RVE-based Micromechanical Analysis of Fiber-Matrix Debonding in Thin Ply FRPC Laminates

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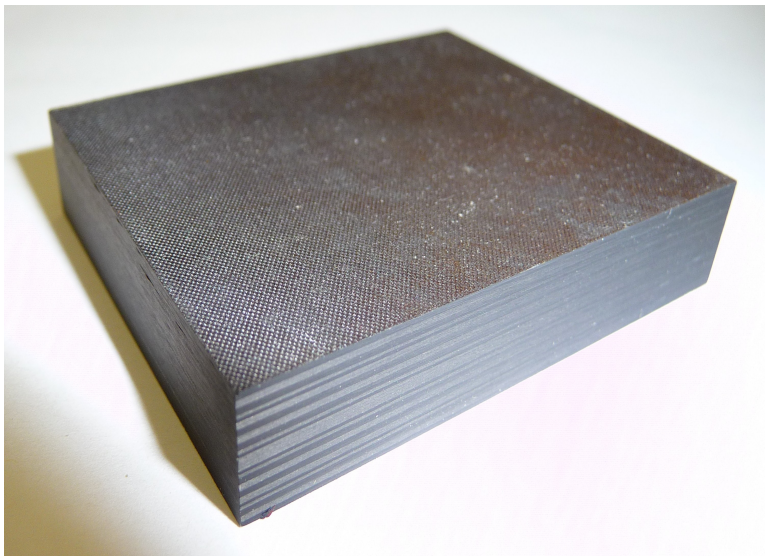
Outline

- Introduction to Thin Ply FRP Laminates
- The rationale of the project
- The model
- References

Introduction to Thin Ply FRP Laminates

What are composite materials?

(a) Egyptian mud bricks.



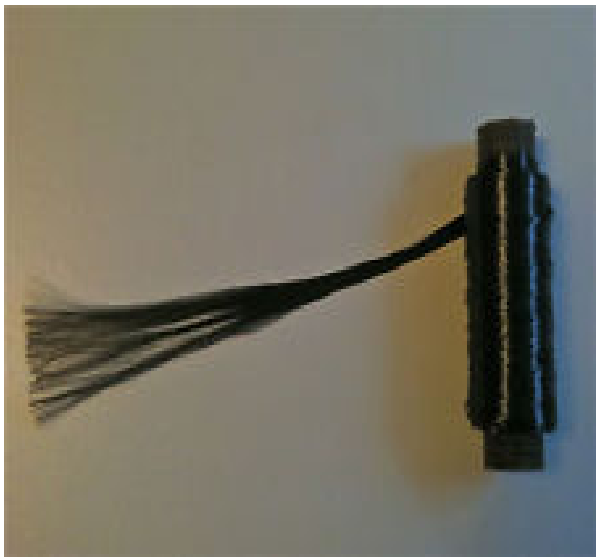
(b) Fiber reinforced polymer (FRP) laminate.

What are composite materials?

More important than any one new application is the new 'materials' concept itself. It marks a shift from concern with substances to concern with structures, a shift from artisan to scientist as man's artificer, a shift from chemistry to physics as the basic discipline, and a shift, above all, from the concrete experience of the workshop to abstract mathematics, a shift from starting with what nature provides to what man wants to accomplish.

Peter Drucker, *The Age of Discontinuity*, 1969.

