- SEPARATION TECHNIQUES FOR CDW – BEST PRACTICE

- DEVELOPMENT OF A SEPARATION PROCESS FOR GYPSUM-CONTAMINATED CONCRETE AGGREGATES

- ALTERNATIVE SEPARATION TECHNIQUE FOR CDW – OPTOELECTRONIC SEPERATION

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Overview about separation techniques

dry processes	wet processes
separation by density	separation by density
– air classifier	– upcurrent sorter
– screening/wind sifting combina-tions	– thin film separation
– air jig	– float-and sink-separation
	– water jig
separation by magnetic or electric properties	separartion by wettability- - surfa-ce properties
– macnetic separation	– flotation
– separation by el. conductivity	
separation by optical properties	
– optoelectronic separation – separation by color	
– hand-picking	
– separation by particle shape or size	

Sorting: separation of a material mixture according to type of material using physical characteristics

Distinction of the sorting process
- according to the used features
- in dry and wet processes
- to the task in the process sequence

In recycling plants is the sorting
- the removal of foreign materials
- the separation of the components

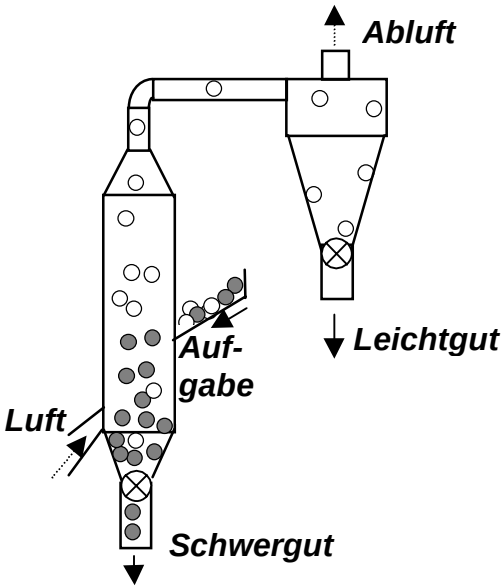
Sorting cases are almost exclusively found in stationäry recycling plants.

- SEPARATION TECHNIQUES FOR CDW – BEST PRACTICE

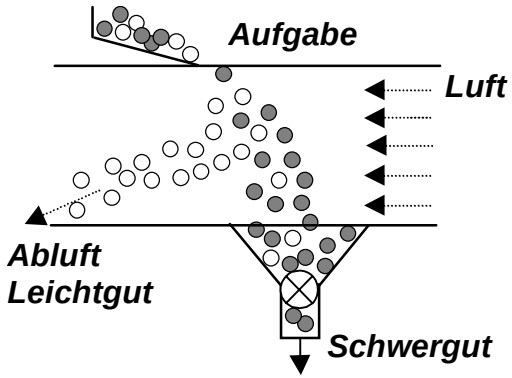
dry processes

Techniques for dry separation by density

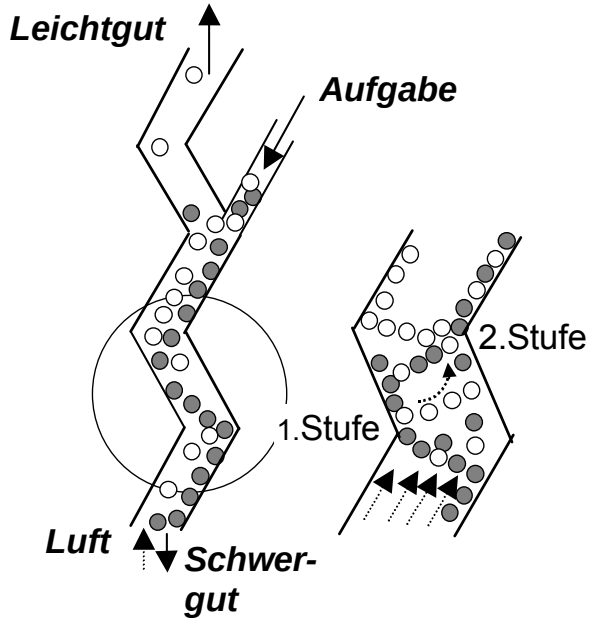
vertical air classifier



horizontal air classifier



zigzag air classifier

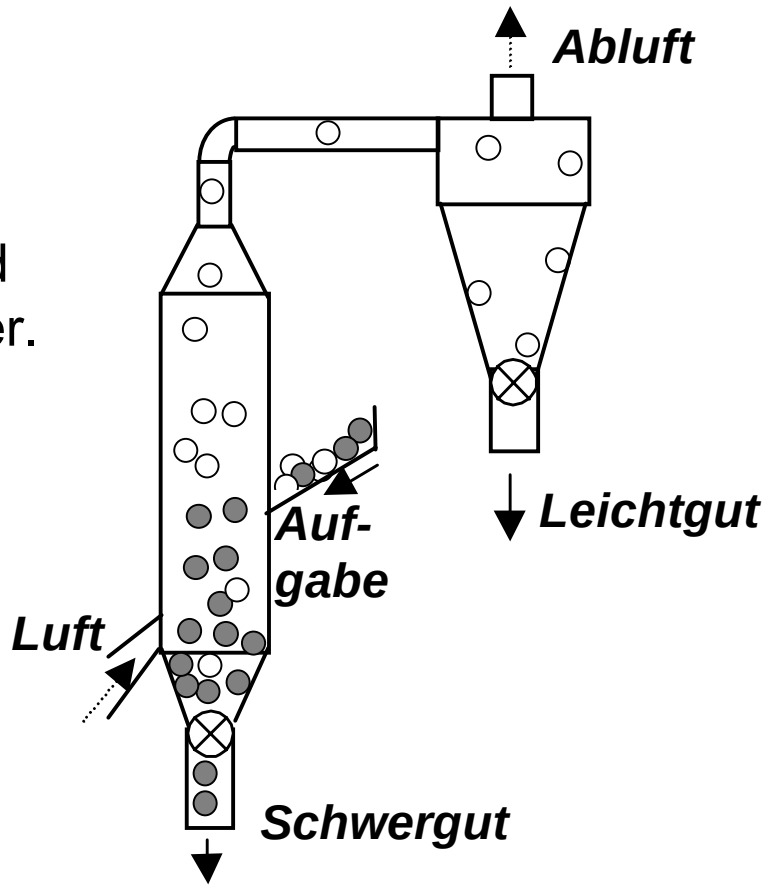


Vertical air classifier

Operation

In the air classification the fraction is given from the side in the process space. The separation is effected by the upward flow of air.

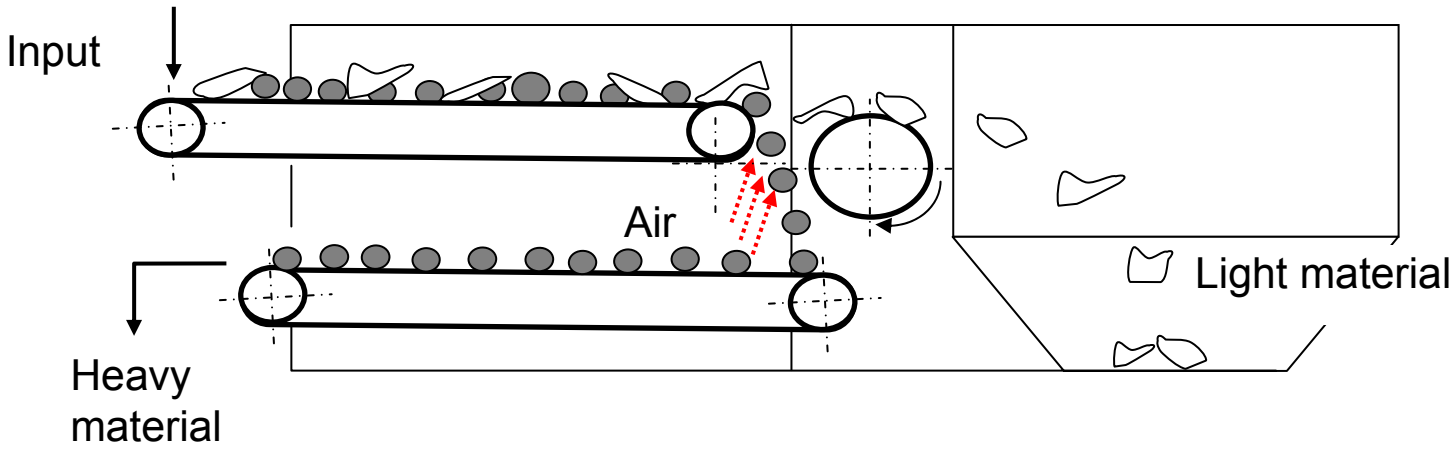
The light materials, for example wood or plastic parts are deposited in a filter.



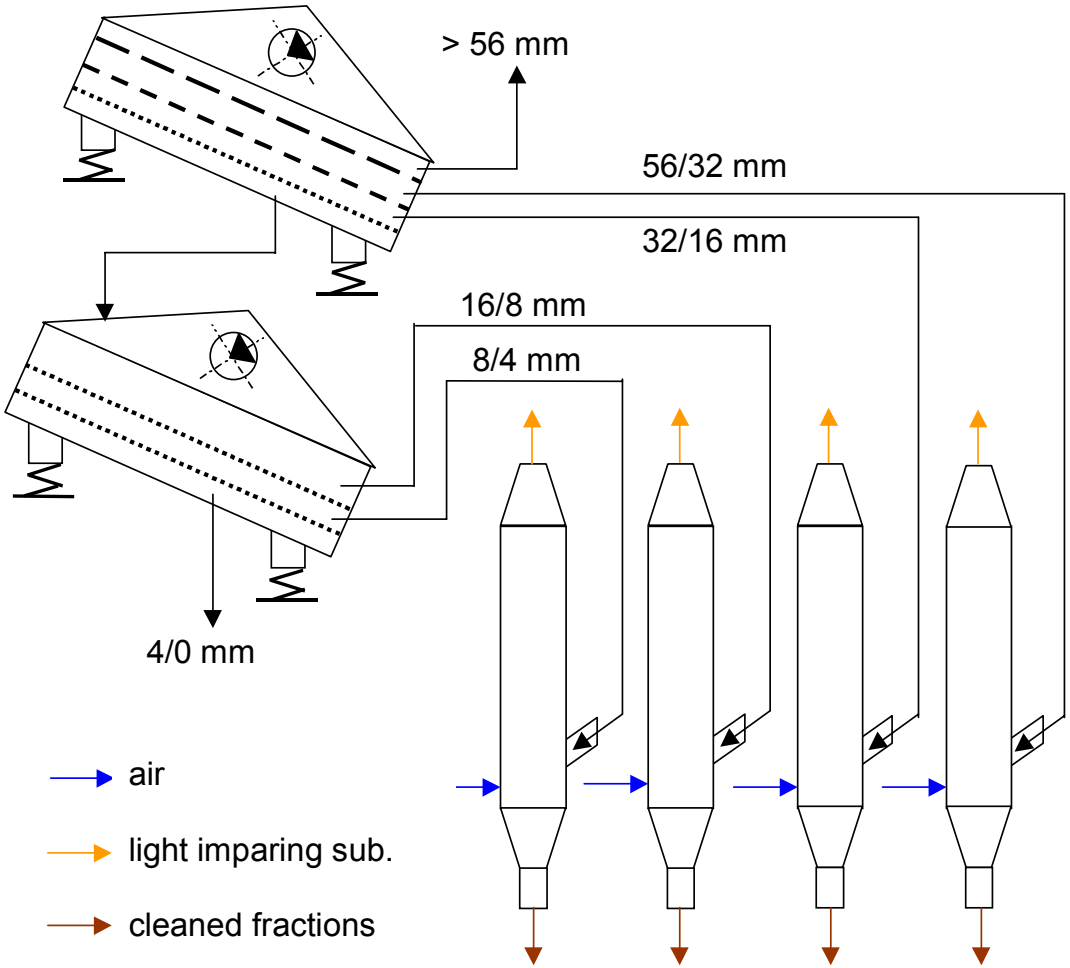
Air classifier combined with conveyor belt

Operation

The material is transported along a wide, horizontal conveyor belt to separation of the particles. At the discharge edge, the material flows through a directed air flow from a slot. The light material is carried along by the air stream and by support from the rotating drum transported into the expansion space. The heavy is unaffected by the air stream on the discharge conveyor and is transported away.



