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## **Influence of the flax fibre chemical composition on mechanical properties of epoxy biocomposite**

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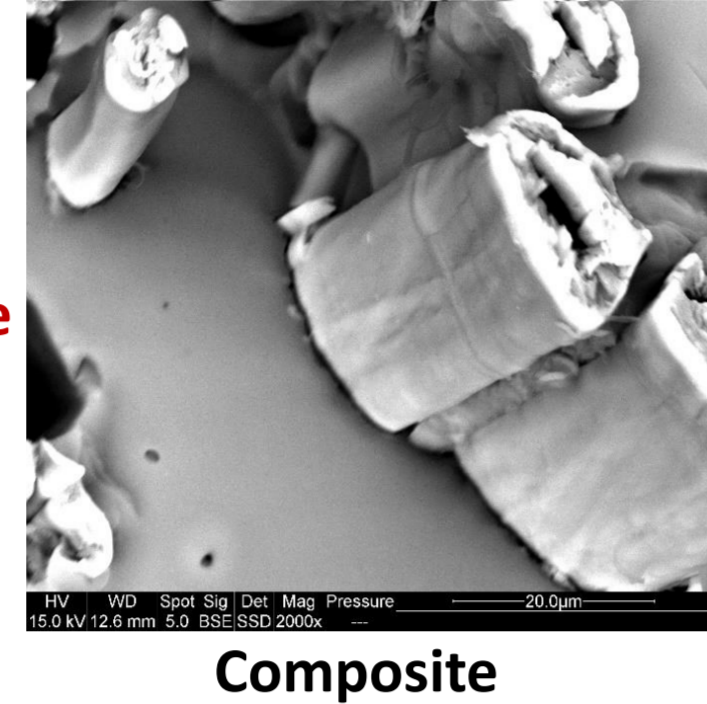
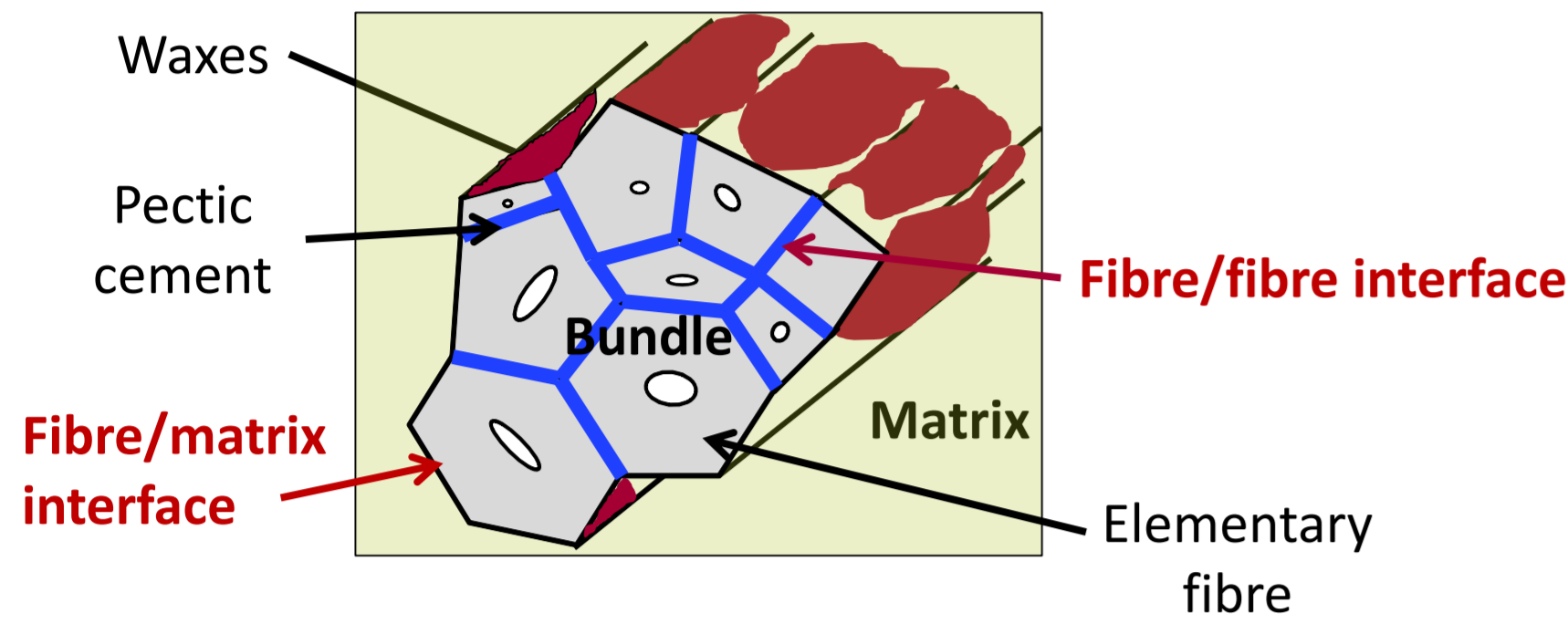
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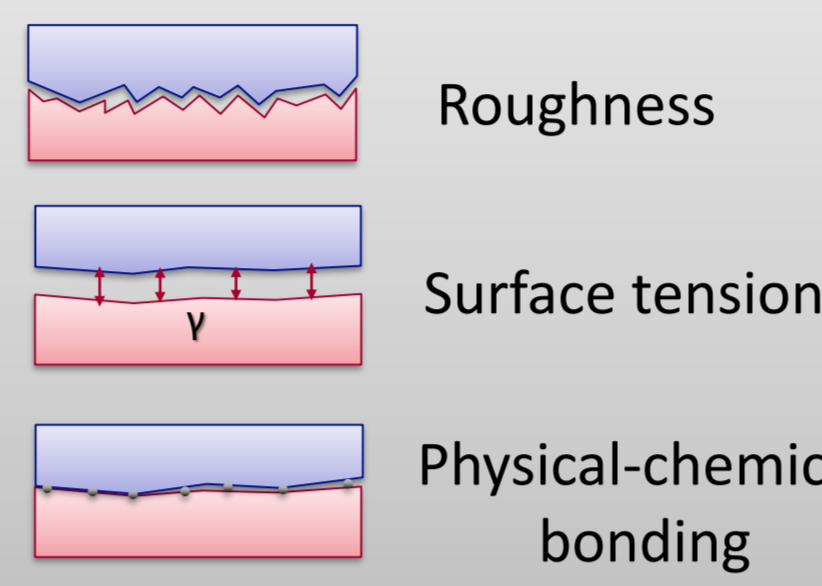
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## CONTEXT

Natural fibres based composites are increasingly used mainly because of their low density and positive life cycle assessment. Nevertheless an improvement of their mechanical properties is required. A better control of the **fibre/matrix interface** and of the **intra-fibrillar interface within the fibre bundles** has to be established.

