SECOND INTERNATIONAL
SLAG VALORISATION SYMPOSIUM
THE TRANSITION TO SUSTAINABLE MATERIALS MANAGEMENT

KATHOLIEKE HOGESCHOOL
BRUGGE - OOSTENDE

Ferromolybdenum slag as valuable resource material for the production of concrete blocks

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SMART-PRO²

Outline

- Introduction
- Production process
- Materials in use
- FeMo-slag
- Mix design
- Properties of ‘R-blocks’
- Bringing the product to the market
- Conclusions

Introduction

- Dirk Van Den Hende
  - Van Den Hende Beton N.V. (www.vandenhendebeton.be)
  - Concrete products : blocks, pavement, garden,...
- Luc Boehme
  - Catholic University College of Bruges & Ostend
  - Faculty of Engineering Technology - Department of Construction
  - Head of Department
  - Promoter of the research-group "Recycling of C&DW"
- Idea based on former research project "recyMblock"

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Introduction

- Recycling slag in building materials
- Case:
  - Concrete blocks
  - Natural aggregates
    - become scarce
    - expensive
  - Substitute for gravel and limestone: secondary aggregates e.g. recycled concrete aggregates and slags

Introduction

- Benefits from using secondary aggregates
  - Less expensive
  - Reduction of the amount of waste

- Flemish environmental law: ‘*VLAREA*’
- Sustainable development: saving ecosystems
- Various by-products can be used

Introduction

- Various by-products can be used in concrete blocks
  - Mixed construction and demolition waste (Boehme L)



  - Crushed clay brick (Poon *et al*)
  - Bottom ashes and granulated blast furnace slags (Yüksel & Bilir)
  - Recycled concrete aggregates (Pimienta P *et al*)

Introduction

- Effective use of recycled resources in concrete = reducing harmful effects on the environment
- Not valuable solid wastes become valuable alternative to virgin aggregates
- Possible effects that can cause deterioration of the end-product must me investigated.

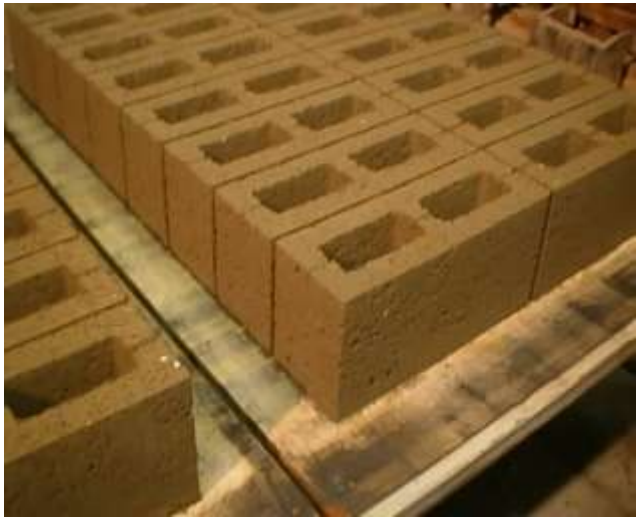
  - In this case: use of ferromolybdenum slag in concrete blocks for masonry work

Production of concrete blocks

- Concrete blocks
  - Apparent density : 1350 to 1750 kg/m³
  - With cavities or full
  - High percentage of fine aggregates
  - Low percentage of water and gravel
  - Low dosage of cement compared to ordinary fresh concrete
  - Dry, stiff mixture

