LEEMA - Low Embodied Energy Insulation Materials and Masonry Components for Energy Efficient Buildings

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Objectives

Large Industries	S&B INDUSTRIAL MINERALS	GR
	Etex Group (Redco)	BE
	SCHLAGMANN BAUSTOFFWERKE	DE
	THERMAL CHERAMICS de FRANCE	FR
	Morando S.r.l.	IT
	FIBRAN	GR
SME	FENIX TNT S.r.o.	CZ
	AMS Solutions	GR
Universities – Research Institutes	NATIONAL TECHNICAL UNIVERSITY OF ATHENS	GR
	MPA University of Stuttgart	DE
	Centre Scientifique et Technique de la Construction (BBRI)	BE
	MFPA University of Weimar	DE
	D'APPOLONIA SPA	IT
	Architects Council of Europe (ACE)	BE

- ✓ 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
- ✓ Improvement of **durability and energy performance** at building level
- ✓ Safer and cleaner indoor building environment due to **incombustibility and absence of organic/fibrous compounds**
- ✓ Use of **wastes of industrial minerals exploitation, recycled rejects from the glass industry and industrial by-products**

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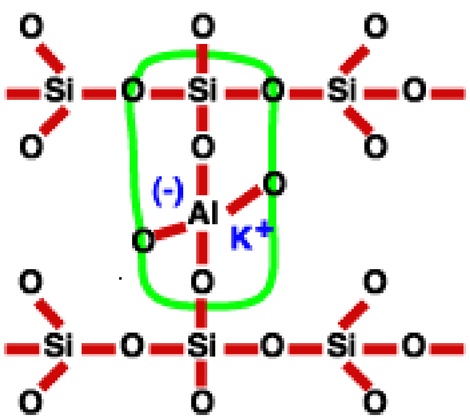
Insulating Inorganic Incombustible Materials and Masonry Components