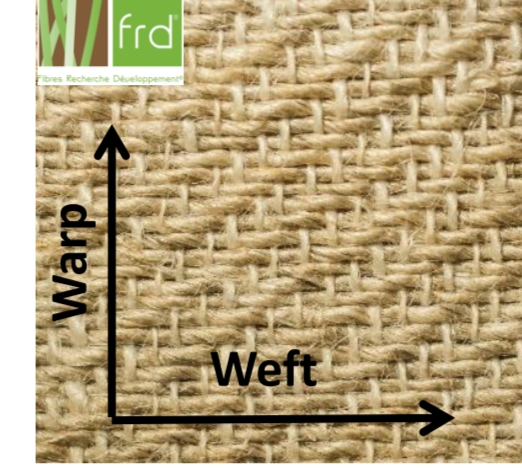


### Factors involved at the interface

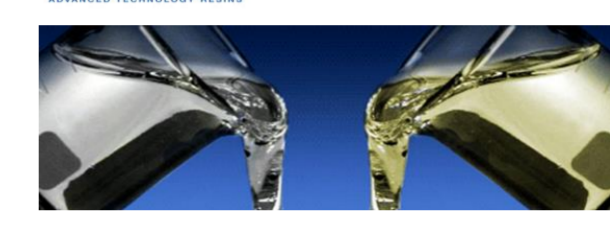


## MATERIALS

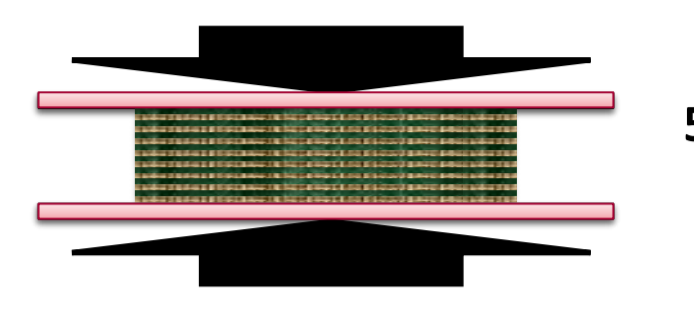
Quasi-unidirectional flax fibre fabric UD29, FRD, France



Structural epoxy system Resin 1800/hardener 1805 ratio 100/17 %wt Resoltech, France

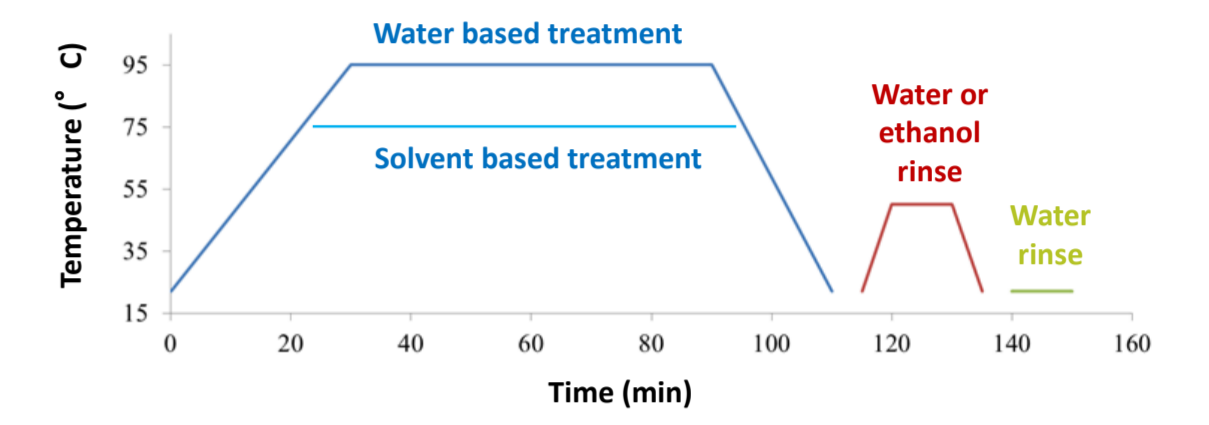


Composite processing : Thermo-compression 8 layers of UD29 impregnated with epoxy resin during 6h at 60°C for curing + 15h at 60°C of post-curing



50 bar  
60°C

## WASHING TREATMENTS



PEG : polyethylene glycol (non ionic) - LAS : alkyl benzene sulfonate (anionic) - HEPD : 1-hydroxyethane 1,1-diphosphonic acid (chelating agent)

