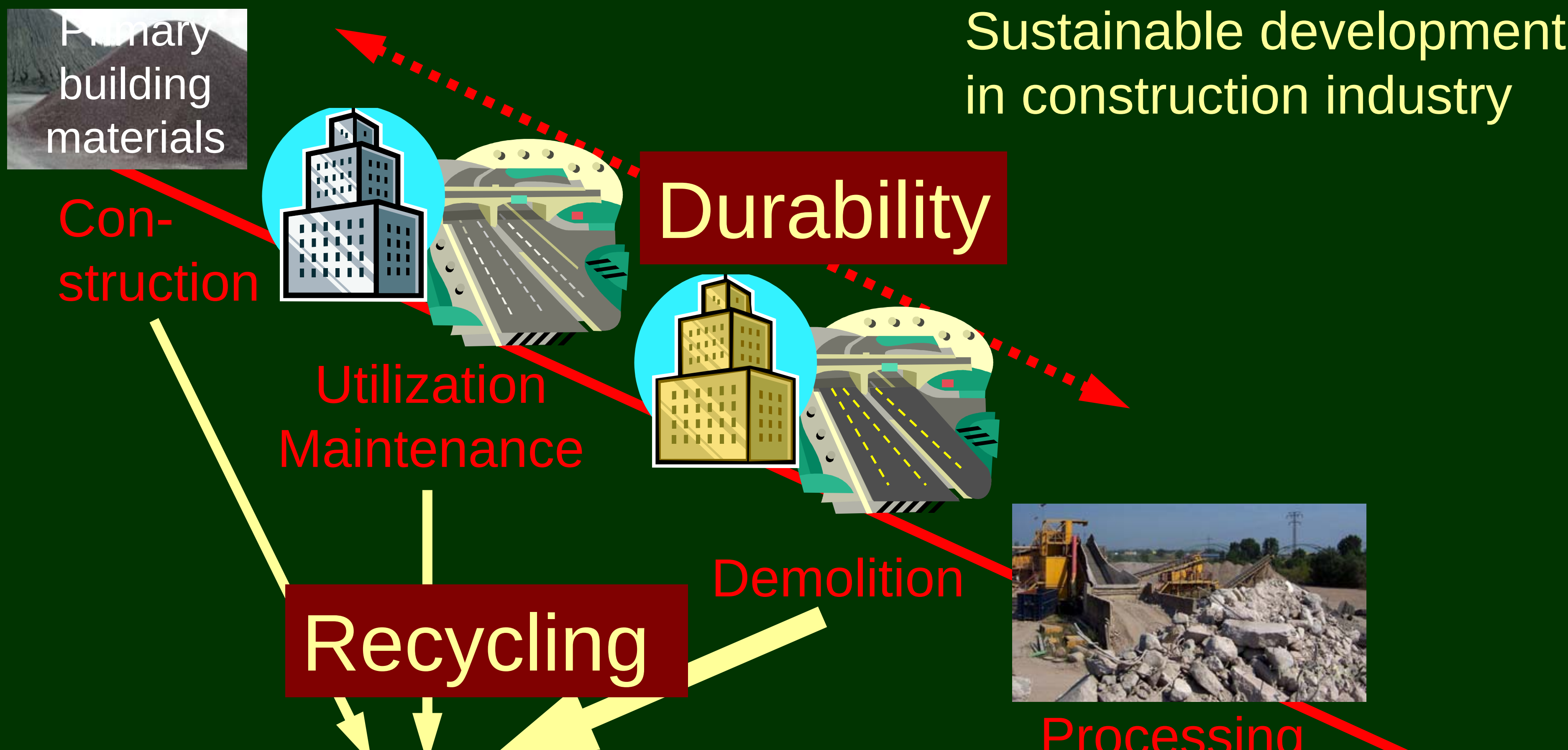
Recycling of construction and demolition waste – Status and new utilisation methods

Prof. Dr.-Ing. habil. Anette Müller

20. CODATA
October, 23-25, 2006; Beijing

Sustainable development in construction industry

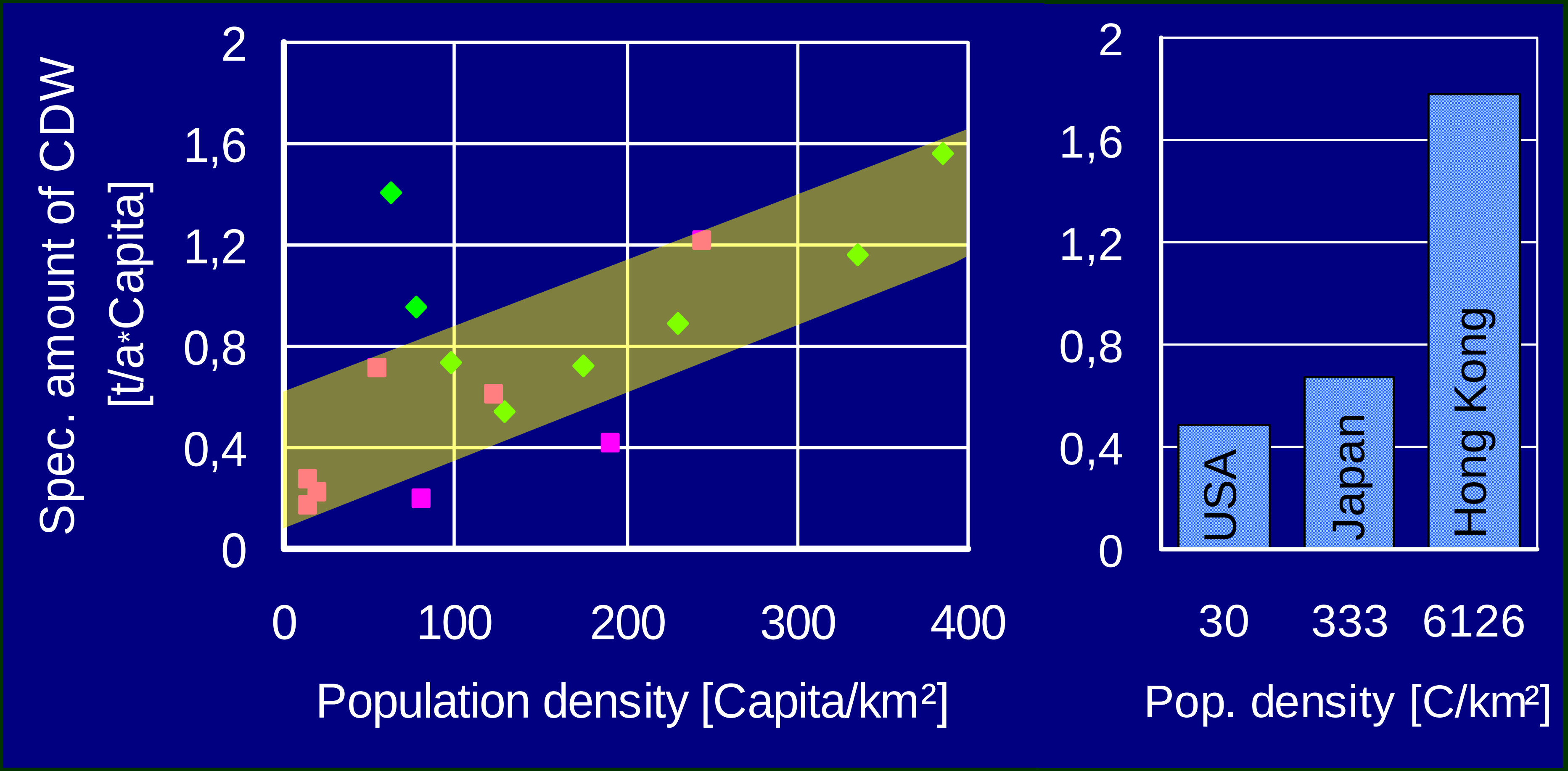


CDW is the umbrella term for very wide range of materials which are generated by all construction activities.