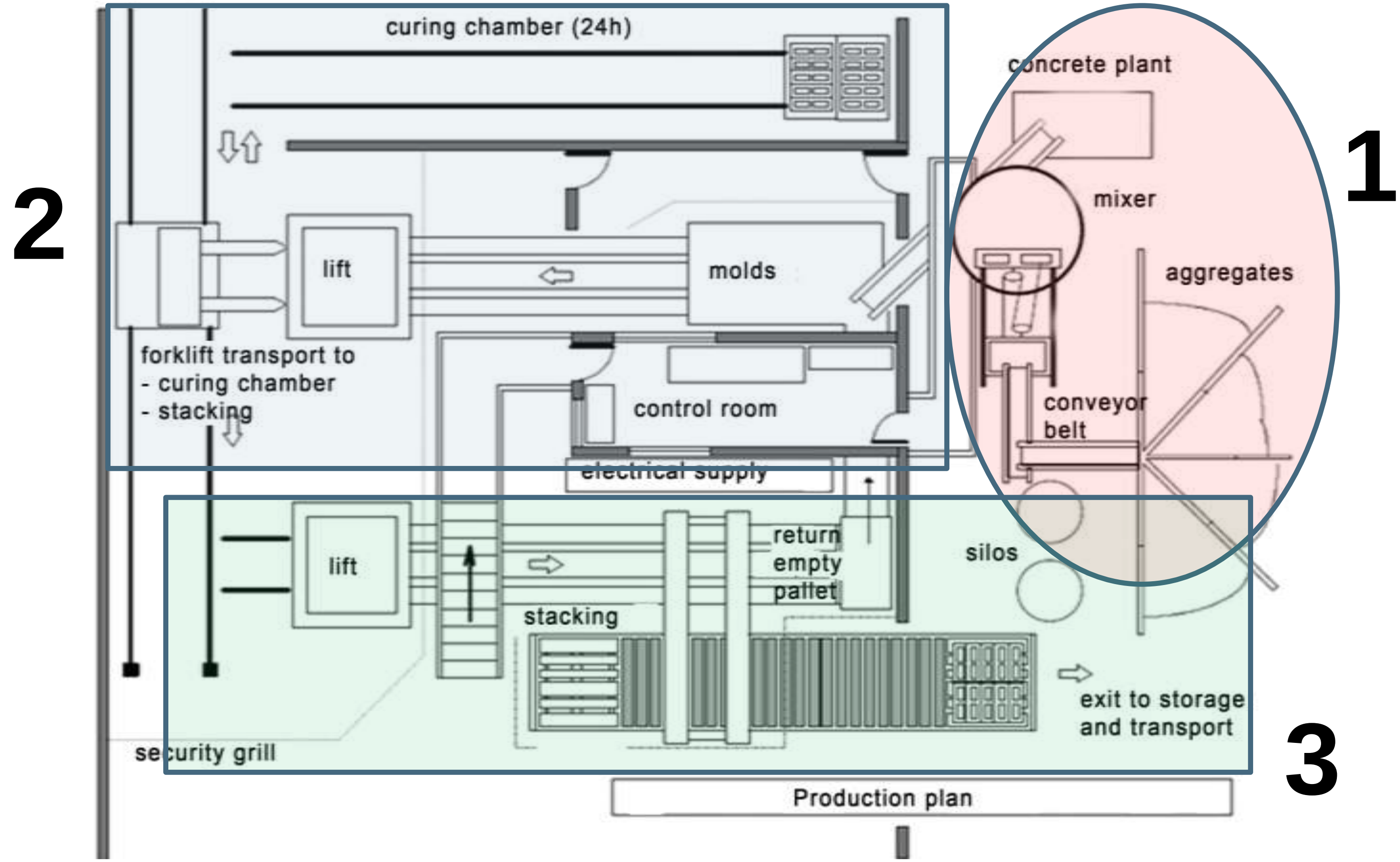
Production of concrete blocks

- Production process
  1. Batching and mixing
  2. Molding and curing
  3. Storage and transportation



Production of concrete blocks

- Schematic overview



Materials

- Classic raw materials
  - **Cement**
    - Considerations
      - High early strength needed
        → rapid hardening CEM I-type
      - Resistant to certain chemicals (sulphates, chlorides, ..) and ASR
        → CEM III - type