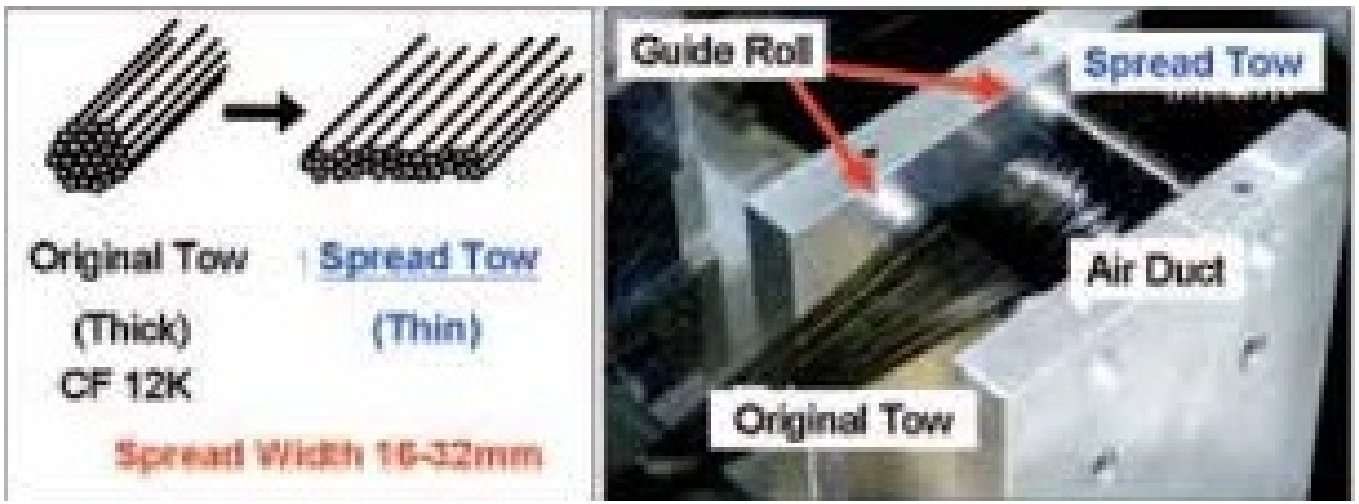
Fiber Tows and Prepreg



(c) Carbon fiber tow.

(d) Carbon fiber prepreg.

Spread tow technology



↘ THE RATIONALE OF THE PROJECT

Problem

- Strength advantages due to a positive size-effect with decreasing ply thickness [3]
- Good experimental knowledge
- Predictive capability, especially for failure, is scarce (WWFE-II and WWFE-III) [4]