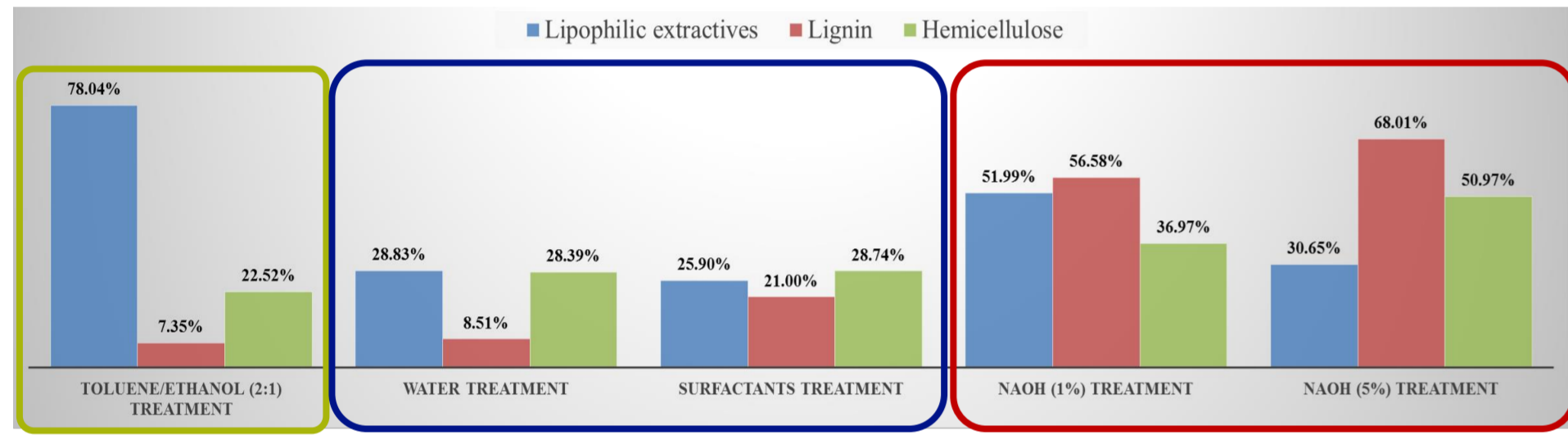
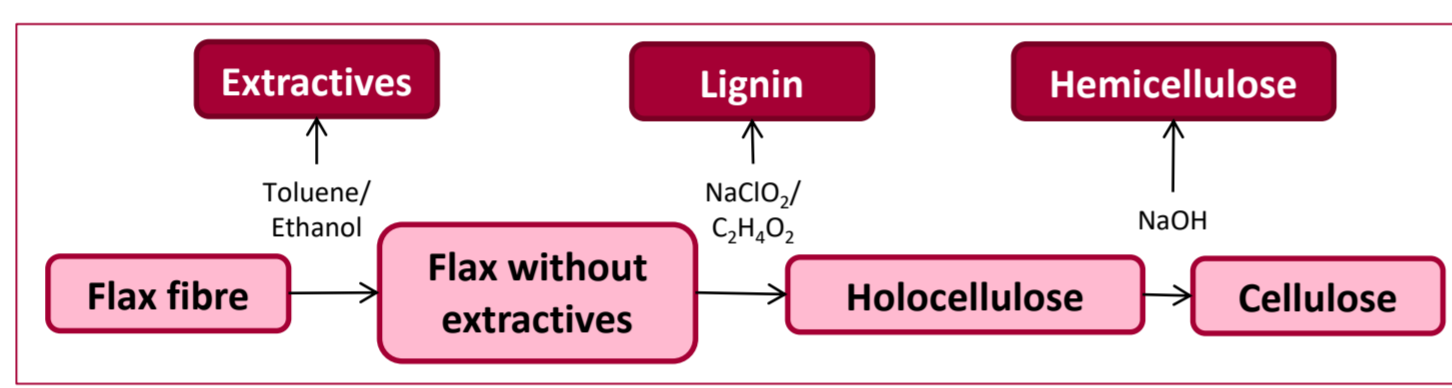
## OBJECTIVES

Study the influence of different washing treatments on the flax fibre fabrics properties and the flax/epoxy composite microstructure and mechanical properties

## FLAX FIBRE FABRICS PROPERTIES

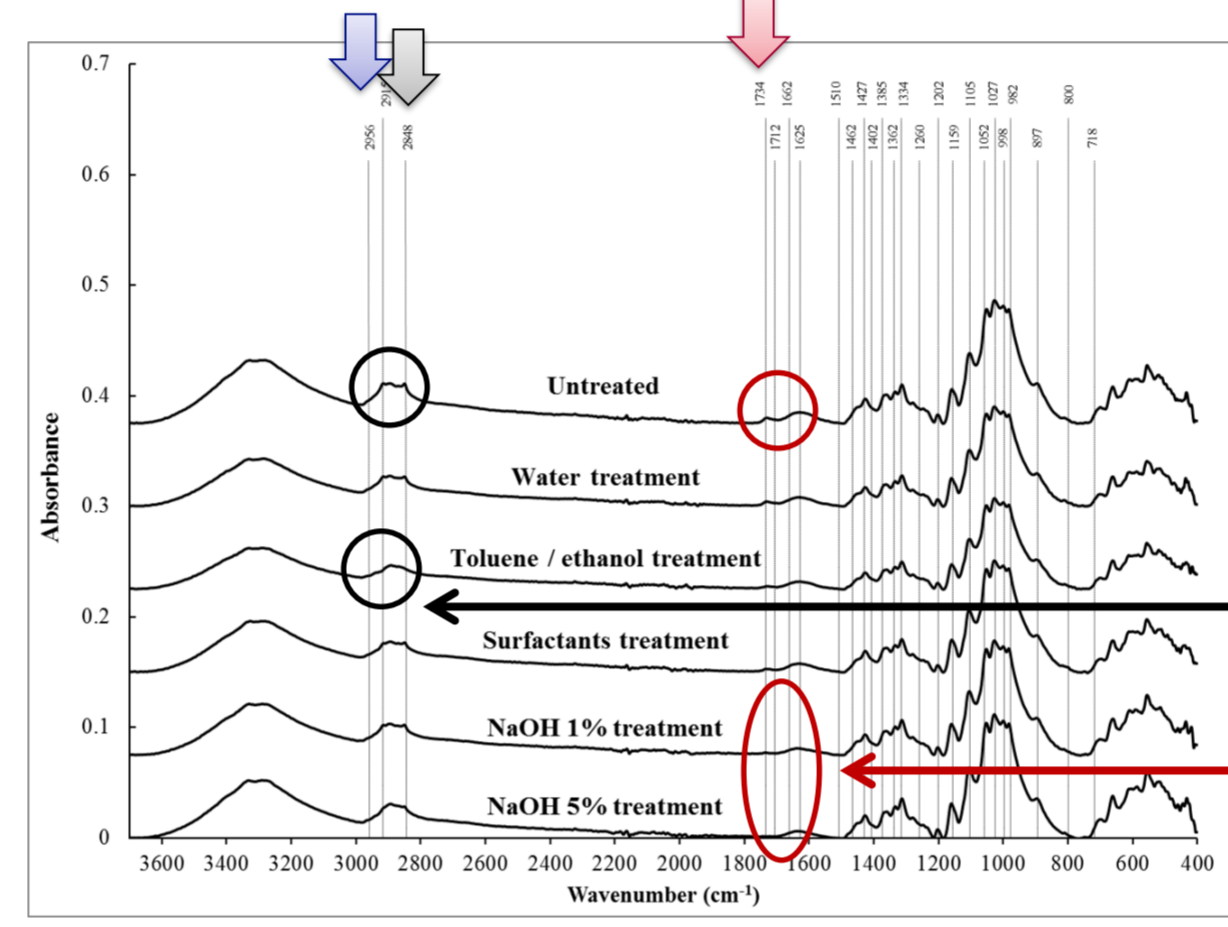
### Chemical composition

- Successive extractions TAPPI T-264 / ASTM D1104-56 / ASTM D1103-60 / ASTM D1102-84
- Ajustment of the values to the same amount of cellulose
- Weight loss (%) of each component vs. untreated fibre