Materials

- Classic raw materials
  - Sand
    - Riverbeds
      - → round shape
      - Upstream: little or no fines; max 5mm
      - Downstream: fine; □ 1mm
    - Sea → fine & edged
    - Quarry → fine sand + lot of filler
  - Aggregates
    - Same sources
    - Larger particle size → 2mm up to 16mm (mostly max 8mm)

Ferromolybdenum slag

- Ferromolybdenum
  - alloy of iron & molybdenum
  - primarily used as additive in steel production (steel, cast irons, nonferrous)

- FeMo-slag
  - not expected to be hazardous
  - in Flanders: 20.000 to 25.000 t/y
  - granulated fraction used in concrete: 14.330 to 19.500 t/y
  - (CDW: 9.441.000 t/y; steel slag 1.900.000 t/y; nonferrous slag 325.000 t/y; bottom-ashes 310.000t/y) *(VITO)*

Ferromolybdenum slag

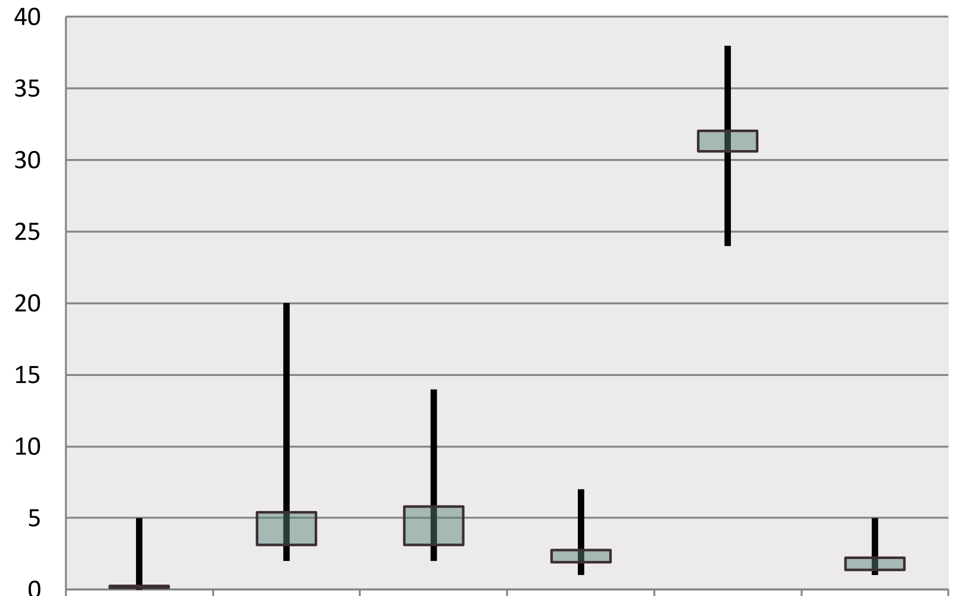
FeMo-slag typical composition

Unknown or Variable Composition Substance	Ferromolybdenum Slags
Synonyms/Trade Names	FeMo Slags
Formula:	By-product obtained during alumino-silicothermic reduction of roasted molybdenite concentrates (tech mo oxide) to produce Ferromolybdenum
TYPICAL COMPOSITION	
Parameter / Component	In % (mass)
Silicon	ca. 10 – 40
Aluminium	ca. 2 – 20
Iron	ca. 4 – 25
Molybdenum	ca. 0 – 2
Magnesium	ca. 0 – 5
Calcium	ca. 0 – 10

(The REACH Molybdenum Consortium)

Ferromolybdenum slag

Chemical composition FeMo-slag



	% Mo	% Fe	% Ca	% Al	% Si	% Mg
min	0,12	3,10	3,10	1,90	30,60	1,40
uplim	5,00	20,00	14,00	7,00	38,00	5,00
lowlim	0,00	2,00	2,00	1,00	24,00	1,00
max	0,61	7,50	9,60	3,60	33,30	3,40
mean	0,27	5,40	5,82	2,76	32,06	2,25

