An improved methodology to assess the organic biodegradability and the biomethane potential of solid organic wastes for anaerobic digestion





6th International Conference on Sustainable Solid Waste Management
Naxos, 13–16 June 2018

Rémy Bayard, Ruben Teixeira Franco, Pierre Buffière
DEEP Laboratory, Université de Lyon, INSA Lyon

AD optimization #1

➢ Biomass selection

Nowadays, the diversification of AD inputs is quite wide, as energy can be recovered from almost all types of organic wastes, forages or catch/energy crops.

Several heterogeneous feedstocks are targeted to implement AD, including biowaste, organic fractions from MSW, and residual municipal waste.





- Biowaste (BW)

- agro-industries (food processing waste), and agriculture,
- green and food waste

- Residual Municipal Solid waste (RMSW)

Segregated fraction from MBT of MSW

High variability of the feedstocks might be problematic to control the AD process

AD optimization #2

➢ Storage

Open-air storage

Hay storage

Ensiling

Ensiling, hay, and open air-storage are three methods commonly used for biomass conservation before AD. The last one is mostly applied for agricultural wastes, due to the simplicity and low cost of the operation. However, open-air storage facilities are important source of **ammonia and odor emissions**, and should lead to **substantial energy losses.**

These drawbacks can be reduced if an efficient ensiling is carried out. According to the literature, **ensiling** lead to full conservation of **biochemical methane potential (BMP)** of specific catch crops even after 1 year.

AD optimization #3

➢ Pretreatments: cutting, mixing-pulping, cooking…

A solution could be an accelerating of the degradation of the substrates by pretreatment in order to get the higher gas yield in a shorter time.

Milling hammer

Crusher pump

Pulping

Cooking

A suitable pretreatment method should destruct the lignocellulosic structure and thereby release the sugars contained in the biomass to make them more available for the bacteria.

Objective : Determining bioreactivity on solid waste for anaerobic digestion

➢ For what?

Determination of BioMethane Potential (BMP) is not enough to select biomass, and optimize storage, and pretreatment. Biomass conversion to methane can be assumed to be strongly dependent of the accessibility of organic compounds to microbial population. Bio-accessibility is supposed to be linked to the biochemical composition, but also to the water solubility of biomass.

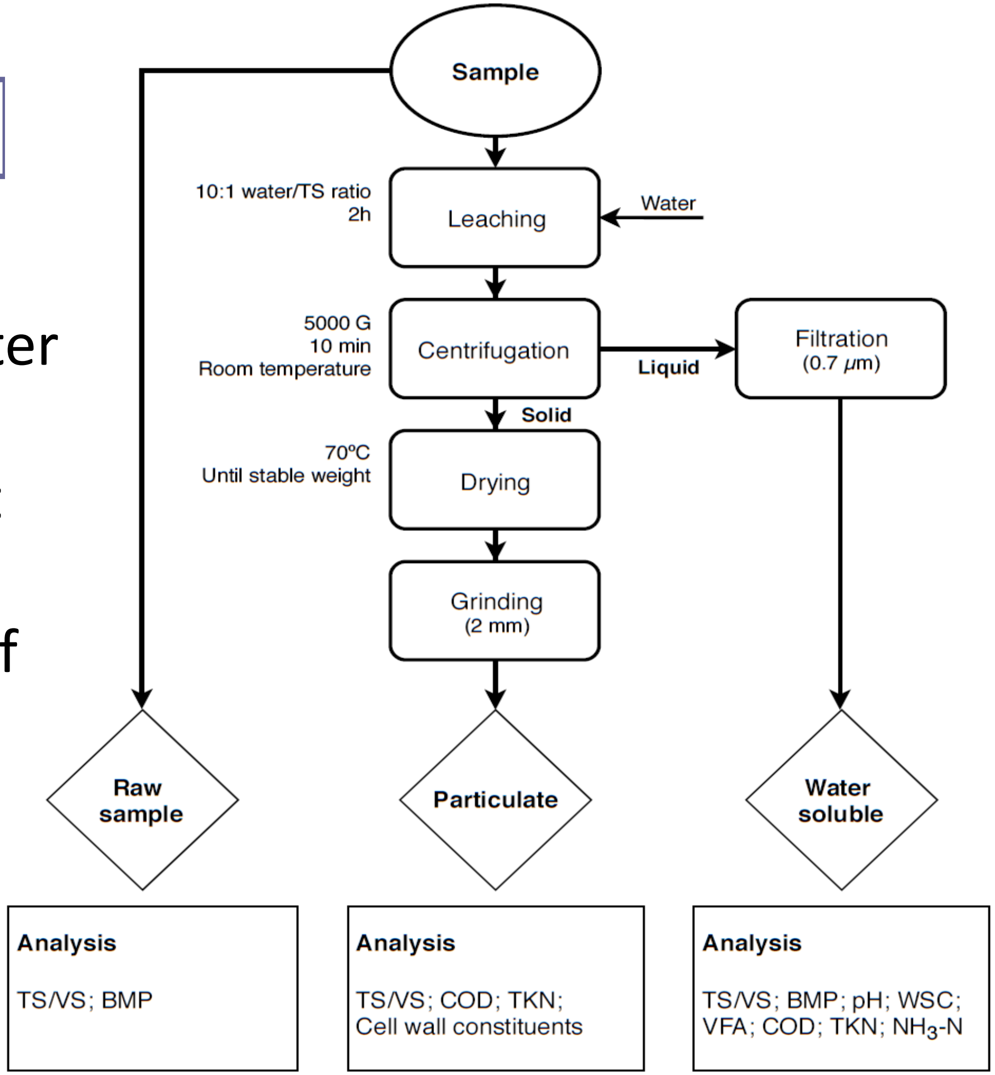
A better knowledge of solid waste characteristics to