The Idea: Inorganic Polymers

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

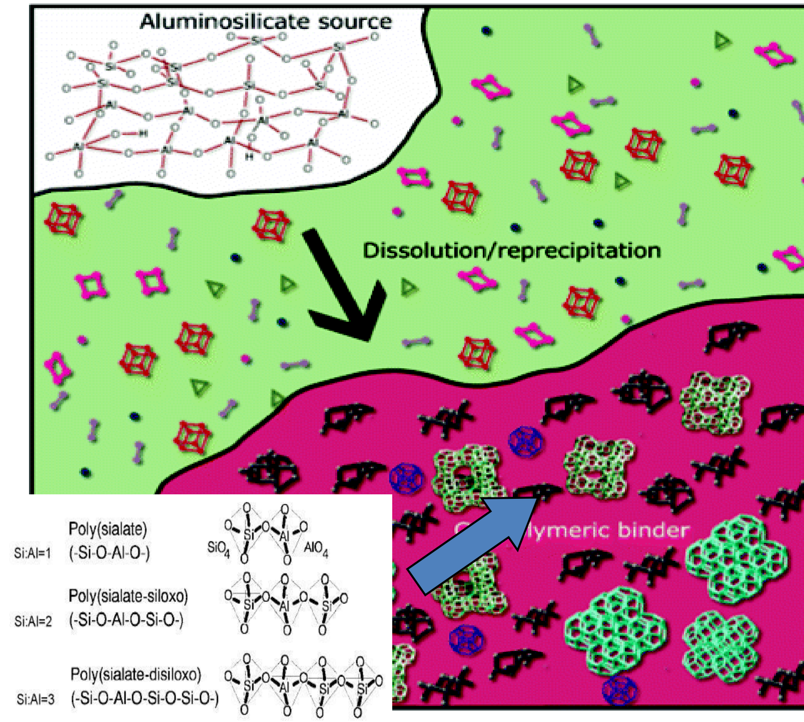
Components

1. NaOH/KOH

2. Dissolved SiO_2

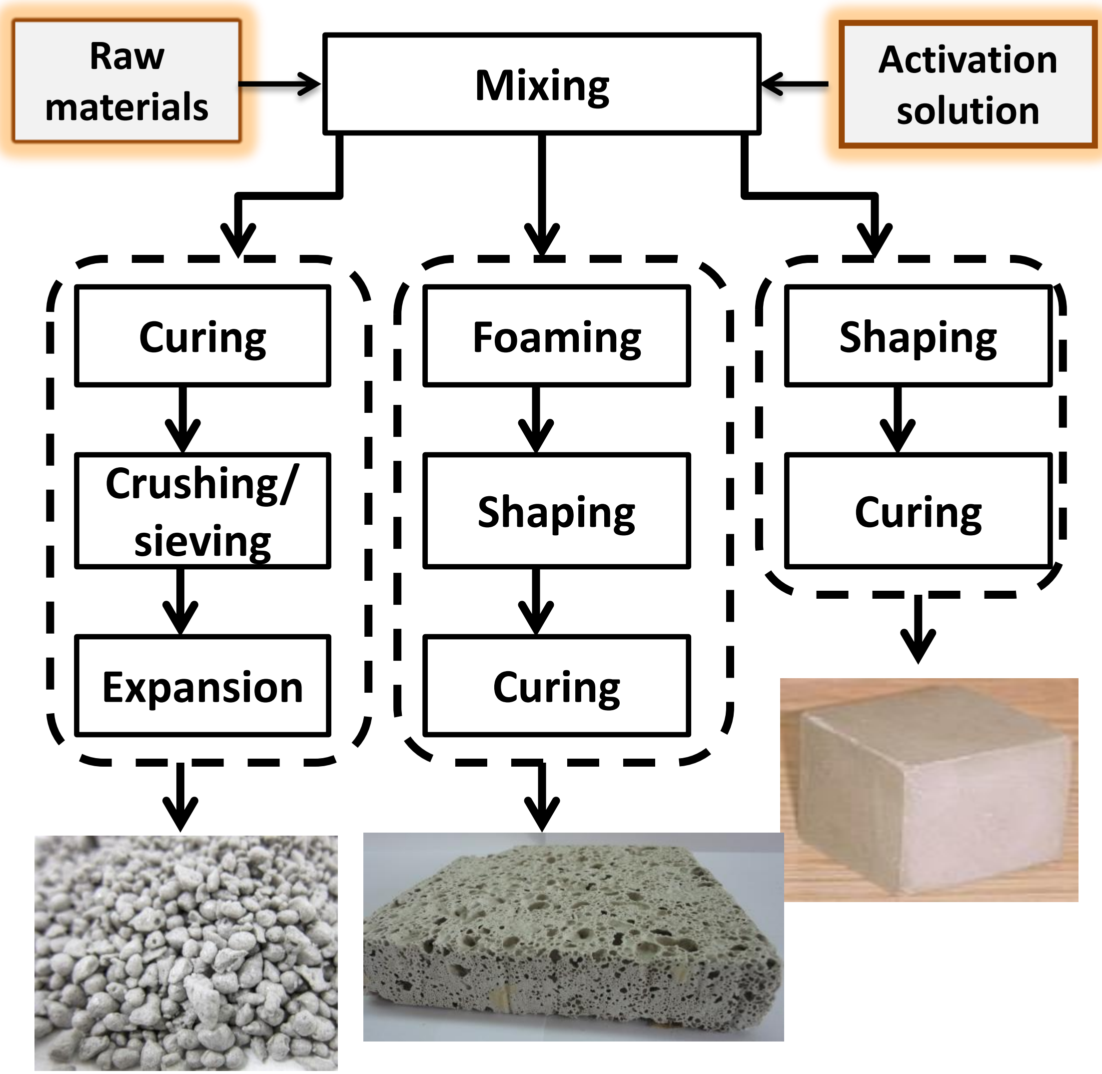
3. Water

Schematical representation of reaction**



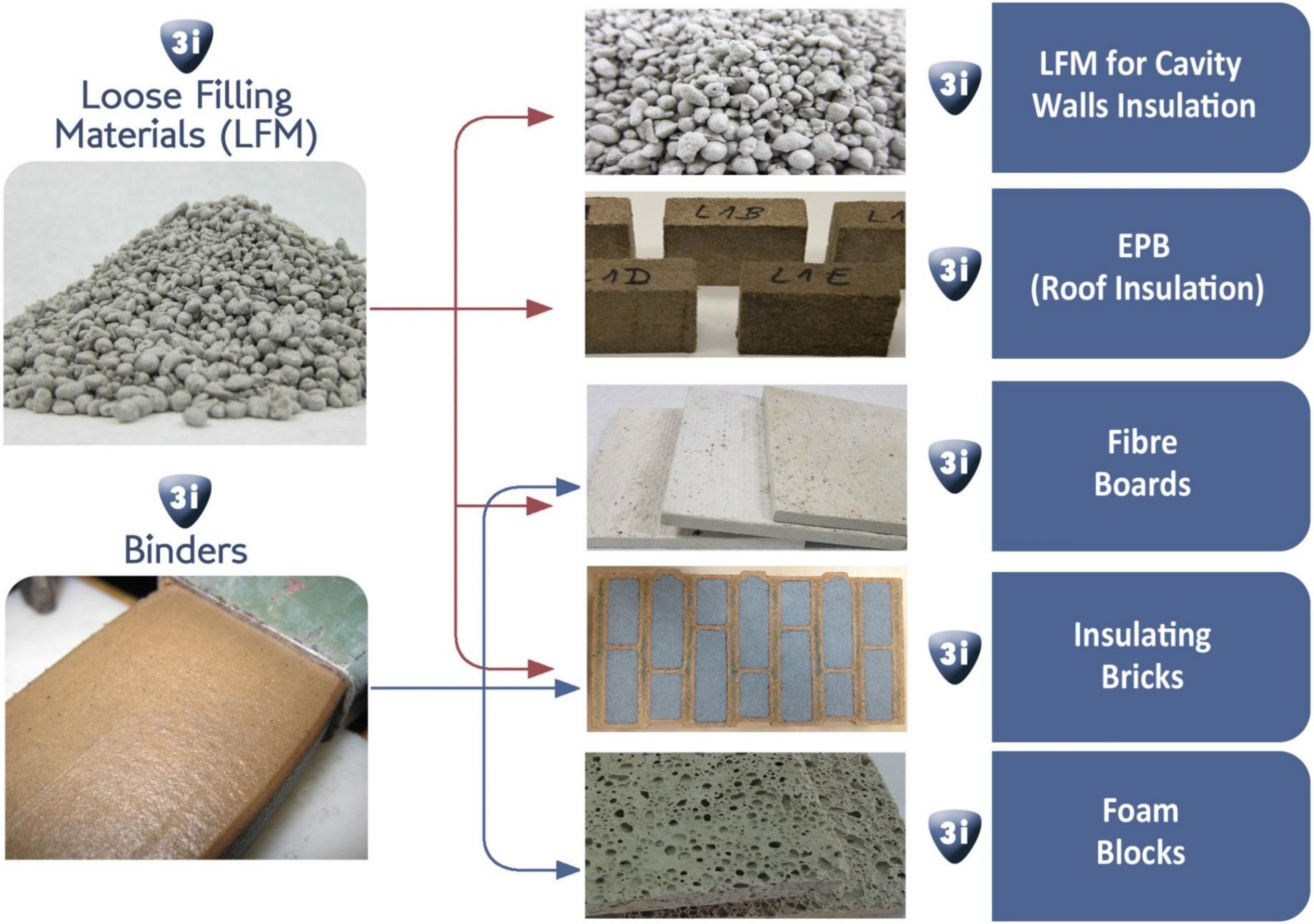
* ***Do Geopolymers Actually Contain Nanocrystalline Zeolites? A Reexamination of Existing Results**
J. L. Provis, G.C. Lukey, J. S. J. van Deventer

Low energy production



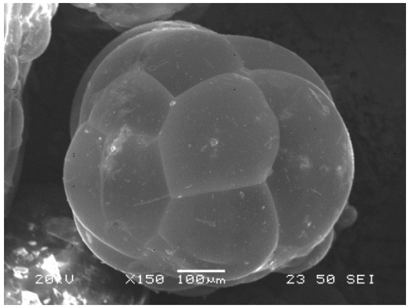
- ✓ Use of mineral tailings-wastes, recycled glass and other industrial by-products
- ✓ Curing at low temperatures (50-100 ^{o}C) for 24-72h to obtain mechanical properties
- ✓ Expansion using energy efficient Infrared Heating