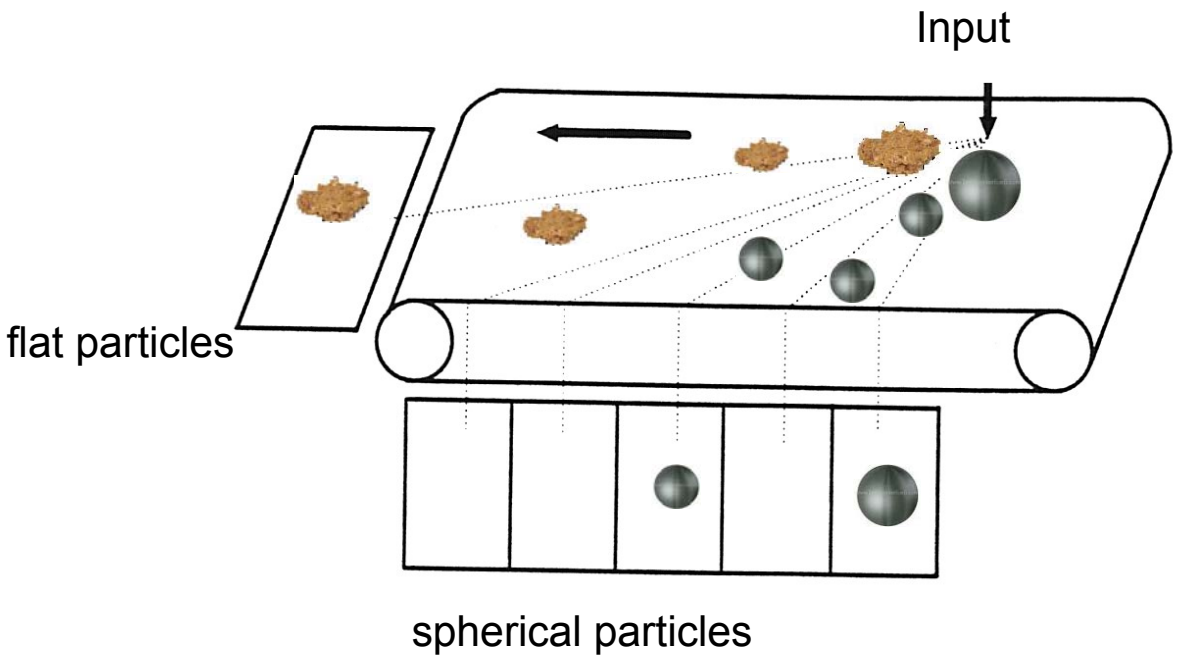
Combination of screening/air classifying in CDW recycling



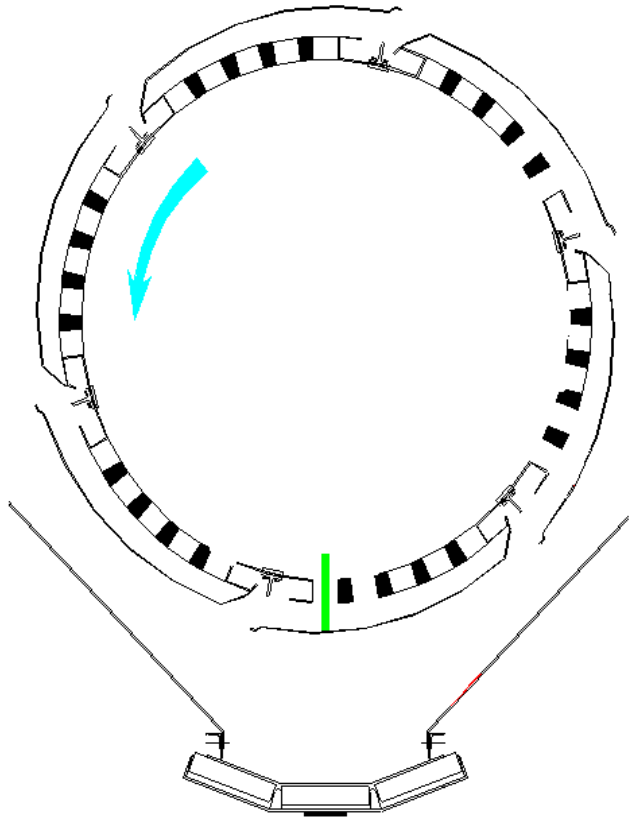
Kellerwessel 1993

Techniques for dry separation by particle shape

? jerking table ?



3D-Sorting drum



Quelle: Jarno Busschers
Busschers Staalwerken B.V., NL

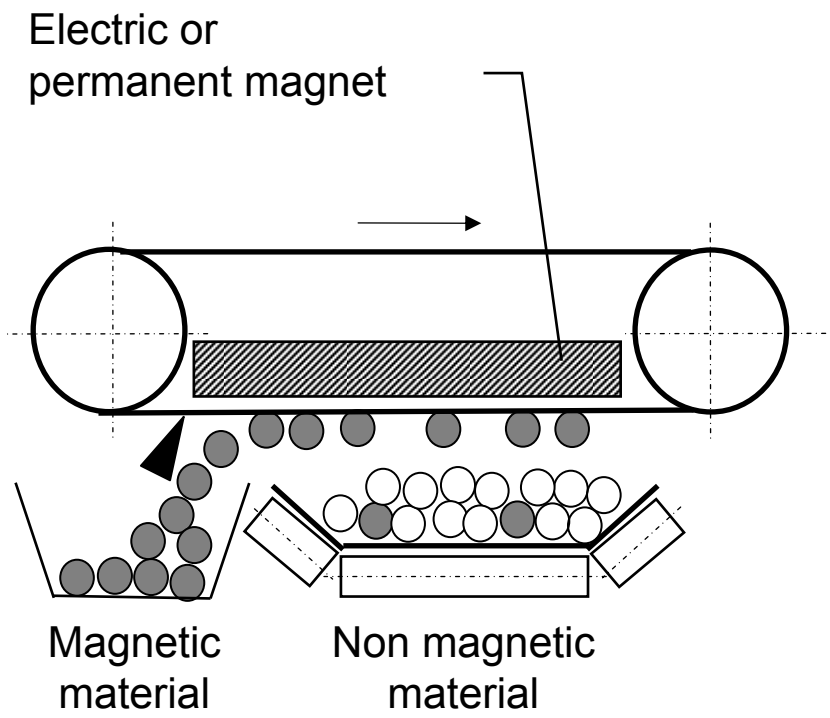
3D-Sorting drum

Quelle: Jarno Busschers
Busschers Staalwerken B.V., NL

Techniques for dry separation by magnetic or electric proberties

Over band magnetic separator

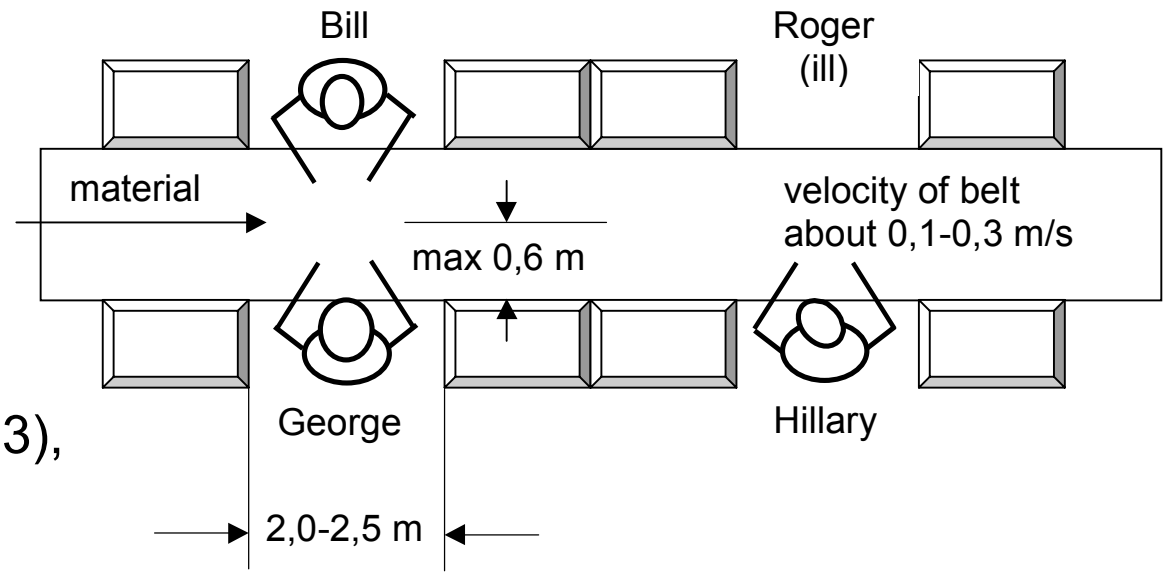
Operation
A conveyor belt with magnets, which usually is perpendicular to the direction, remove coarse magnetic components out of the materials.



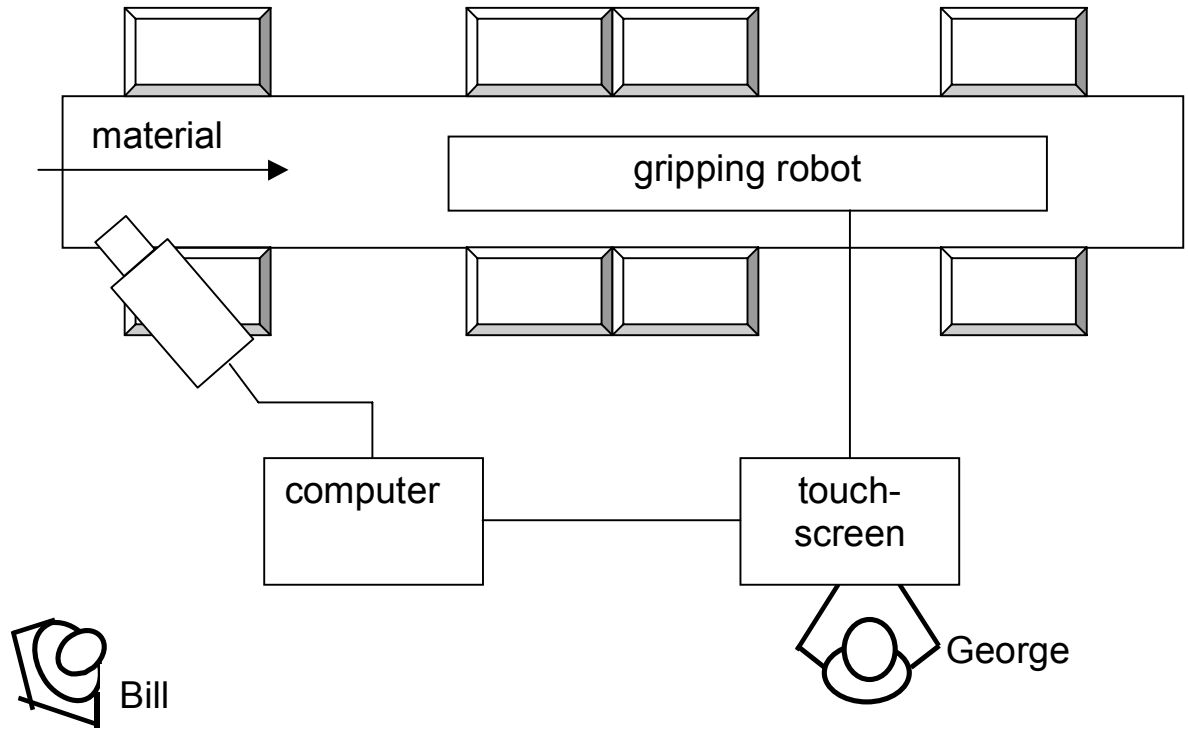
Techniques for dry separation by optical properties

Picking belt

Operation
8 light materials can be picked up from the belt for instance:
plastic (1),
polystyrene (2),
empty boxes and buckets (3),
paper (4),
cardboard (5),
wood (6),
glass and bottels (7),
mineralic insulating material (8)



Picking with sorting robot



- SEPARATION TECHNIQUES FOR CDW – BEST PRACTICE

wet processes

Parameter for wet processing

1. Density for separation

- Upcurrent Sorter ≈ 1400 kg/m³
- Thin-film Separation ≈ 1400 kg/m³
- Water Jig

$$q = \frac{\rho_H - \rho_{Fl}}{\rho_L - \rho_{Fl}}$$

ρ_H : density of heavy component

ρ_L : density of ligh component

ρ_{Fl} : density of fluid

- sharpness of division increases with increasing q, materials with finer particles can be treated
- $q < 1{,}5$ division not possible
- $q > 1{,}5$ division for particle size > 2 mm possible

Parameter for wet processing

2. Quality of separation

- content of impairing substances after separation < 1 mass-%

- water soluble substances and fine particles < 0.063 µm can also be reduced by wet separation

- water content of output after dewatering about 10 mass-%

Parameter for wet processing

3. Comparison

- water circuit and waste water treatment necessary, sludge often contains hazardous components