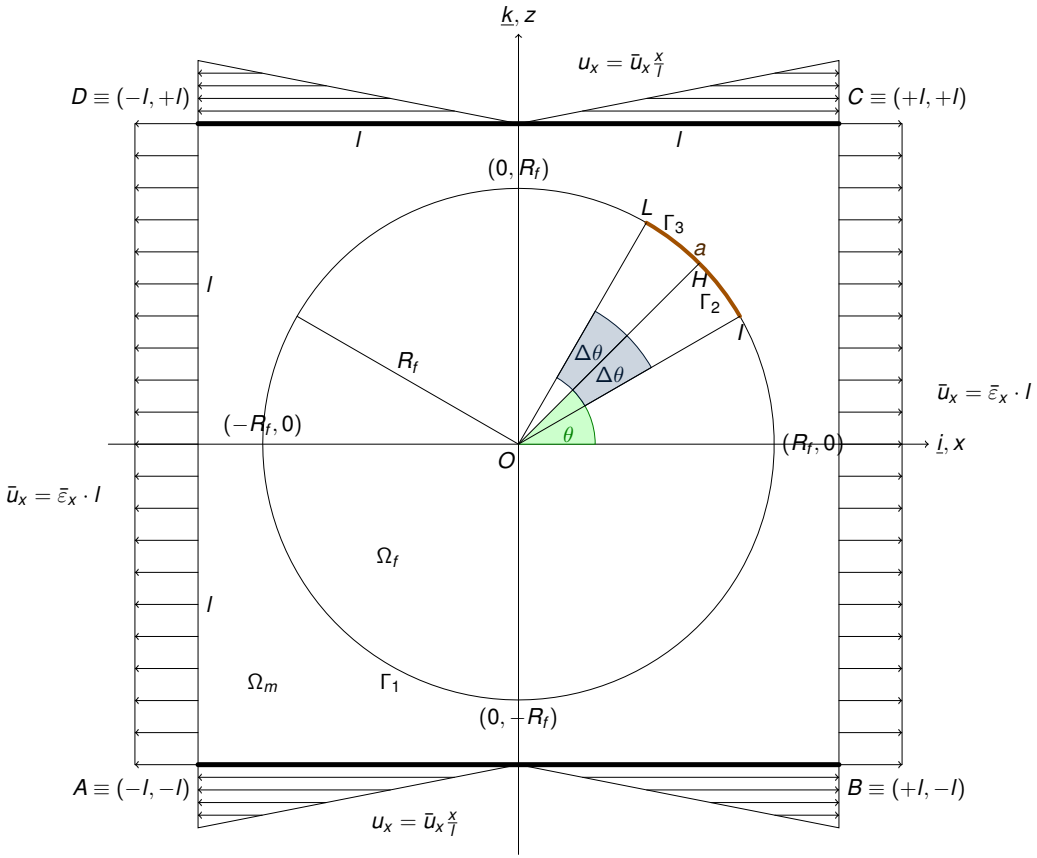
Objective & Method

$$G_{*c} = G_{*c}\,(\textit{geometry}, \textit{fiberorientation}, \textit{elastic properties}) \quad (1)$$

- Micromechanical analysis
- Design of Reference Volume Element (RVE)
- Finite Element Simulation

