Research on sustainable construction materials

Research Team

Raw Materials Exploitation & Sustainable Energy Solutions

National Technical University Of Athens

Hydro Pyro Metallurgical Processes

CHEMICAL ANALYSIS & PHYSICAL PROPERTIES

ENVIRONMENTAL CHARACTERISATION

The Challenge

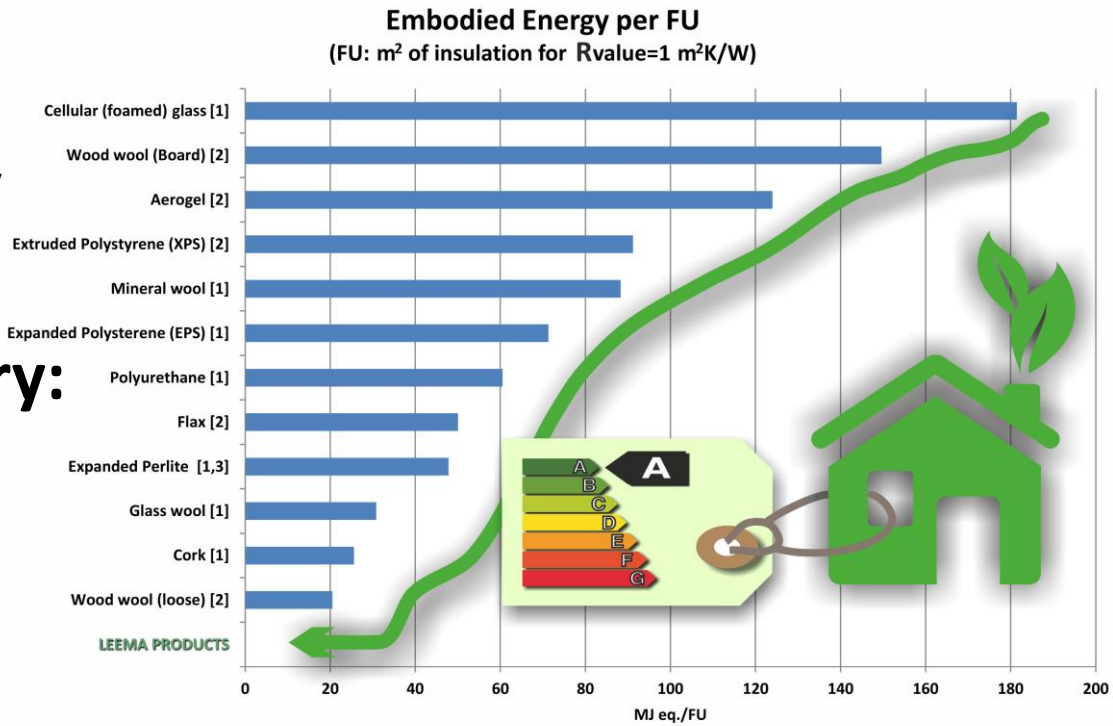
"Greener, Energy Efficient and Resource Efficient Europe"

- **"20-20-20 objective":**

✓ 20% reduction of greenhouse gas emissions,
✓ 20% reduction of energy consumption,
✓ 20% share for renewable energy

Challenge for construction industry:

- Reduce manufacturing Energy
- Provide building components with improved thermal properties



Embodied energy per FU was calculated using values of Embodied Energy (cradle to gate), density and thermal conductivity from:
[1] 'Inventory of Carbon & Energy (ICE)' 1.6a, Hammond & Jones, 2008
[2] http://www.greenspec.co.uk/
[3] https://perlite.org/

How to increase thermal performance?

