Hyperspectral imaging applied to demolition waste: recycled products quality control

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Aim of the study

The study was addressed to investigate the possibility to apply an HyperSpectral Imaging (HSI) based approach in order to perform a quality control of recycled aggregates from Demolition Waste (DW) for high-value ‘green concrete’ production.
The EU “C2CA” project

This study was developed with thanks to the financial support of the European Commission in the framework of the FP7 Collaborative project

Advanced Technologies for the Production of Cement and Clean Aggregates from Construction and Demolition Waste

(C2CA)

Grant Agreement No. 265189

Sapienza University target is addressed to design and set up an analytical platform, based on HSI sensors, in order to check the quality of products resulting from the implemented C&D recycling process.

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The importance of quality control in recycling process

1. Characterization of input streams
   Correct recycling process implementation

2. Quality control of output streams
   - Detection of unwanted materials presence
   - Recovery of “clean” products to put again into the market

An accurate quality certification of products obtained by recycling processes can give a better economical value
Construction and Demolition Waste (C&DW)

C&DW is a material resulting from construction, remodeling, repair, or demolition of utilities, structures, and roads.

This kind of waste is really heterogeneous:

- Paper
- PVC
- Steel
- Carpets
- Wood
- Gypsum
- Roof
- Brick
- Glass
- Cables
- Isolation
- Concrete
Why is C&DW a problem?

C&D Waste disposal is a real problem, considering:
- obsolescence of existing buildings
- continuous development of construction activity

1. Landfills are filling up and some others will be closed in the near future
2. Illegal dumping

It is wise to find new alternatives other than landfilling C&D debris

Proper management of the amount of generated C&D can save money, preserve resources and protect the environment.
C&DW recycling

There is the potential to recycle many elements from demolition waste.

The main goal of the project is to widely replace primary raw materials through recycling of EOL concrete.

Recycling advantages:
1. reduction of waste disposed off in landfill (environmental benefits)
2. recovering of a lot of different materials (wood, plastic, glass, …)
3. reduction of natural resources depletion
4. saving money
Advanced Dry Recovery (ADR)

C2CA project investigates a combination of:
- smart demolition,
- grinding in an autogenous mill,
- novel dry classification technology (ADR)

uses kinetic energy to break the water bond in order to remove the fines and light contaminants
ADR quality control

- Determination of the quality of feed and product streams
- Control of the process
- Products quality assessment at the different set up

Exploring the possibility of C&DW classification by optical sensor, based on HyperSpectral Imaging (HSI), is the main aim of Sapienza University into C2CA

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Quality control of ADR output

*Coarse fraction*

End-of-life concrete can be used to recover **CLEAN** aggregates for new concrete production.

Contaminants are absent or below levels fixed by the market.

**Characterization** is important in order to set up **efficient sorting** and/or **quality control system**: HSI was applied in order to recognize aggregates from contaminants in this study.
HyperSpectral platform

Investigated spectral range:
1000 - 1700 nm

The equipment has been realized by DV srl (Italy)

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Demolition waste sample

Analyzed samples were provided by Strukton company (NL) and collected from a concrete building demolition site in Groningen (NL).

Resulting from the DW stream processing by ADR at TUDelft (Delft, NL)

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Hyperspectral imaging analysis

Main goals of the HSI analyses:

- Collect spectral signatures of representative materials of a typical DW stream in a recycling plant
- Development of a procedure to check ADR output quality by HSI
- Recognition of different materials constituting the waste stream
Experimental set up

The experimental set up was realized as a real case, being representative of a typical DW stream handled in a recycling plant.

Particles arranged in lines
Training image

Particles arranged in lines randomly
Validation image

The experimental set up was realized as a real case, being representative of a typical DW stream handled in a recycling plant.
Hyperspectral data processing

*Developed procedure*

- Hyperspectral Image Acquisition
- Import File in PC unit
- Reduction Wavelenghts
- Spectra Preprocessing
- PCA model building
- PLSDA model validation

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Spectral data have been analysed using the PLS_Toolbox 7.8 (Eigenvector Research Inc.) running inside Matlab™ environment (version 7.5).
Spectral data analysis

STEP 1
Background noise removal
spectral variables were reduced from 121 to 93

STEP 2
Spectral preprocessing application

Raw spectra

Pre-processed spectra

Detrend, SNV and Mean Center
Explorative analysis and class setting

Principal component analysis was applied as explorative data analysis after preprocessing. Distribution of samples on the score plot is an indicator of similarities in the samples spectral behavior.

After this exploratory step, some pixels of each identified group were selected to set classes onto the score plot and others were removed in order to build the training dataset for the classification model.
PLS-DA model validation

Prediction images resulting from application of the PLS-DA model to the Experimental set up 2

The classes are:

- foam (1)
- gypsum (2)
- wood (3)
- aggregates (4)
- brick (5)
- plastic (6)
Some errors in classification occur. **Sporadic pixels** are misclassified.

- Impurities due to the “dirty” particles nature
- Light scattering problems due to the “rough” and heterogeneous particles surface
“Clean” classification based on the main class for each object

- background (0)
- foam (1)
- gypsum (2)
- wood (3)
- aggregates (4)
- brick (5)
- plastic (6)
Conclusions

✓ The possibility to apply an HyperSpectral Imaging (HSI) based approach to recognize/classify different materials constituting DW products, with particular reference to aggregates and pollutants, was explored.

✓ The results demonstrated that the classification was good and the use of a constraint on the maximum percentage of assigned pixels to each “object” is useful to improve prediction.

✓ The final HD-SW prototype based on HSI was just implemented and the developed classification procedures are running inside. New tests are carrying out in order to validate a larger amount of samples.
Thank you!

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