Amount of CDW per inhabitant in Europe

European countries

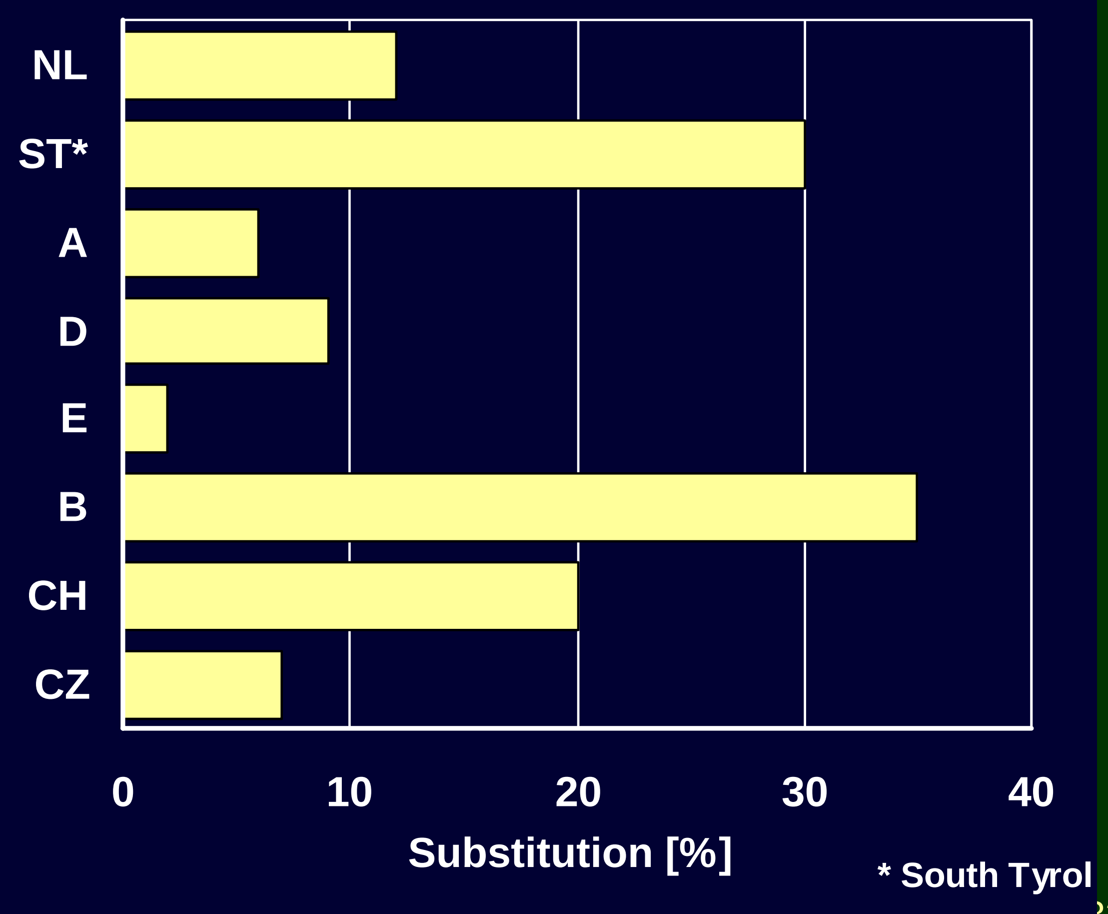
Others



Composition of CDW in Europe

Concrete	2…39 %
Asphalt	6...21 %
Masonry CDW	42…92 %
Mixed rubble	2…11 %

Substitution of natural materials by recycled materials



Ref.: F.I.R. Interforum 2005

Features for classification

Composition	Division in at least three main groups • Concrete + mortar + natural aggregates • All kinds of brick + ceramics • Asphalt
Bulk density (water absorption)	Division in at least two groups • > 2,0 (OD) / 2,2 (SSD) kg/m³ • > 1,5 (OD) / 1,8 (SSD) kg/m³
Content of leach-able substances	Division in at least two groups • Material without contaminations • Material with contaminations lower than certain, defined threshold values

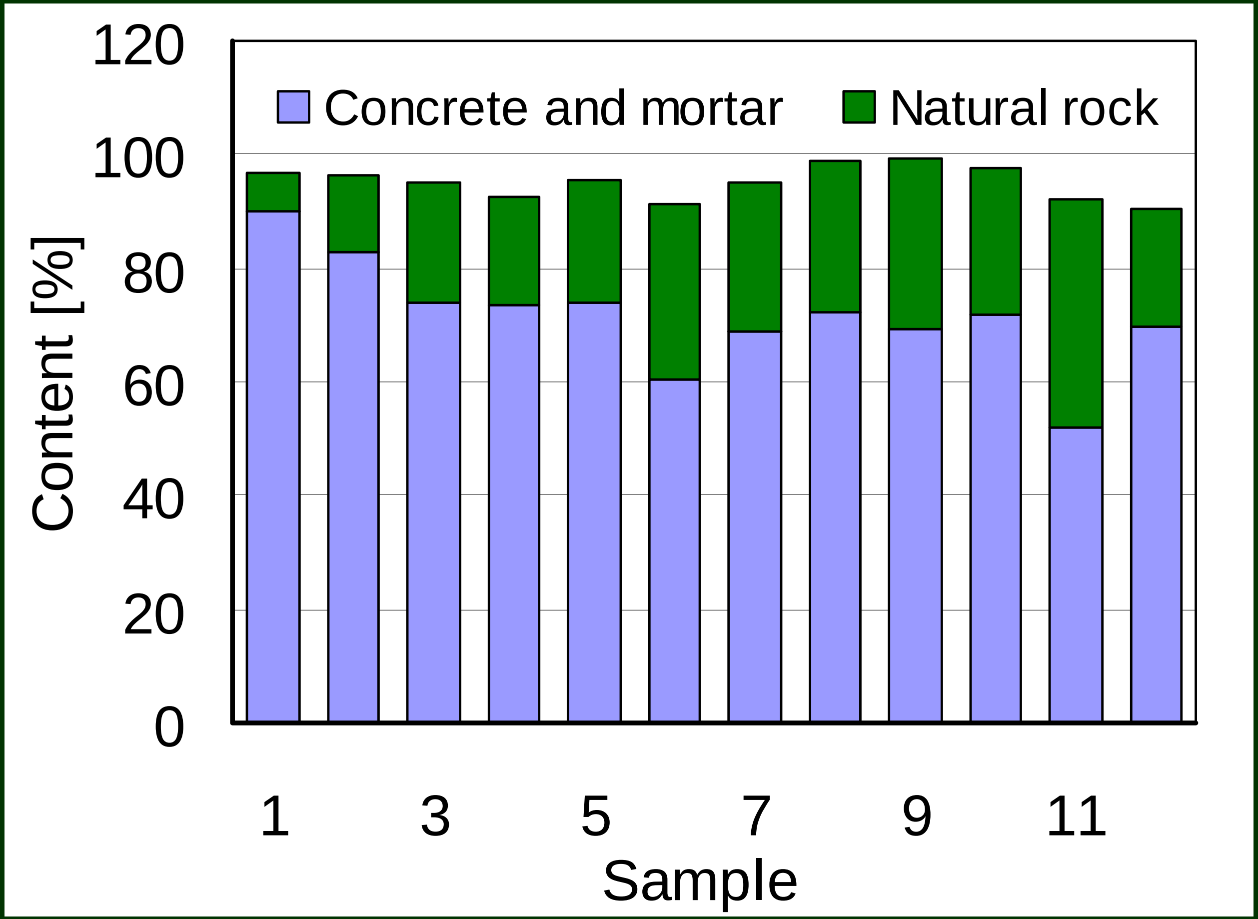
German standard on recycled aggregates DIN 4226-100

Constituents [% by mass]	Type 1	Type 2	Type 3	Type 4
DIN 4226-100: Recycled aggregates	Concrete chippings + crusher sand	Construc-tion chip-pings + c. sand	Masonry chippings + c. sand	Mixed chippings + c. sand
Concrete and natural aggregates	≥ 90	≥ 70	≤ 20	≥ 80
Clinker, non-pored bricks	≤ 10	≤ 30	≥ 80	
Sand-lime bricks			≤ 5	
Other mineral materials (i.e. pored brick, lightweight concrete, no-fines concrete, plaster, mortar, porous slag, pumice stone)	≤ 2	≤ 3	≤ 5	≤ 20
Asphalt	≤ 1	≤ 1	≤ 1	
Foreign substances (i.e. glass, non ferrous metal slag, lump gypsum, plastic, metal, wood, plant residue, paper, others)	≤ 0.2	≤ 0.5	≤ 0.5	≤ 1
OD density/oven dry [kg/m³]	≥ 2000	≥ 2000	≥ 1800	≥ 1500

