Sérgio Francisco dos Santos
São Paulo State University
School of Engineering
Department of Materials and Technology

INCOBRA
NANO - NOCMAT

Content of this talk:

- About UNESP
- About School of Engineering − Campus of Guaratinguetá
- About Department of Materials and Technology
- Introducing research topics
- My research topics:
  - ❖ **Exploring alternative vegetable fibers**
  - ❖ **Functionalization of cellulose fibers**
  - ❖ **Fiber-cement composites**
  - ❖ **Mechanical properties**

São Paulo State University (UNESP)

UNESP is located in 24 cities in the state of São Paulo in Brazil

São Paulo State University (UNESP)

UNESP by the numbers

The economy of São Paulo State is the most developed in Brazil, reaching 33,9% of Brazilian total GDP. There are 645 municipalities, distributed over almost 250 thousand square kilometers where 41 million people live.

- **Influence area of each unit in 100 kilometer of distance almost cover all the state of São Paulo.**

São Paulo State University (UNESP)

UNESP by the numbers

- There are 34 Schools and Institutes and 7 complementary units
- The constructed area 924,019 m^2. It is the size of 227 football pitches.
- Its admission test of 2016 has got 103,677 applicants for 7,355 vacancies in 183 degree options and in 69 careers.
- UNESP has 51,586 students:
  - 37,388 doing undergraduate degree
  - 13,206 doing master's degree and PhD programs
  - 992 in the UNIVESP (Virtual University)
- UNESP has 3,880 professors and 7,071 technical-administrative collaborators.
- UNESP is the second biggest PhD releaser in Brazil. There are 2,969 a year.
- The UNESP is 40 years old and the 4^{th} best university in Brazil, according to in the Brazil QS university ranking, the 8^{th} in Latin America and 27^{th} among BRICS.

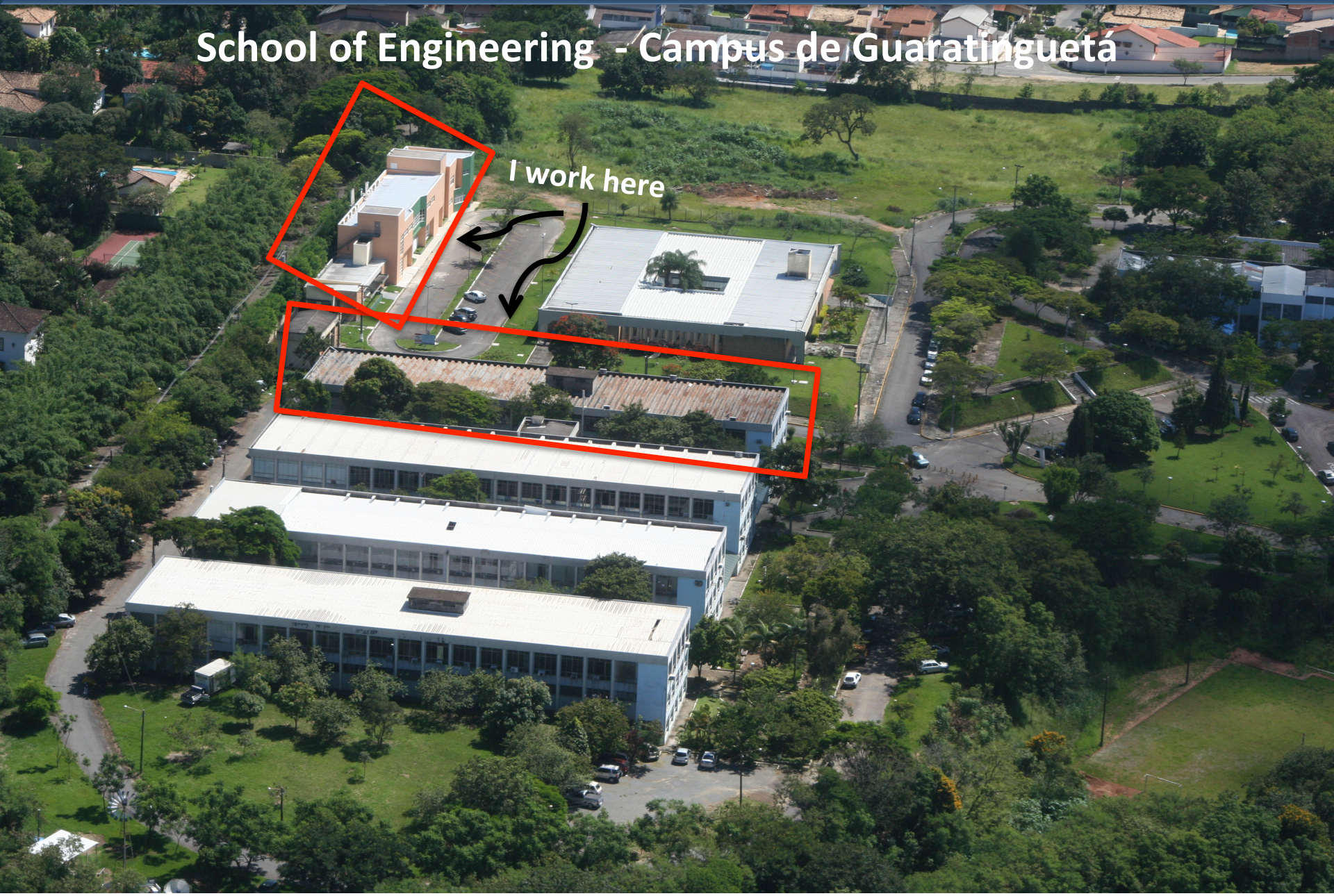
São Paulo State University (UNESP)

School of Engineering - Campus de Guaratinguetá

Entrance

São Paulo State University (UNESP)

São Paulo State University (UNESP)



São Paulo State University (UNESP)

School of Engineering - Campus de Guaratinguetá

- **Undergraduation**: Mechanical Engineering, Civil Engineering, Electrical Engineering, Mechanical Production Engineering, Materials Engineering, Physics (Licentiate and Bachelor's degree), and Mathematics (Licentiate degree).