Solution 1:

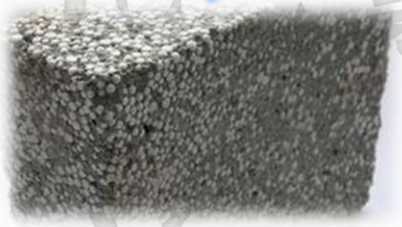
Increasing porosity

	Compr. Strength (MPa)	λ (W/mK)
Lightweight Concrete	1-10	0.06-1.4
Aerated Autoclaved concrete (AAC)	1.3-8.5	0.07-0.21

Solution 2:

Composites with granular lightweight aggregates

EPS Beads

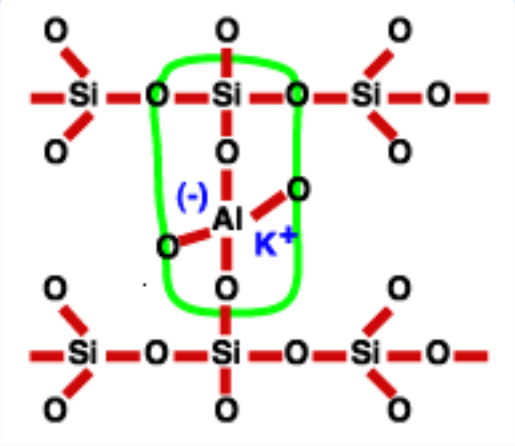


Expanded Perlite

How to increase thermal performance?

- ***Solution 3***: Synthesis and Development of novel materials

Inorganic Polymers



- ✓ Inorganic=incombustible
- ✓ Good mechanical properties- quick compressive strength development
- ✓ Low thermal conductivity coefficient
- ✓ Exploitation of aluminosilicate/ silicate wastes , recycled materials, by-products
- ✓ Energy efficient synthesis process
- ✓ Low carbon footprint
- ✓ Compatibility with current manufacturing processes

Geopolymer foam

Geopolymer cement

Carbon-Geopolymer composites

Fire-proof materials

Natural stone or geopolystone® ?

How to make inorganic polymers?

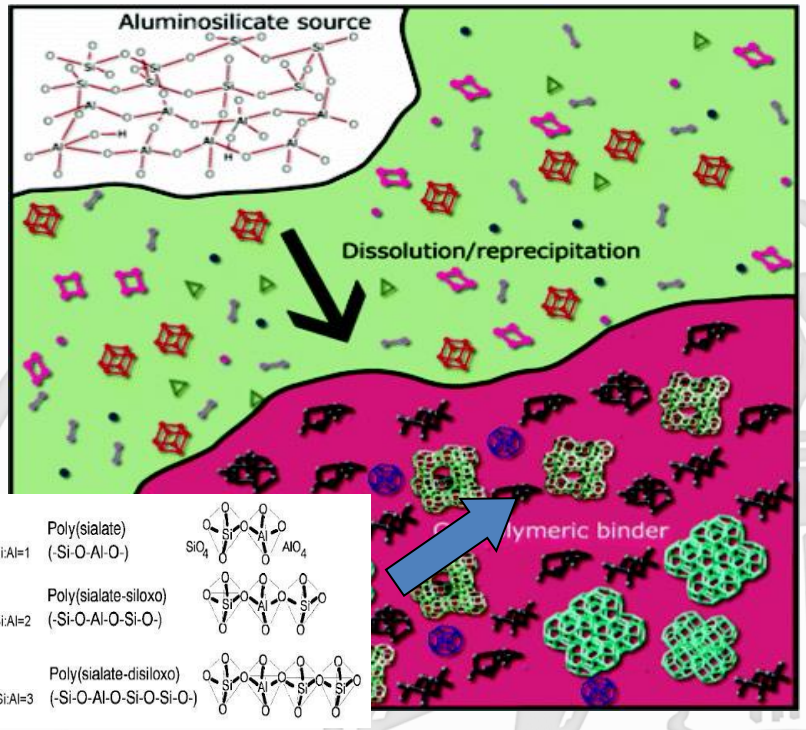
Silicate/ Aluminosilicate raw material

Activation solution

Components

1. NaOH/KOH
2. Dissolved SiO_2
3. Water

Schematical representation of reaction**



** **Do Geopolymers Actually Contain Nanocrystalline Zeolites? A Reexamination of Existing Results**
J. L. Provis, G.C. Lukey, J. S. J. van Deventer