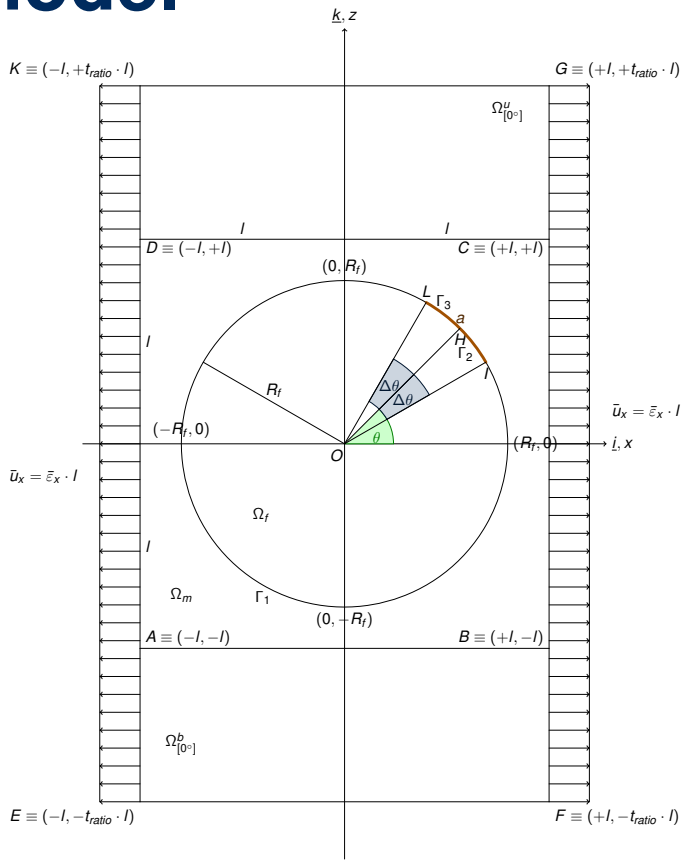
THE MODEL

Single RVE model



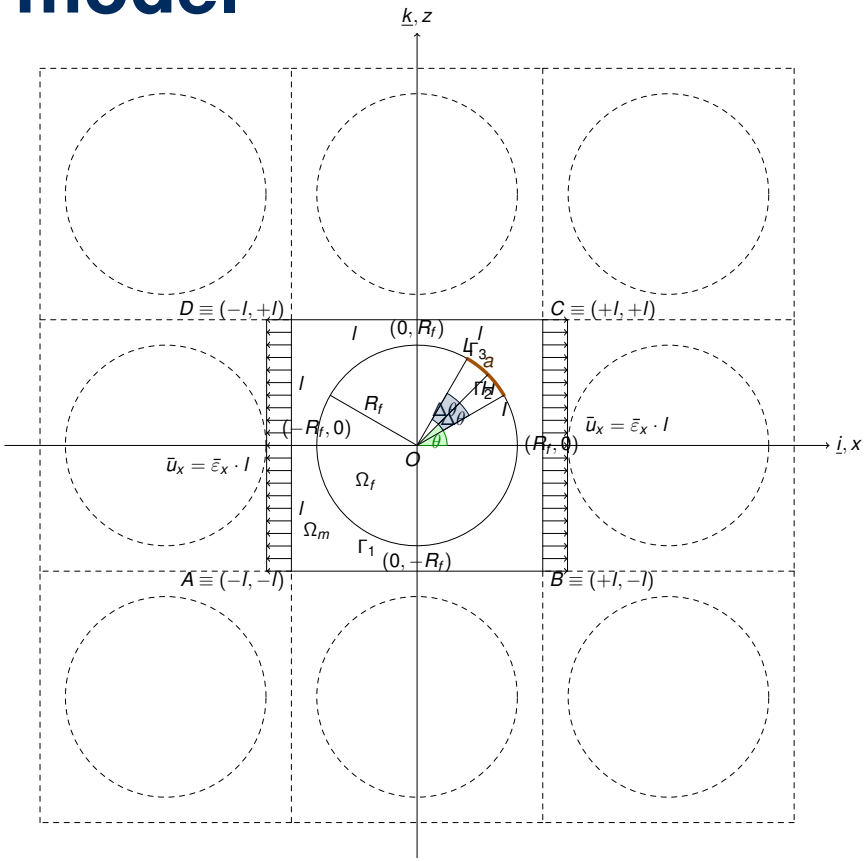
Initial state of single RVE model: crack closed in the radial direction.

Bounded RVE model



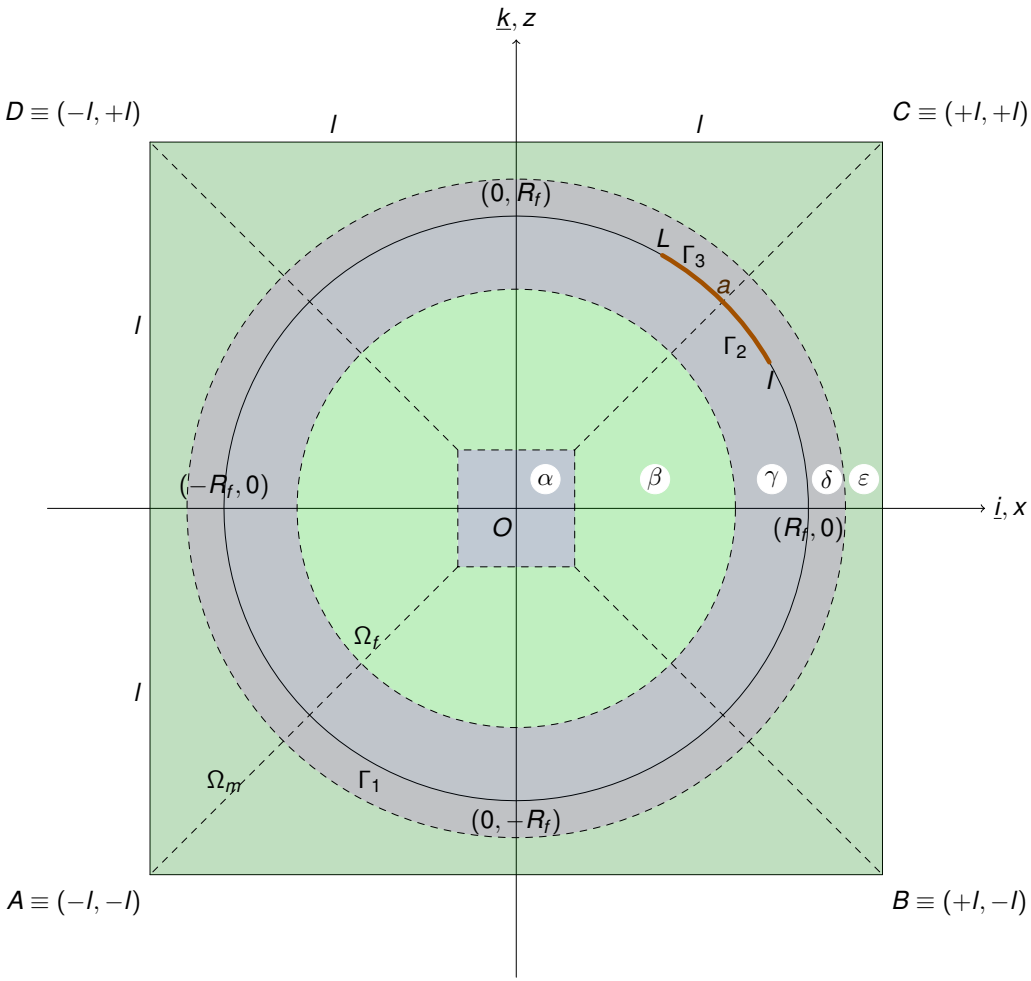
Initial state of bounded RVE model: crack closed in the radial direction.