- **Graduation:** Mechanical Engineering (master's degree and doctorate), Physics (master's degree and doctorate), Production Engineering (professional master's degree), Production Engineering (academic master's degree)

- Physical space: 205,307.41 m²
- Constructed area: 37,962.16 m²
- 2,003 undergraduate students
- 373 graduate students
- 140 professors
- 201 technical-administrative collaborators

São Paulo State University (UNESP)

Department of Materials and Technology - Campus de Guaratinguetá

Lines of Research (MSc and PhD)

A) POLYMERIC MATERIALS AND ADVANCED COMPOSITES

B) CORROSION AND ELECTROCHEMICAL CHARACTERIZATION OF THIN FILMS AND NANOSTRUCTURED MATERIALS

C) LIGNOCELLULOSIC COMPOSITE MATERIALS

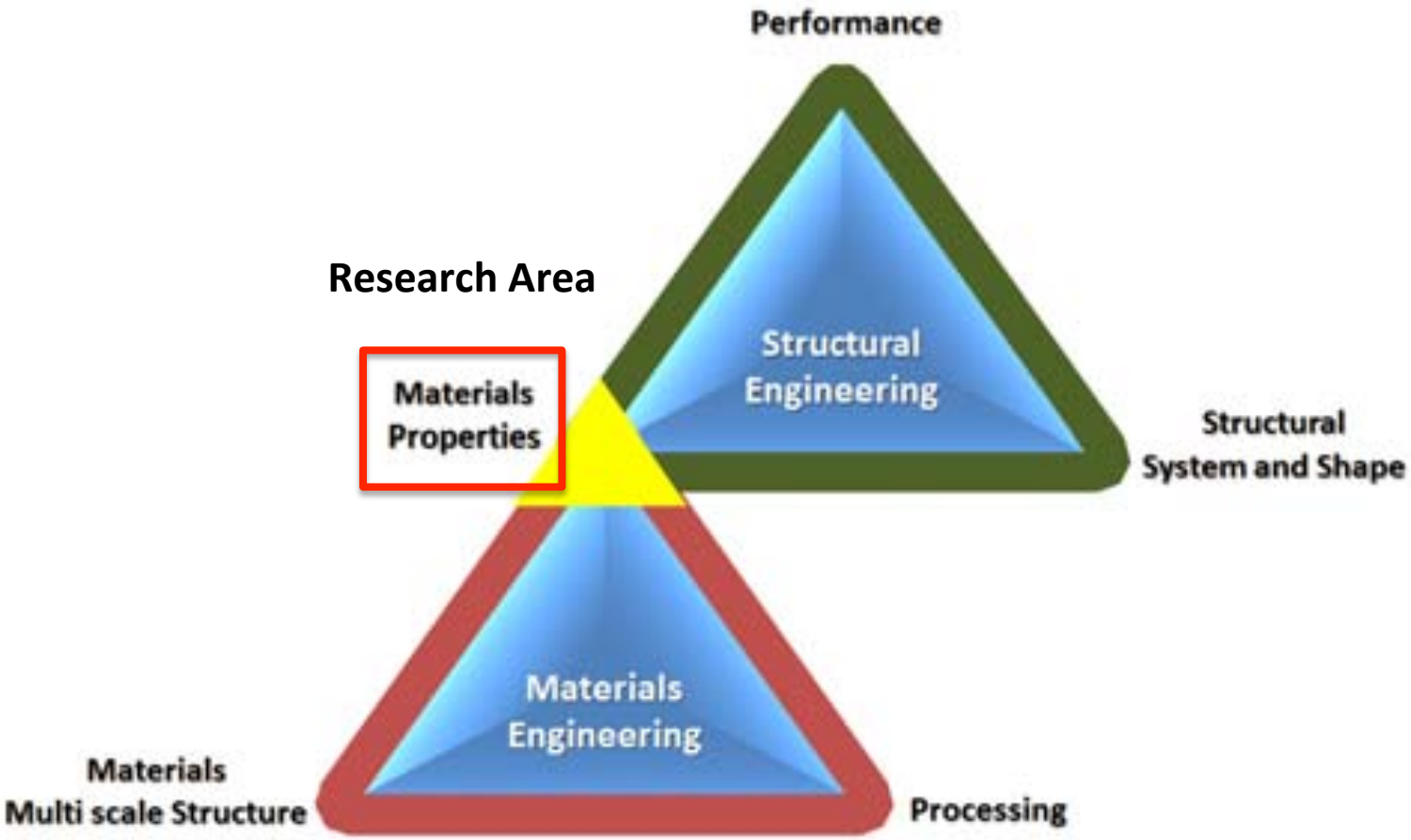
D) PROCESSING AND CHARACTERIZATION OF ADVANCED MATERIALS

