Sorting of mineral construction and demolition wastes by near-infrared technology

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Abstract

Construction and demolition waste (CDW) from building constructions are heterogeneous mixtures, containing clay brick, mineral bounded building materials, like concrete, calcium silicate unit, aerated concrete and lightweight concrete, mortar, plaster, insulation material, wood, plastic etc. Even after processing – such as presorting by hand, single or double-stage crushing, separation of reinforcement by over belt magnetic separators, air sifter for the separation of light components, jigging machines and sieving - the recycled product often remains heterogeneous. In the building industry the amount of composite building materials is increasing nowadays, leading to a more difficult separation. The heterogeneity of recycled aggregates prevents the profitable reuse; therefore, it is necessary to reduce the heterogeneity. Sensor-based single particle sorting devices are the most promising techniques to sort efficiently usable material fractions and to discharge impurities and contaminants from the recyclable fractions. Main focus is the separation of gypsum attachments and composite particles, which cannot be avoided by mechanical crushing. In this project a sorting machine prototype based on a near-infrared technology, which is adapted to mineral building materials, was developed. Furthermore, the sorting rate for different material mixes was determined for different influencing factors, like moisture and pollutions on the surface.

Keywords: Optical Sorting, Near-Infrared Technology, CDW, Identification of Building Materials.

Motivation

For production of high quality recycling products from construction and demolition waste (CDW), it is essential to reduce the heterogeneity of the recycled aggregates (RCA) by separation of certain material fractions. For the reuse of the RCA in recycling concrete, the separation of impurities, e.g. gypsum plasters, is getting more and more important in the future because the amount of gypsum in the waste will increase. The increasing amount of composite materials in the CDW leads to more foreign materials (bricks etc.), which will reduce the quality of the recycled aggregates. If the target is to reuse the recycled aggregates as feedstock in the production, material composites must firstly be separated into unmixed material fractions. Traditional mechanical sorting processes are limited in some points, so that sensor-based single particle sorting devices are investigated to sort efficiently usable material fractions and to discharge impurities and contaminants from the recyclable fractions. The optical sorting process can be integrated in the processing, e.g. after the first crushing step, a sensor-based sorting can be implemented enabling the production of unmixed products.

Results

The first aim was to find suitable identification attributes for the identification of C&DW aggregates. For this about ten varieties of different building materials concrete, lightweight concrete, autoclaved aerated concrete, clay brick, calcium silicate unit, gypsum were collected in unused and recycled state, classified in the size fraction 8/16 mm and analyzed regarding their physical parameters (bulk density and water absorption), mineralogical compositions (XRD) and their typical near-infrared spectra (hyperspectral near-infrared camera KUSTA 2.2MSI) [1]. In figure 1 exemplary spectra of concrete and gypsum are shown. Based on these spectra, a learnset was created to separate the different building materials. The learnset includes both spectra - of unused building materials and of recycled materials. In learnsets, the identified material groups must be included as different types. The learnset was then utilized for a PLS (Partial Least Squares Regression) analysis.

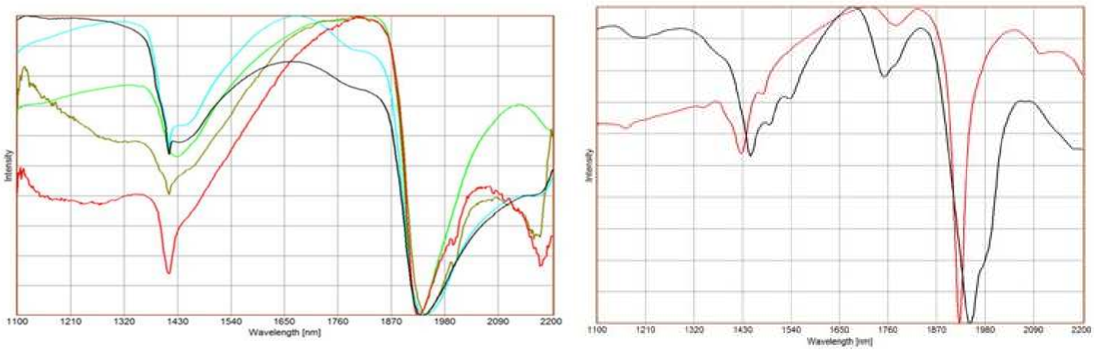

Figure 1: Near-infrared spectra of concrete samples (left) and of gypsum samples (right)

In cooperation with the companies LLA Instruments GmbH and Sesotec GmbH a sorting system has been developed allowing investigations under real conditions, which was used for the following sorting tests on several model mixtures and practical mixtures from a recycling plant. The particles are transported by a conveying system and pass a push-broom based camera system which measures the spectra in reflection mode. The particles are then sorted by compressed air pulses.