Periodic RVE model

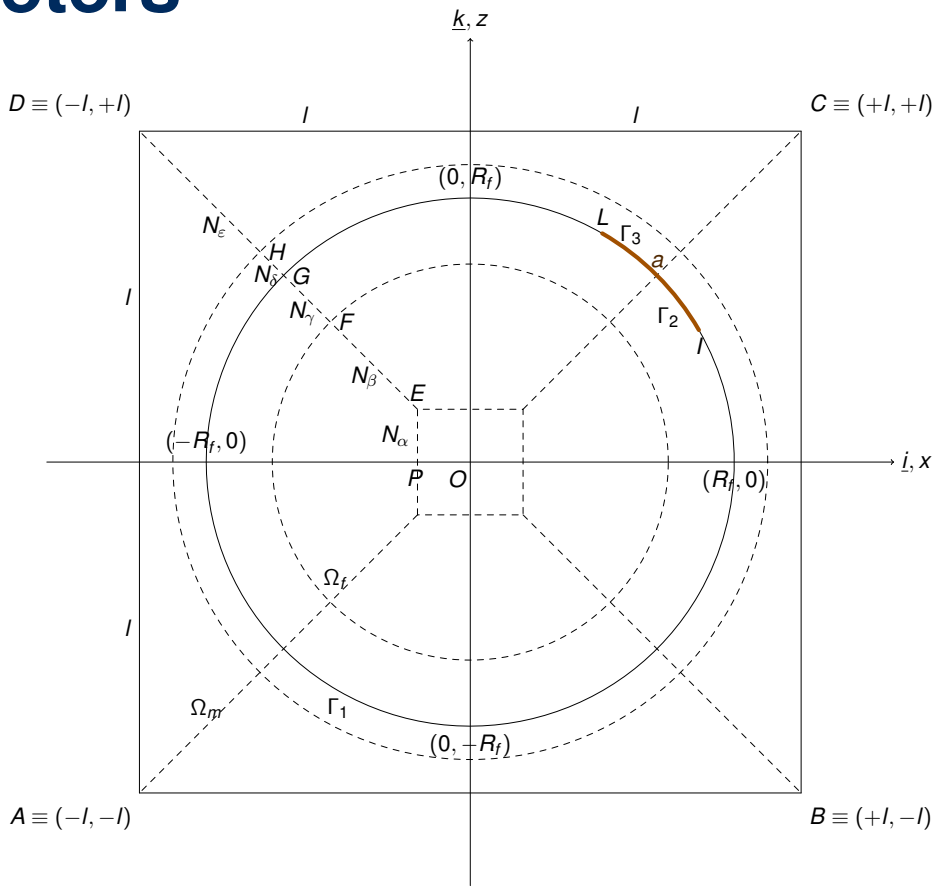


Initial state of periodic RVE model: crack closed in the radial direction.