E) CERAMIC MATERIALS

F) METALLIC MATERIALS

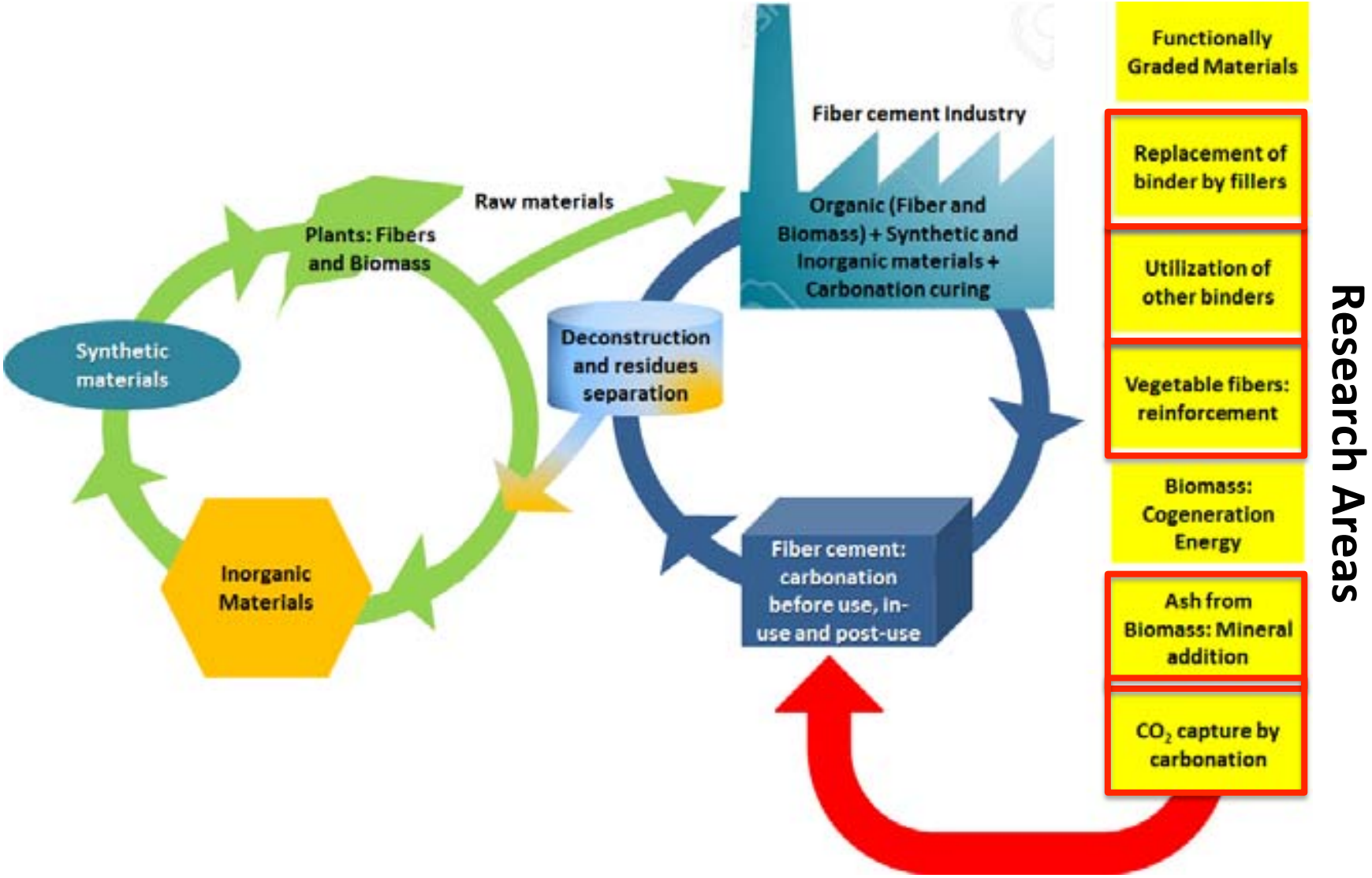
Research Area

Schematic diagram of Integrated Structures and Materials Design: Systemic approach



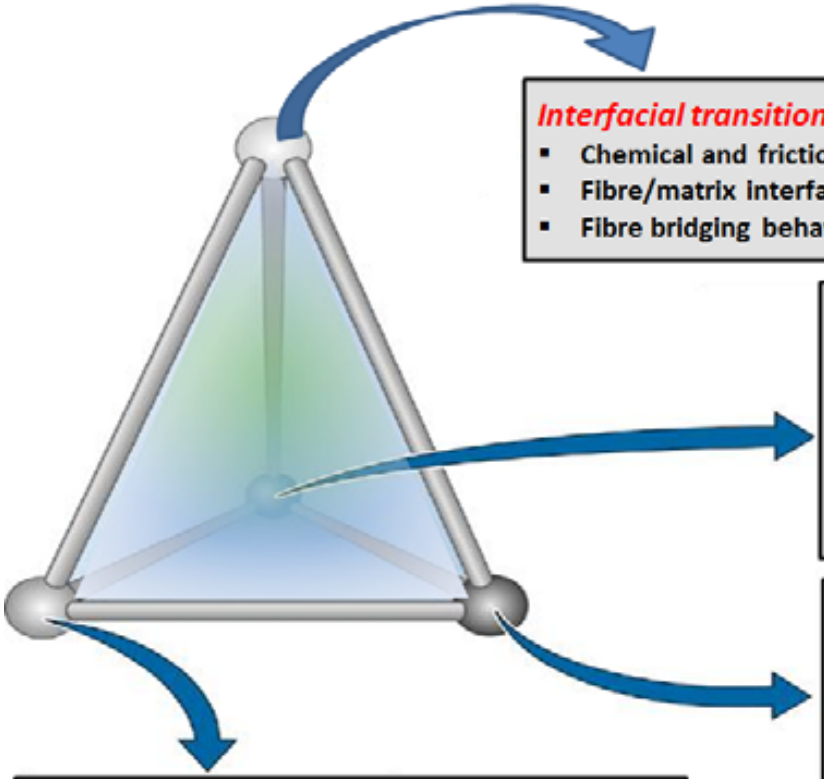
Research Area

Schematic diagram showing a concept process consisting of different approaches to improve the sustainability of the fiber cement industry.