Geopolymer products based on mineral tailings

Silicate/ Aluminosilicate raw material

Mixing

Activation solution

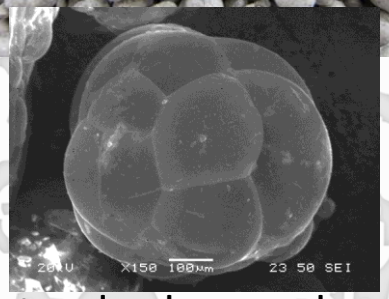
Curing → **Crushing/ sieving** → **Expansion** → **Lightweight granular material**

Foaming → **Shaping** → **Curing** → **Foamed material**

Shaping → **Curing** → **Compact material**

Lightweight Granular Aggregates (LGA)

Material	Application	Loose Bulk Density (Kg/m³)	λ_{10} (mW/mK)	U value (20cm ins)
LGA	For Cavity walls insulation	49.7	36	**0.18**
	For Fibre boards	76.7	39	**0.20**
	For Bricks	38.9	34	**0.17**
Expanded perlite	Granular insulation	50-120	45-70	**0.23-0.35**
EPS beads		15-35	32-40	**0.16-0.20**



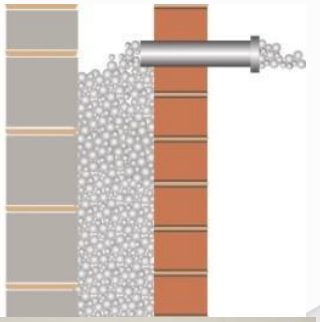
A totally inorganic granular insulation material in the form of lightweight spheres with fine closed cellular pore structure based on mineral tailings, recycled glass and industrial by-products

Main advantages:

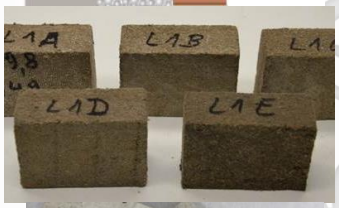
- ✓ Totally inorganic, non-combustible, based on mineral tailings, recycled glass and industrial by-products
- ✓ Excellent thermal performance and easy installation using the standard procedures applied for loose filling insulation materials
- ✓ Properties and grain size can be fine-tuned according to application (λ: 33-45 mW/mK, LBD: 15->120 Kg/m³), to replace traditional lightweight aggregates
- ✓ Low energy consuming expansion using IR heating at moderate temperatures 500-600°C

Lightweight Granular Aggregates - Applications

3I Loose Filling Materials



Cavity Walls insulation (Expanded Perlite, EPBs, stone-glass wool)



Lightweight boards (Fesco or Perlite boards)

Fibre cement boards

Insulating Bricks (Perlite Filled insulating bricks)

Other applications: Mortars, Plasters, Concrete, Cryogenics etc.

Geopolymer Binders

Material Type	Compressive Strength (MPa)	Flexural Strength (MPa)	λ (W/mK)	Density (Kg/m³)
Geopolymer binders	21	6	0.19	1480
	28	8	0.26	1600
Geopolymer based mortars	20		0.29	
Cement			72	1860
Clay Bricks			80-130	1890-2000

Main advantages:

- ✓ Based on mineral tailings (wastes)
- ✓ Mechanical properties obtained after curing at low temperatures (~70 °C) after a few days
- ✓ Compatible with traditional aggregates and conventional shaping methods (moulding or **extrusion**)
- ✓ Suitable for the production of pre-fabricated non-structural construction elements
- ✓ Embodied energy (for a typical perlite-based geopolymer) ~ 1.37 MJ/kg (cement 5.2 MJ/kg, fired ceramic bricks 3 MJ/Kg)

Shaping and Production processes for products based on geopolymer binders

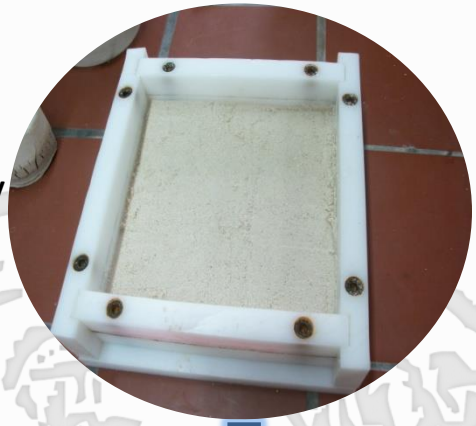
New perspectives for the production of geopolymer based bricks, boards or prefabricated elements