### 3 evolutions according to the treatment nature :

- Toluene/Ethanol : removal of lipophilic extractives
- Water, surfactants : global weak extraction
- NaOH : strong extraction of lignin and hemicellulose

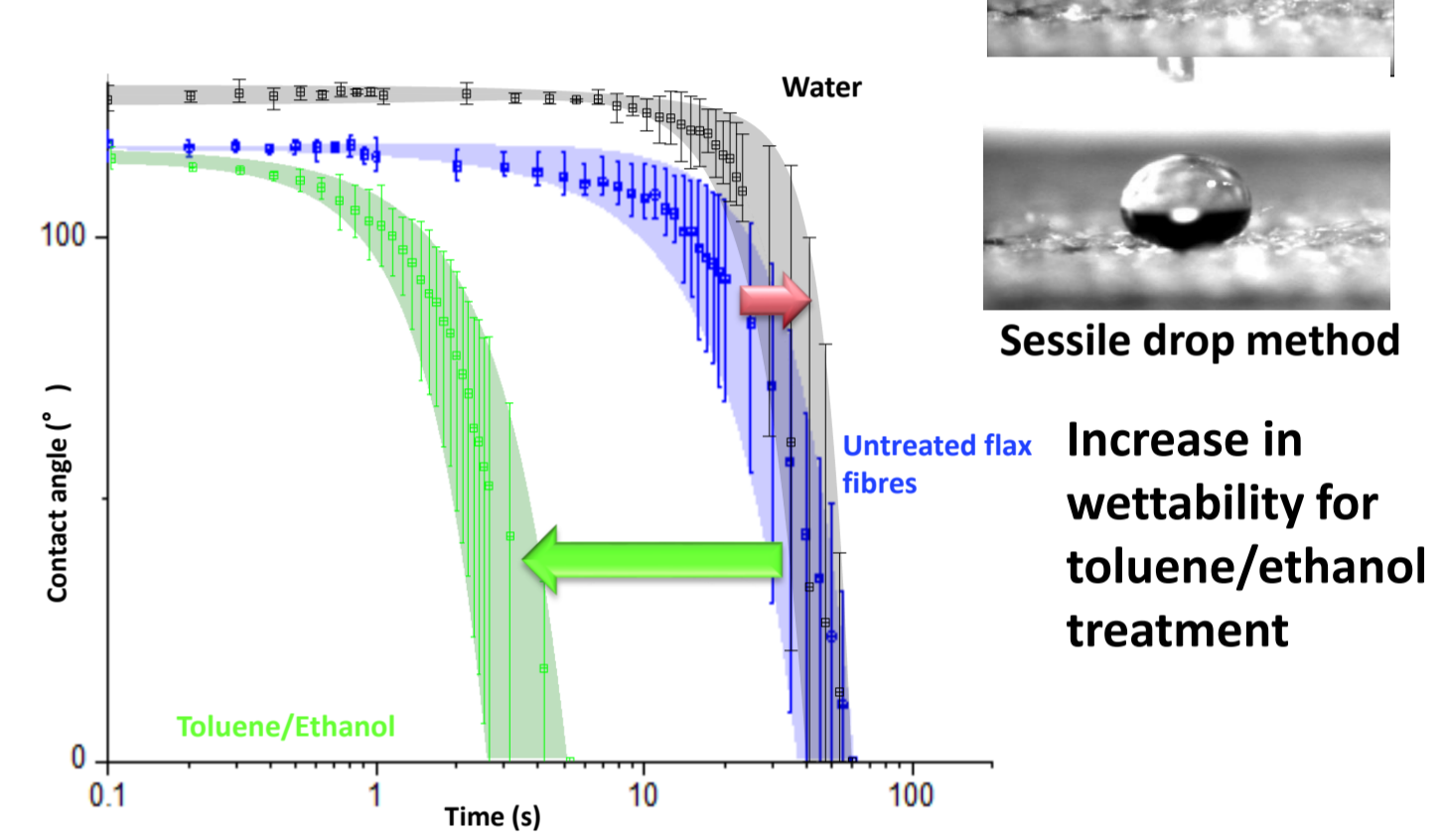


### FTIR analysis (ATR)

Untreated  
Water treatment  
Toluene/ethanol treatment  
Surfactants treatment  
NaOH 1% treatment  
NaOH 5% treatment