Mesh regions

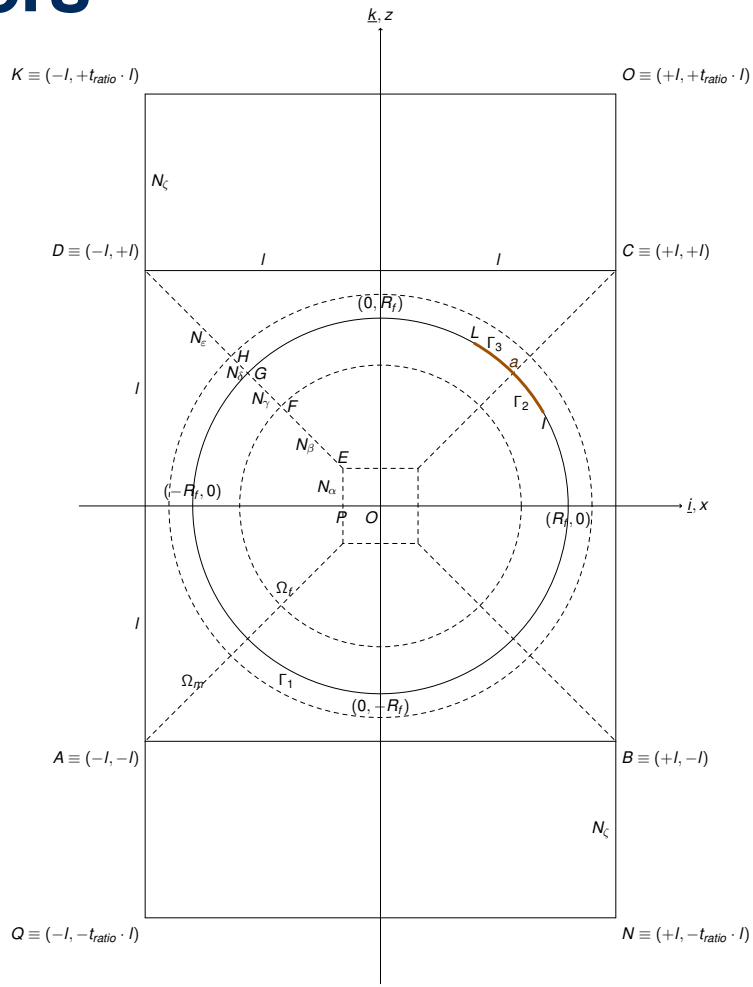


Mesh parameters



$E \equiv (-f_1 \cdot R_f, +f_1 \cdot R_f)$ $F \equiv f_2 R_f\,(-\cos 45°, \sin 45°)$

Mesh parameters



Features

Method
ABAQUS/STD static analysis + VCCT + J-integral.

Type
Static, i.e. no inertial effects. Relaxation until equilibrium.

Elements
CPE4/CPE8

Interface
Tied surface constraint & contact mechanics

Input variables
R_f, V_f, material properties, interface properties.

Control variables
θ, $\Delta\theta$, $\bar{\varepsilon}_x$.

Output variables
Stress field, crack tip stress, stress intensity factors, energy release rates, a.

Features

Method
ABAQUS/STD static analysis + CZM.

Type
Static, i.e. no inertial effects. Relaxation until equilibrium.

Elements
CPE4/CPE8 + COH2D4

Interface
Cohesive elements.

Input variables
R_f, V_f, material properties.

Control variables
Interface properties, maximum stresses at crack onset, energy release rates, applied strain.

Output variables
θ, $\Delta\theta$, a, stress field, peak crack boundary stresses.

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THANK YOU!