Ref.: DIN 4226-100

Properties of real concrete CDW

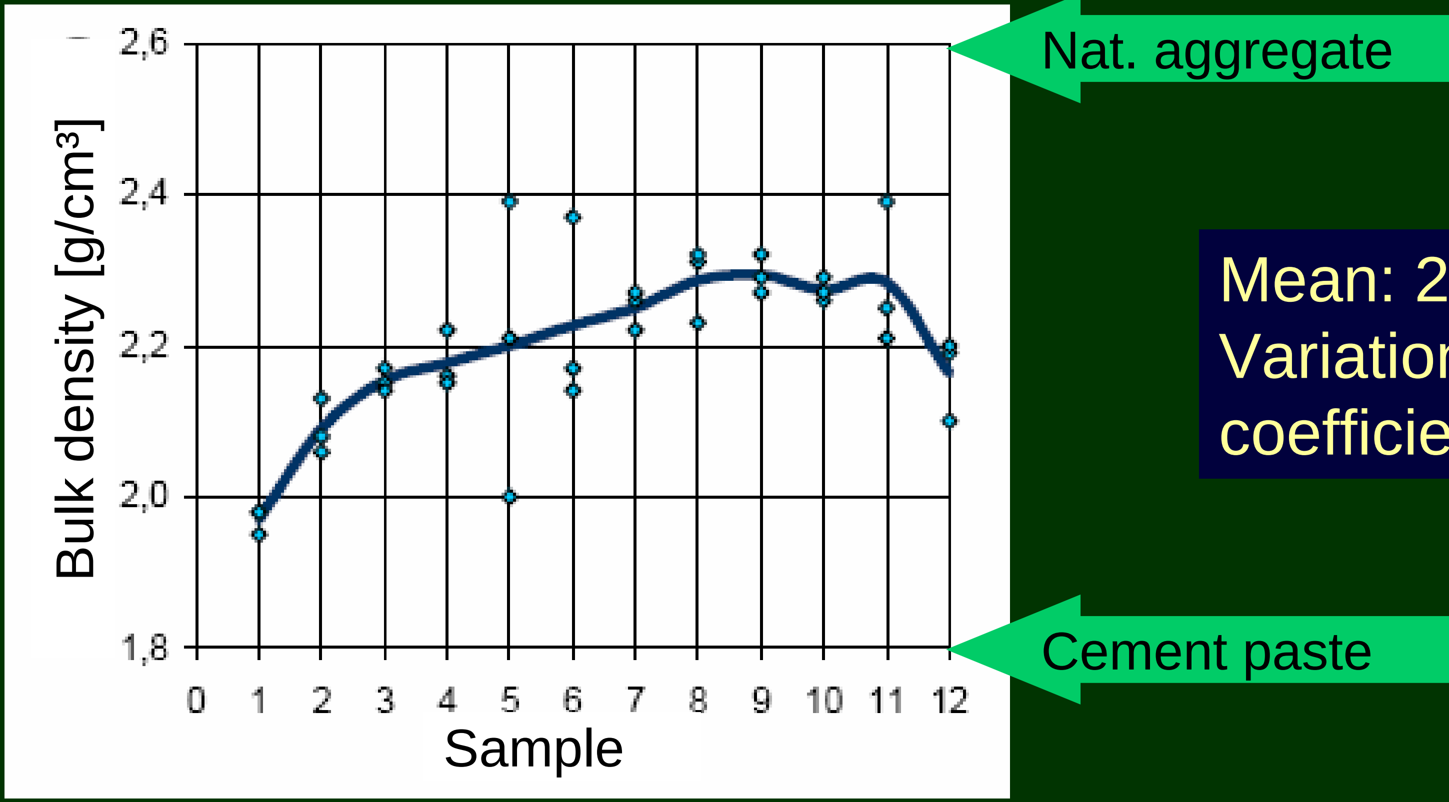
Composition of processed concrete from one recycling plant



Mean: 95.1 %
Variation coefficient: 3.1 %

Ref: SERGIO CIRELLI ANGULO 2005

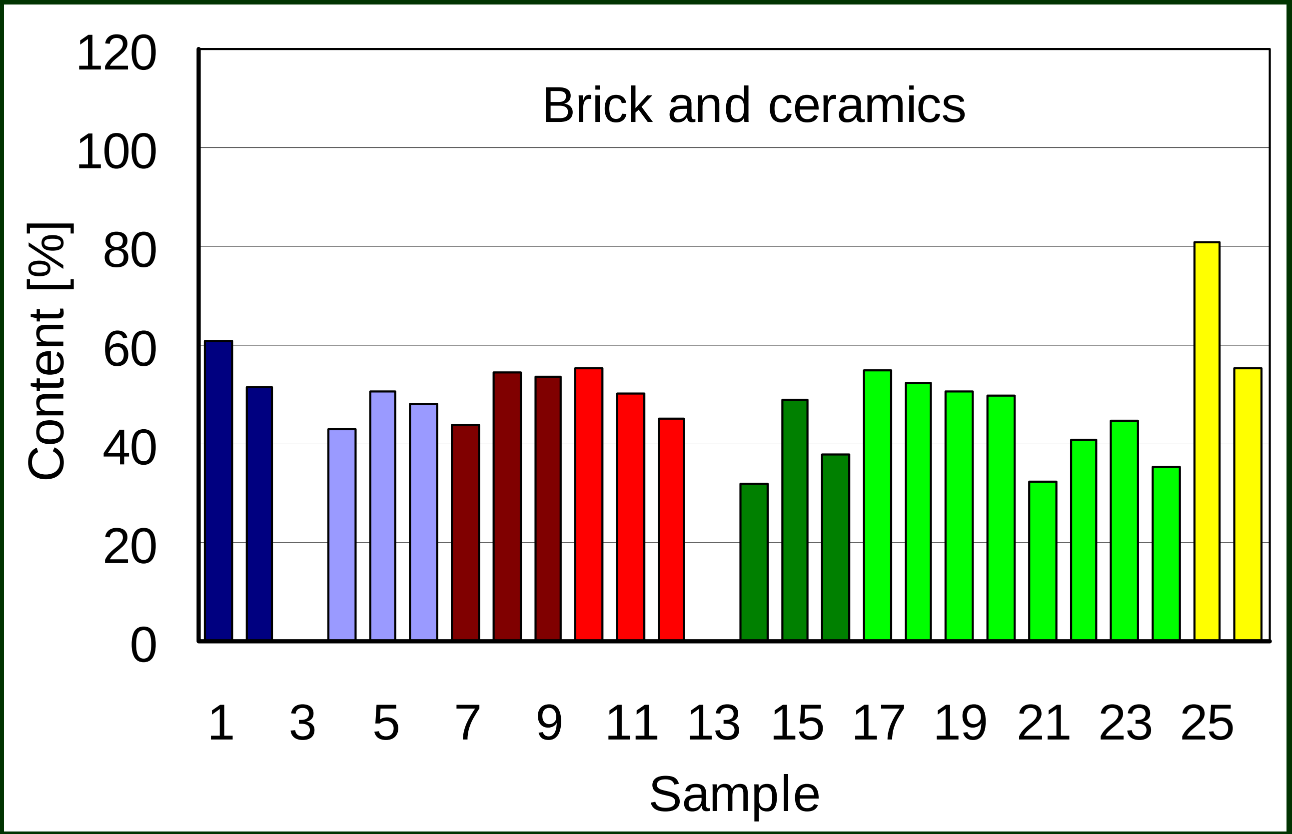
Bulk density of processed concrete from one recycling plant