### Surface properties

Water contact angle measurements



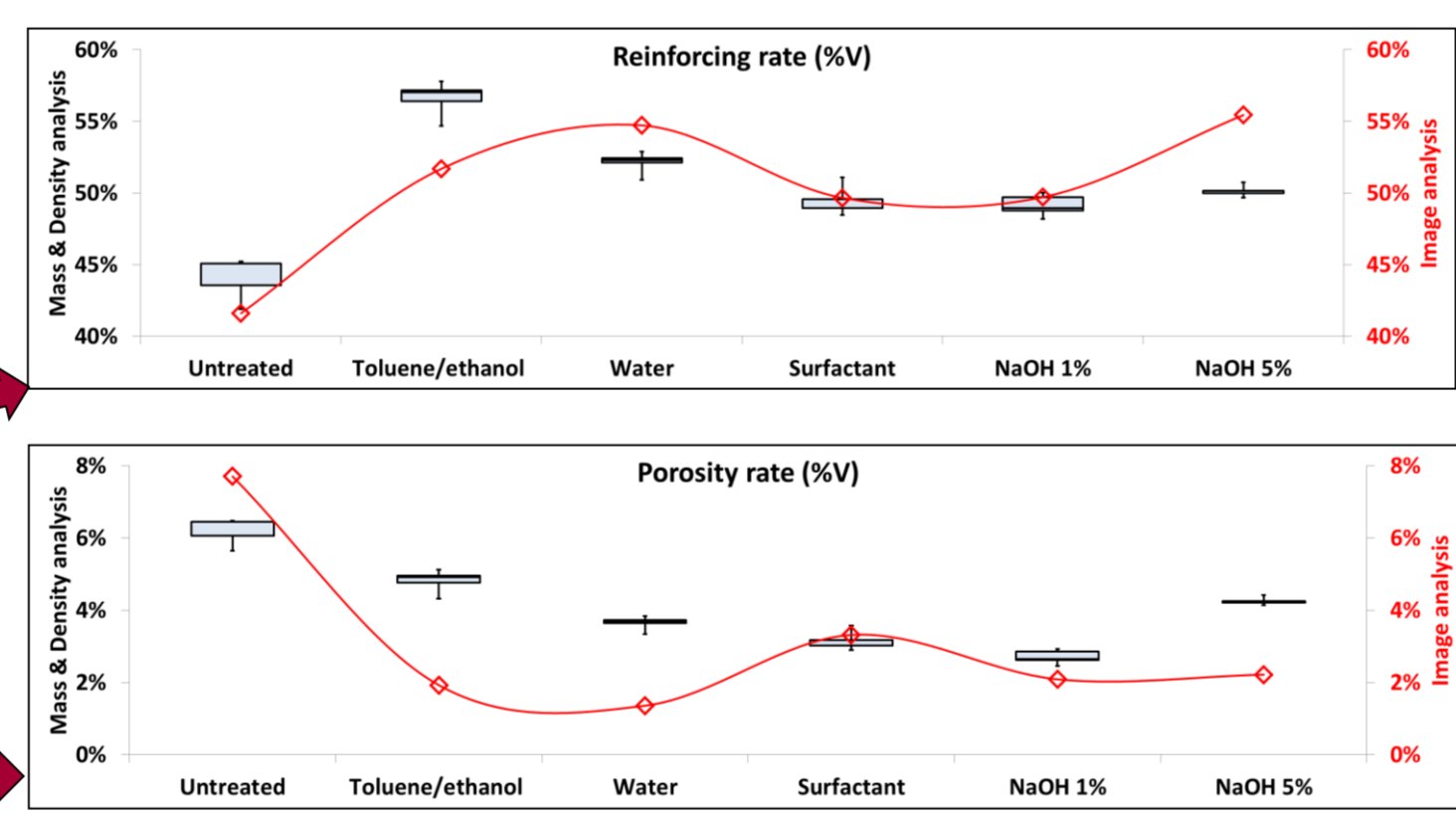
Increase in wettability for toluene/ethanol treatment

## FLAX / EPOXY COMPOSITE MICROSTRUCTURE

### POROSITY

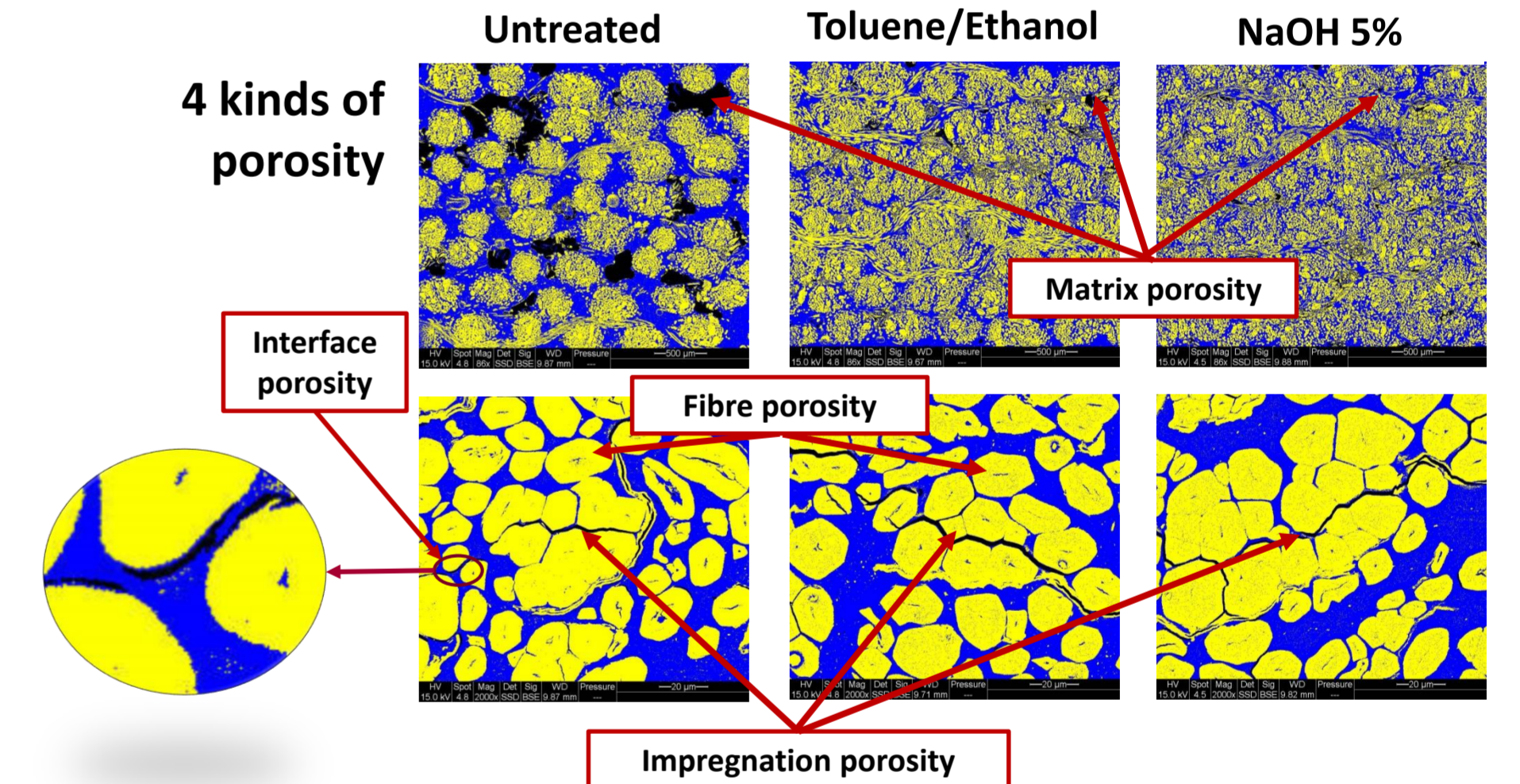
#### Method 1 : gravimetry and density analyses

- Mass reinforcing rate obtained from woven areal density
- Weight content of matrix obtained from difference between composite areal density and woven areal density
- Volume rates :  $\%v_{(Reinf)} = \%w_{(Reinf)} \cdot \frac{\rho_{Comp}}{\rho_{Reinf}}$   
 $\%v_{(Matr)} = \%w_{(Matr)} \cdot \frac{\rho_{Comp}}{\rho_{Matr}}$   
 $\%v_{(Por)} = 1 - (\%v_{(Reinf)} + \%v_{(Matr)})$