Research Area

The tetrahedral interrelation of the main constituents of the complex cement based composite design



Interfacial transition zone
- Chemical and frictional bond
- Fibre/matrix interface sliding
- Fibre bridging behaviour

Challenge: to control

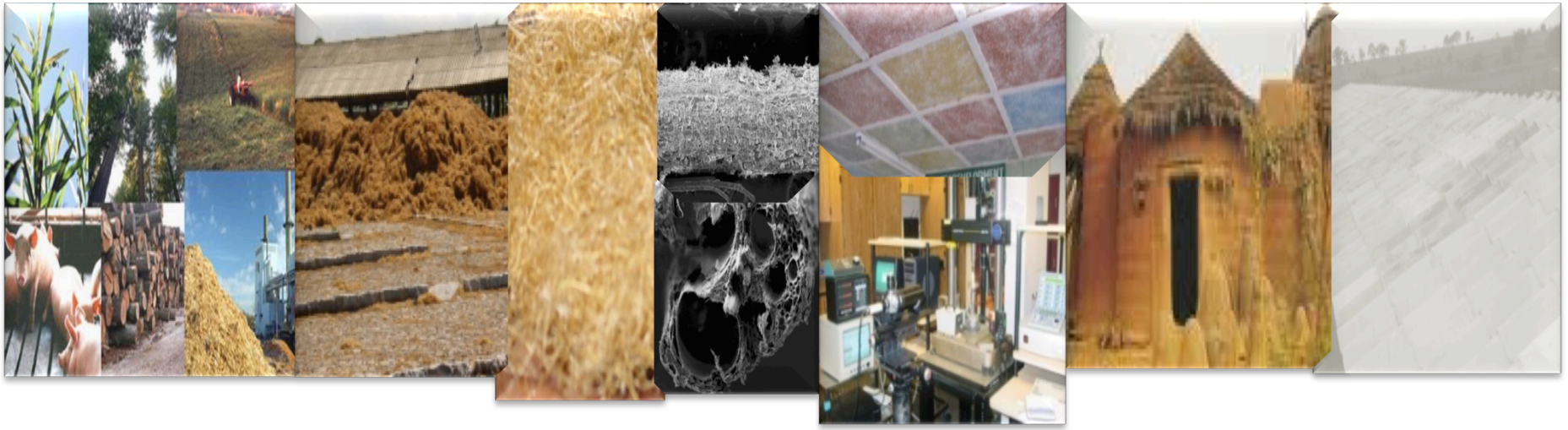
Fibre
- Type: Lignocellulosic and synthetic
- Mechanical, physical and chemical properties
- Lignocellulosic: Refinement or nanofibrillation
- Content
- Diameter and length distributions
- Aspect ratio

Processing
- Fabrication methods (e.g. Hatschek and Extrusion)
- Industrial or Pilot scale
- Curing method (e.g. thermal and accelerated carbonation)

Matrix
- Type: Binder, pozzolanic, filler
- Particles size distribution
- Particles packing technology
- Water/binder ratio
- Rheological properties in the fresh state

Research Area: Example

POTENTIAL USE OF COLLOIDAL SILICA IN CEMENT BASED COMPOSITES: EVALUATION.



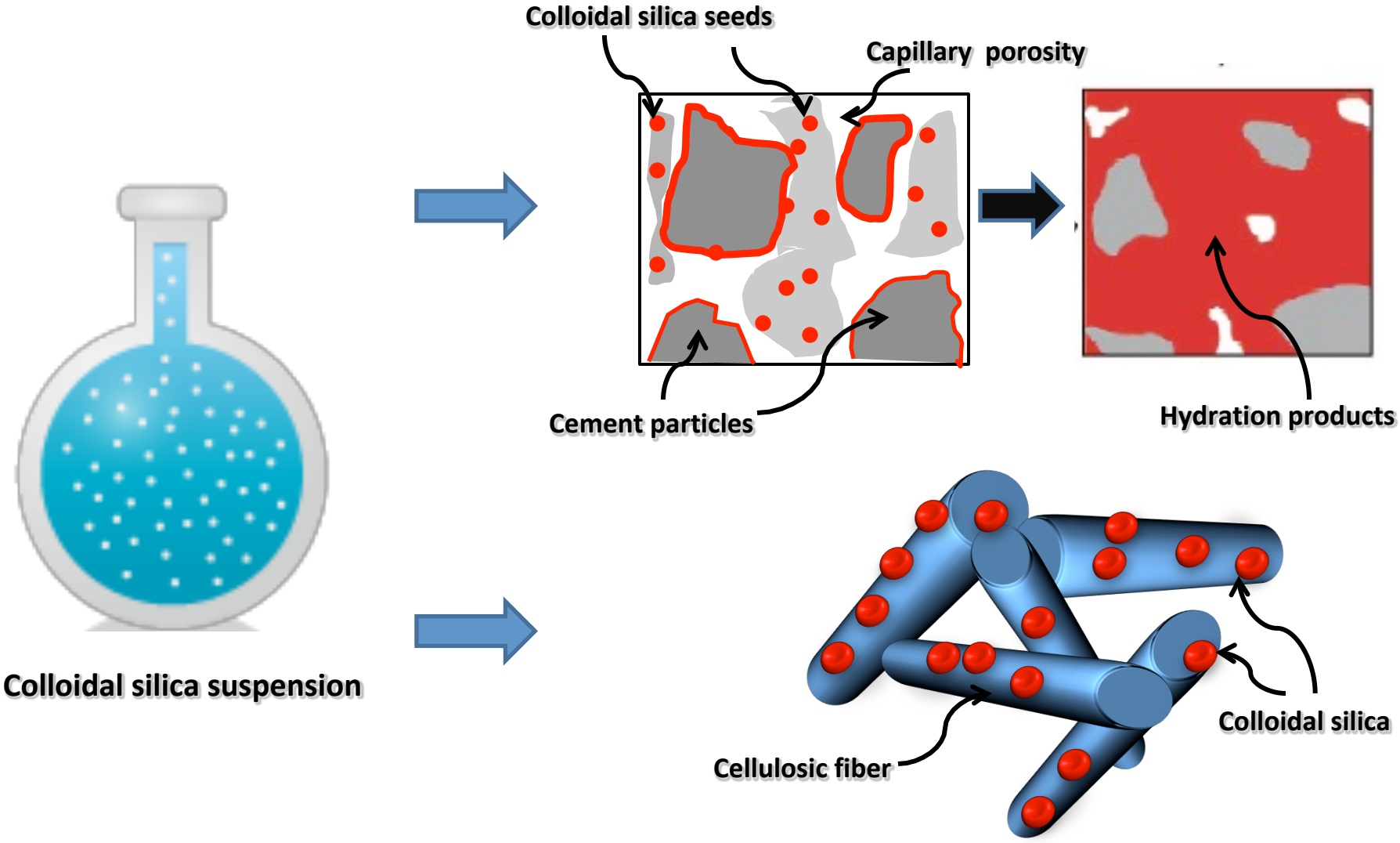
Research Area: Example

Why not use colloidal silica suspension in cement based composites?