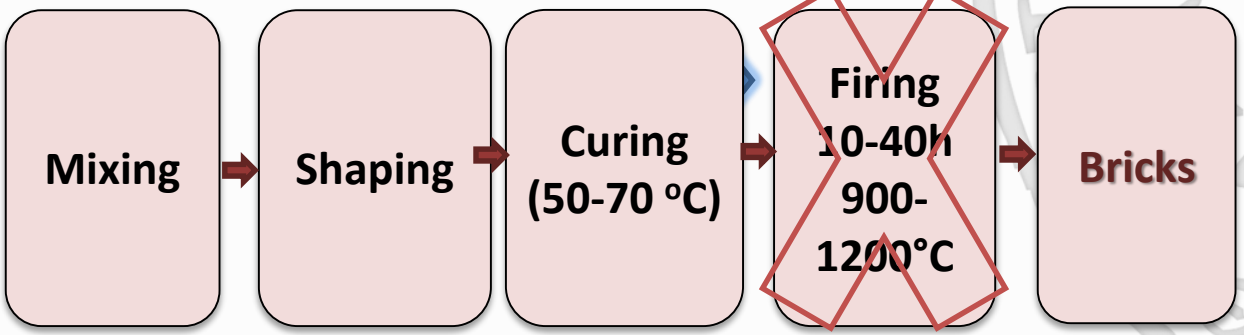
Extrusion

Process compatibility with clay products

Moulding

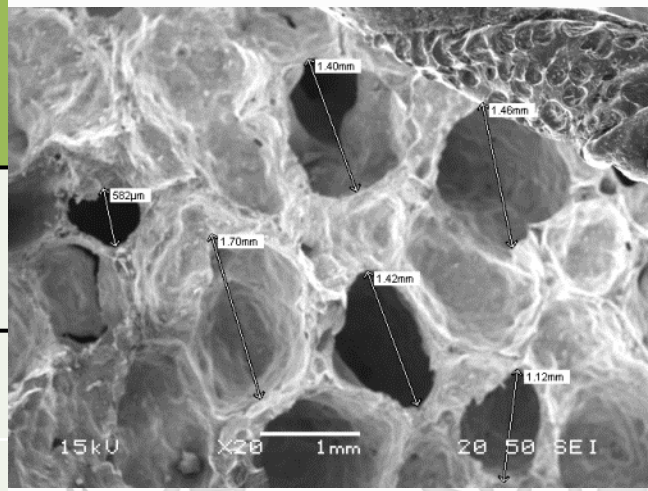
Process compatibility with prefabricated elements





3I Foam Blocks

Material Type	λ (mW/mK)	Density (Kg/m³)	Compressive Strength (MPa)	U (20cm thick.)
LEEMA 3I Foamed Blocks	62-119	344-680	0.7-2.7	**0.31-0.60**
Aerated Concrete	600-1400	200-1600	1-10	**3.0-7.0**
AAC	70-210	300-800	1.3-8.5	**0.35-1.05**
Organic Insulating Products	24-39	29-55	0.07-0.15	**0.12-0.20**



Main advantages

- ✓ Based on perlite wastes
- ✓ Foamed using inorganic or organic foaming agents
- ✓ Mechanical properties obtained after curing at low temperatures (~70 °C) after a few days
- ✓ Easy to cut – retain shape and strength
- ✓ Density >500 Kg/m³ → compressive strength comparable to Autoclaved Aerated Concrete Blocks (AAC)
- ✓ Density <500 Kg/m³ and λ <0.075 W/mk → rel. high compressive strength (>1 Mpa)