Mean: 2.20 g/cm³
Variation coefficient: 4.4 %

Ref: SERGIO CIRELLI ANGULO 2005

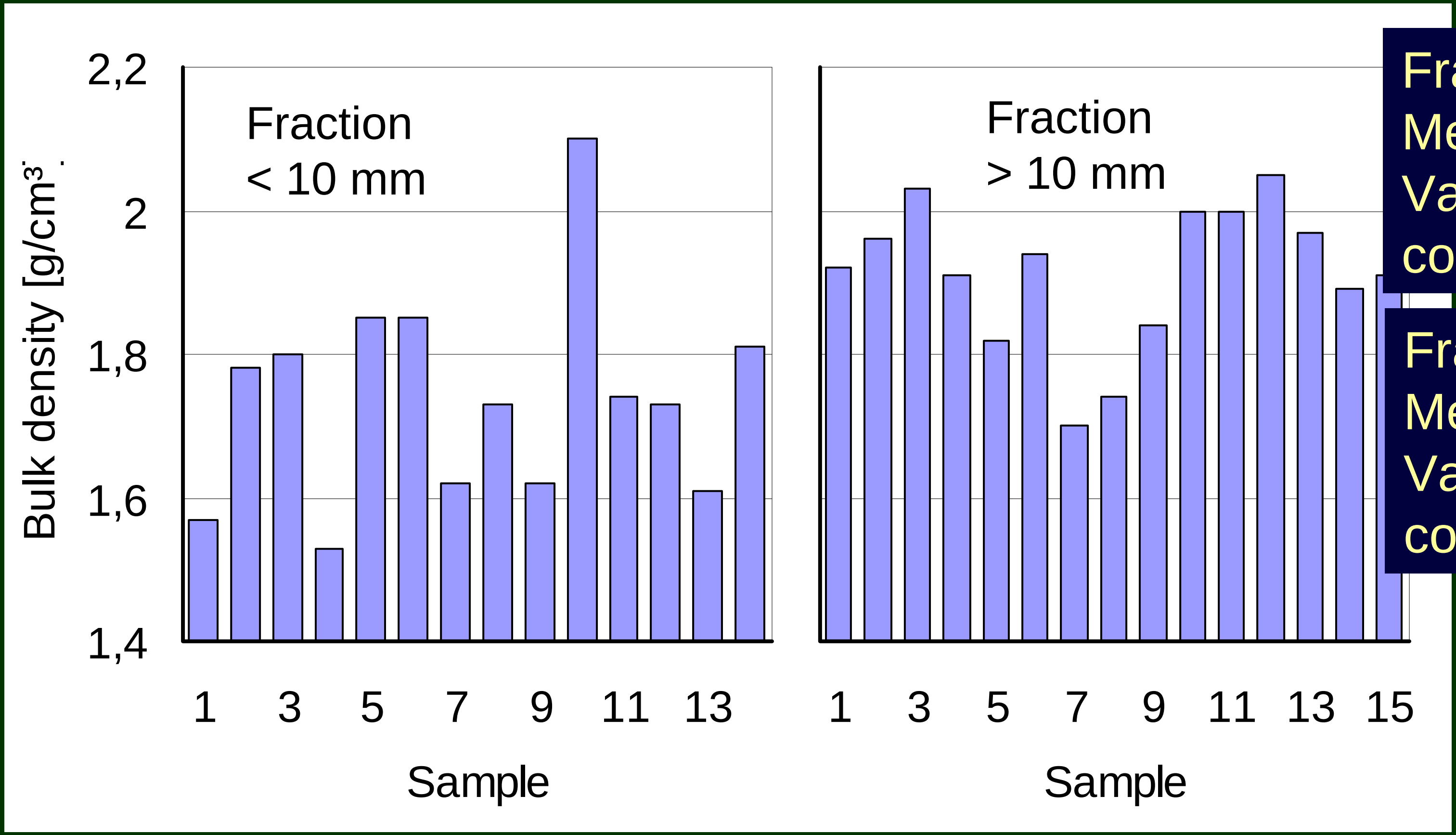
Composition of processed masonry from several recycling plants



Mean: 48.3 %
Variation coefficient: 21.3 %

Ref.: WINKLER 2001

Bulk density of processed masonry from several recycling plants



Fraction < 10 mm
Mean: 1.74 g/cm³
Variation coefficient: 8.5 %

Fraction > 10 mm
Mean: 1.91 g/cm³
Variation coefficient: 5.3 %

Ref.: WINKLER 2001

Conclusion: Considerable fluctuations in composition and density

Concrete CDW: Caused by composite nature of concrete more than by composition

Masonry CDW: Caused by composition

Consequences for reuse in closed loops

High-grade applications not realizable so far due to unstable quality of processed CDW

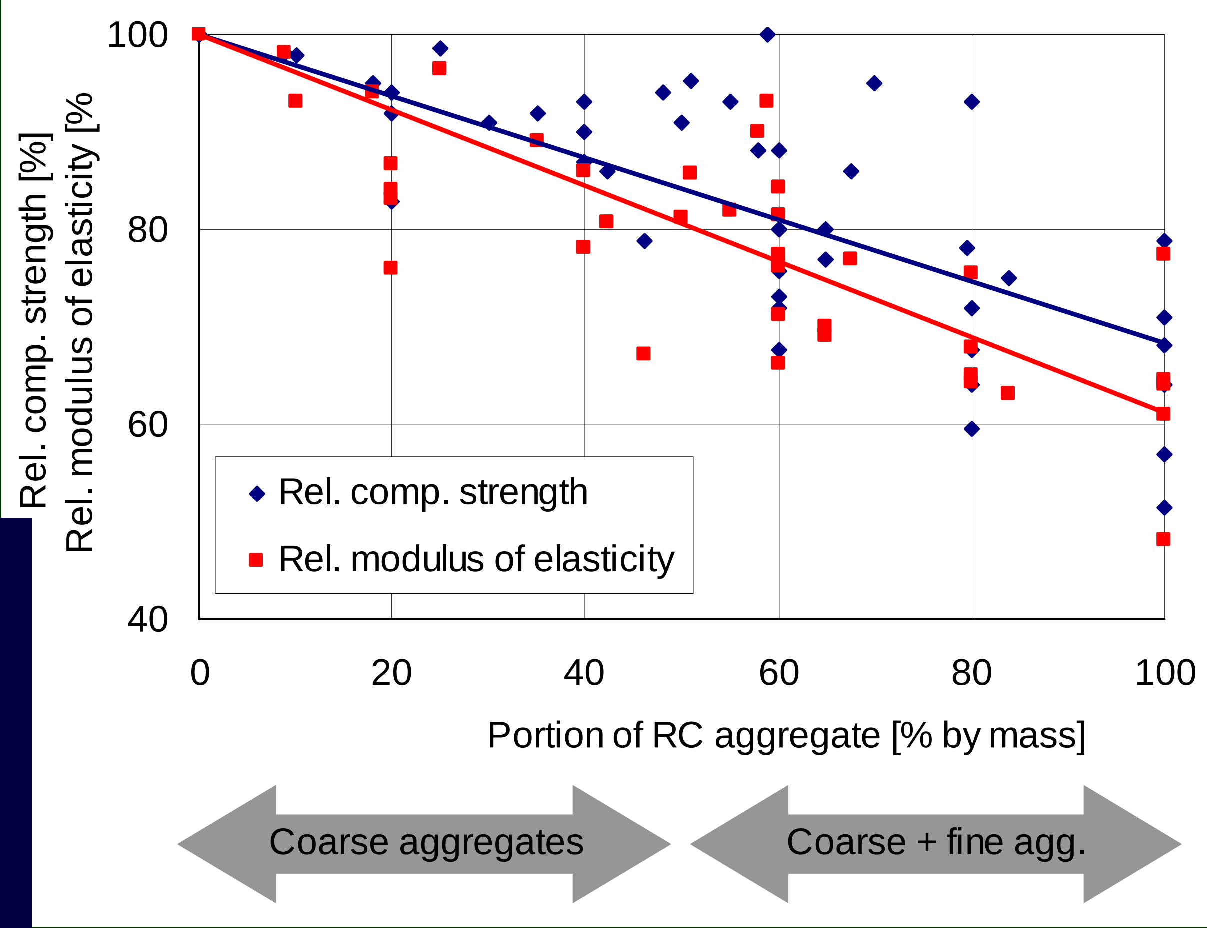
Technologies for quality improvement and homogenization have to be developed

Coarse recycled concrete aggregates: Composites of cement paste and natural aggregate


Consequences of the composite nature on properties of secondary concretes

- ⇨ Fresh concrete: Increase of water absorption and loss of workability caused by additional porosity of the adhered cement paste
- ⇨ Hardened concrete: Loss of compressive strength caused by increased porosity.
- ⇨ Hardened concrete: Loss of modulus of elasticity as a result of higher porosity <u>and</u> higher content of CSH phases.
- ⇨ Further effects on shrinkage, creep and durability.