There is strong interest to ***include functionalities*** in materials for building construction to make them **smarter and more sustainable.**

Research Area: Example

Colloidal Silica as a nanostructured modifier



Objectives

- **To verify the effects of the colloidal silica on the mechanical and physical behavior of the fiber-cement.**

Materials

Specific surface and specific density

Raw material	BET(single-point) (m^2/g)	Specific density (g/cm^3)
Ordinary Portland cement - CPV-ARI	1.0	3.1
Limestone filler	1.1	2.8

Physical and chemical characteristics: Colloidal silica suspension

Size range (nm)	Specific surface area (m^2/g)	Density (20 °C) (kg/m^3)	Stability (20 °C) pH	Content of Na_2O (%)
8.5 – 9.7	300	1210-1219	9 – 11	0.5 - 0.6

Materials

Unrefined unbleached *Eucalyptus* pulp

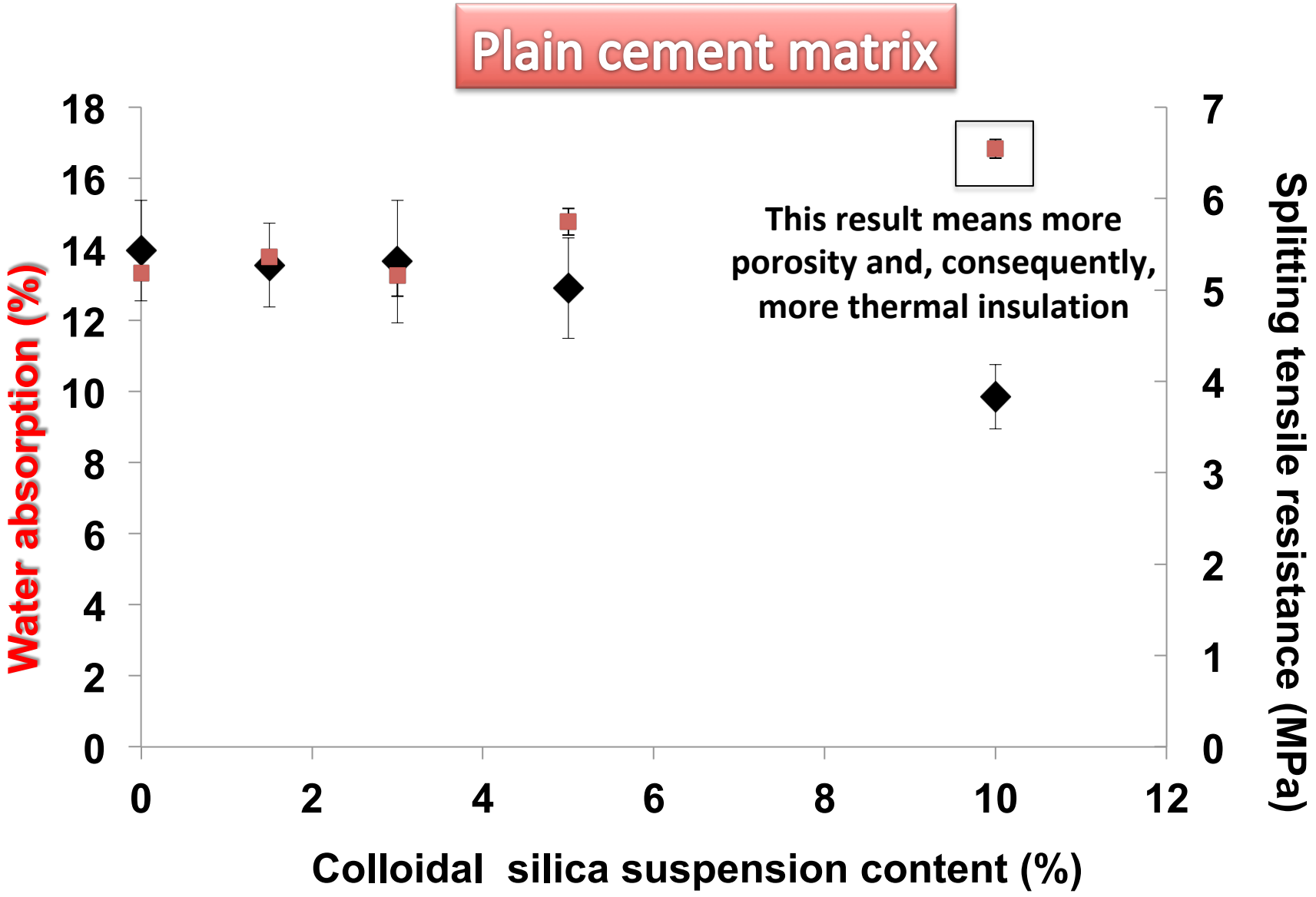
Pulp CSF (mL)	Length [b] (mm)	Average width (µm)	Aspect ratio	Fibrous material (10^6 fibers/g)	Fines [c] content (%)
664	0.83 ± 0.05	16.4 ± 0.2	51	18 ± 1	25.7 ±0.6

[a] Fibers were analyzed by a Pulptec™ MFA-500 Morphology Fiber and Shive Analyser – MorFiTrac.