- **Evaluate the storage and its operating conditions ;**
- **Determine the pretreatment effets ;**
- **Optimizing the design of the AD process (L/S ratio, co-digestion, mixing, kinetic conversion …) ;**
- **Modeling all the steps of the AD process and having a better understanding of the biological activities.**

Analytical procedure for solid waste characterization

Multiphasic analysis procedure

The **procedure** was based on water extraction of the raw sample, which enabled the measurement of the contributions of **water-soluble** and **particulate phases** of biomass dedicated to anaerobic digestion

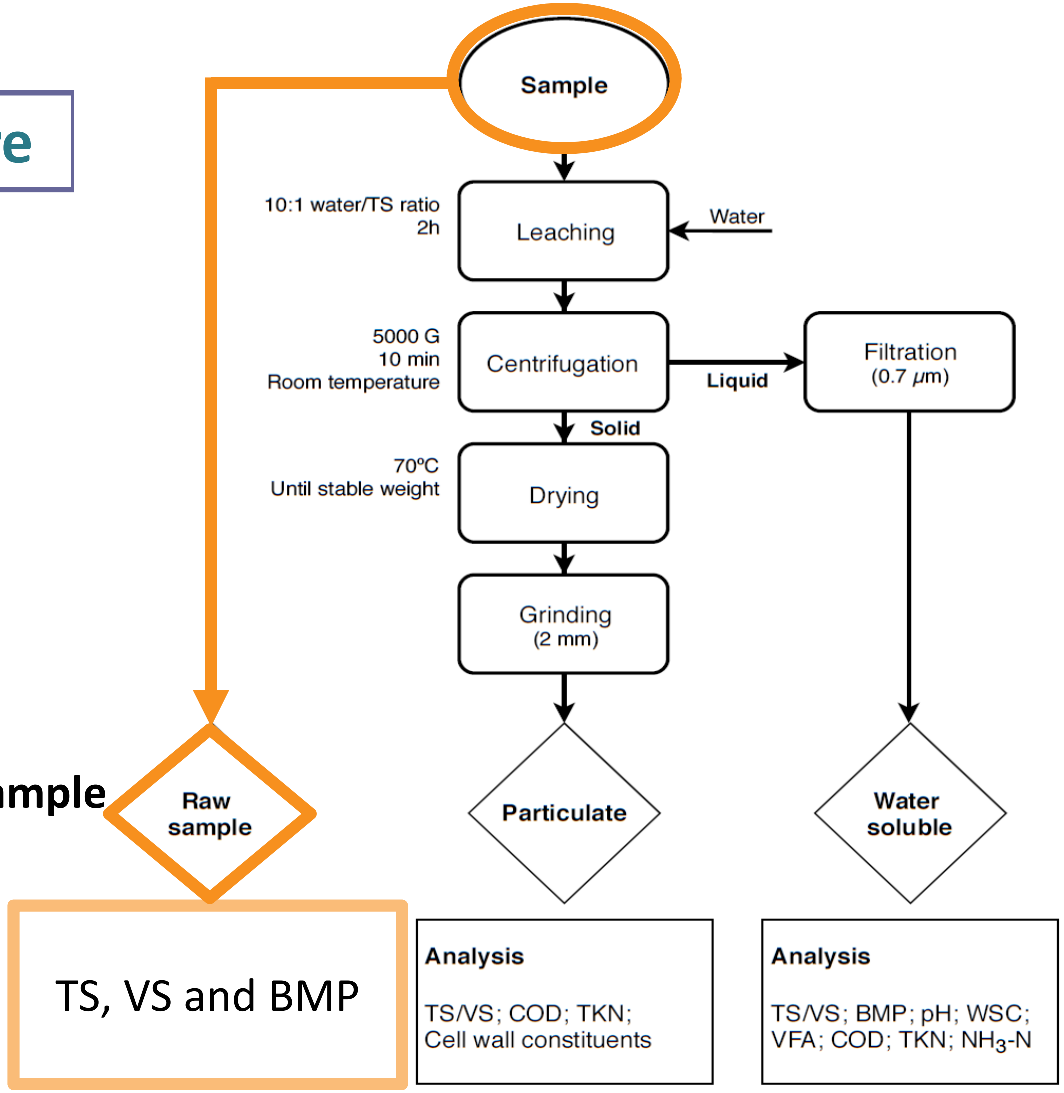


Flowchart of the experimental methodology

Analytical procedure for solid waste characterization

Multiphasic analysis procedure

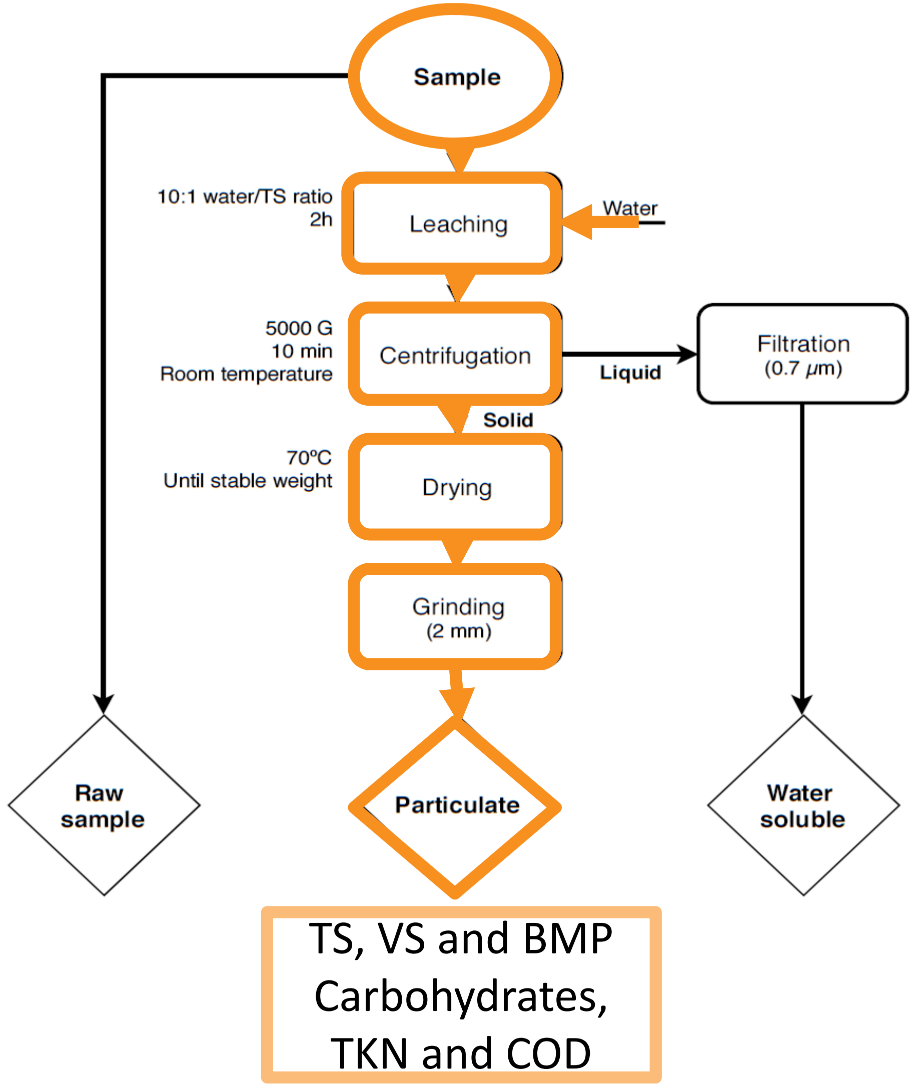
Raw Sample



BMP

Analytical procedure for solid waste characterization

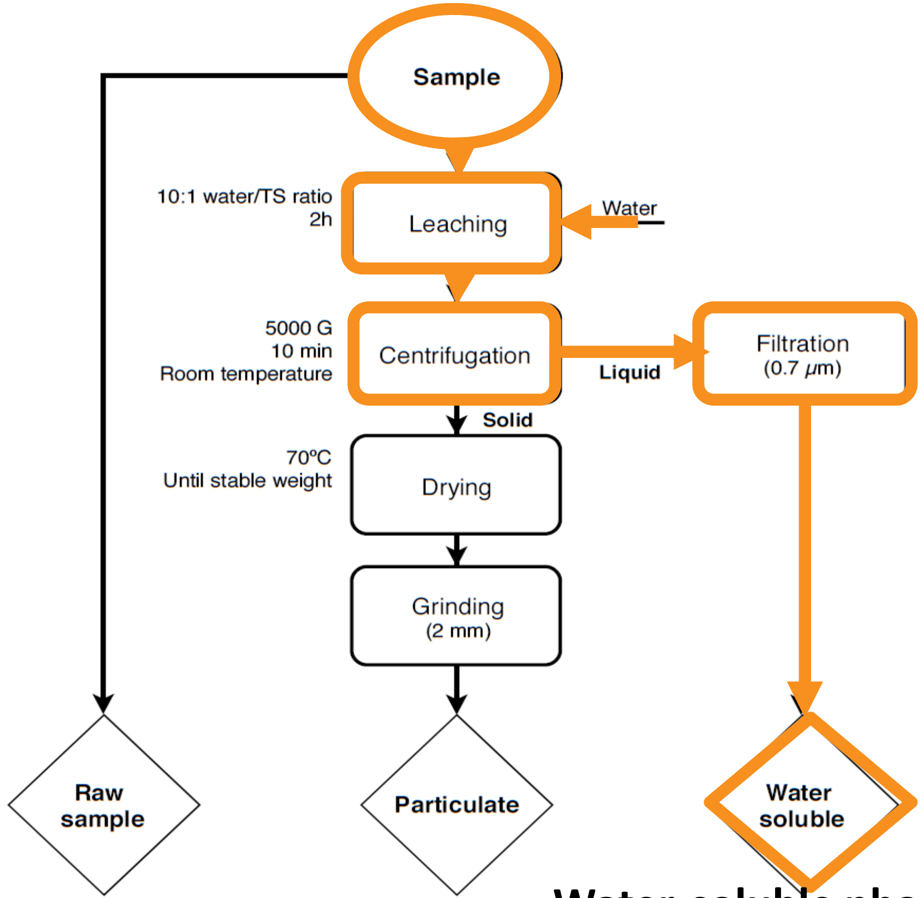
Multiphasic analysis procedure



Particulate phase

Analytical procedure for solid waste characterization

Multiphasic analysis procedure



BMP

Water-soluble phase

TS, VS, pH and BMP
VFA, Sugars, alcools,
Carbohydrates, TKN-NH3 and
COD

Illustration: Application on catch crops & cattle manures

Storage effect : Ensiled or not

Trials were carried out with two different types of **catch crops** and two different **cattle manures**, and study the effects of 3 months of **storage ensiling.**

Nevertheless, this procedure should be suitable for other types of biomass, such as energy crops or urban organic waste, and pretreatments, to evaluate potential inputs for AD and to optimize the design of biogas plants