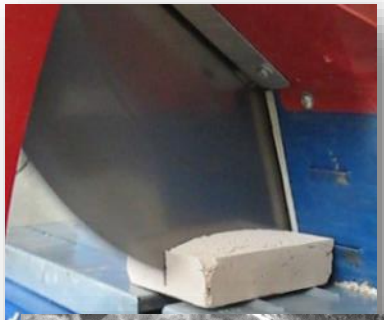
RESEARCH ACTIVTIES – Targeted applications

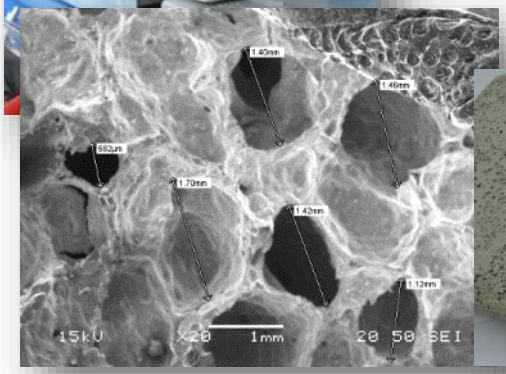
LEEMA
Low Embodied Energy Insulation Materials

Scientific coordination

Low Embodied Energy Advanced (Novel) Insulation Materials and Insulating Masonry Components for Energy Efficient Buildings

- Significant reduction of the embodied energy at component level
- 15% cost reduction compared to existing solutions
- Improved durability
- Improvement of the quality of the building indoor environment



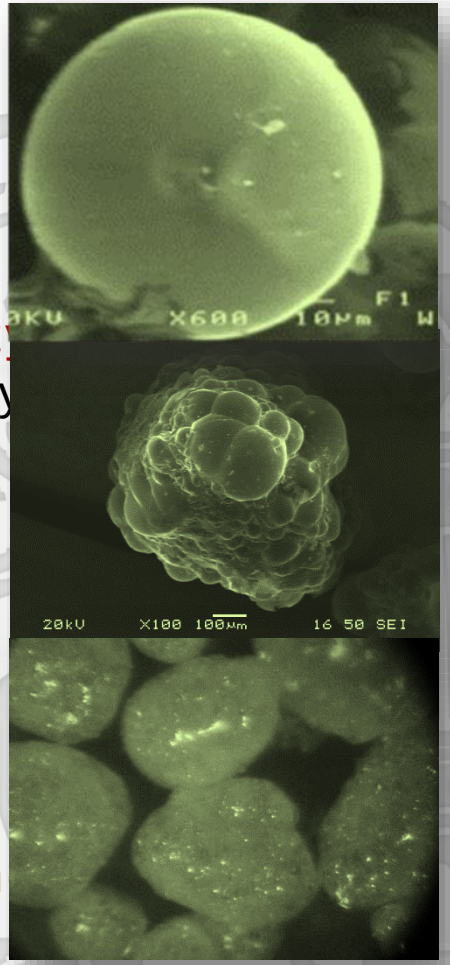


RESEARCH ACTIVTIES – Targeted applications

Lightweight aggregates

Inorganic materials produced from minerals with the following properties can be tested

- ✓ Bulk density: 50-300 kg/m^3
- ✓ Thermal conductivity (depends on bulk densit
  Materials 0,034 W/m.K (minimum) has already developed
- ✓ Good mechanical properties
- ✓ Low water adsorption
- ✓ Lab experiments have shown good compatibility with cement
- ✓ Fire resistant materials
- ✓ Embodied energy much lower than polystyren beads



Research Team: Raw Materials Exploitation & Sustainable Energy Solutions

RESEARCH ACTIVTIES – Construction industry

SUStainable, **innovative and energy-efficient CONcrete** based on the integration of all-waste materials

The increase of EU competitiveness requires new ideas, innovative and cost-effective products and self-sufficiency in materials and processes. The environmental protection policy demands that all technological achievements should be as environmentally friendly as possible with as low embodied energy as possible. The challenge for the construction sector therefore is dual: the development of original, high added value products based on EU resources that will also be eco-sustainable and eco-friendly. The SUS-CON project meets the challenge by introducing a **waste-based lightweight concrete** with **improved thermal, acoustic and insulation performance.**