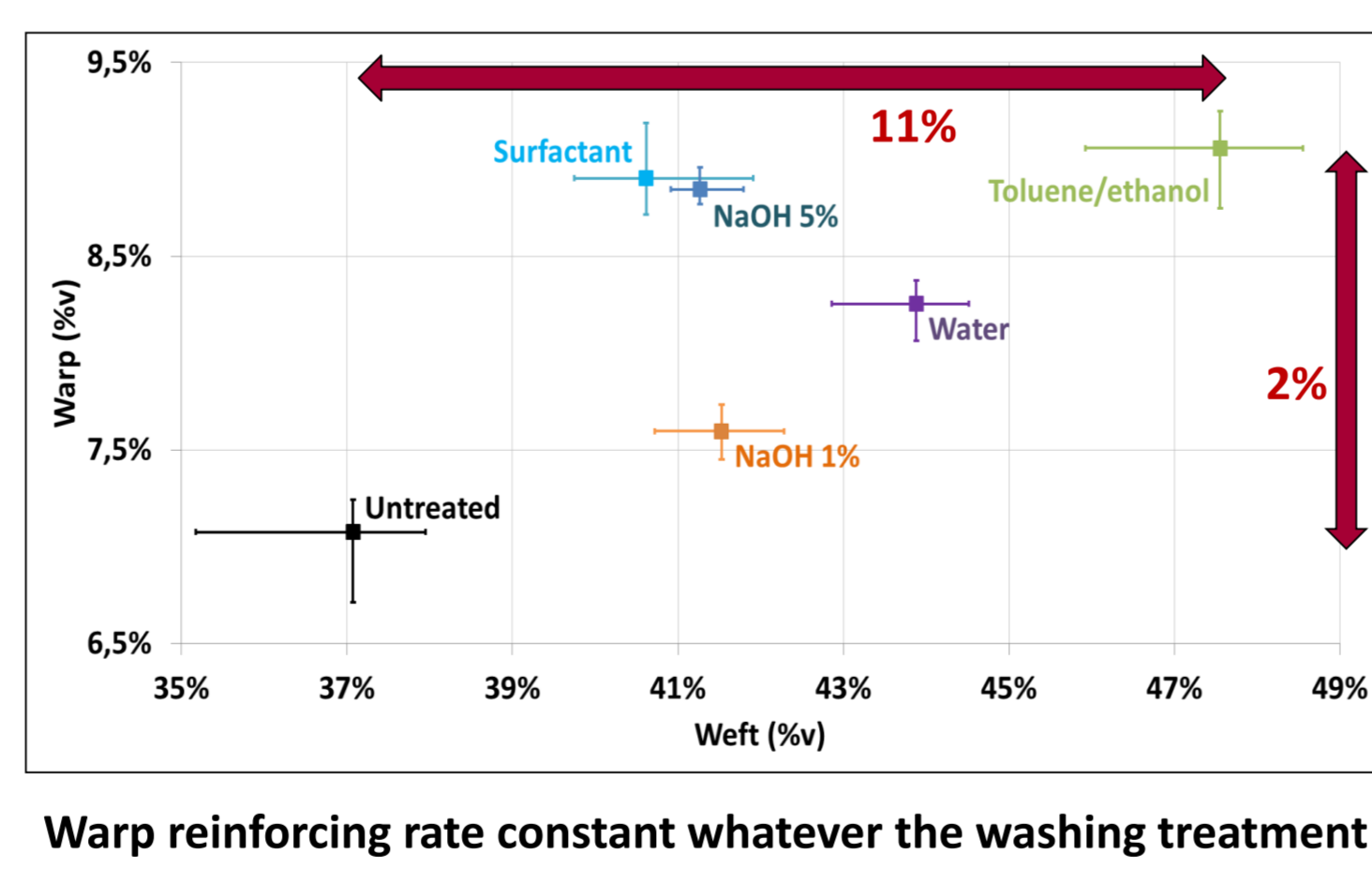
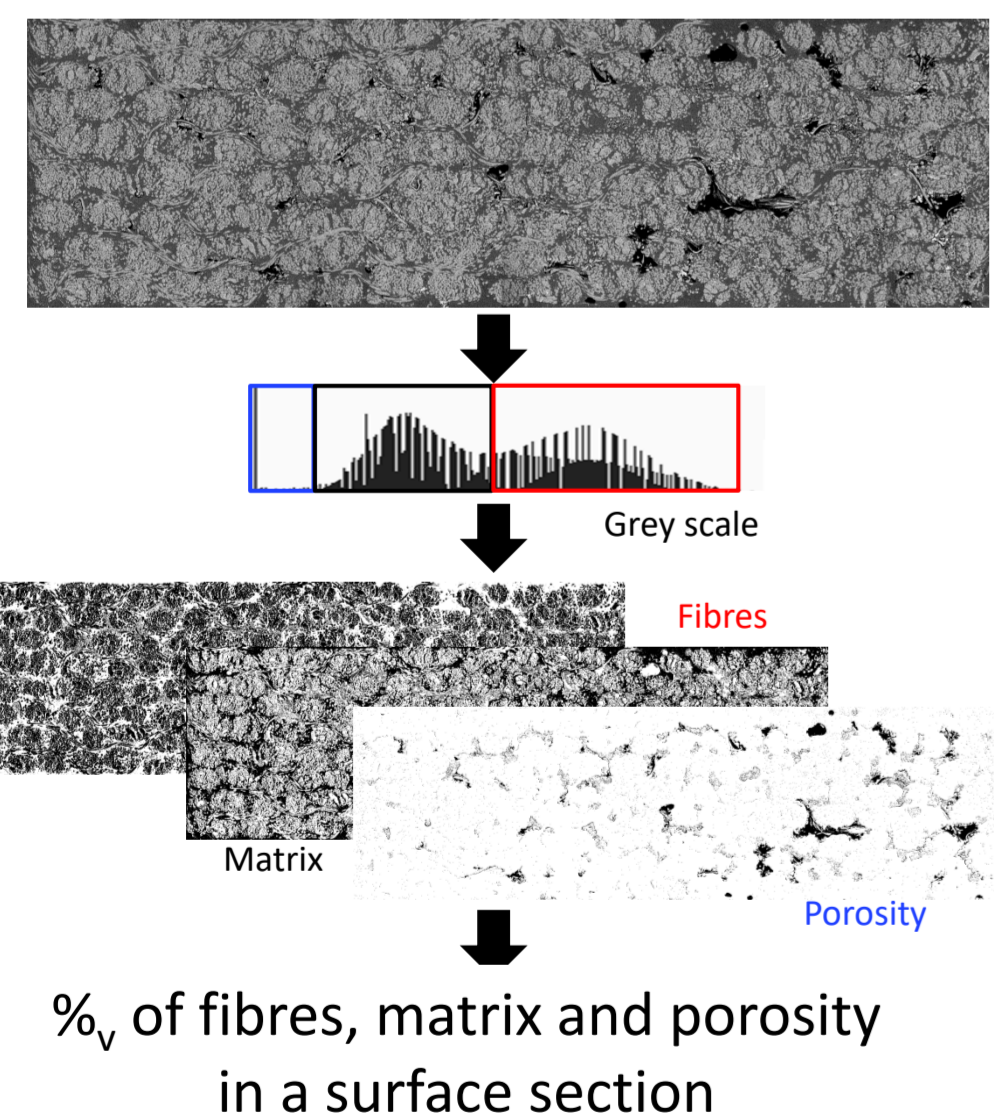