The LEEMA Products



3I Loose Fill Materials (3I LFM)

Material	Application	Density (Kg/m³)	λ_{10} (W/mK)	Comp. Res. (psi at 2")	EE (MJ eq./FU)
LEEMA 3I LFM	For Brick cavities/EPBs	44.8	0.034	24.7	**11**
	For Fibre boards	96.5	0.041	67.8	**34**
	For Cavity walls insulation	60.6	0.038	37.7	**21**
Expanded perlite	Commercial Loose Fill insulation	50 – 120	0.045 – 0.070		**53**
EPS beads		15 - 35	0.032 – 0.040		**82**



Main advantages

- ✓ **Lightweight,** multifunctional, **inorganic**, inert and **incombustible**
- ✓ **Synthetic:** Can be **fine-tuned** according to application; (d: 15 to >120 kg/m^3)
- ✓ **Excellent thermal performance:** λ 0.034 – 0.041 W/(mK)
- ✓ **Sustainable**: based on wastes and recycled raw materials, expanded at moderate temperatures (500 – 600 °C) compared to expanded perlite (~ 1200°C) using IR heating
- ✓ **54% to 76% lower embodied energy** per FU (*FU: 1 m^2 of insulation with a R = 1 m^{2}K/W)*
- ✓ Preliminary simulations: 3I LFM can reduce space heating energy demands by 70%
- ✓ **Free flowing and easy to install** using **standard procedures**

3I Binders

Material type		Compressive Strength (MPa)	Flexural Strength (MPa)	Thermal conductivity (λ) (W/mK)	Density (Kg/m^3)
LEEMA 3I Binders	Alk. act.	21	5.97	0.1921	1484
	Alk. Silicate act.	28	7.76	0.2641	1604
Cement				0.72	1860
Clay Bricks				0.62-1.3	1300-2080
Clay tiles				0.8-1.3	1890-2000

Main advantages:

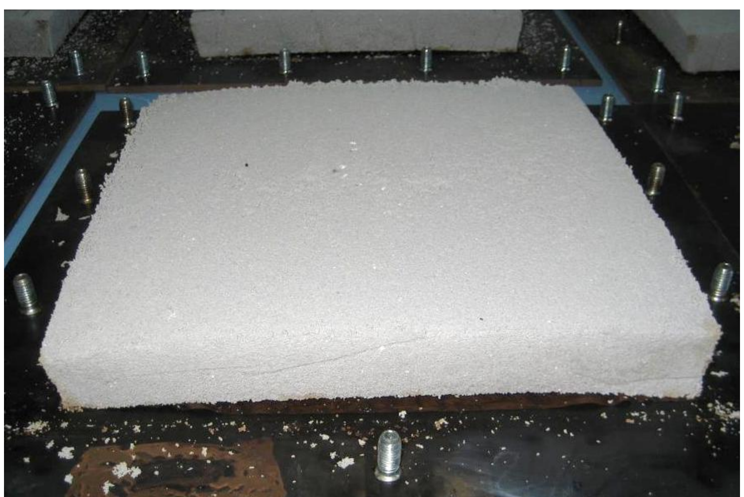
- ✓ Based on mineral tailings (wastes)
- ✓ Mechanical properties obtained after curing at low temperatures (~70 ^{o}C) after a few days
- ✓ Compatible with traditional aggregates and conventional shaping methods (moulding or **extrusion**)
- ✓ Suitable for the production of pre-fabricated non-structural 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)

3I Fibre Boards, 3I EPBs

3I Fibre boards

3I Loose Fill Materials replacing expanded perlite or exfoliated vermiculite

- ✓ Successful Pilot scale production – No significant changes in production process
- ✓ λ 0.11-0.14 W/(mK)
- ✓ Similar density (up to +5%) but higher flexural strength (up to +44%)
- ✓ 3I binders could be used to replace cement, using moulding or extrusion as shaping methods