REFERENCES

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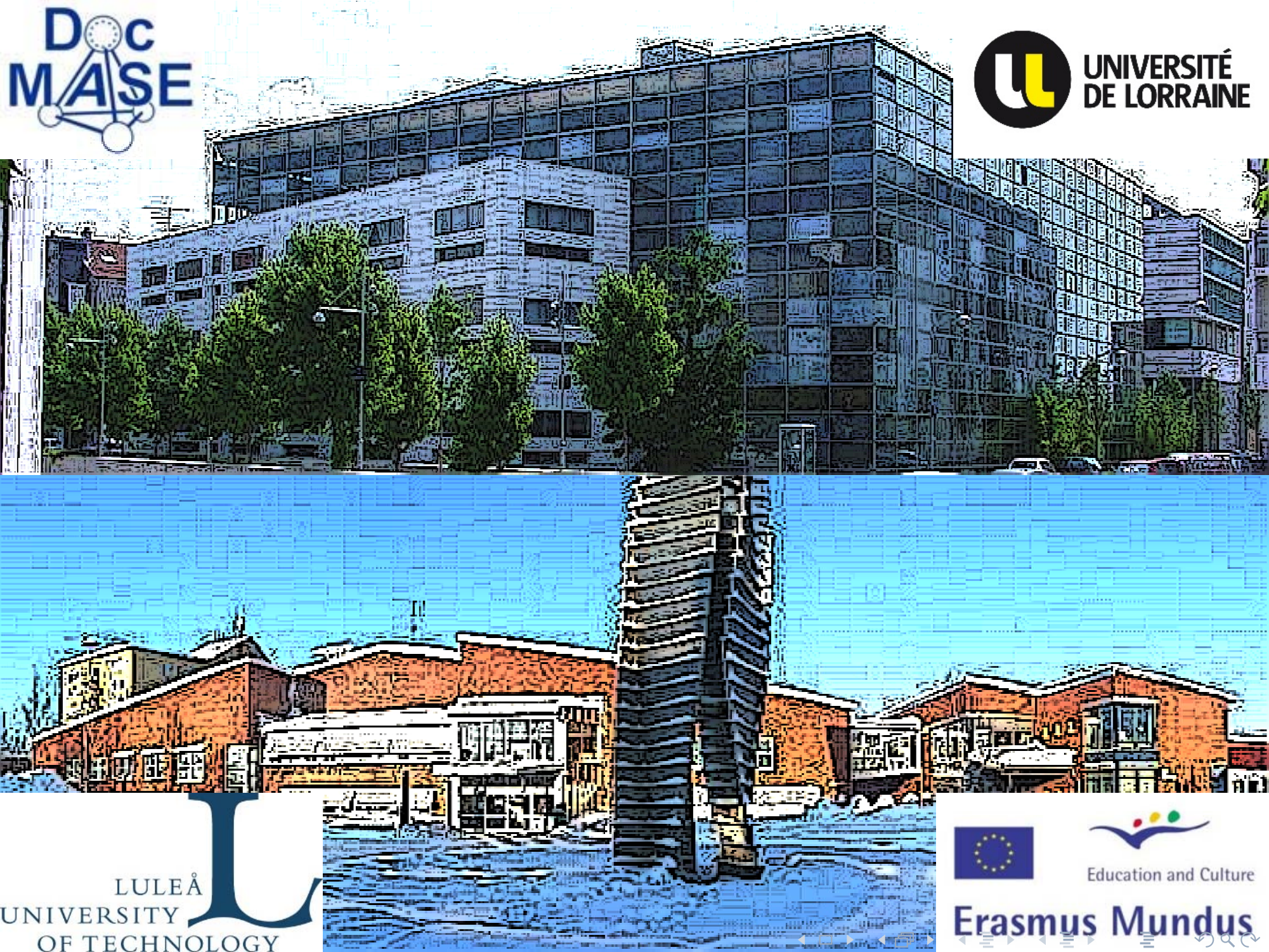
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