Mechanical properties vs. portion of recycled aggregates



Replacement of coarse and fine aggregates

Δ Strength $\rightarrow$ 32 %

Δ E-modulus $\rightarrow$ 39 %

Replacement of coarse aggregates only

Δ Strength $\rightarrow$ 16 %

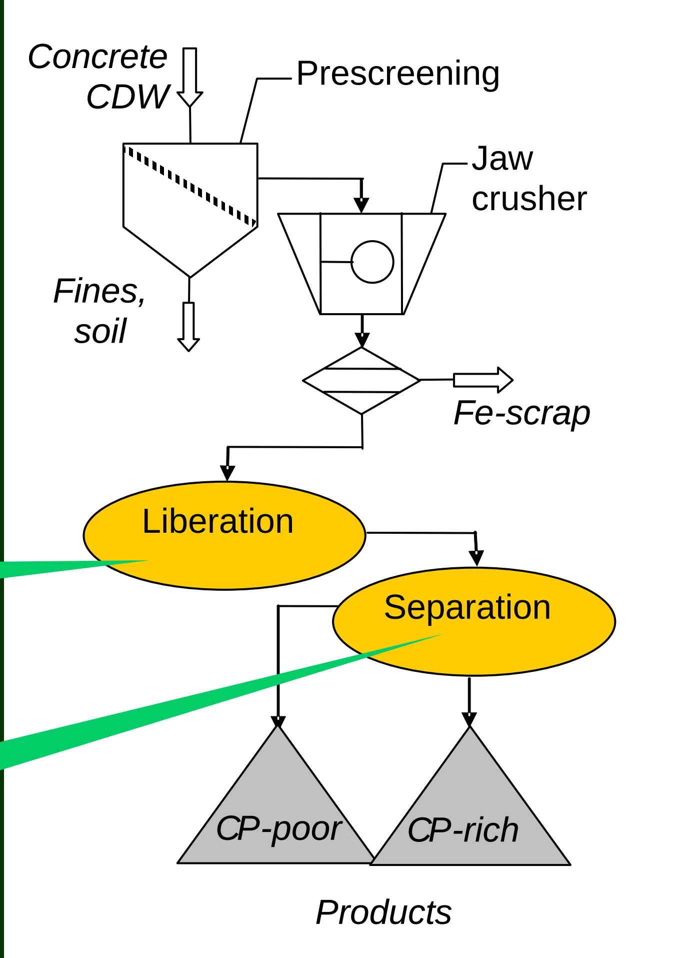
Δ E-modulus $\rightarrow$ 20 %

Consequences for quality improvement of coarse recycled aggregates

Generation of cement paste free aggregates with suitable techniques for liberation and separation

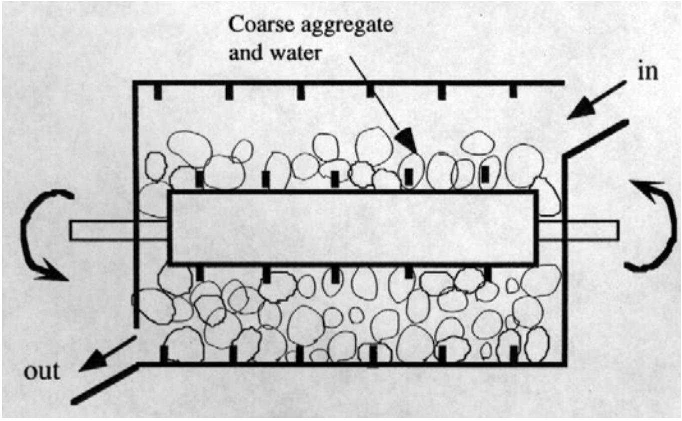
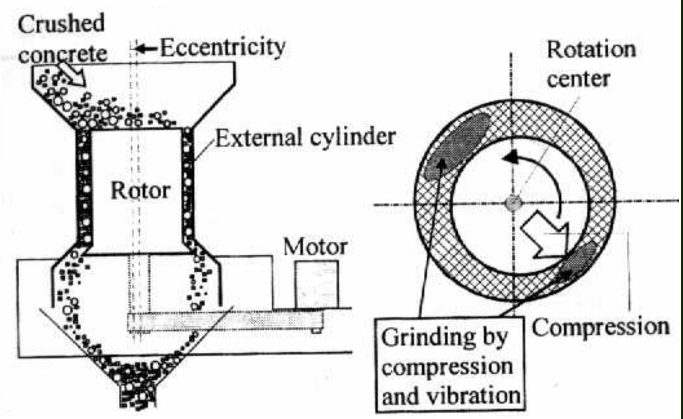
Mechanical or thermal liberation

Separation by particle size or density

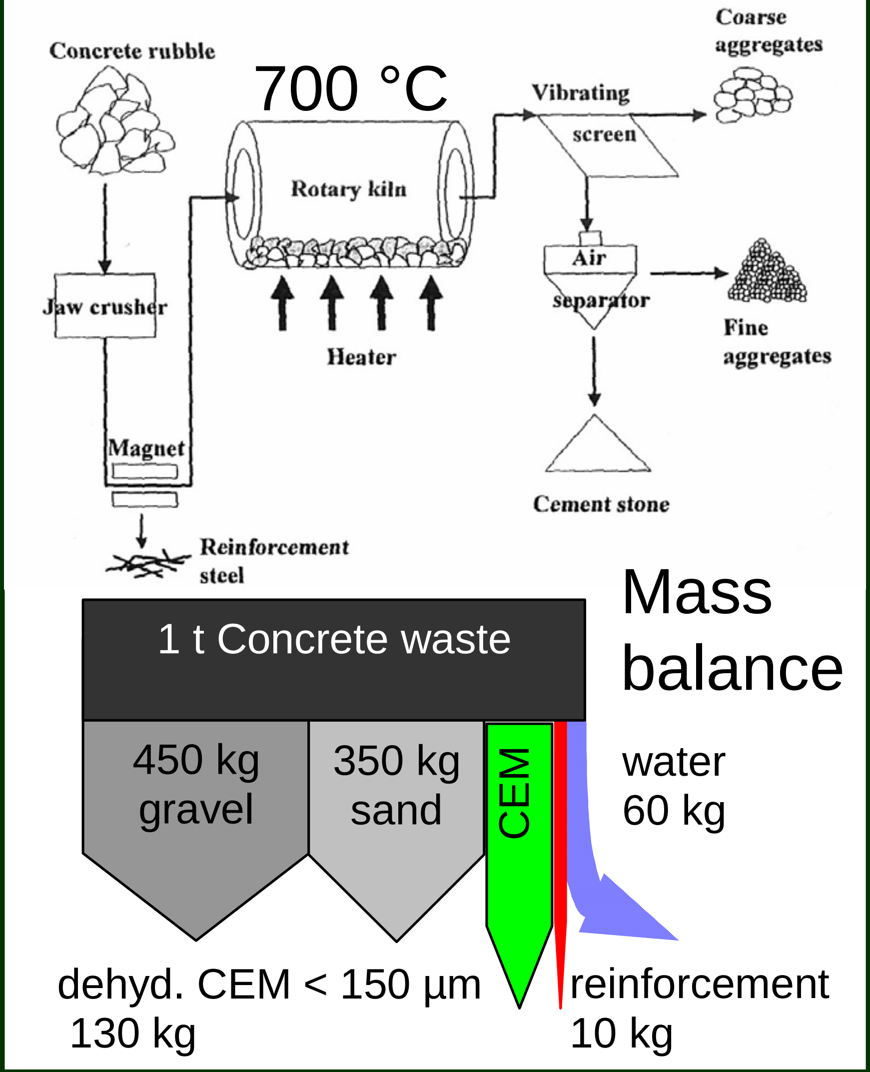


Removal of adhering cement paste by abrasion stress

External cylinder: Ø 720 mm; height 800 mm
Rotor: Ø 720 mm; height 800 mm; 500 U/min
Eccentricity: 11.7 mm