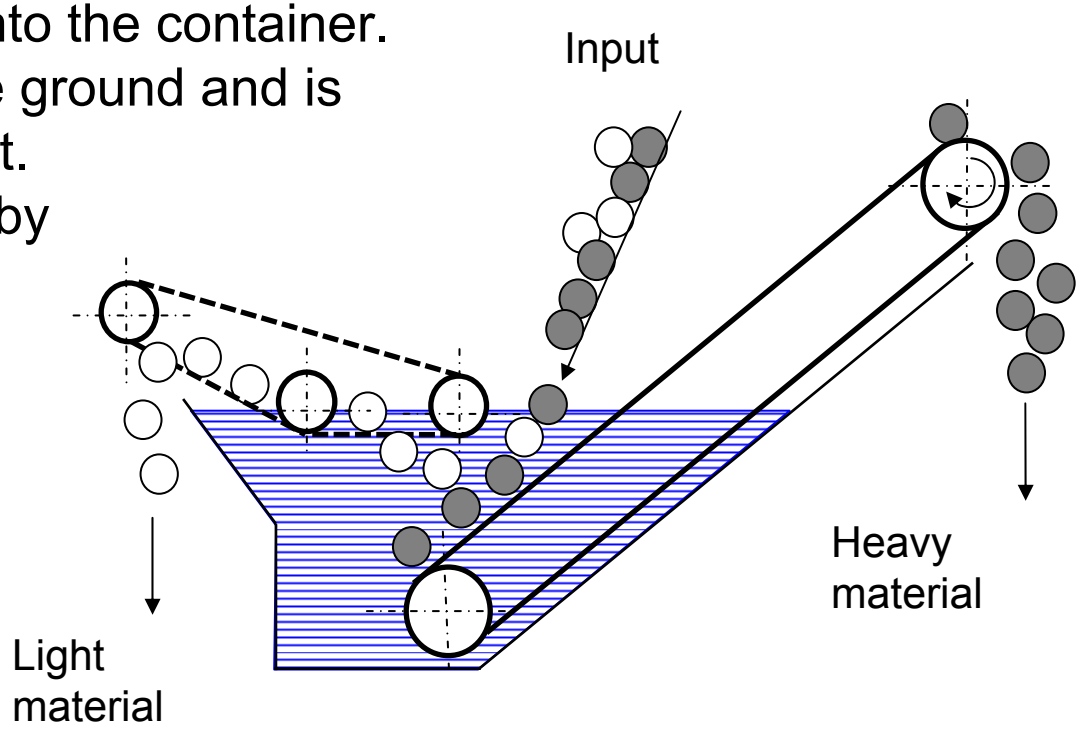
- in stationary facilities possible

	Capacity [t/h]	Particle size [mm]	Amount of water [m^3/h]
Upcurrent sorter	50 bis 150	4/32	50 bis 100
Thin-film separator	120 bis 180	4/80	250
Water jig (pulsation by air pressure)	120	0/32	290
Water jig (pulsation by vibration)	160	0/40	ca. 100

Techniques for wet separation by density

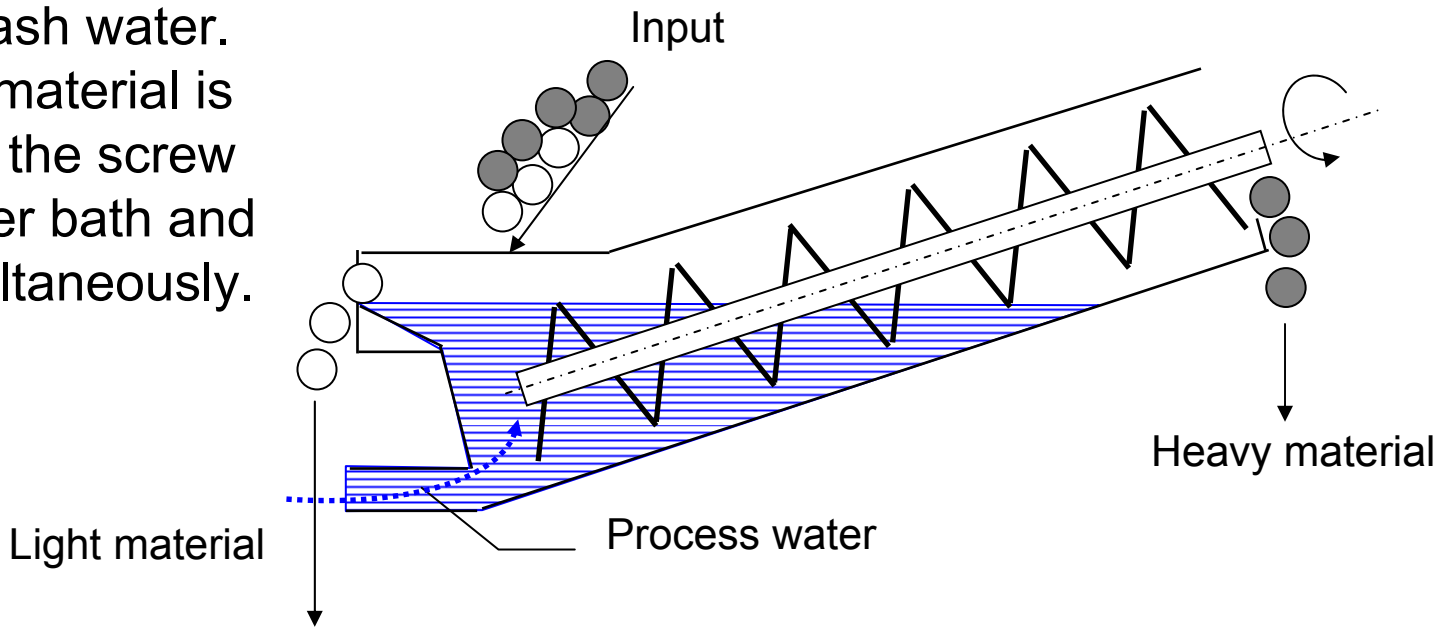
Float-and-sink separator: light product separator

Operation
The material to be cut is fed into the container.
The heavy material falls to the ground and is discharged via a conveyor belt.
The light material is removed by a separate conveyor belt.



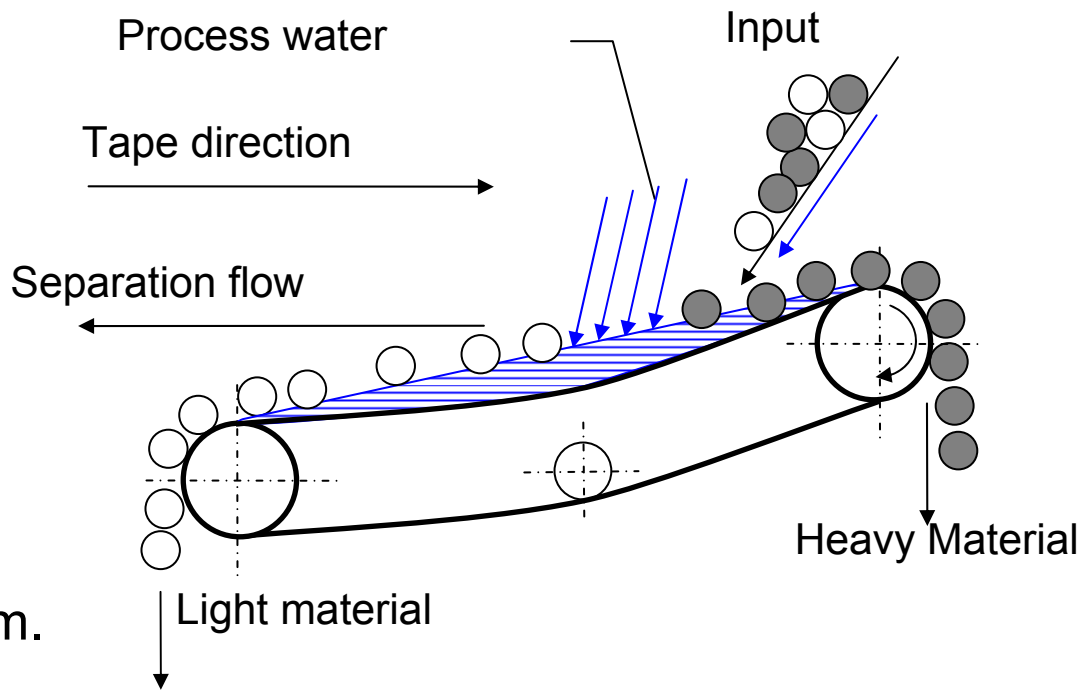
Screw-type upcurrent sorter

Operation
The material to be cut is introduced at the end of the screw in the water tank.
The screw mixes the material and breaks it up.
The contaminants are transported by flowing wash water.
The purified material is conveyed by the screw from the water bath and drained simultaneously.



Thin film separation:aquamator

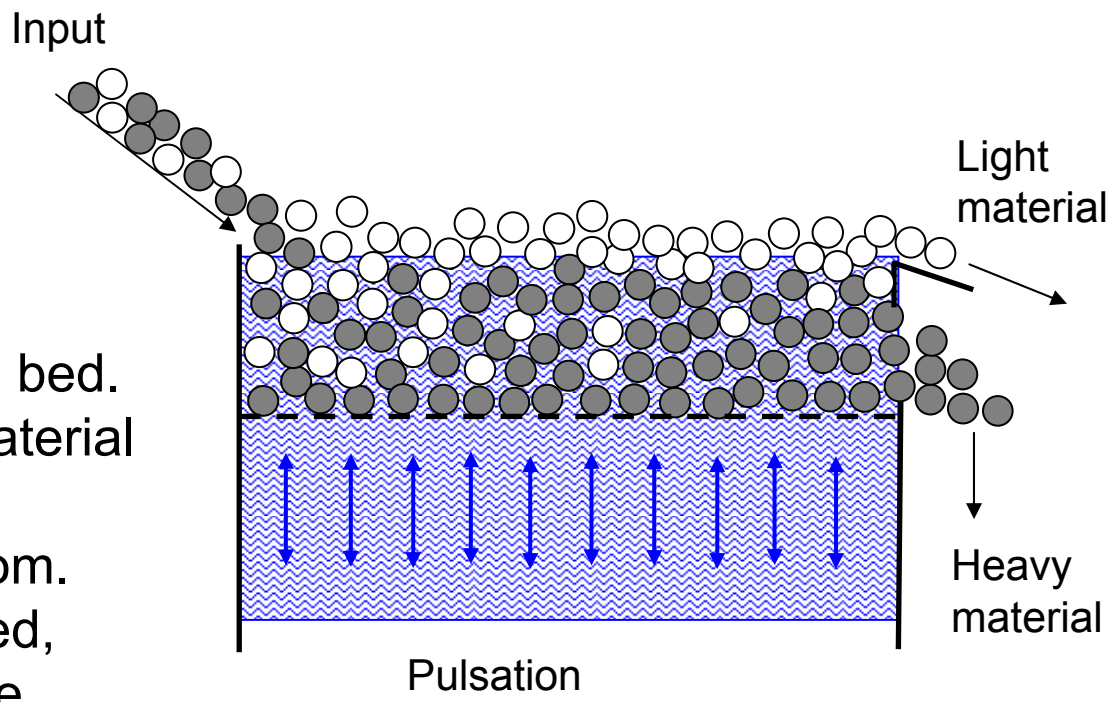
Operation
The Aquamator consists of a conveyor belt with hutch.
The material to be cut,
which is already mixed
with water is placed opposite
to the tape direction.
The separation flow is
generated by water jets.
Impurities are removed by
the separation flow.
The purified material is
discharged with the tape
drive located on a higher drum.



Pulsator jig

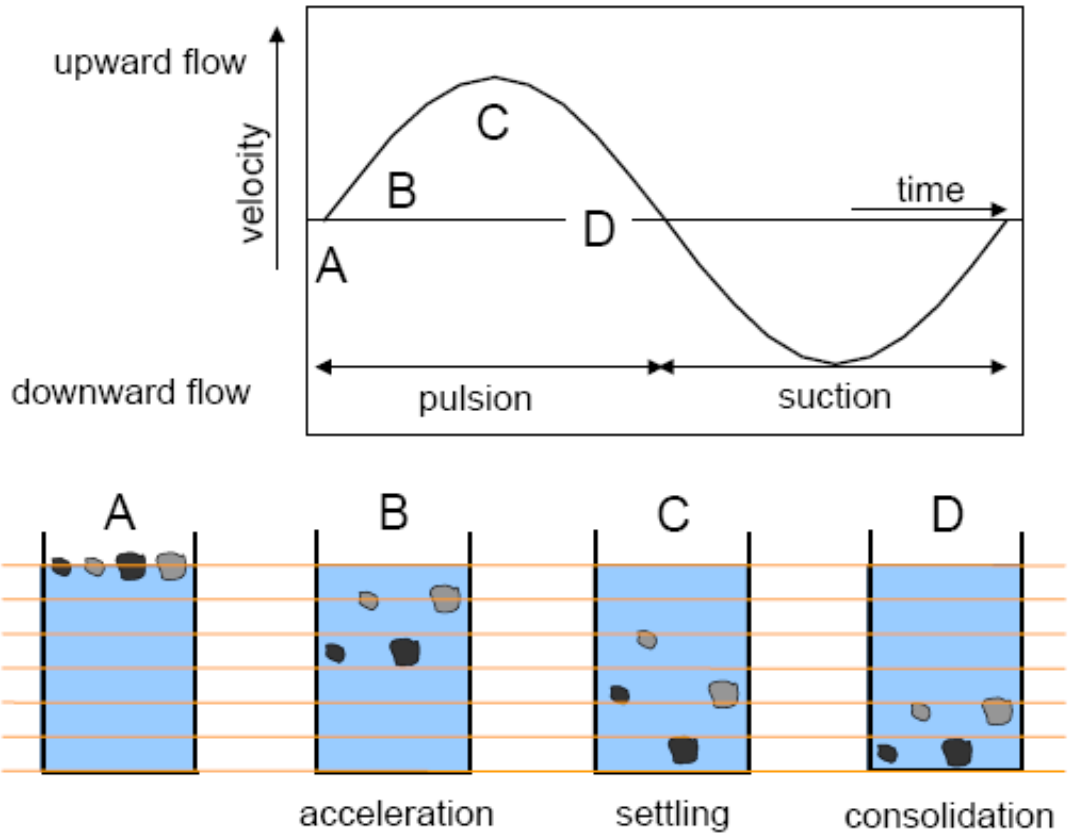
Operation

In a layer from material, the heavy grains separate from the lightweight grains, as they are lifted up by an upward pulsating fluid flow.
A stratification according to density takes place.
The material to be cut is conveyed through the jig bed.
At the end of the jig bed material with higher density is concentrated at the bottom.
As fluid mainly water is used, but this is influenced by fine materials in its density.