DESIGN FLEXIBILITY

Custom made products designed according to application

PRODUCTS	Compressive strength (MPa)	Thermal conductivity (W/mK)
GEO screed underlay_P-18	11,50	0,180
GEO panel_P-17	6,50	0,167
GEO block_P-31	8,50	0,311
GEO block_P-21	15,00	0,205
GEO block_P-16	5,50	0,157
GEO panel_R-35	7,00	0,344
GEO block_R-27	18,00	0,266
GEO block_T-32	4,00	0,323
Perlite Geoblock_P	4,00	N/A
Perlite Geopanel_R	6,00	N/A

DEMONSTRATION ACTIVITIES

Production of prefabricated elements (compatible with conventional production practices)

Mockup assembling for online monitoring and product evaluation

Benefits - Impact

- **Wastes exploitation**
- **High-added Value**
- **Lightweight**
- **Improved Thermal Properties**
- **Low CO_2 footprint**
- **Low Embodied Energy**

SUS-CON

Research Team: Raw Materials Exploitation & Sustainable Energy Solutions

RESEARCH ACTIVTIES – Construction industry

Development of insulating concrete systems based on novel low CO_2 binders for a new family of ecoinnovative, durable and standardized energy efficient envelope components

CONCEPT

The overall concept of the project builds on previous research on new cement binders to develop a novel family of low CO_2 binders based on Belite, Ye'elimite and Ferrite phases (BYF cements). In BYF technology, the superior early age strength contribution of calcium-sulfo-aluminates (CSA) is combined with durability provided by belite. The raw materials and the production process for BYF cements, are similar to those of Portland cement (OPC), but the CO_2 emissions are lower as shown in preliminary LCA calculations due to:

- **lower calcium content of the raw materials (less limestone usage)**
- **lower clinker burning temperature of around 1250 - 1300°C**
- **lower grinding energy demand**

These same factors also results in a significantly lower embodied energy than OPC.

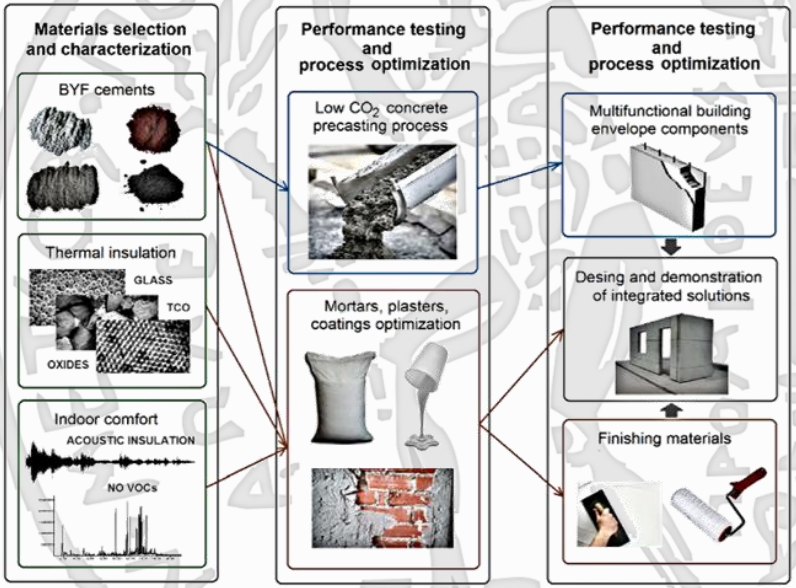
Combining these novel binders with insulating materials and advanced functional finishing methods will permit the development of novel concrete systems with low CO_2 and low embodied energy suited for a wide range of envelope components, without compromising technical, health and environmental standards.

Material science research on BYF cement and concrete and on advanced finishing materials like mortars, plasters, paints or coatings, will lead to the development of concrete elements with reduced embodied energy, improved insulation properties and providing multifunctional surface properties like:

- **thermal reflection**
- **anti-stain**
- **antibacterial**
- **self-cleaning**

METHODOLOGY

The barycenter of the project lies on innovation activities and bridging barriers to market for building envelope components made with low CO_2 BYF binders. The overall methodology is conceived to bring results from materials science research and apply them into industrial applications, with a strong market oriented approach.



