic aggregate components and calcium-aluminum-silicate-hydrate (C-A-S-H) binder in mortar samples from the robust concrete of the sepulchral corridor of the Tomb of Caecilia Metella, 1st C BCE, Rome. The results of innovative micrometer-scale analytical maps indicate that Pozzolane Rosse tephra components–scoria groundmass, clinopyroxene, and leucite crystals–contributed to pozzolanic pro-

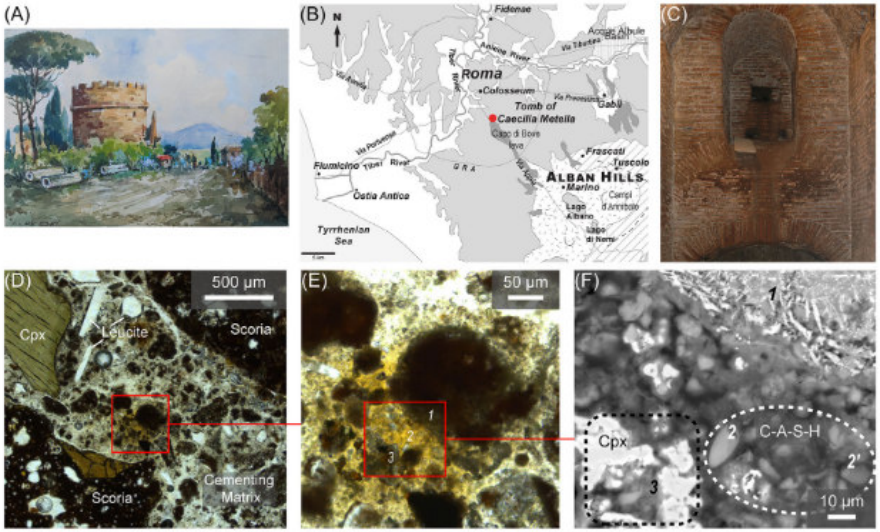

FIGURE 1 The Tomb of Caecilia Metella. (A) The cylindrical structure with the Colli Albani volcano in the background (L. de Bei, courtesy of A. Masic). (B) Geologic map showing location of the tomb at the tip of the Capo di Bove lava flow (after Jackson and Marra, reference 8). (C) Brick-faced concrete of the sepulchral corridor (M. Jackson). (D, E) Pozzolane Rosse tephra components in the mortar fabrics, plane polarized light (PPL) showing the interfacial zone of a microscoria (*1*), the C-A-S-H binding phase of the cementing matrix (*2*), and the altered rind of a clinopyroxene crystal (*3*) of the 06-CMETELLA-C2 mortar sample. (F) SEM-BSE image showing these features at higher magnification: acicular features in the interfacial zone (*1*), an altered C-A-S-H domain (*2*) and wispy features (*2'*) in the binding phase, and the diffuse border of the clinopyroxene (*3*) (see also Figure 4)

....The ancient material provides an important reference for the long-term behavior of innovative, environmental-friendly concrete infrastructure fabricated with reactive glasses....

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Interesting applications to report

In the **large massive slabs** (thickness 3-6 m - volumes >10,000 m^3) with **quasi-adiabatic maturation** we adopted a combination of pozzolanic cement and pure crystalline limestone.

In terms of heat development this solution perform even better than CEM III


Intesa San Paolo Tower slab > 12.000 m^3


Regione Piemonte Tower slab >12.000 m^3


Galeazzi Hospital slab > 33.000 m^3

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Pozzolan cement

Used for almost 100 years

Golden Gate Bridge, San Francisco, Built with Pozzolanic cement from Philippines

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Pozzolanic cement produced in Italy at Buzzi Unicem:

CEM IV/A (P) 42.5 R (Pozzolan content: 25 %)

CEM IV/A (P) 42.5 N

CEM IV/B (P) 32.5 R – SR (Pozzolan content: 40 %)

CEM II/B (P) 32.5 R

In 5 different plants, from the Sicily to the Alps using 5 different natural pozzolans

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A new white pozzolanic cement is now available also in Germany

Dyckerhoff | **Dyckerhoff GmbH / Werk Amöneburg**

DYCKERHOFF WEISS BLUE STAR

Puzzolanzement EN 197-1 - CEM IV/A (P) 42,5 R

Daten gemäß EN 196

	typische Werte	Anforderung aus EN 197-1	
Mechanische Daten:			
Druckfestigkeit 2 Tage [MPa]	31	≥	20,0
Druckfestigkeit 28 Tage [MPa]	55		42,5 - 62,5

High strengths, good water demand, excellent whiteness, low CO_2!