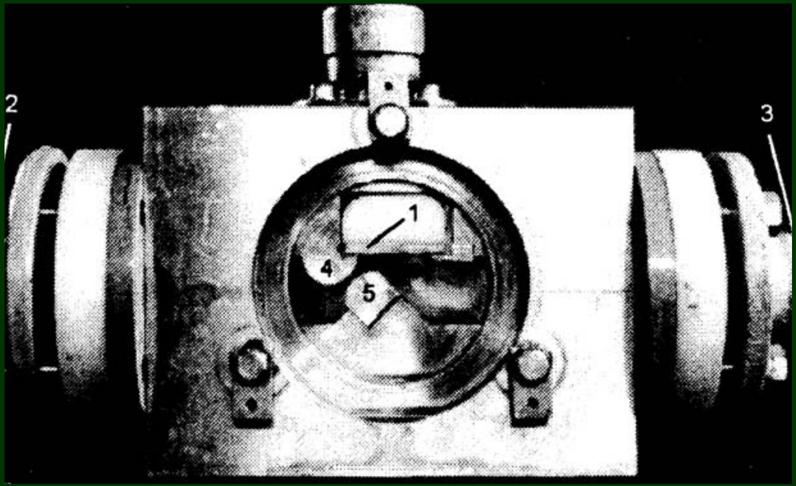
Reference	Kasai [1993]	Yanagibashi [2002]
Operating mode		
Material parameter		
Virgin aggregates	ρ = 2.62 g/cm³ WA → 0	ρ = 2.5...2.61 g/cm³ WA = 1.2...3.6 %
Secondary aggregates	ρ = 2.52 g/cm³ WA = 3.0 %	ρ = 2.4...2.53 g/cm³ WA = 1.8...5.4 %

Applying of thermal stress



Ref.: MULDER 2002

Applying of cavitation stress



Flow cavitation chamber with specimen (1)

Degree of separation between 46 und 90 %

Ref.: MOMBER 2004

Applying of high performance sonic impulses (HPSI)

Electrical energy

Disruptive electrical discharge under water

Shock wave
- Pressure amplitudes up to 100 MPa
- Rise time < 5 µs

Reflexions at interfaces of different density

Generation of pressure and tensile stresses

Failure at the interfaces

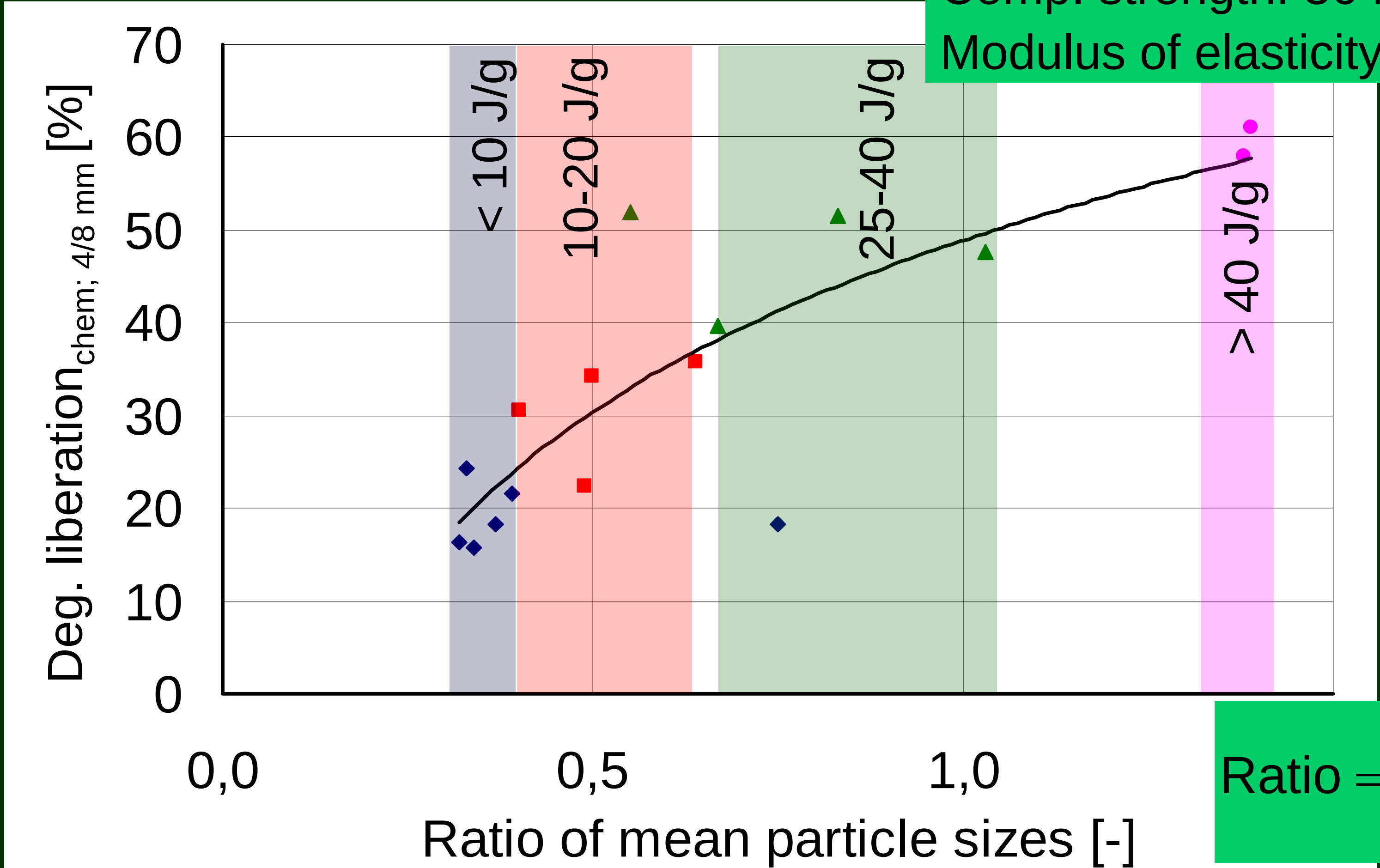
Ref.: LINSZ 2004

Degree of liberation versus ratio of size reduction

Concrete B 25: 300 kg/m³ CEM I 32,5 R + 180 kg/m³ water + 1902 kg/m³ quartz sand and gravel AB 16