Coordinator:
Thanassis Karalis
R&D Specialties Manager
Global Specialties Market
S&B Industrial Minerals S.A.

Email ID:
T.Karalis@sandb.com

Project Website:
www.experl.eu

Innovative and high added value micro-perlite based materials

ExPerl

Research project funded under Collaborative Project Scheme

COOPERATION

Efficient exploitation of EU perlite resources for the development of a new generation of innovative and high added value micro-perlite based materials for the Chemical, Construction and Manufacturing industry.

www.experl.eu

Development of high added value end-products based on new expanded perlite materials, including high thermal and acoustic insulation preformed panels, boards, bricks, plasters, vacuum insulating panels and paints, coatings.

Breakthrough perlite expansion technologies

based on:

- *Microwaves*
- *Indirect heating*
- *Surface Vitrification, Hardening and coating techniques*

consuming 30% less energy, cleaner and environmentaly friendly (almost zero solid wastes and emissions) and cost-effective as compared to the conventional expansion techniques.

New expanded materials

APPLICATIONS

Perlite based coatings

Phyllomat can replace talc in solvent and water borne coatings guaranteeing better rheological properties and hiding power. New perlite based fillers have a very low mass density and can be used to obtain paints with good opacity. *µ-spheres* can replace quartz in water borne coatings resulting in significant cost reduction and giving to the coating thermal insulation properties. It also improves the workability and rheological properties of the product and reduces the mass density.

Perlite based bricks with $\lambda_{dry,23}$= 0.070 W/mK , have a more than 10 times lower thermal conductivity than POROTON® the commonly used clay bricks (0.8 W/mK), 20% lower thermal conductivity than that of special insulating bricks currently available in the market, and considerably lower density (≤ 0.6 kg/m^3) than the density of common clay bricks (1.4kg/m^3). The brick reaches the German passive house standard.

Perlite based plasters

- ✓ Lower abrasivity
- ✓ Lower water absorption
- ✓ Increased compressive and flexural strenght compared to the cement plasters by 70% in the plastering machine and between 20% (comp.) and 30% (flex.) in the lab.

Perlite based vacuum insulating panels

Vacuum panels with perlite Flakes (mean density: 170 kg/m^3) have thermal conductivity between 6 and 8 mW/mK and can be successfully used in refrigators, freezers and thermal transport boxes. Their low cost and good service life time can make them suitable also for building applications.

Insulating Panels/Boards with improved fire resistance, good thermal (λ=65-85 mW/mK) and acoustic insulation properties compared to XPS, recyclable, non-oil derivative and with low CO_2 footprint.

ExPerl

www.leema.eu

The energy and the resources used to create a building product and a building are a measure of sustainability. In fact, the overall environmental impact of the building sector can be reduced and the sustainability of buildings improved through the use of advanced building materials with low embodied energy.

THE LEEMA PARTNERS:

S&B	Coordinator: S&B Industrial Minerals S.A, GR
Etex	Etex Group (Medici), BE
Schlagmann Poroton	Schlagmann Baustoffwerke GmbH&Co KG, DE
Morgan	Thermal Ceramics, IT
	National Technical University of Athens, GR
Dappolonia	D'Appolonia, IT
morando	Morando, IT
IMPI	Institute of Materials Research and Testing at the Bauhaus University Weimar, DE
	University of Stuttgart, DE
	Architects Council of Europe CAE Services GEIE, BE
bbri	Belgian Building Research Institute (BBRI), BE
	Fenix TNT s.r.o, CZ
fibran	Fibran s.a, GR
	Advanced Management Solutions Ltd, GR

Low Embodied Energy Advanced (Novel) Insulation Materials and Insulating Masonry Components for Energy Efficient Buildings

3i inorganic insulating incombustible

MATERIALS FOR ENERGY EFFICIENT BUILDING

The LEEMA project has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement No. 285059 (Call FP7-EeB-NMP.2011-1)

SEVENTH FRAMEWORK PROGRAMME

MATERIALS

Aim of the project

Development of a new generation of **inorganic insulation materials** and building insulation masonry components ("3I") with **lower embodied energy (>50%)** and **lower cost (15%)** and upgraded properties compared to the commercial ones. New formulations and products will be called "3I" materials, since they will be **Inorganic, Insulating and Incombustible**.