Chemical analysis of FeMo-slag used in concrete blocks at VDH jan/08 – nov/10

Ferromolybdenum slag

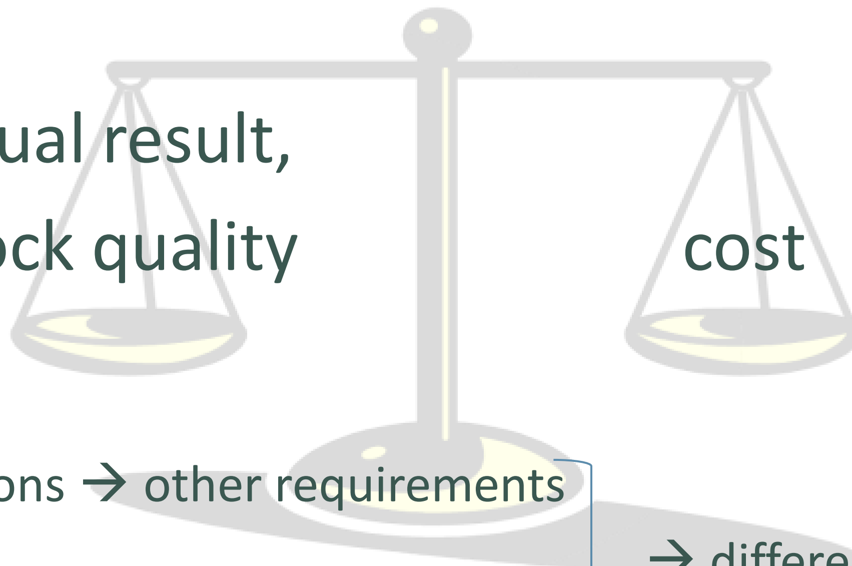
- FeMo-slag environmental quality

mg/kg TDS	As	Cd	Cr	Cu	Hg	Pb	Ni	Zn
FeMo	4 - 15	0.1 - 0.3	41 - 799	180 - 357	< 0.2 - 0.5	49 - 118	29 - 129	105 - 504

(VITO)

Mix Design

- Mix design = complex balance



- Different applications → other requirements
- Different aggregates but similar mechanical properties of the blocks

→ different mixing formulas

Mix Design

- Mixing formulas for blocks (wt%)

Aggregates	Block for foundation masonry	FeMo-Block for foundation masonry	Block for industrial visual masonry
Sand 0/1 (quarry)	15%	15%	10%
Sand 0/2 (sea)	20%	15%	
Sand 0/2 (river)			30%
Stone 2/4 (quarry)			50%
Stone 4/6.3 (quarry)			
Stone 2/6,3 (quarry)	50%	25%	
Stone 6,3/14 (quarry)	15%		10%
FeMo slag		45%	
Cement CEM I 52,5 N	145 kg/m3		
Cement CEM III/A 42,5 N		180 kg/m³	
Cement CEM III/A 52,5 N			180 kg/m3

Mix Design R-blocks

- Mixing formulas for R-blocks (with FeMo-slag)

Mix Formula standard foundation block					
sieve passthrough [%]					
mesh [mm]	0/1 qr	0/2 sea	2/6,3 qr	6,3/14 qr	Standard
0.08	1.5	1.5	0.8	0.5	1.0
0.125	7.1	2.0	1.2	0.5	2.1
0.25	81.0	14.0	1.8	1.0	16.0
0.5	97.4	90.0	1.9	1.0	33.7
1	99.1	95.0	2.1	1.5	35.1
2	99.8	100.0	5.6	1.5	38.0
4	100.0	100.0	45.9	2.0	58.3
8	100.0	100.0	100.0	2.5	85.4
16	100.0	100.0	100.0	100.0	100.0