[b] Length weight in length.

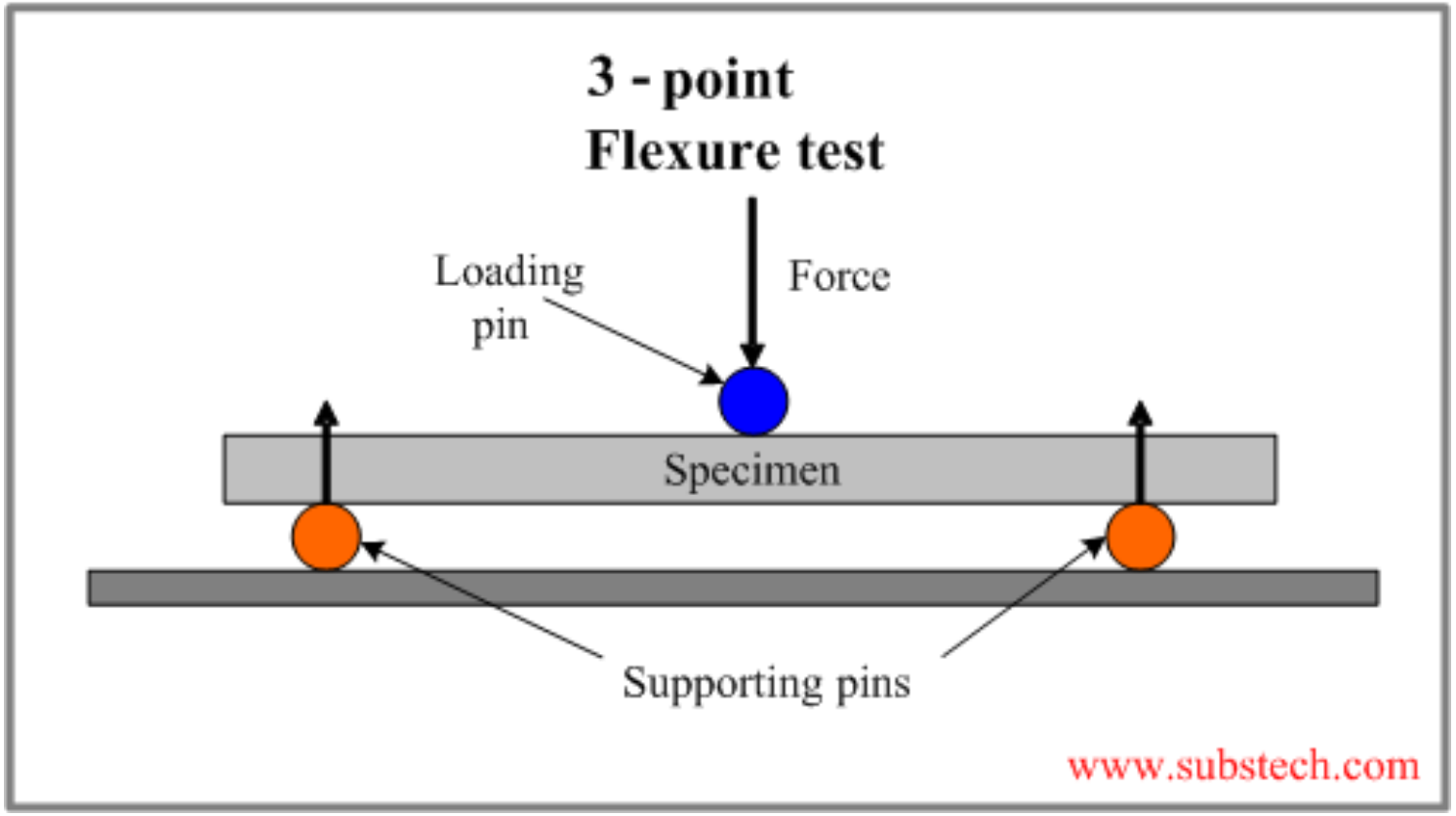
[c] A fine element was considered as any detected object present in the pulp with dimensions lower than those of fibers, i.e., length under 200 µm or width under 5 µm.

Results


Plain cement matrix
This result means more porosity and, consequently, more thermal insulation
Water absorption (%)
Splitting tensile resistance (MPa)
Colloidal silica suspension content (%)
0
2
4
6
8
10
12
14
16
18
0
1
2
3
4
5
6
7