Application on catch crops & cattle manures

The phase distribution of the various components of interest

- **Non-measured properties were determined with the following mass balances**

$$COD_{RS}[kg/kgVS_{RS}] = COD_{WS}[kg/kgVS_{RS}] + COD_{P}[kg/kgVS_{RS}]$$

$$BMP_{P}[L_{STP}/kgVS_{RS}] = BMP_{RS}[L_{STP}/kgVS_{RS}] - BMP_{WS}[L_{STP}/kgVS_{RS}]$$

- **The biodegradability of each fraction was calculated from BMP and COD values considering the theoretical BMP of 0.35 LSTP/kgCOD, as described below:**

$$BD\ (\%) = \frac{BMP[L_{STP}/kgVS]}{COD\ [kg/kgVS] \times 0.35}$$

Results COD balance

M : Cattle Manure
CC : Catch Crop
E : Ensiled

	CC1-F	CC1-E	CC2-F	CC2-E	M1-F	M1-E	M2-F	M2-E
Raw sample								
COD ($g_{O2}/kgVS_{RS}$)	1280	1527	1296	1553	1476	1204	1314	1310
Water-soluble phase								
COD ($g_{O2}/kgVS_{RS}$)	100	464	184	1074	275	146	133	183
% COD_{RS}	**7.8**	**30.4**	**14.2**	**69.2**	**18.6**	**12.1**	**10.2**	**14.0**
WSC (% COD_{RS})	0.10	0.11	9.9	0.09	0.0	0.0	0.0	0.16
VFA (% COD_{RS})	3.1	16.0	0.72	18.3	2.2	2.3	5.8	10.6
Particulate phase								
COD ($g_{O2}/kgVS_{RS}$)	1180	1063	1112	479	1201	1058	1181	1127
% COD_{RS}	92.2	69.6	85.8	30.8	81.4	87.9	89.8	86.0

- COD of raw sample was 1204-1533 g/kg_{VSRS} for the tested feedstocks.
- COD distribution varied greatly depending on the feedstock. The COD of the water-soluble phase was 100-1074 g/kg_{VSRS}, which represents a contribution to the total COD of 8-69%.
- Furthermore, the highest water-soluble COD values correspond to the ones of ensiled catch crops.-

Results BMP balance

CC : Catch Crop M : Cattle Manure E : Ensiled

	CC1-F	CC1-E	CC2-F	CC2-E	M1-F	M1-E	M2-F	M2-E
Raw sample								
BMP ($L_{STP}/kgVS_{RS}$)	270±14	300±12	335±34	410±7	288±14	255±7	257±6	217±2.0
Water-soluble phase								
BMP ($L_{STP}/kgVS_{RS}$)	20±0.6	72±5	41±2.3	190±28	77±1.1	38±0.3	43±4	48±1.8
% BMP_{RS}	**7.3**	**24.1**	**12.3**	**46.3**	**26.9**	**15.1**	**16.6**	**22.2**
Particulate phase								
BMP ($L_{STP}/kgVS_{RS}$)	250±20	228±24	294±46	220±37	210±13	217±8	215±27	169±8
% BMP_{RS}	92.7	75.9	87.7	53.7	73.1	84.9	83.4	77.8

- The BMP values varied widely within the set of tested raw material
- The preparation mode also had an impact on the BMP of the feedstocks. Ensiling had a positive effect on the methane production of catch crops, and negative effect for cattle manure.
- Distinct distributions of BMP were found among the feedstocks. Indeed, contribution of water-soluble phase to the BMP of the raw sample ranged from 7% to 46%.
- And its distribution was affected by ensiling with the increasing of the contribution of water-soluble phase.