Comp. strength: 36 N/mm²

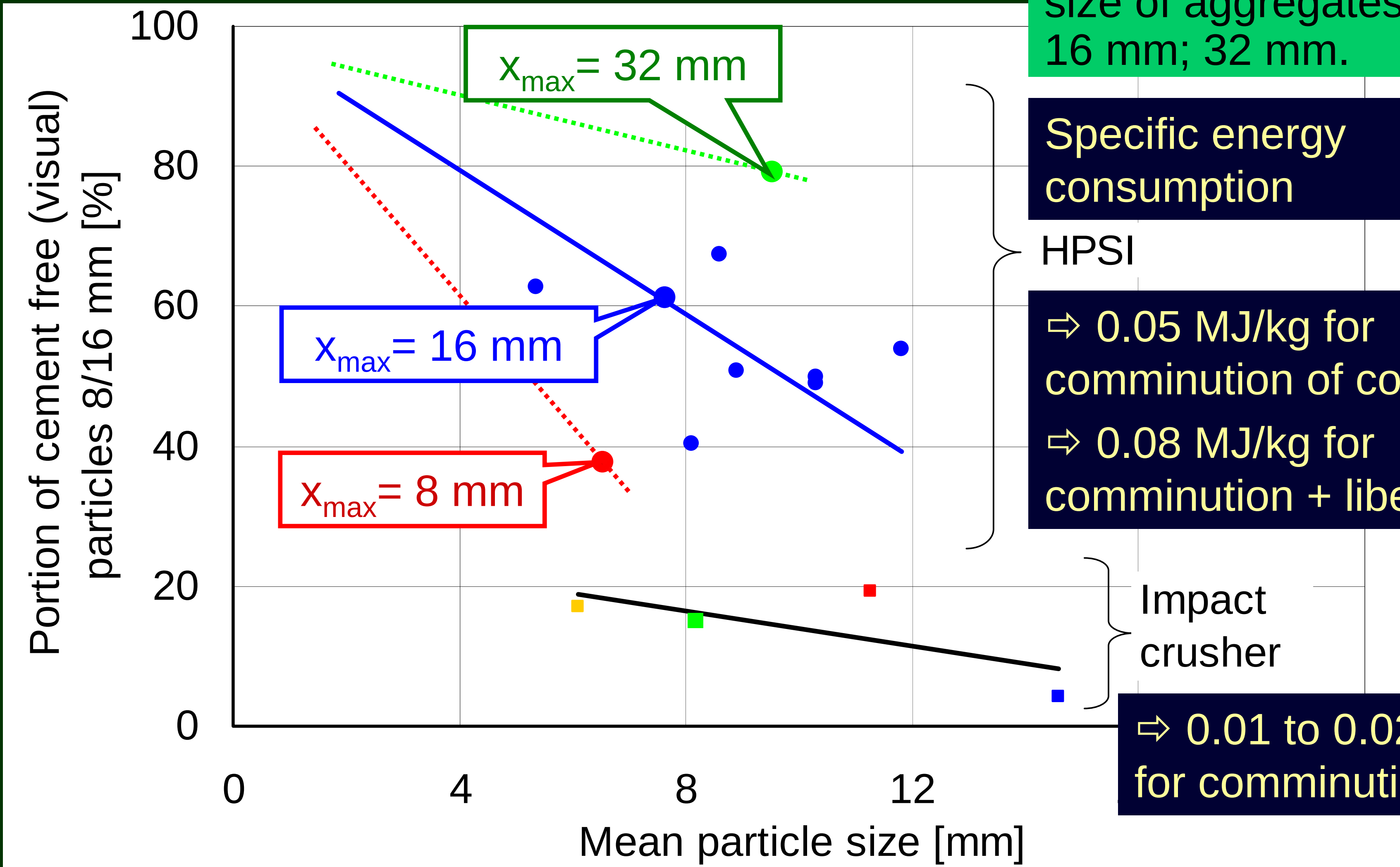
Modulus of elasticity: 33 kN/mm²



$$\text{Ratio} = \frac{x_{m,\text{ original aggregate}}}{x_{m,\text{ crushed product}}}$$

Degree of liberation after treatment in impact crusher or by HPSI

Concrete B 25 with varying maximum particle size of aggregates: 8 mm; 16 mm; 32 mm.



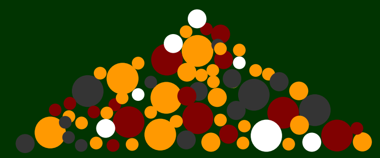
Specific energy consumption

HPSI:
- ⇨ 0.05 MJ/kg for comminution of concrete
- ⇨ 0.08 MJ/kg for comminution + liberation

Impact crusher:
- ⇨ 0.01 to 0.02 MJ/kg for comminution

Expanded granulates from masonry rubble

Masonry CDW as mixture of different materials



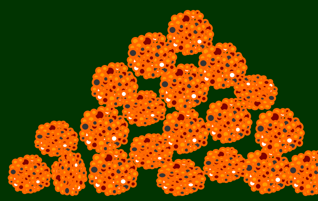
Crushing and grinding

Addition of SiC as expanding agent

Mixing and shapening

Thermal treatment

Lightweight aggregate



Raw materials

Masonry CDW 0/4 mm from a recycling plant as matrix material

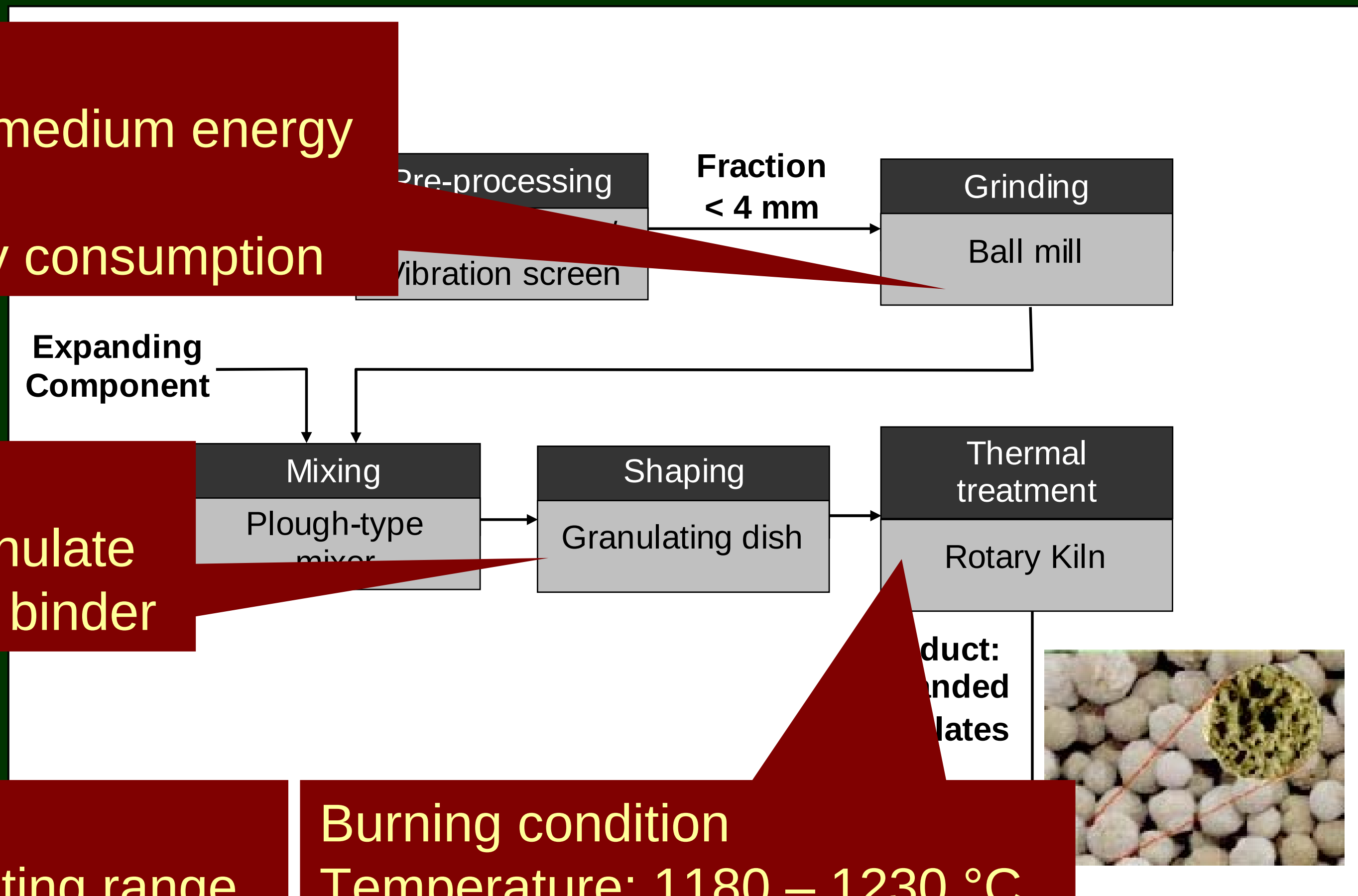
SiO_2	Al_2O_3	FM
[%]		
63,1	17,7	19,1

Aerated autoclaved concrete from AAC plant as additional material to increase the heterogeneity