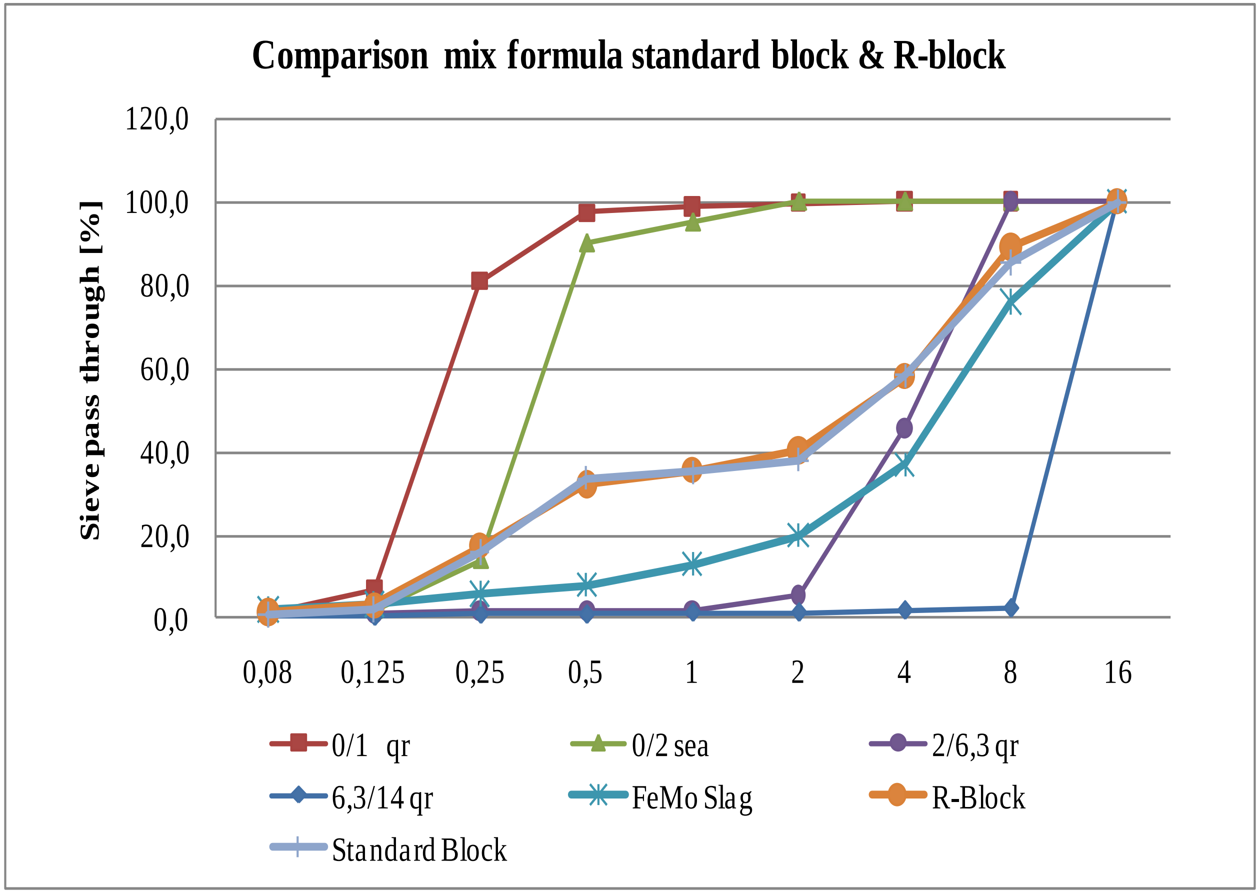
	0/1 qr	0/2 sea	2/6,3 qr	6,3/14 qr	Result
Mix [%]	15	20	50	15	100