Pulsator jig

Phenomena during an idealised jigging process



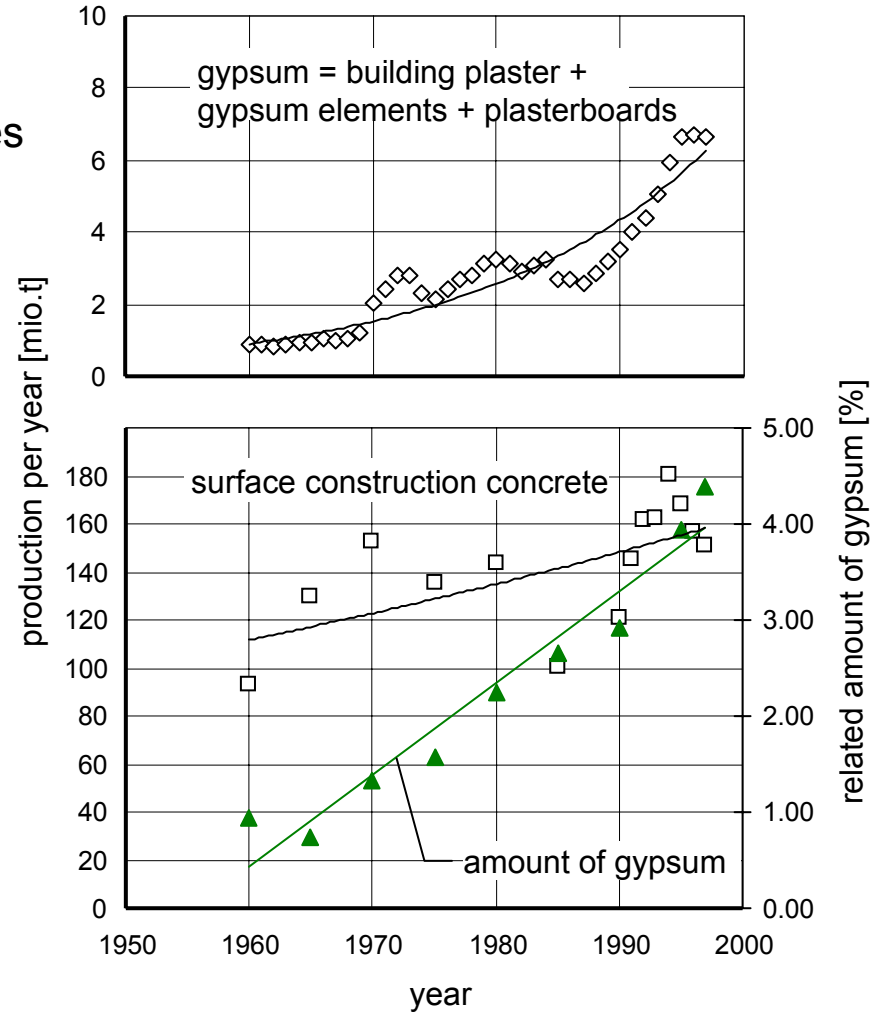
Pulsator jig for separation gypsum from concret aggregates

- DEVELOPMENT OF A SEPARATION PROCESS FOR GYPSUM-CONTAMINATED CONCRETE AGGREGATES

Initial situation

Motivation

- Use of gypsum building materials in all types of buildings increases
- Selective demolition does not take place because of either economic reasons or technical reasons
- Recycled aggregates containing gypsum can not be used



Initial situation

- Objective of the research project: Separation of the gypsum from the rubble of demolished apartments of precast concrete

  - Example for a building made of precast concrete slabs containing gypsum in bathroom element and in floors
  - Composition of the demolished material
    - calculation:

      Gypsum content in building materials:

      - 3.1 m-% from the floor

      - 6.6 m-% floor + bathroom element [Mettke, A.; et al..: Technical University Cottbus, Cottbus 2008]
    - experimental:

	average	standard deviation	variation coefficient	min	max
	[mass-%]		[%]	[mass-%]	
concrete and gravel	**93.75**	1.70	1.81	90.49	95.39
brick	**2.85**	1.59	55.73	1.20	6.18
gypsum	**2.73**	1.11	40.52	**1.80**	**5.35**
foreign materials	**0.65**	0.21	31.63	0.36	0.96

Initial situation

- Effect of the gypsum in unbound layers and in concrete
  - Heaving, expansion and strain softening due to:
    - formation from ettringite - $3\ CaO \cdot Al_2O_3 \cdot 3\ CaSO_4 \cdot 32\ H_2O$
    - formation from thaumasit - $CaSiO_3 \cdot CaCO_3 \cdot CaSO_4 \cdot 16\ H_2O$
  - Leach out of sulfate and contamination of the ground and the ground water
- Requirements on C&D aggregates

	composition	leachable sulfate
DIN 4226-100 (Type 1: concrete aggregates)	gypsum < 0.2 M-%	< 0.8 M-%
TL Gestein-StB	group „mineral lightweight materials, mineral wool“ < 1.0 M-%	no requirements
LAGA	no requirements	600 mg/l in eluate

Initial situation

- Consequence:

  In current building regulation (DIN 4226-100, TL-Gestein StB, LAGA) the use of recycled aggregates made of CDW from apartment buildings without separation of gypsum is not allowed.

- Intention:

  Development of a separation process for gypsum-contaminated concrete aggregates based on a modification of the jigging technology

Why a modification of the jigging technology?

Initial situation

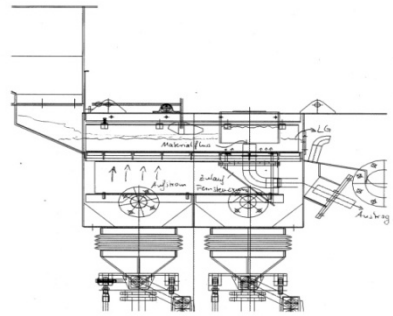
- Challenge for the jigging technology:
  Small differences of the densities of concrete and gypsum

Quotient of bulk density for evaluation the separation of concrete and gypsum					
	bulk density	bulk density	quotient of separation		
	OD	SSD[1]		OD	SSD
	[g/cm³]	[g/cm³]			
gypsum from bath-room element	1.55	**1.88**	concrete A – gyp. bathroom	2.60	1.70
gypsum from floor	1.90	**2.08**	concrete A – gypsum from floor	1.59	1.39
concrete A	2.43	**2.50**	precast concrete - gypsum bathroom	2.25	1.57
precast concrete	2.24	**2.38**	precast concrete - gypsum from floor	1.38	1.28
[1]: calculated by full water impregnation					

q < 1.5 separation by jigging is not possible

Development / Implementation

- Development, construction and test of the modified jigging machine
  - Development of jigging technology (experimental device „Triple A“)



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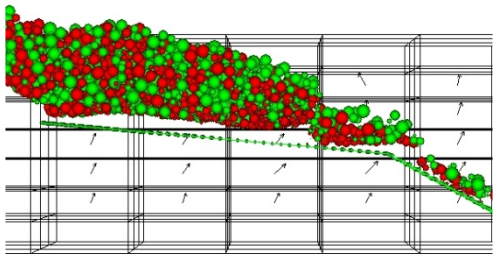
  - Process simulation by Software Particle Flow Code (PFC)



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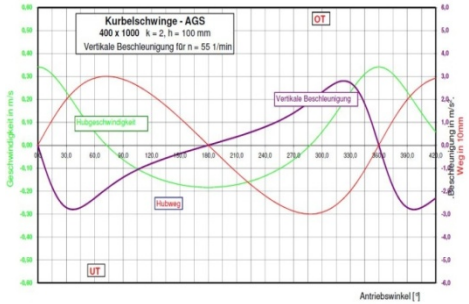
  - Modification of the pulsation diagram



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  - Technical implementation

Development / Implementation

- Experimental equipment at the recycling plant

Development / Implementation

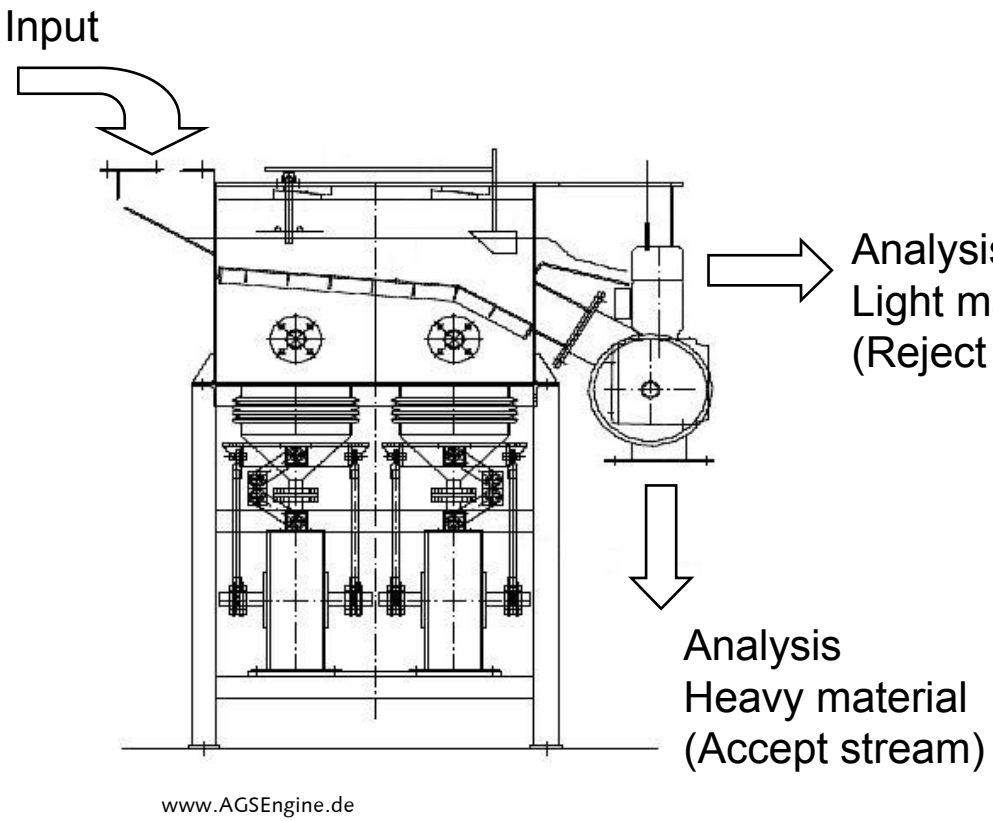
- Experimental equipment at the recycling plant

- Overview of all experiments

Test	parameter
machine set up	
V 1	mixture [mass-%] concrete A + brick + gypsum bathroom 60 + 20 + 20
V 2	
V 3	
V 4	
V 5	
influence of particle size	
V 6	mixture [mass-%] concrete A + brick + gypsum bathroom 60 + 20 + 20
influence of repeated treatment	
V 7	mixture [mass-%] concrete A + brick + gypsum bathroom 60 + 20 + 20

Test	parameter
concrete with variable contents of gypsum	
V 8	concrete A – gypsum bathroom
V 9	concrete A – gypsum from floor
quality of concrete	
V 10	mixture concrete A – concrete B
mixtures from precast concrete slabs	
V 11	precast concrete slabs material 4/45 mm
V 12	masonry aggregates
V 13	gypsum aggregates
V 14	precast concrete slabs material 0/63 mm
V 15	gypsum aggregates