Using as raw materials silicate/alumino-silicate wastes of industrial minerals exploitation, recycled rejects from the glass industry, mineral wastes with high alkali content as alkali activators.

Development of inorganic polymeric materials free from the drawbacks of the current inorganic polymers ("geopolymers")

3I Loose Filling Granular Materials

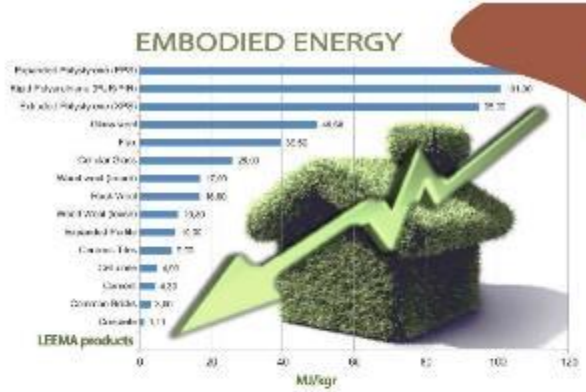
Offering superior performance compared to existing solutions (rock and glass wool blankets/granulates, common expanded perlite, polyurethane bubbles).

A wide range of products has been developed with densities 12-100 Kg/m^3 and λ 0.032-0.045 W/m·K, to be used as bulk insulation in cavity walls, or as a replacement of expanded perlite in formed products.

3I Binders

Geopolymeric Binders, using mineral tailings (perlite, bentonite etc.) as raw material, have been developed to replace the cementitious binders in fiber cement boards or the ceramic body of bricks. The new binders have densities as low as 1400 Kg/m^3 and compressive strength as high as 42 MPa.

FORMED PRODUCTS



3I Expanded Perlite Boards

3I Expanded Perlite Boards (EPBs) have been developed using 3I Loose Fill Materials, to replace the current Fresco Boards. The new 3I EPBs have thermal conductivity values below 0.05 W/m·K.

3I Fibre Cement Boards

3I Fibre Cement Boards (FC) have been developed using 3I Loose Fill Materials as a replacement of expanded perlite or exfoliated vermiculite. The new 3I FC Boards have thermal conductivity values 0.11-0.14 W/m·K and increased compressive and flexural strength compared to traditional Calcium Silicate Boards.

3I Bricks

3I Bricks have been developed, with thermal conductivity as low as 0.9 W/m·K, using 3I Loose Fill Materials in the brick cavities. The new 3I Binders have been also successfully used to replace the ceramic brick body, lowering the embodied energy of the brick by more than 80%.

3I Foam Boards

Novel Foamed geopolymer boards with density as low as 300 Kg/m3 and thermal conductivity 0.06 W/m·K were developed, combining 3I Binders with suitable foaming agents.

Coordinator:

Alessandro Largo

Strada Statale Appia KM 706+030,
c/o Cittadella della Ricerca, 7,
Brindisi, 72100, Italia

Email ID:

alessandro.largo@cetma.it

Project Website:

http://www.sus-con.eu/

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 285463

SUStainable, innovative and energy-efficient CONcrete, based on the integration of all-waste materials

www.sus-con.eu

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SUS-CON products designed according to application:

Selection of suitable binding systems based on wastes (fly ash, slag, perlite tailings) and appropriate waste aggregates (tyre rubber, PU foam, recycled aggregates), giving the desired rheological and final product

SUS-CON products are suitable for:

- ready-mixed applications: floor screed underlay
- pre-cast applications: blocks panels

DEMONSTRATION ACTIVITIES

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Benefits - Impact

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- Lightweight
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