Mix Formula R-block					
sieve passthrough [%]					
mesh [mm]	0/1 qr	0/2 sea	2/6,3 qr	FeMo	Result
0.08	1.5	1.5	0.8	2.2	1.6
0.125	7.1	2.0	1.2	3.5	3.2
0.25	81.0	14.0	1.8	6.0	17.4
0.5	97.4	90.0	1.9	8.0	32.2
1	99.1	95.0	2.1	13.0	35.5
2	99.8	100.0	5.6	20.0	40.4
4	100.0	100.0	45.9	37.0	58.1
8	100.0	100.0	100.0	76.0	89.2
16	100.0	100.0	100.0	100.0	100.0

	0/1 qr	0/2 sea	2/6,3 qr	FeMo	Result
Mix [%]	15	15	25	45	100

Mix Design R-blocks

- Mixing formulas for R-blocks (with FeMo-slag)



Mix Design R-blocks

- Mixing formulas for R-blocks (with FeMo-slag)
  - optimal particle size distribution for the mix
  - testing the mix in production
    - Influence on distribution of fresh concrete in the mold
    - Influence on compacting the block
    - Visual effects
    - Influence on mechanical properties
    - Influence on W/C-ratio
      - Mechanical properties such as compression strenght
      - Stability of the freshly produced blocks
      - Spreading the mixture evenly in the mold
- → fine tuning of the mix

Properties of the R-blocks

- BENOR-certificate
  - NBN EN 771-3+A1: Specification for masonry units - Part 3: Aggregate concrete masonry units (Dense and light-weight aggregates), 2005
  - PTV 21-001: Technical Prescriptions: Masonry blocks in concrete, 2006.

Technical Property	Description
Category of the block	Category I: blocks for load bearing masonry
Type of masonry (A = outside; B= visual; C = foundation; D= all other)	Type C (automatically complies for type D): blocks for foundation masonry (and other indoor masonry)
Size tolerance class	D1 (L, W, H : +3, -5 mm)
Shear strength	0,15 N/mm²
Reaction to fire	Euro class A1
Vapour permeability	µ = 5/15
Durability	complies
Toxic substances	none

To the market

- Questions to be answered
  - Is it okay to use FeMo-slag, a waste product?
    - Industrial by-product that can be used in construction applications
    - Several regulations on secondary raw material
  - What are the risks?
    - Chemical contaminations interacting with cement? Causing swelling & damage to the end-product ? Causing visual damage?
  - Visual perception?
  - Influence on the weight?
    - Ergonomics on construction site & cost of transportation
    - Isolation properties? Weight reduction without loss of strenght?
    - Weight increase? Soundproofing? ..

To the market

- First test results of “FeMo-block”
  - Solid block
  - No weight loss
  - FeMo-slag was visible at the outside
  - FeMo-slag: looks like glass, different colours and shades of green and blue
  - People will start asking questions
- More intensive testing & communication to the public
- “FeMo-block” →’Recy-block’ → ‘R-block’