The results of the sorting experiments of the collected materials in size 8-16 mm can be summarized as follows. Concrete and clay brick can be distinguished in the near-infrared spectrum. Autoclaved aerated concrete and calcium silicate unit can also be very well recognized in the near-infrared region. Lightweight and normal concrete cannot be distinguished from each other in the near-infrared spectrum. Gypsum shows specific adsorption bands and is therefore well detectable. A distinction between dense and porous clay brick is not possible at the present state of knowledge. The main influencing factors on the sorting rate are the moisture and the pollutions on the surface of the RCAs. A decreasing of the sorting rate for moist material was detectable for organic material (-30%), aerated concrete (-18%), calcium silicate unit (-86%) and clay brick (-20%). Gypsum can be detected better in moisture state (+38%). For concrete the moisture did not influence the recognition. The degree of pollution has an influence on the sorting rate for gypsum (-22%), aerated concrete (-16%), calcium silicate unit (-3%) and concrete (-7%). Clay brick can be recognized better in recycled state (+14 %). For example, in table 1 a sorting process in five single steps of a real mixture in dry state is shown [2]. The table shows the summary of all sorting rates of the used materials and also the rate of falsely sorted material in each step.

Table 1. **5-**Step-Sorting of a praxis mixture in dry state

		Weight in kg		Content of material in wt.-%					
		sample weight	weight of sorted out material	thereof organic	thereof gypsum	thereof aerated concrete	thereof calcium silicate unit	there-of brick	thereof concrete
1.	organic material	0.13	0.18	47.4	20.9	0.1	4.9	0.5	0.4
2.	gypsum plaster	0.43	0.37	0.9	79.0	0.0	0.0	0.0	1.5
3.	aerated concrete	0.14	0.16	11.0	0.0	99.2	0.0	0.0	0.1
4.	calcium silicate unit	0.29	0.23	0.4	0.0	0.0	68.9	0.1	1.4
5.	Brick	0.74	0.70	6.2	0.0	0.0	0.0	84.0	3.8
		Discharged material		66.0	99.9	99.4	73.7	84.5	7.1
		Undischarged material		34.0	0.1	0.6	26.3	15.5	92.9
		Sum		100	100	100	100	100	100

In the first step, organic materials such as plastic and wood were discharged. The plastic material included also transparent foils, which undetectable in the near-infrared region in remission. This explains the lower sorting rates of organic material. The carton of the gypsum cardboards was identified as organic material. In step 2, gypsum and gypsum cardboards were discharged and so on. For explanation of table 1: In step 1 47.7 wt.-% of the weighed 0.13 kg organic material were identified as organic material and discharged in step 1. Additionally, 20.9 % were identified from gypsum material as organic material due to the adherent cardboard on plasterboard. In addition, 0.1 wt.-% of aerated concrete, 4.9 wt.-% of calcium silicate unit, 0.5 wt.- % of clay brick and 0.4 wt.-% of concrete and were incorrectly detected and / or false discharged. This means that 66.6 wt.-% of the organic material were correctly discharged and 33.4 wt.-% were incorrectly discharged in step 1. In step 2, 79 wt.-% of the gypsum could be discharged. Along with the 47.4 wt.-% gypsum from step 1 gives a total of 99.9 wt.-% of gypsum which could be separated. Only 0.1 wt.-% could be found in the sorted, usable material fraction. In the future more investigations are planned to reach higher sorting rates for clay brick and calcium silicate unit.

Conclusion

The general suitability of near-infrared sensors for sorting of aggregates from CDW was investigated. Material specific characteristics to distinguish building materials were identified. The results indicate that especially gypsum can be separated successfully with a sorting rate of approximately 99.9 %. The sorting rate of the different building materials ranges between 80 and 99 %, which is very high, taking into account that the particle sizes vary greatly, and the surfaces of the recycled materials is polluted. It can be observed, that the sorting rates of humid material are mostly smaller than in dry state (i.e. at equilibrium with local humidity). In the future, more investigations are necessary to optimize this method.

Acknowledgement

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