- Analysis



- Amount of material
- Screening
- Handsorting
- Density

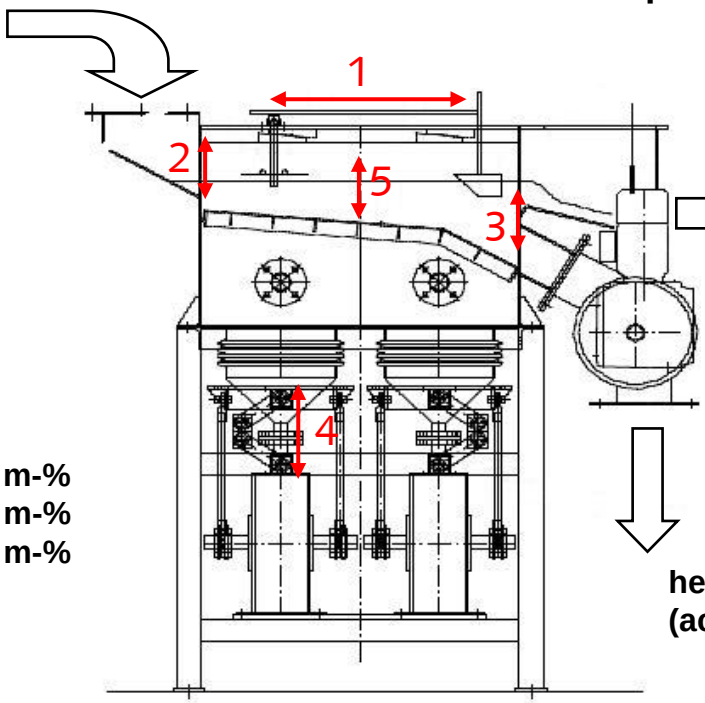
Results of investigations

- Influence of machine set up

mixture

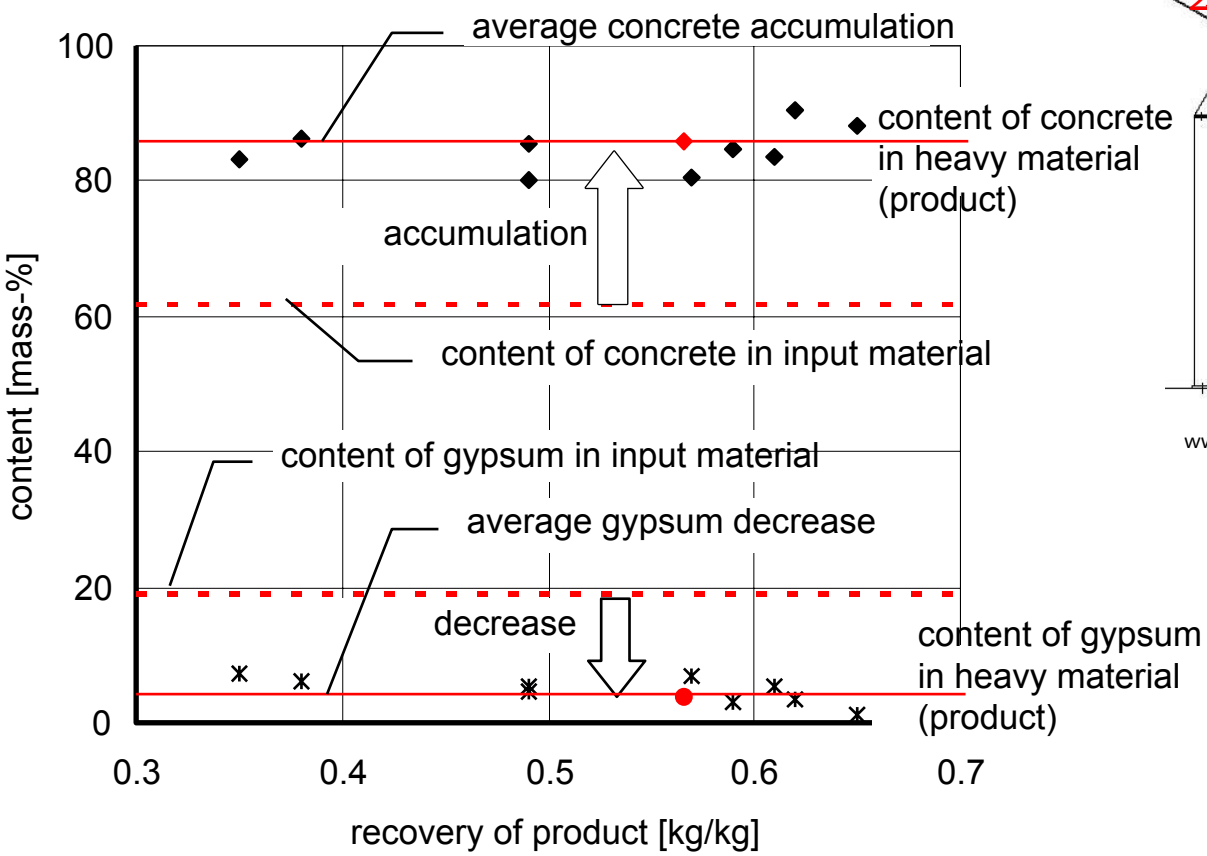
concrete	**60 m-%**
+ brick	**20 m-%**
+ gypsum from bathroom element	**20 m-%**

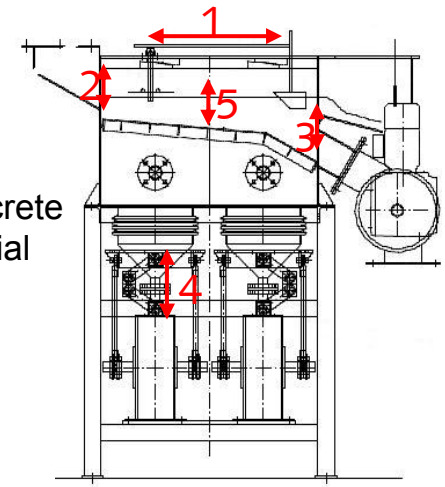
Variables of machine set up



Results of investigations

- Influence of machine set up

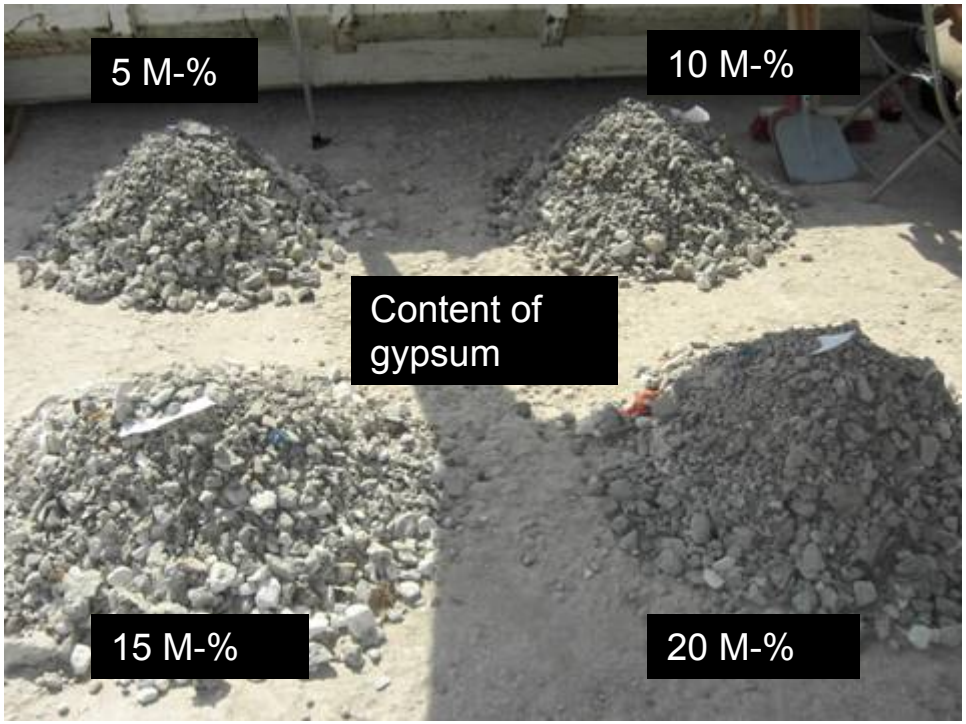




Content of concrete and gypsum after the jigging in dependence on recovery of product for different machine set up

Results of investigations

- Influence of content of gypsum and type of gypsum
  - Content of gypsum



mixture I – IV

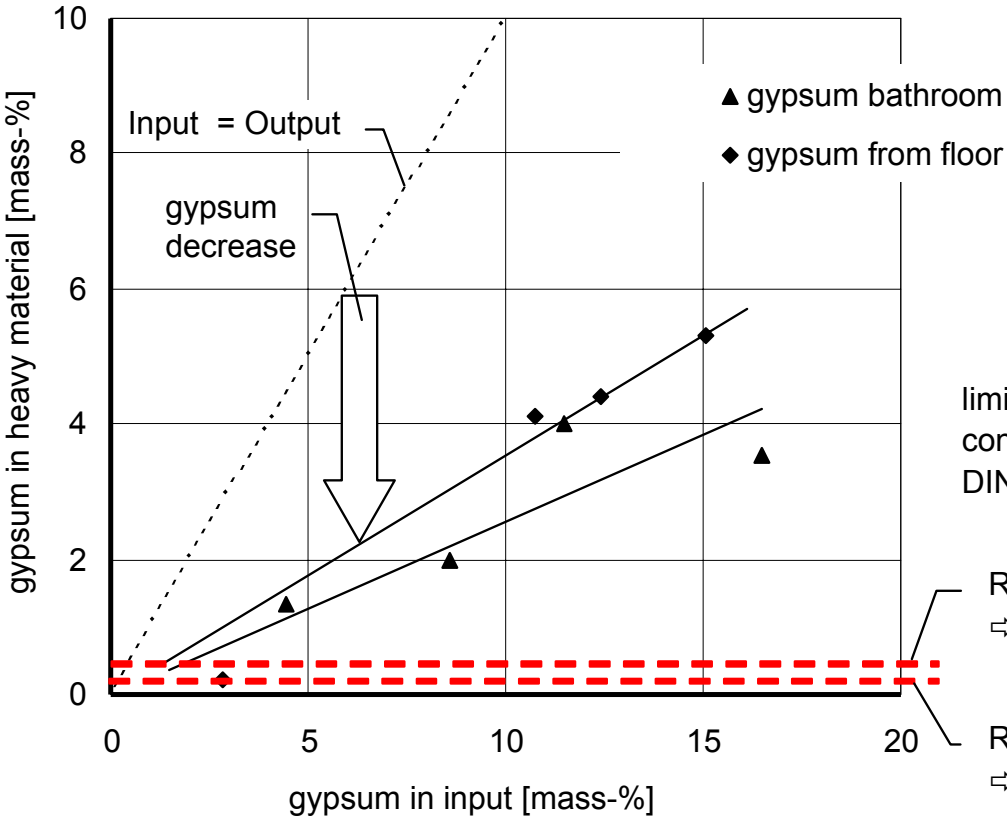
concrete A	**95 - 80 m-%**
+ gypsum from bathroom element	**5 - 20 m-%**

mixture V – VIII

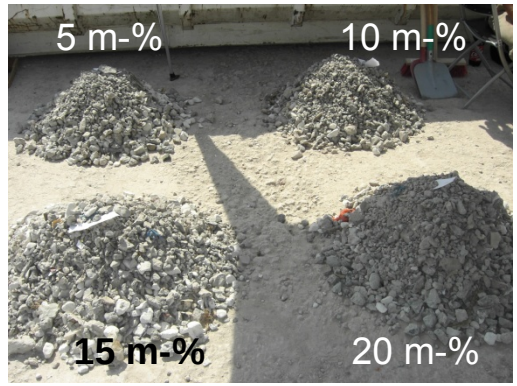
concrete A	**95 - 80 m-%**
+ gypsum from floors	**5 - 20 m-%**

Results of investigations

- Influence of content of gypsum and sort of gypsum



content of gypsum



limits for
content of gypsum
DIN 4226 -100

RC-Type 2: 0.5 %
⇨1.6 % gypsum in input

RC-Type 1: 0.2 %
⇨ 0.7 % gypsum in input

Content of gypsum in heavy material after the jigging in dependence on the content of the input material

Quotient of bulk density for valuation the separation of concrete and gypsum

	bulk density OD [g/cm³]	bulk density SSD¹ [g/cm³]	Quotient of separation	OD	SSD
gypsum from sanitary room	1,55	1,88	concrete A – gyp. sani. room	2,60	1,70
gypsum from floor	1,90	2,08	concrete A – gypsum from floor	1,59	1,39
concrete A	2,43	2,50	precast concrete - gyp. sani. room	2,25	1,57
precast concrete	2,24	2,38	precast concrete - gypsum from floor	1,38	1,28