SiO_2	Al_2O_3	FM
[%]		
53,0	4,4	42,6

Silicium carbid waste < 100 µm as expanding component

Manufacturing process



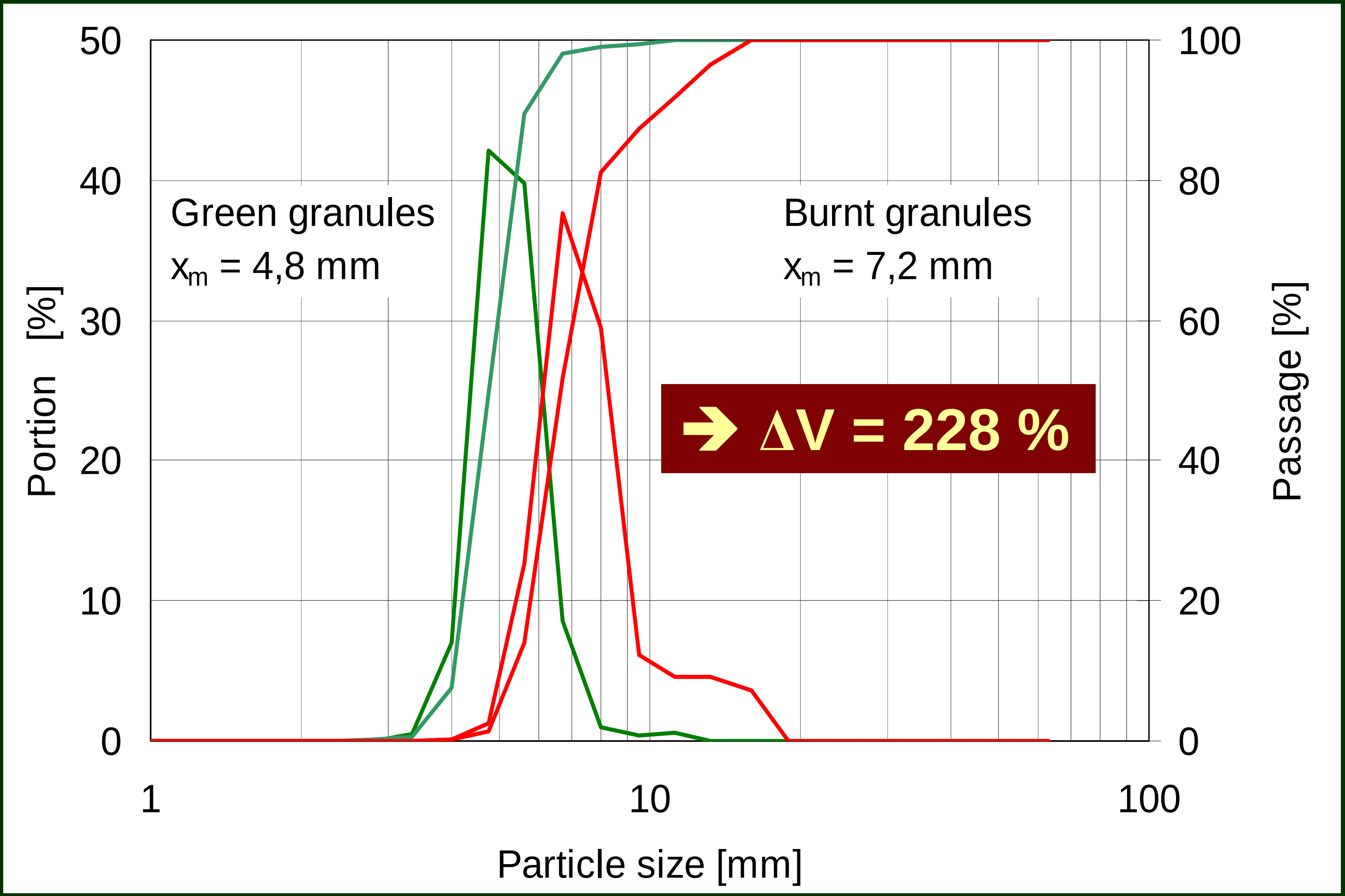
Grindability
Masonry CDW – medium energy consumption
AAC – low energy consumption

Shaping
Easily able to granulate without additional binder

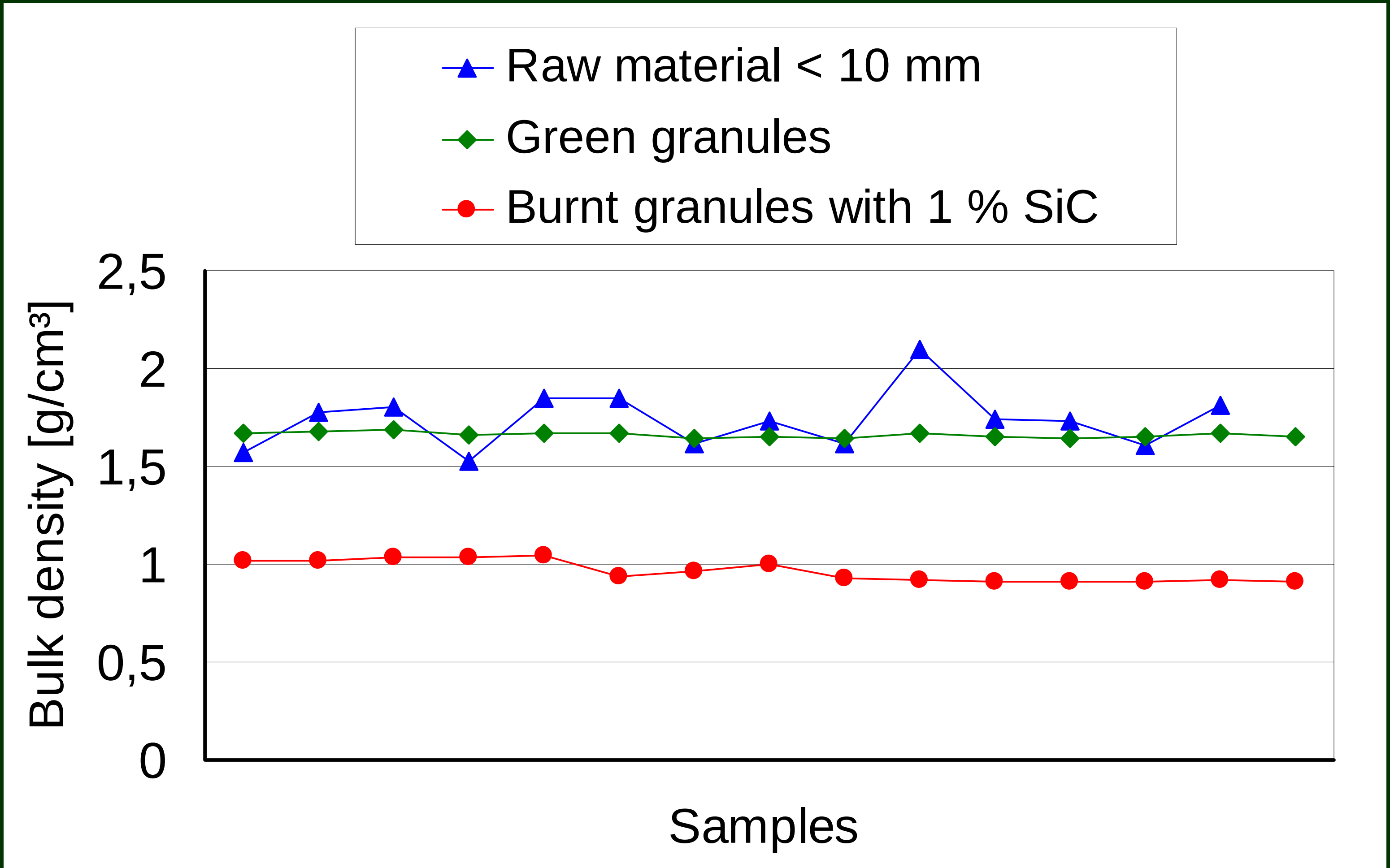
Influence of AAC
Shortening of melting range
Max. content of AAC: 50 %

Burning condition
Temperature: 1180 – 1230 °C
Residence time: about 20 min

Expanding process during the thermal treatment



Effect of the processing on homogeneity



First application tests

- Manufacturing of blocs and cubes in a precast concrete plant
- Volumetric substitution of the normally used expanded clay 4/8 mm by CDW aggregate 4/8 mm

	CDW aggregate	Expanded clay
Bulk density of concrete [kg/m³]	1130	870
Com. strength [N/mm²]	11,90	6,16
Thermal conductivity [W/mK]	0,35	0,24
Freeze-thaw resistance: E_{dyn} change [%]	- 2,6	- 67,9

1 Sustainable development in construction industry

2 Classification and properties of recycled construction materials from CDW

3 Closed loop of materials from concrete CDW

4 Utilization of masonry CDW as raw material

5 Summary and prospects

Summary

1. Construction and Demolition Waste is characterized by rather large variation range of the composition as well as the physical properties.
2. Main field of application of CDW: Unbounded systems like fills and embankments.
3. Reuse of concrete CDW as secondary aggregates requires incorporation of liberation techniques into the processing.
4. As advanced liberation technique the treatment by high performance sonic impulses results in clear quality improvement.

5. Reuse of masonry CDW in construction requires technologies which improve quality and homogeneity.

6. Own experiments show feasibility of masonry CDW as raw material for manufacturing of lightweight granulates.

7. Properties of the lightweight granulates are rather constant and at least equal to those of other mineral lightweight materials.

Further research must be aimed at

⇨ the scale up of both technologies,

⇨ examinations of product quality and uniformity and

⇨ comparative studies about the energy demand.

Thank you for your attention !

Homepage: www.uni-weimar.de/Bauing/aufber/