- Small differences between both methods  
→ Image analysis method is a more local method so that differences may occur for less homogeneous composite
- Decrease in the porosity whatever the washing treatment

### 4 kinds of porosity

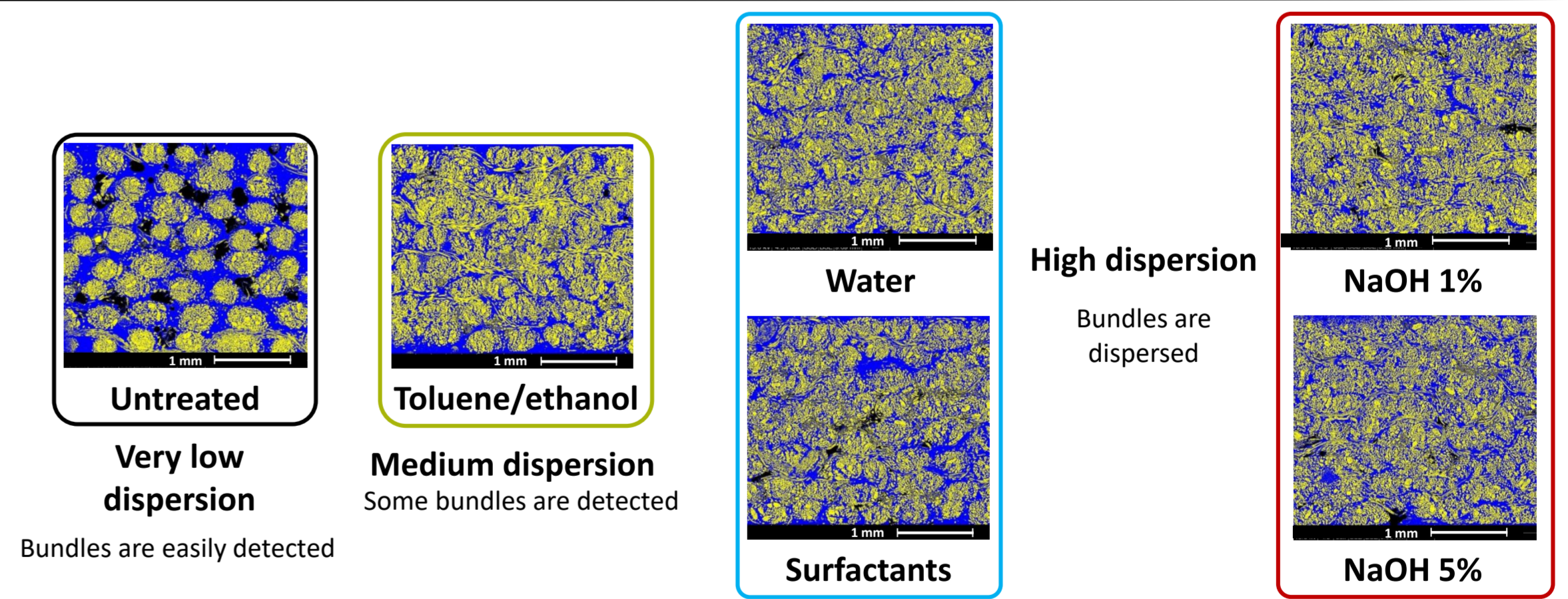


#### Method 2 : image analysis



Warp reinforcing rate constant whatever the washing treatment

### DISPERSION



Very low dispersion  
Bundles are easily detected

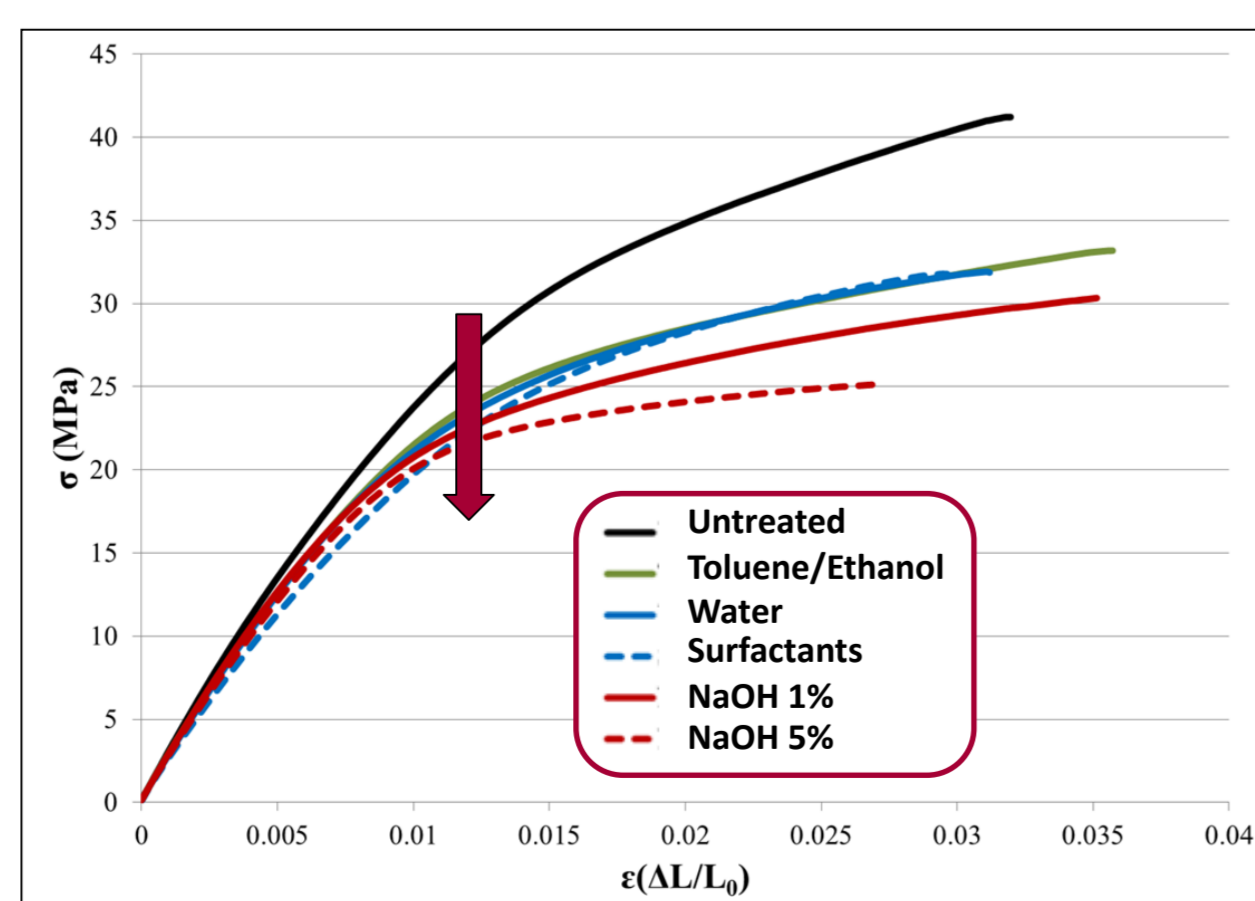
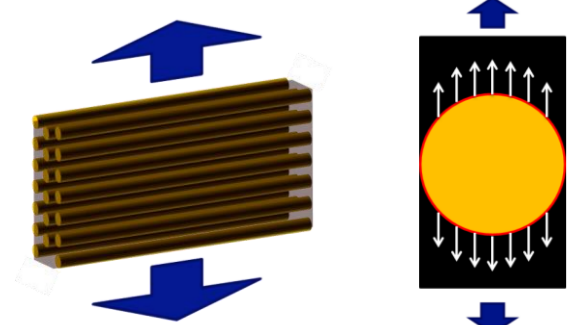
Medium dispersion  
Some bundles are detected

High dispersion  
Bundles are dispersed

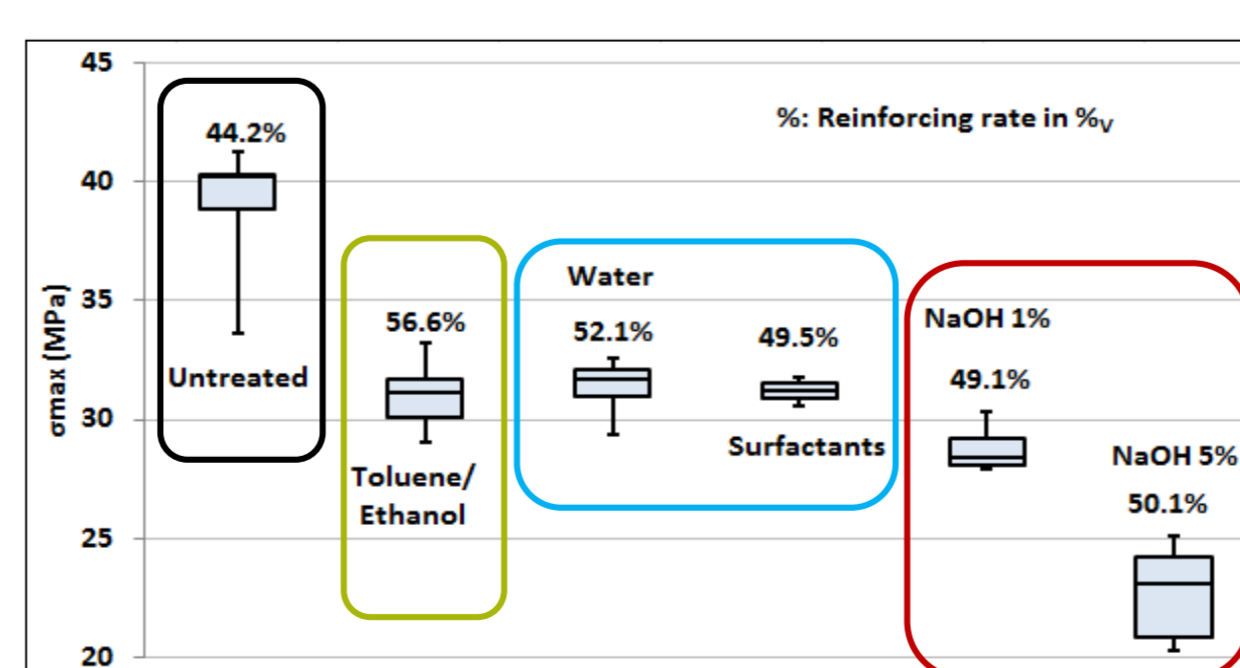
Improvement of the fibre dispersion within the composite

## FLAX / EPOXY COMPOSITE MECHANICAL PROPERTIES

Similar warp reinforcing rate (2%)  
Interface properties  
Transverse tensile tests



Shift of the elastic-plastic transition to lower strength for more drastic extraction condition



Decrease in the maximum strength for each treatment even if the dispersion was improved

### Two assumptions:

- Bad elementary fibre / matrix interface
- Fibre components removal → variations in the stress accommodation within the composite

## CONCLUSIONS

**Chemical composition :** Toluene/Ethanol : extraction of lipophilic components  
Water, surfactants : weak extraction  
NaOH : strong extraction of lignin and hemicellulose

### Microstructure :

- Decrease in the porosity rate, mainly matrix porosity, whatever the treatment
- Improvement of the fibre dispersion within the composite depending on the treatment

### Mechanical properties :

Decrease in the transverse mechanical properties due to either a bad elementary fibre / matrix interface, or variations in the stress accommodation within the composite