¹: calculated by full water impregnation

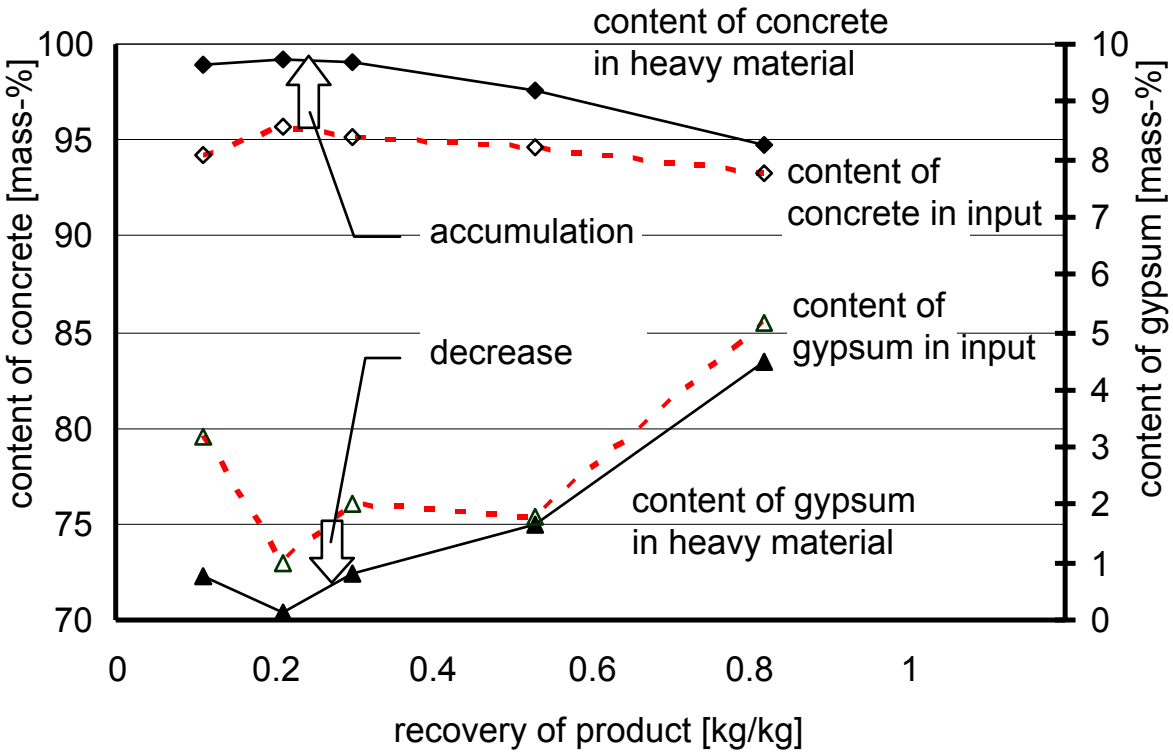
Results of investigations

- Separation of mixtures from precast concrete slabs

precast concrete slabs	**4/45 mm**
concrete and gravel	**93.75 M-%**
brick	**2.85 M-%**
gypsum	**2.73 M-%**
foreign materials	**0.65 M-%**

Results of investigations

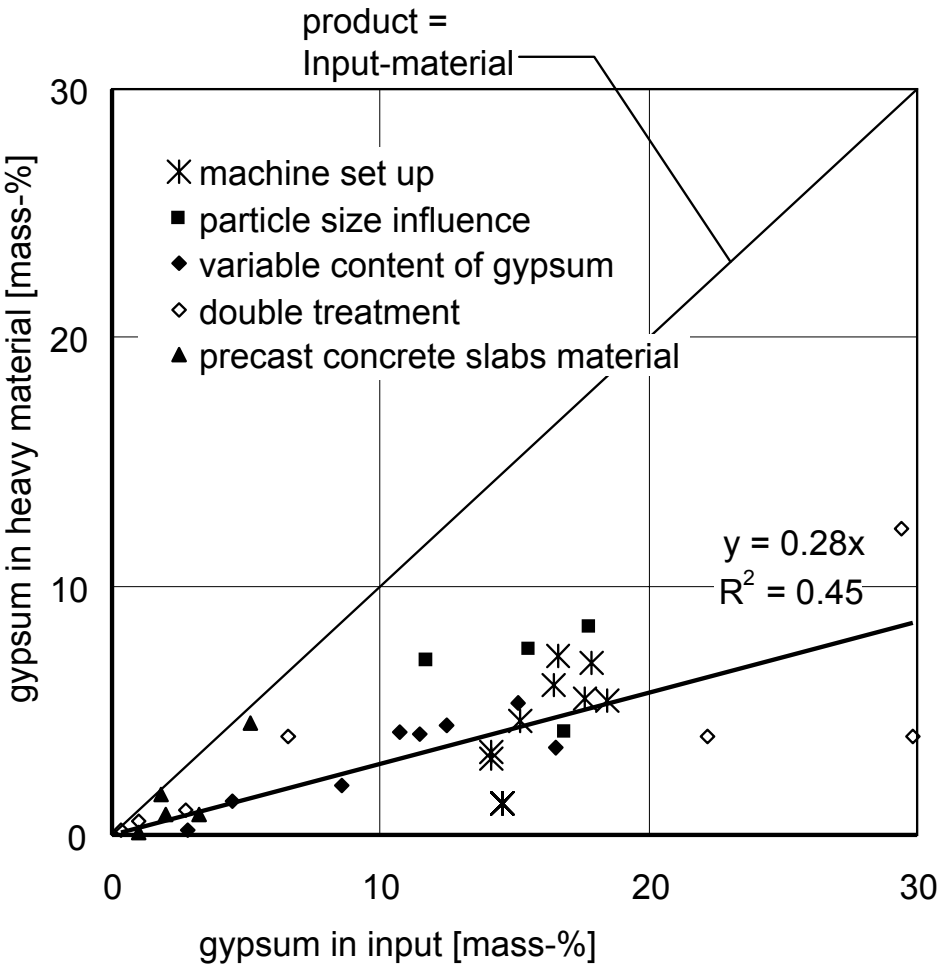
- Separation of mixtures from precast concrete slabs



Content of concrete and gypsum after the jigging in dependence on recovery of product

Results of investigations

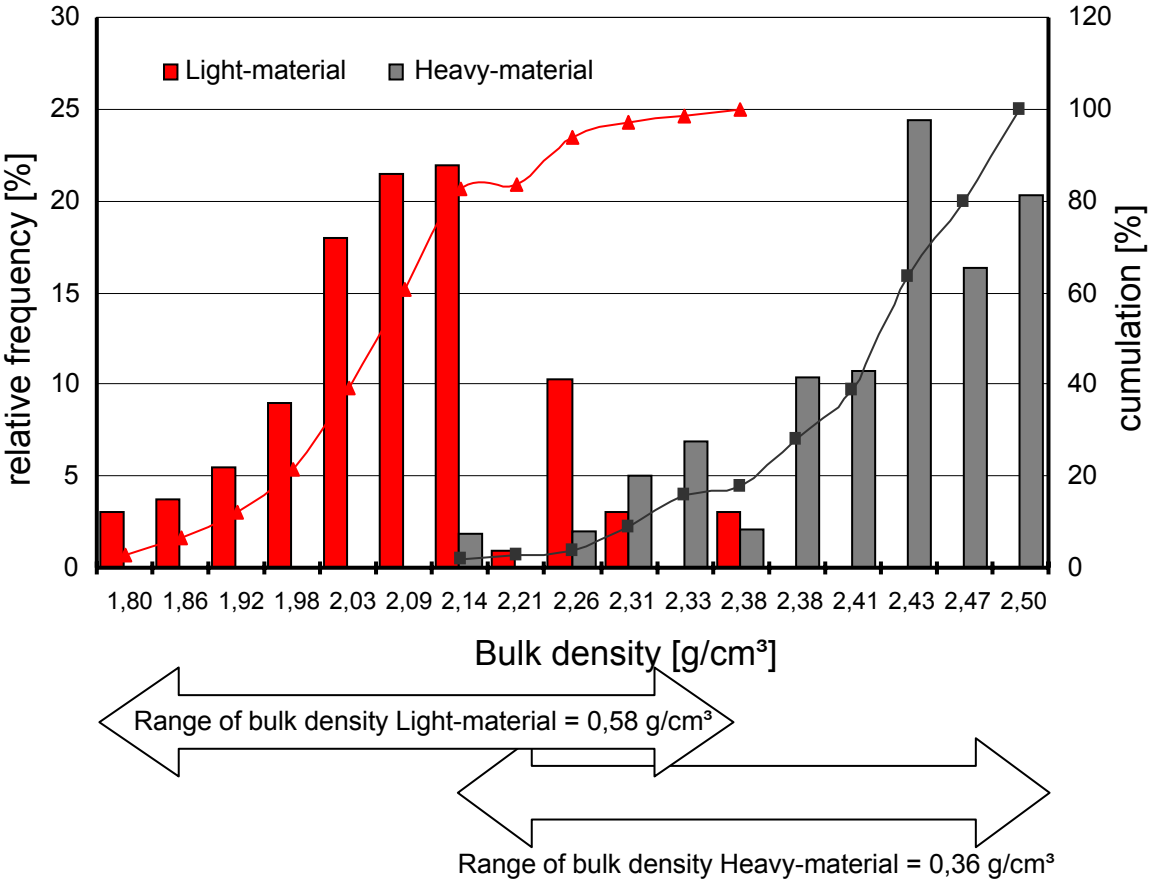
- Summarizing of selected results



comparison
content of gypsum in input versus
content of gypsum in product

Results of investigations

- Results concrete – gypsum – separation



Results of investigations

- Results concrete – gypsum – separation
  - Separation of mixtures from precast concrete slabs in several steps

Change of content of precast concrete slabs material after the jigging			
	average	min	max
	gypsum [mass-%]		
Content in Input-material	2.7	1.8	5.4
single treatment	0.8	0.5	1.5
double treatment	0.2	0.1	0.4
	concrete [mass-%]		
Content in Input-material	93.8	90.5	95.4
single treatment	99.0	97.4	99.8
Double treatment	100	100	100

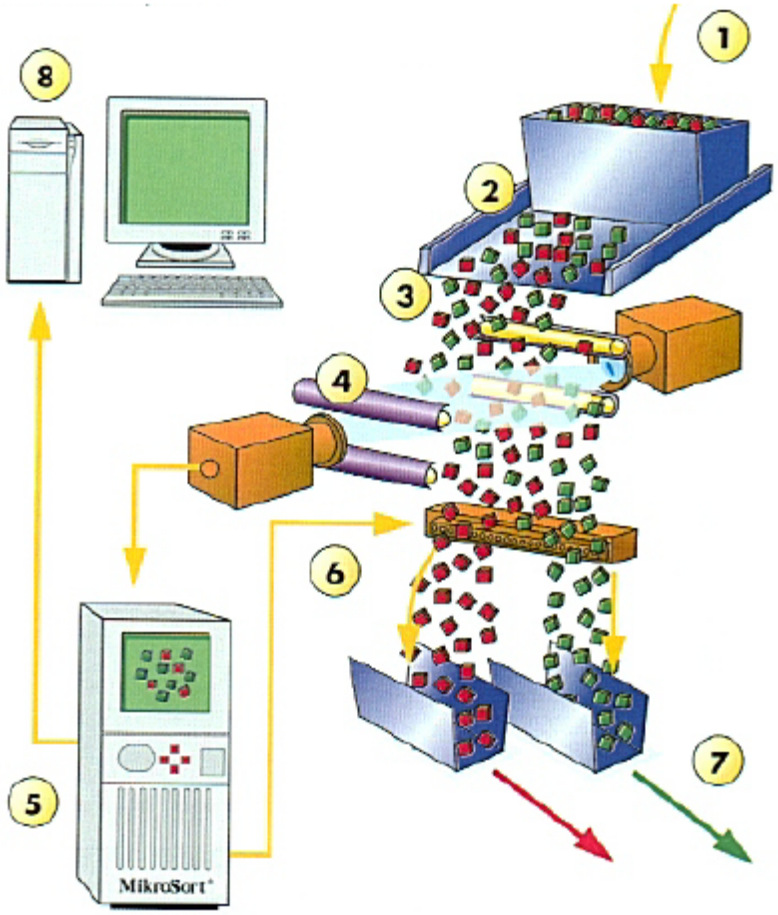
Calculated content of gypsum and concrete after single treatment and double treatment of the jig.