Methodology

Modulus of rupture

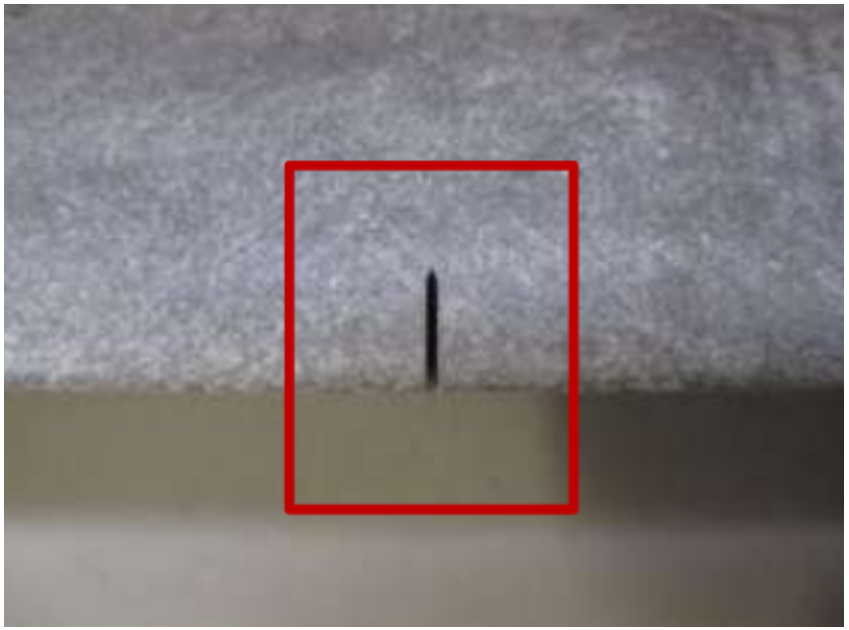


✓ **Modulus of rupture: 5 mm/min**

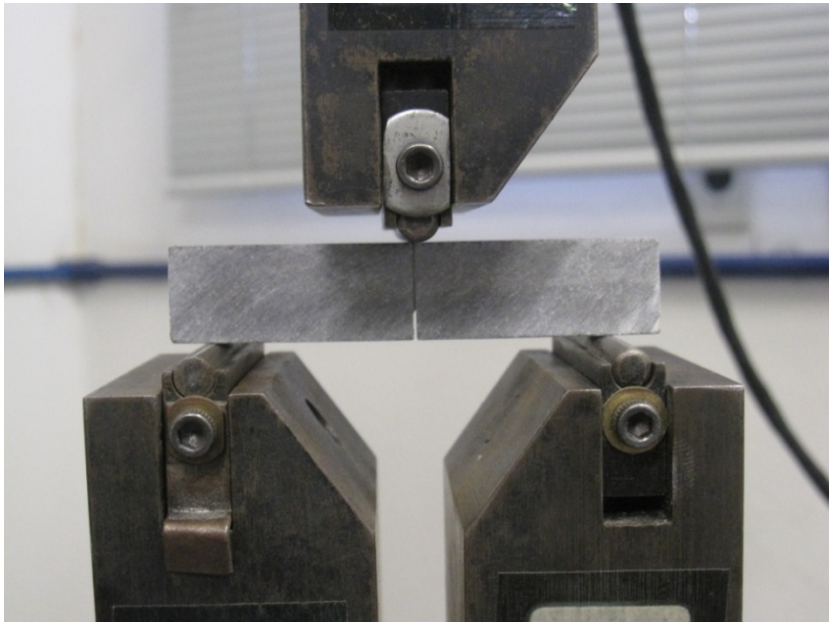
$$MOR = \frac{3}{2} \cdot \frac{P_{max} \cdot S}{b \cdot w^2}$$

Methodology

Fracture toughness and Energy of fracture



SENB (single-edge notch bending)



Three-point bending configuration

- ✓ Fracture toughness: 15 mm/min → Catastrophic crack propagation
- ✓ Energy of fracture : 10 μm/min → Stable crack propagation

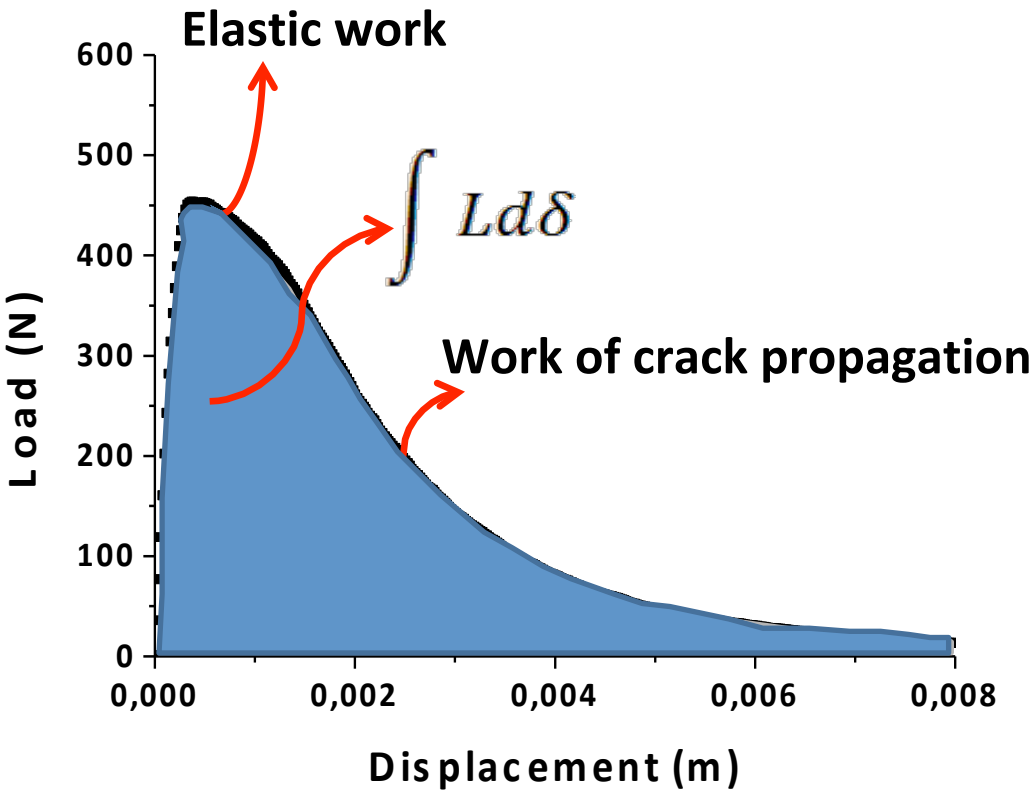
Methodology

Fracture toughness

$$K_{Ic} = \frac{P_{max}}{b \cdot w^{3/2}} \cdot y(\alpha)$$

$$y(\alpha) = \frac{S}{w} \cdot \left[\frac{3\alpha^{1/2}}{2(1-\alpha)^{3/2}}\right] \cdot \left[1.99 - 1.33\alpha - (3.49 - 0.68\alpha + 1.35\alpha^2) \cdot \frac{\alpha(1-\alpha)}{(1+\alpha)^2}\right]$$