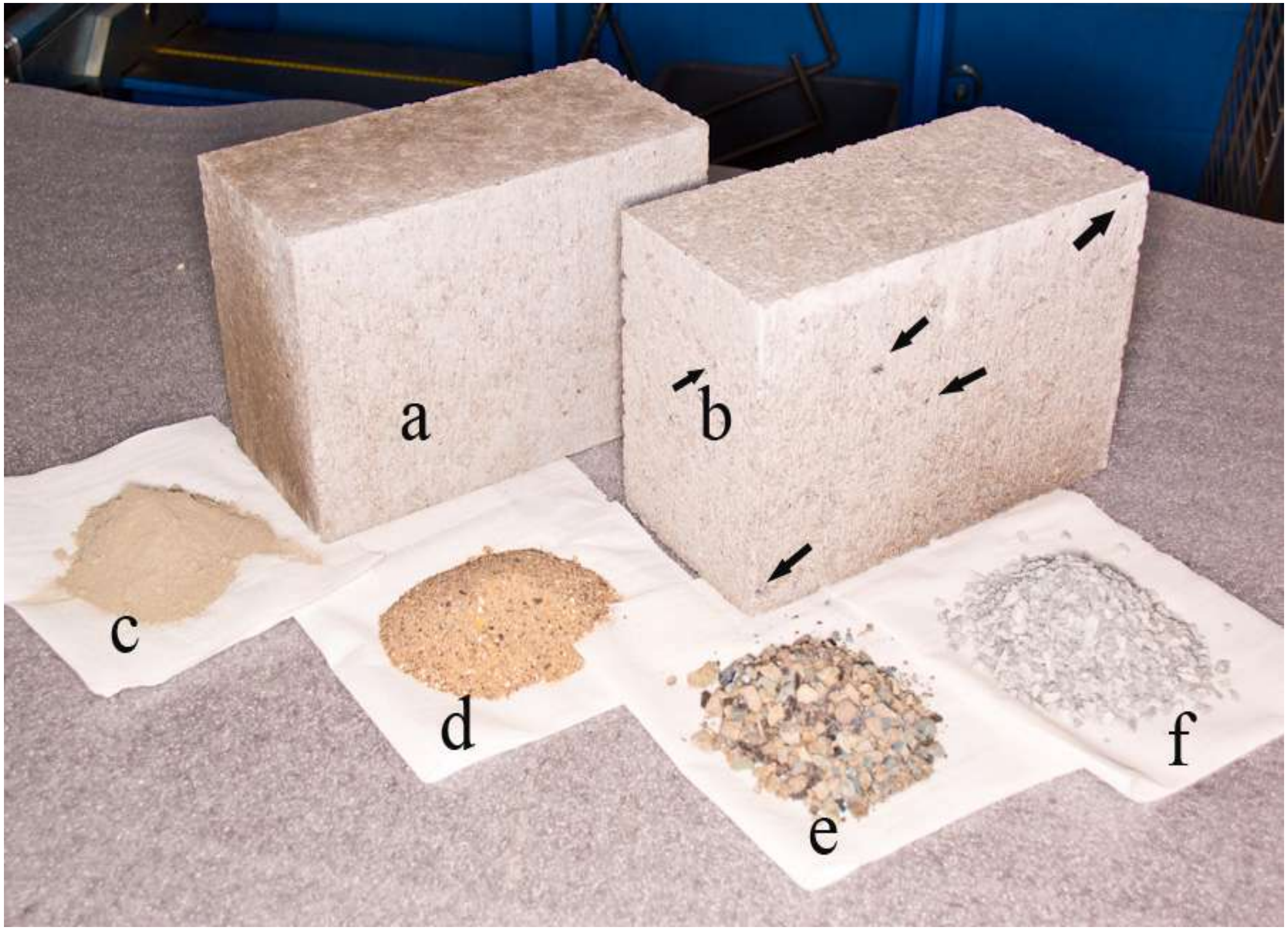
To the market

- Bringing 'R-block' to the market
  - 2006/04/01: **CE- labelling** !
    - New European Standard EN 771 – 3
  - Next step: **BENOR** → important for the Belgian Market
    - Chemical & mineralogical study: FeMo-slag acts as an inert material → aggregate for concrete
    - Physical study: NBN EN 993-1 → every 2000 tons
    - Influence on hydraulic reaction of cement?
    - Durability tests: frost & thaw, ASR → no risk
    - Environmental safety → VITO → leaching within limits

To the market

- ‘R-block’

a. Reference = standard block
b. R-block
c. Cement
d. Sand
e. FeMo-slag
f. Stone 2/6,3



Conclusions

- FeMo-slag
  - Can successfully be used to manufacture concrete blocks
  - All properties meet BENOR requirements
  - No hazard to human life or the environment
- ‘waste-to-product’ is not easy
  - Prejudice of “waste” → ‘industrial by-product’
- Marketing the product
  - CE-label, BENOR certificate,..., → “eco-label”
  - Open communication with client
  - Competitive price

Contact

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