Conclusions

- Recycled aggregates produced of CDW from apartment buildings made of precast concrete slabs contain a high content of gypsum.
- The separation of gypsum is necessary for the reuse of the Recycled-Concrete-Aggregates as new concrete aggregate or in road construction
- In experiments was detected, that the gypsum can be separated from concrete aggregates by a jigging processes although the differences in density are rather small.
- The content of gypsum in the input material of 2.7 mass-% is reduce
  - to 0.8 m-% by single treatment
  - to 0.2 m-% by double treatment
- The recovery of the product amounts between
  - 50 % at a content of gypsum in the input of 20 mass-%
  - and 85 % at a content of gypsum in the input of 5 mass-%
- There are further quality improvements of the RCA as a result of the jigging process:
  - An increase of bulk density of the product compared to the input-material
  - A coarser particle size distribution of the product compared to the input-material

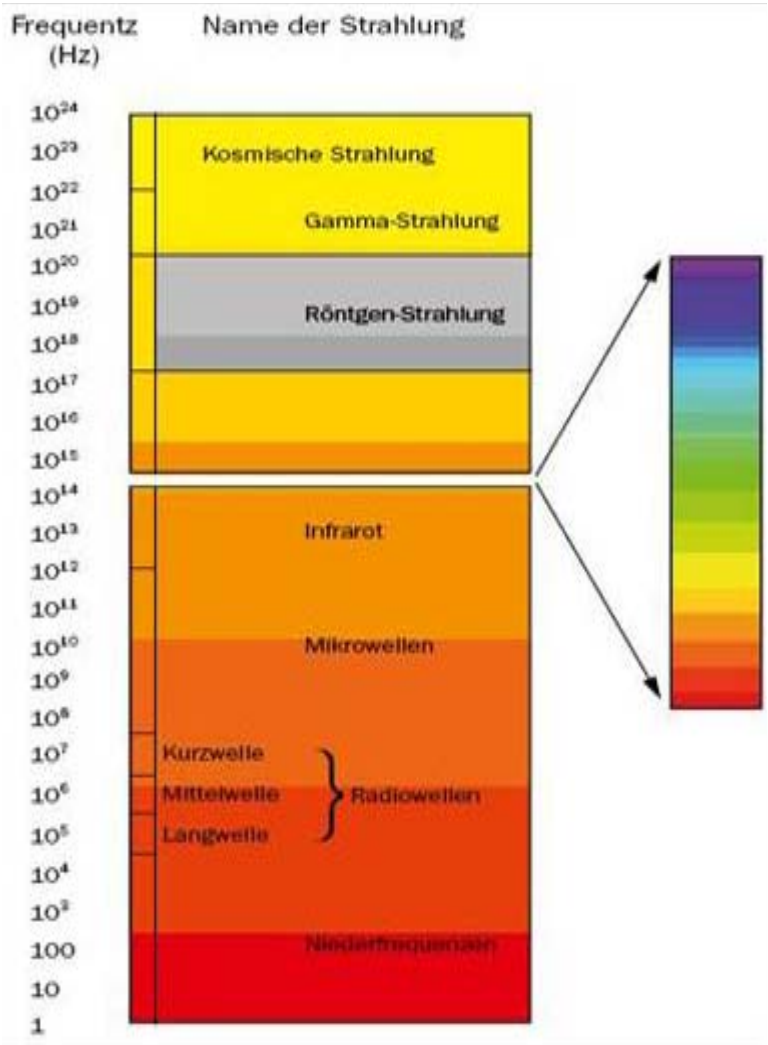
- ALTERNATIVE SEPARATION TECHNIQUE FOR CDW – OPTOELECTRONIC SEPERATION

Optoelectronic separation



nach Mogensen

1	product flow over a width of 1200 mm
2,3	dropping into a free fall
4	pass a CCD color line camera
5	state-of-the-art signal-processor, indentification of 8000 objects per second
6	separation by compressed-air pulses from 256 jets with dosed compressed-air pulses depending on grain size
7	conveyer belt for product flow and reject flow



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Optoelectronic separation

Spectra	Application
X-ray (roentgen)	Battery sorting Processing of industrial minerals, Metals of different density
Visible light	Separation of metals such as brass and bronze, Sorting glass, paper processing, sorting of industrial minerals
Near-infrared (NIR)	Plastic sorting (LVP), PET processing, Wood from bulky refuse

- Concrete and red brick mixtures

Sample 13,14,15

are mixtures of concrete and red brick

Sample		C (concrete)	B (red brick)	Total
13	Mass [grams]	11,866	2,443	14,309
	Content [%]	82.9	17.1	100.0
14	Mass [grams]	9,568	5,785	15,353
	Content [%]	62.3	37.7	100.0
15	Mass [grams]	1,911	13,665	15,576
	Content [%]	12.3	87.7	100.0

- Concrete and red brick mixtures

Sorting Results

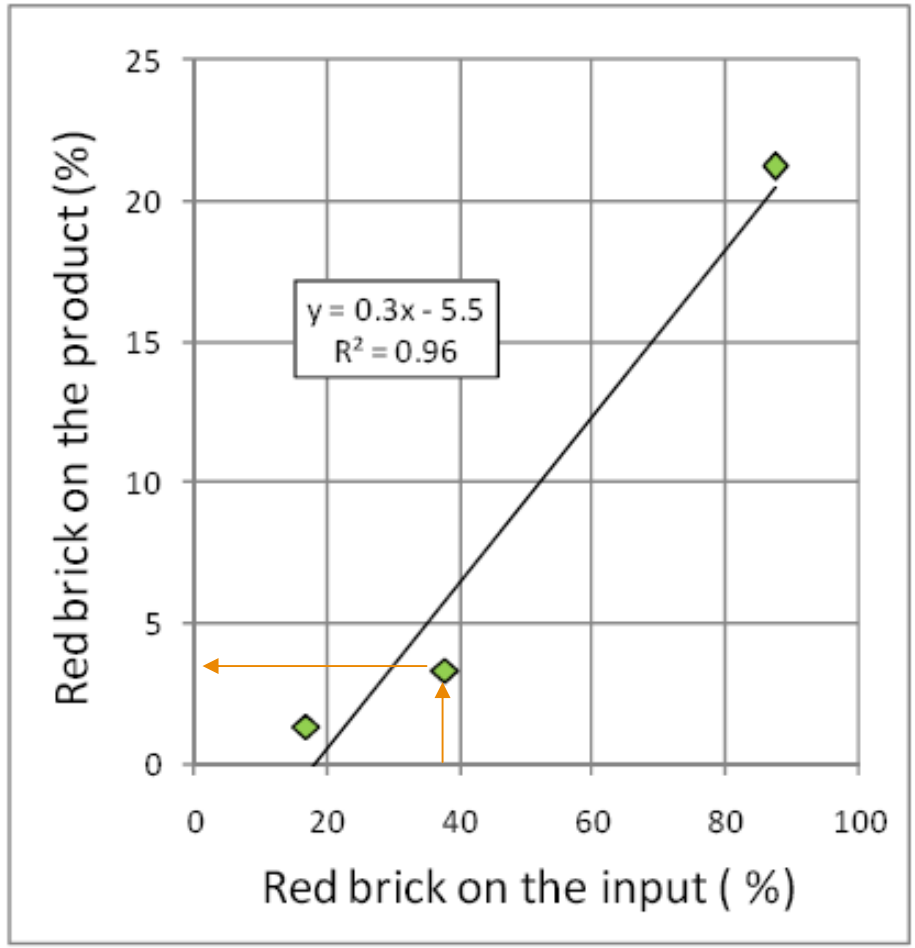
$$\text{Purity}(\%) = \frac{\text{mass}_{\text{gypsum, accept}}}{\text{mass}_{\text{total, accept}}} \times 100$$

$$\text{Recovery}(\%) = \frac{\text{mass}_{\text{accept}}}{\text{mass}_{\text{input}}} \times 100$$

		Sample 13			Sample 14			Sample 15		
		Input	Accept	Reject	Input	Accept	Reject	Input	Accept	Reject
Concrete	[g]	11,866	11,686	180	9,568	9,220	348	1,911	1,565	346
Red brick	[g]	2,443	155	2,288	5,785	312	5,473	13,665	422	13,243
Red brick	[%]	17.1 →	1.3	92.7	37.7 →	3.3	94.0	87.7 →	21.2	97.5
Purity	[%]	82.9	98.7		62.3	96.7		12.3	78.8	
Mass recovery	[%]		82.8	17.2		62.1	37.9		12.8	87.2

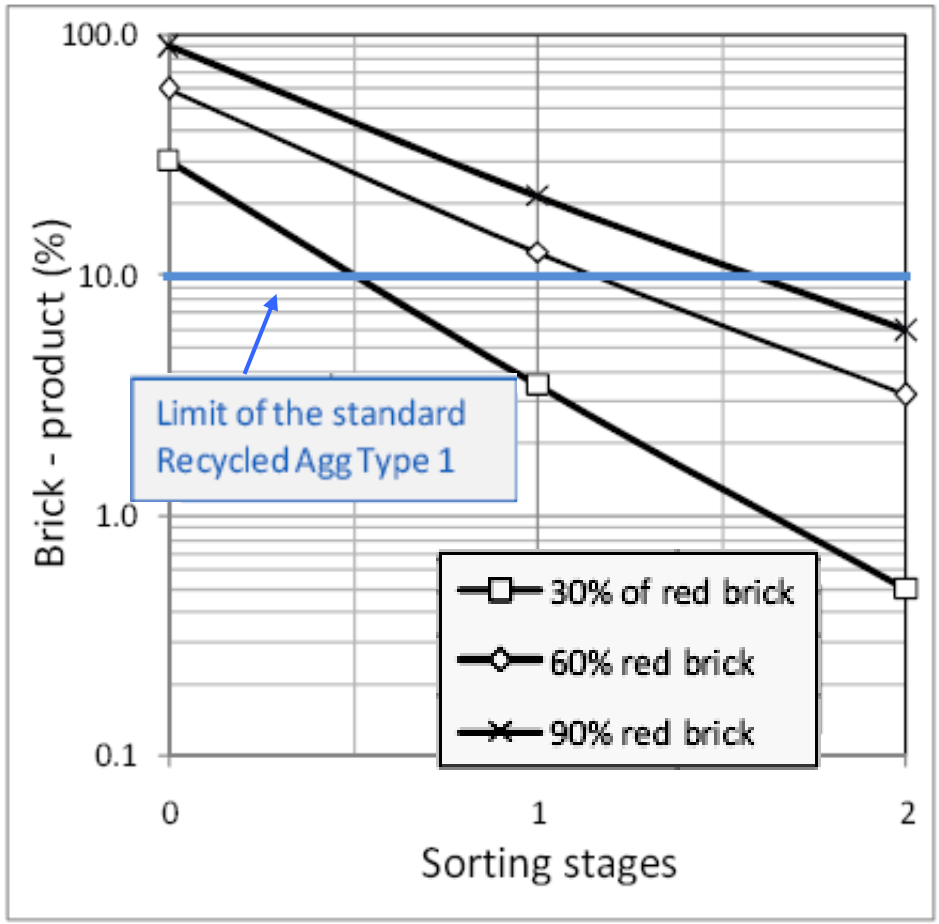
- Concrete and red brick mixtures

Sorting Results



- Concrete and red brick mixtures

Sorting Results



- Gypsum composites and Mixed C&DW aggregates mixtures

Sample 10,11,12 are mixtures from Gypsum composites and Mixed C&DW aggregates

Sample		GP (gypsum+ paper)	GW (gypsum+ wood)	GA (gypsum+ nat. agg.)	GP+GW +GA	XA (recycled aggregate)	Total
10	Mass [g]	68.7	68.7	68.6	206	22,364	22,570
	Content [%]	0.3	0.3	0.3	0.9	99.1	100.0
11	Mass [g]	1,508.7	1,508.7	1,508.6	4,526	27,537	32,036
	Content [%]	4.7	4.7	4.7	14.1	85.9	100.0
12	Mass [g]	3,125.7	3,125.7	3,125.6	9,377	7,788	17,165
	Content [%]	18.2	18.2	18.2	54.6	45.4	100.0

- Gypsum composites and Mixed C&DW aggregates mixtures

Sorting Results

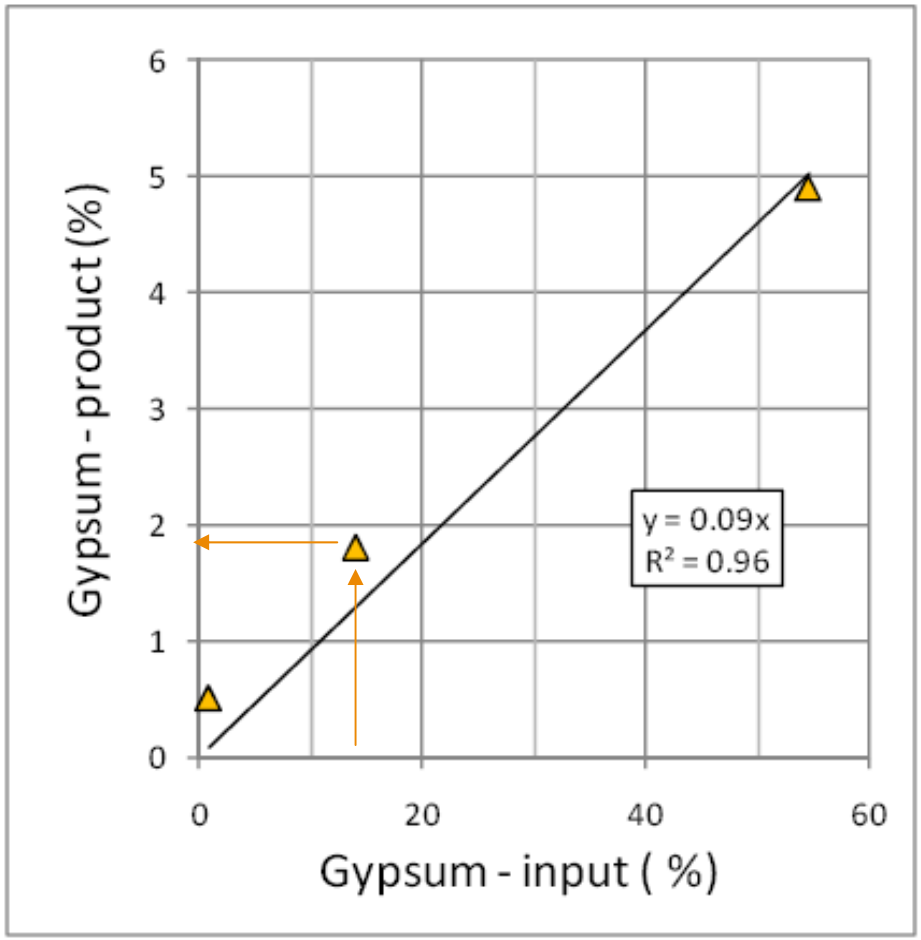
$$\text{Purity}(\%) = \frac{\text{mass}_{\text{gypsum, accept}}}{\text{mass}_{\text{total, accept}}} \times 100$$

$$\text{Recovery}(\%) = \frac{\text{mass}_{\text{accept}}}{\text{mass}_{\text{input}}} \times 100$$