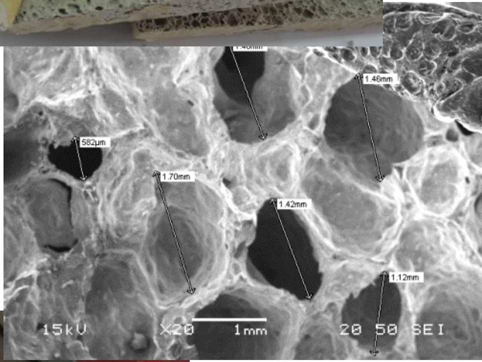
3I EPB

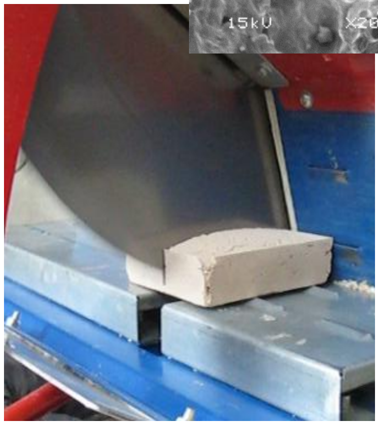
3I Loose Fill Materials replacing expanded perlite in Fesco boards

- ✓ λ< 0.05 W/(mK)
- ✓ Density ~150 Kg/m^3
- ✓ Flexural Strength ~0.35 MPa

3I Foam Blocks

Material Type	λ (W/(mK))	Density (Kg/m^3)	Comp. Strength (MPa)	1/R for 20cm thickness (… is approx. U – value) (W/(m^{2}K))
3I Foamed Blocks	0.06 – 0.115	400-800	0.7 – 2.7	**0.3-0.6**
Autoclaved Aerated Concrete	0.07-1.4	200-1600	1-10	**0.35-7.0**





Main advantages

- ✓ Foamed inorganic polymers
- ✓ Sustainable: Based on perlite wastes
- ✓ 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

3I Fibre boards, 3I EPBs

Material type	Density (Kg/m^3)	Thermal conductivity (λ_{10}) W/mK	Comp Strength (MPa)	Flex. Strength (MPa)
3I EPBs	288	0.068	0.34	0.85
Reference (Fesco Boards)	162	0.052	0.29	0.79
3I FC Boards	920	0.133	-	11.7
Reference (FC Boards)	930	0.111	-	9.7

3I EPBs

- ✓ 3I Loose Fill Materials replacing exp. Perlite
- ✓ Totally inorganic – No use of bitumen or fibrous materials
- ✓ Similar properties to commercial Fesco Boards

3I Fibre boards

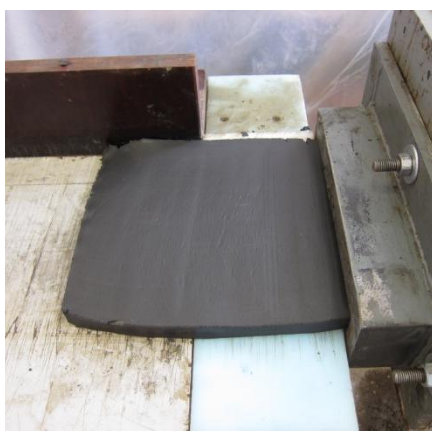
3I Loose Fill Materials replacing exp. perlite or exfoliated vermiculite

- ✓ Successful Pilot scale production – No significant changes in production process
- ✓ 3I LFM leads to similar density (up to +5%) but higher flexural strength (up to +44%),
- ✓ 3I binders could be used to replace cement, using moulding or extrusion

3I Insulating Bricks

The "simple approach": 3I Loose Fill Materials replacing expanded perlite

- ✓ λ value of infill 0.035 W/(mK) (-12.5-20% compared to perlite)
- ✓ Same production process
- ✓ Overall brick λ value ≤ 0.090 W/(mK)
- ✓ Embodied energy under evaluation, estimated reduction 10-15%



The "futuristic" approach:

3I binders replacing the ceramic brick body

- ✓ ≈ Mechanical properties, similar density and λ without using porosity modifiers
- ✓ Similar production process, **without firing** (>60% lower embodied energy)
- ✓ Optimized **Extrusion** under soft-clay conditions

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Thanks for your attention!

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