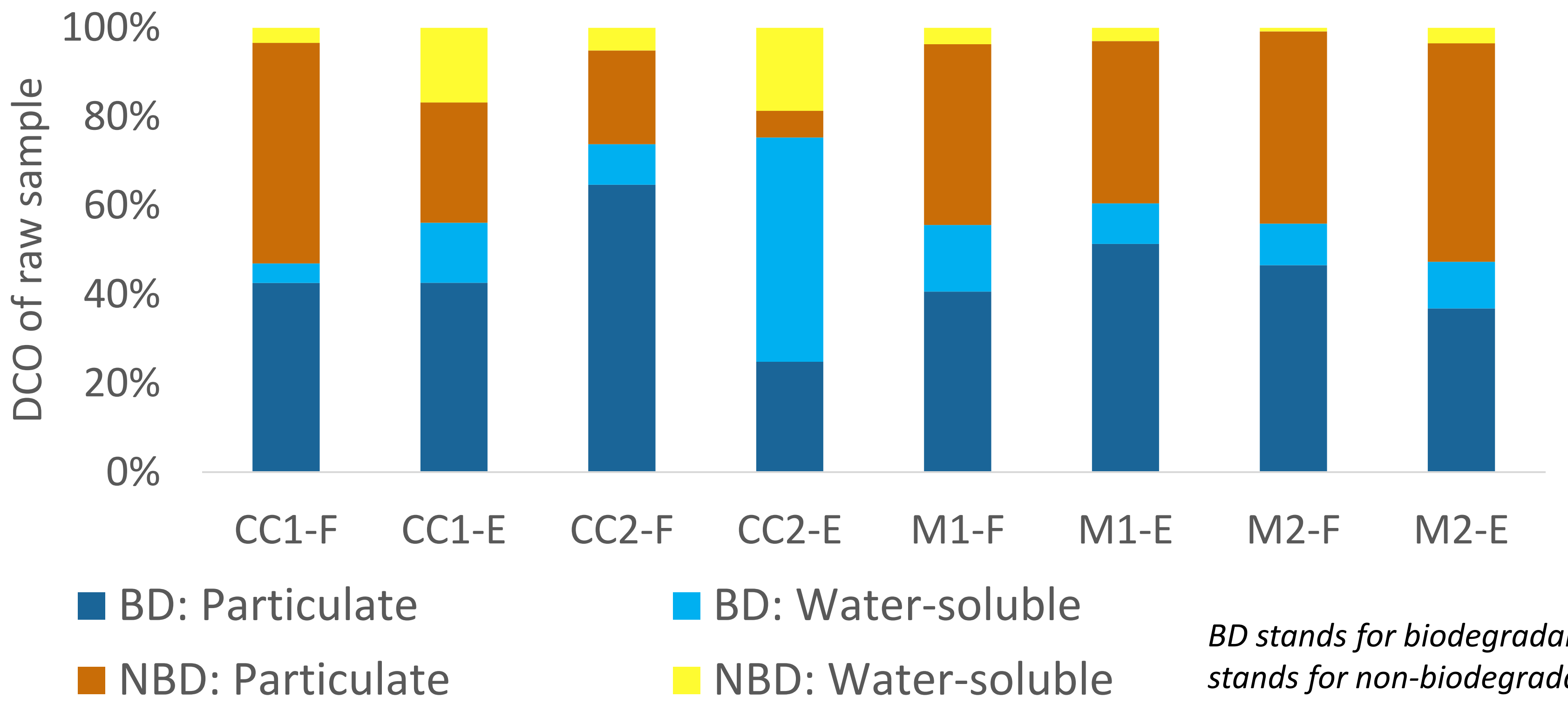
Results BMP/ COD : anaerobic biodegradability of feedstocks and its phase distribution on a DCO basis

F : Fresh

CC : Catch Crop

M : Cattle Manure

E : Ensiled



BD stands for biodegradable; NBD stands for non-biodegradable

Significant differences in biodegradability rate were found for some feedstocks before and after ensiling.

Conclusions

- A complete methodology was successfully applied to assess the organic biodegradability and the biomethane potential of different catch crops and cattle manures. This procedure evidenced a significant impact of the origin of biomass and its management conditions on the BMP and the biodegradability rates

- Distinct distribution of COD and BMP were found among feedstocks: contribution of the water-soluble phase was 8-69% to the COD and 7-46% to the BMP of the raw sample.

- **Ensiling**: The highest water-soluble contributions to BMP corresponded to the ones of efficient ensiled biomass

- This type of multiphase analysis may also provide important data on the efficiency and comparison of various pretreatments

Acknowledgements

The Auvergne-Rhône-Alpes Region for the doctoral fellowship attributed to this PhD thesis

La Région Auvergne-Rhône-Alpes

Laboratory team, notably David Lebouil, Hervé Perier-Camby, Nathalie Dumont and Richard Poncet

deep

Franck Barra for his permanent availability for discussion and raw material supply.

Thank you for your attention!

REMY BAYARD

Associate Prof,

DEEP Lab. INSA Lyon, France

remy.bayard@insa-lyon.fr

Tel : +33-4-72-43-87-53

Ευχαριστώ