		Sample 10			Sample 11			Sample 12		
		Input	Accept	Reject	Input	Accept	Reject	Input	Accept	Reject
Gypsum	[g]	206	101	105	4526	490	4,036	9,377	357	9,020
Recycled Aggregate	[g]	22,364	22,159	205	27,537	26,280	1,257	7,788	6,895	893
Gypsum	[%]	0.9 →	0.5	33.9	14.1 →	1.8	76.2	54.6 →	4.9	91.0
Purity	[%]	99.1	99.5		85.9	98.2		45.4	95.1	
Mass recovery	[%]		98.6	1.4		83.5	16.5		42.2	57.8

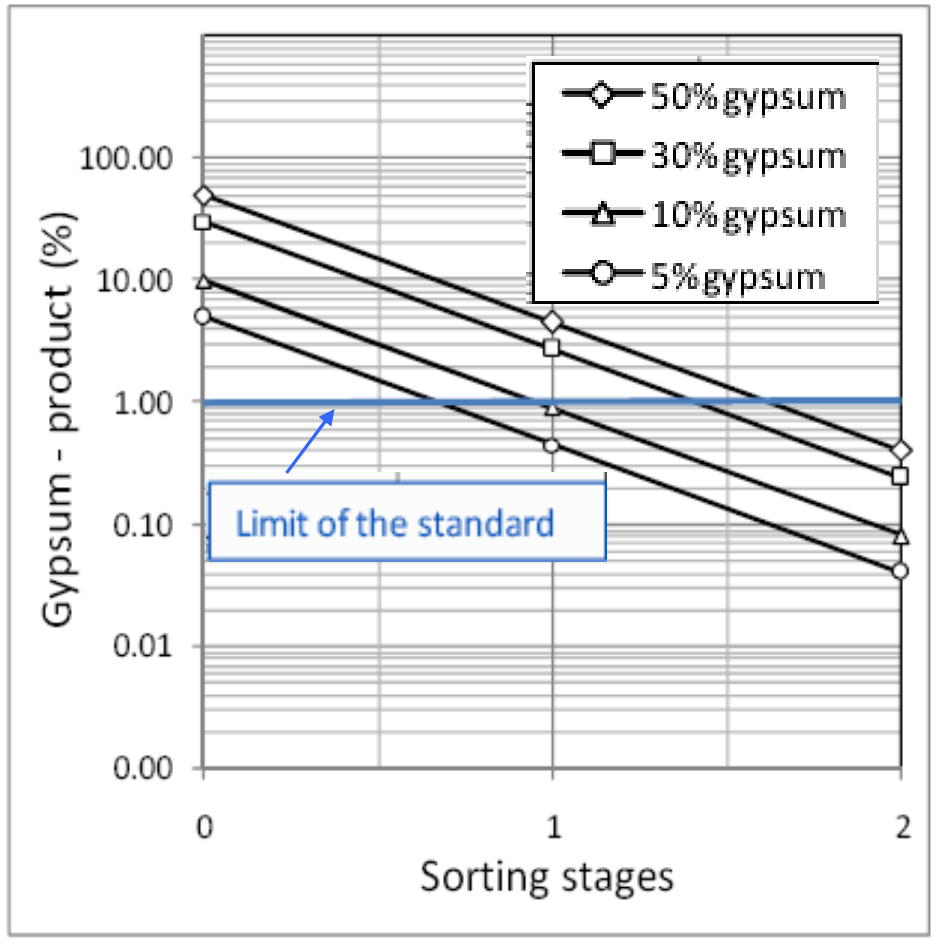
- Gypsum composites and Mixed C&DW aggregates mixtures

Sorting Results



- Gypsum composites and Mixed C&DW aggregates mixtures

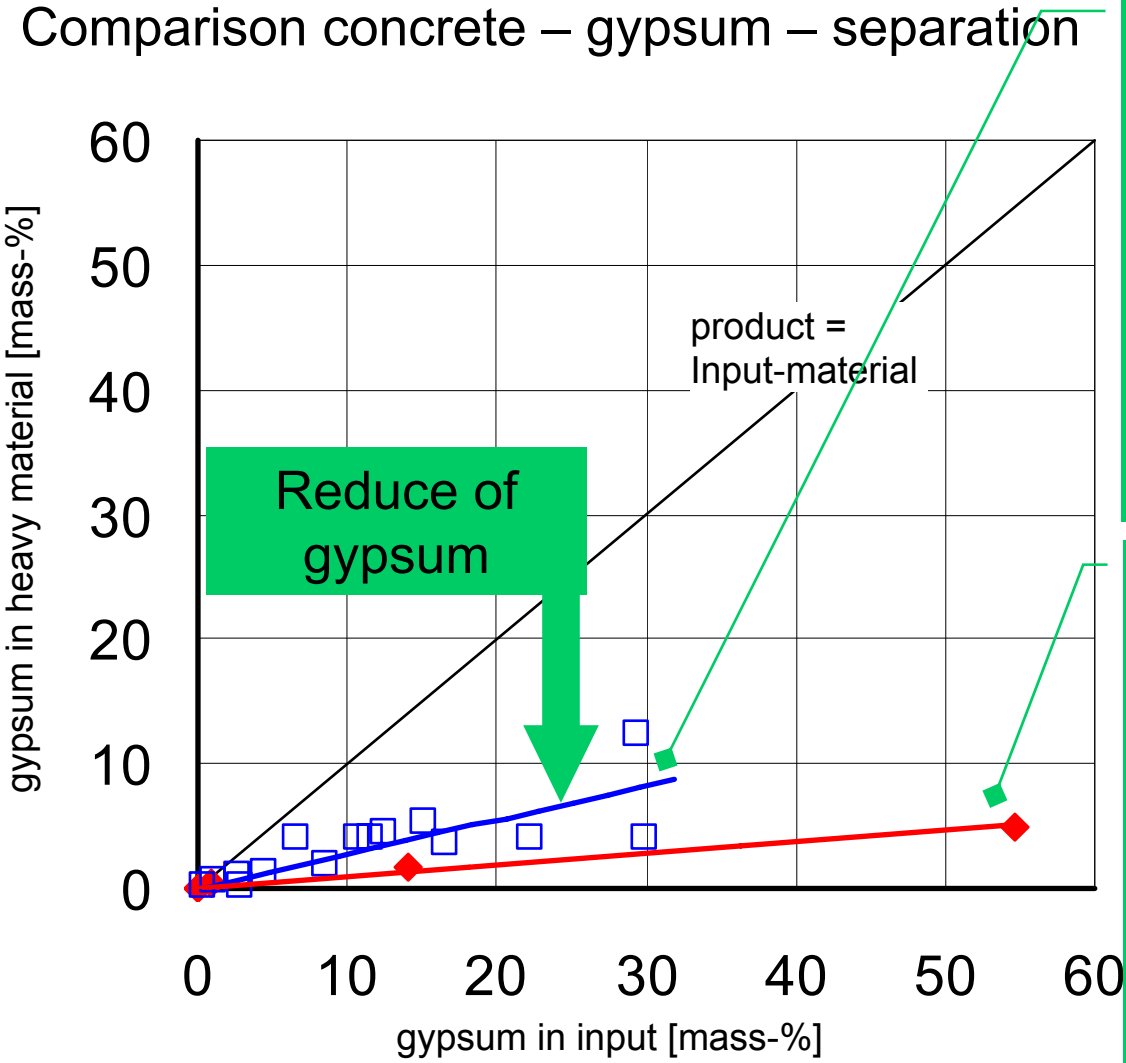
Sorting Results

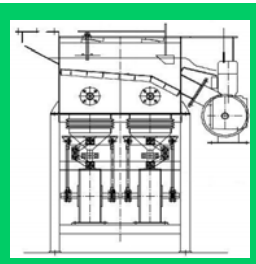


Conclusion

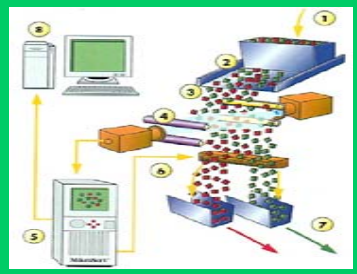
- Gypsum will increase in C&DW aggregates in future demand of separation
- Automatic optical sorting is suitable to separate gypsum and brick particles from concrete particles
- High concentration of gypsum and red brick in the input material can require two stages of processing
- Gypsum separation can be combined with red brick sorting
- The quality of C&DW aggregates can be improved significantly by automatic optical sorting

- Comparison concrete – gypsum – separation





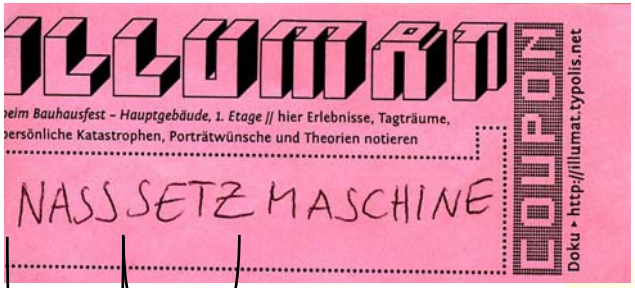
Jiging:
Amount of gypsum in product =
0,274*gypsum in Input



Optical sorting:
Amount of gypsum in product =
0,092*gypsum in Input

The sorting process must be selected under consideration of the parameters of the components to be separated. The following selection parameters are important:

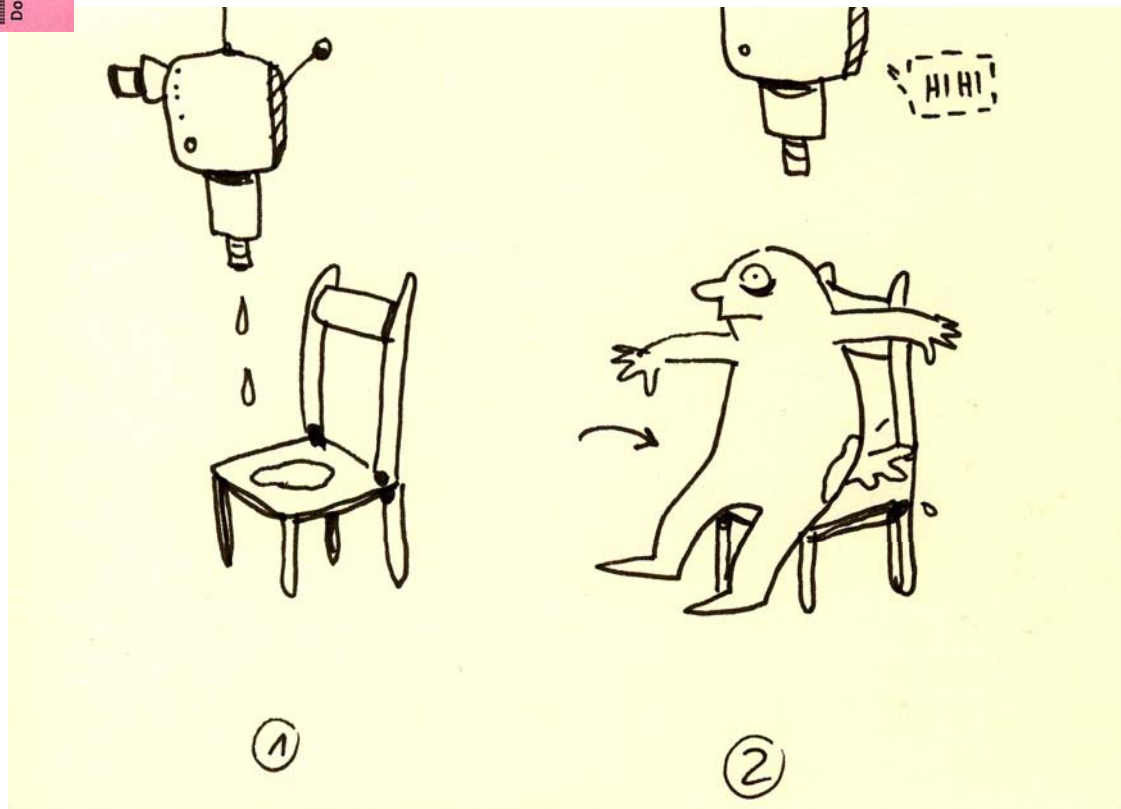
- Composition of the material
- Quality requirements for the product
- Material characteristic such as density, magnetic properties ...
- Particle size
- Plant concept
- Amount of material



setz = take place
= jig

nass = wet

ILLUMAT
- automat for spontaneously drawing

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your attention !
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