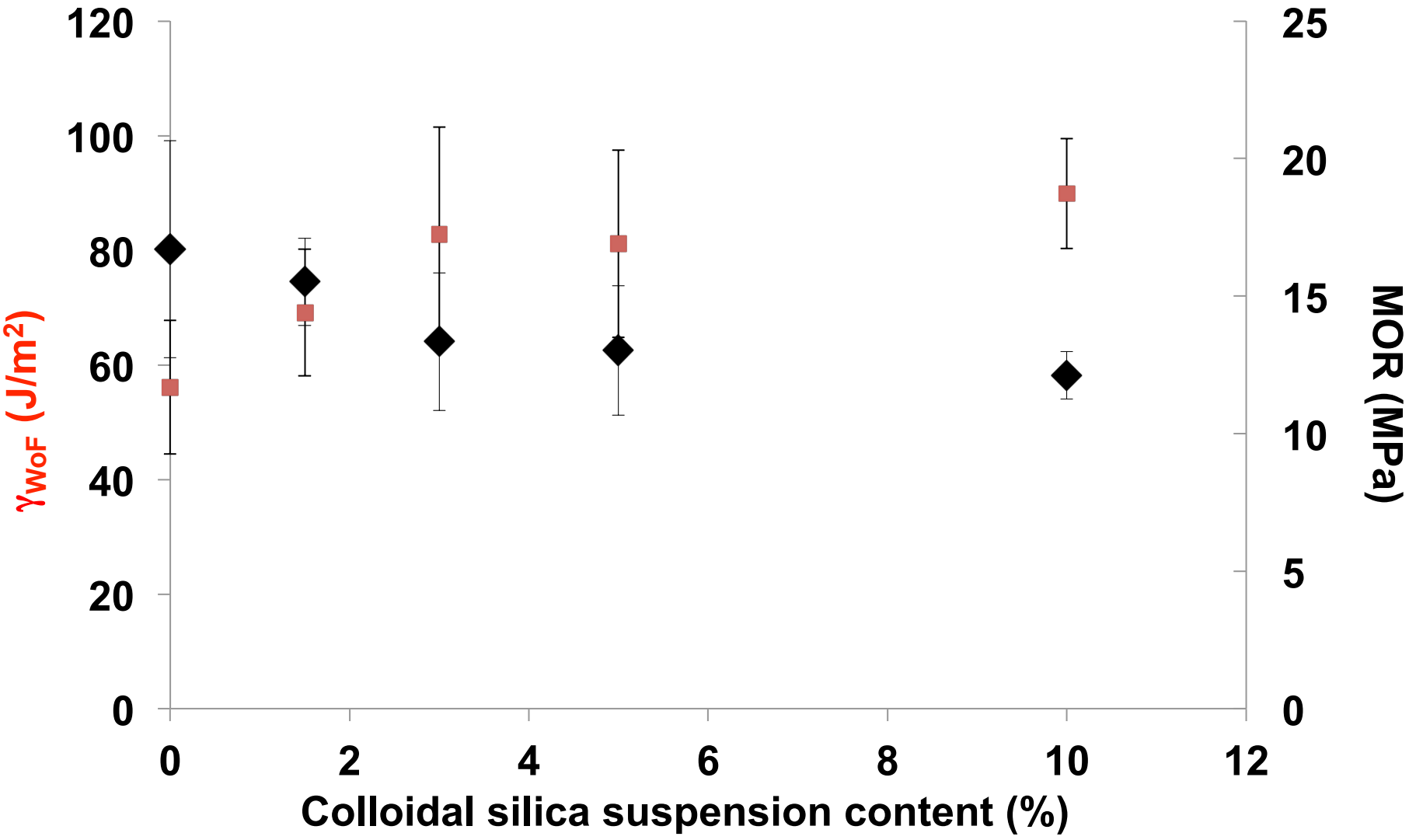
Methodology



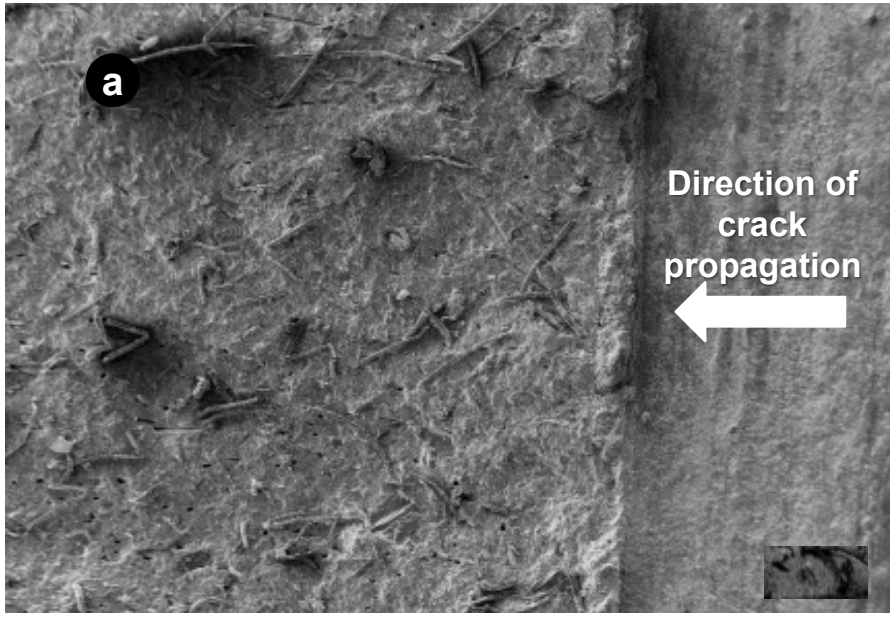
Energy of fracture

$$\gamma_{WoF} = \frac{1}{2A}\int Ld\delta$$

Results

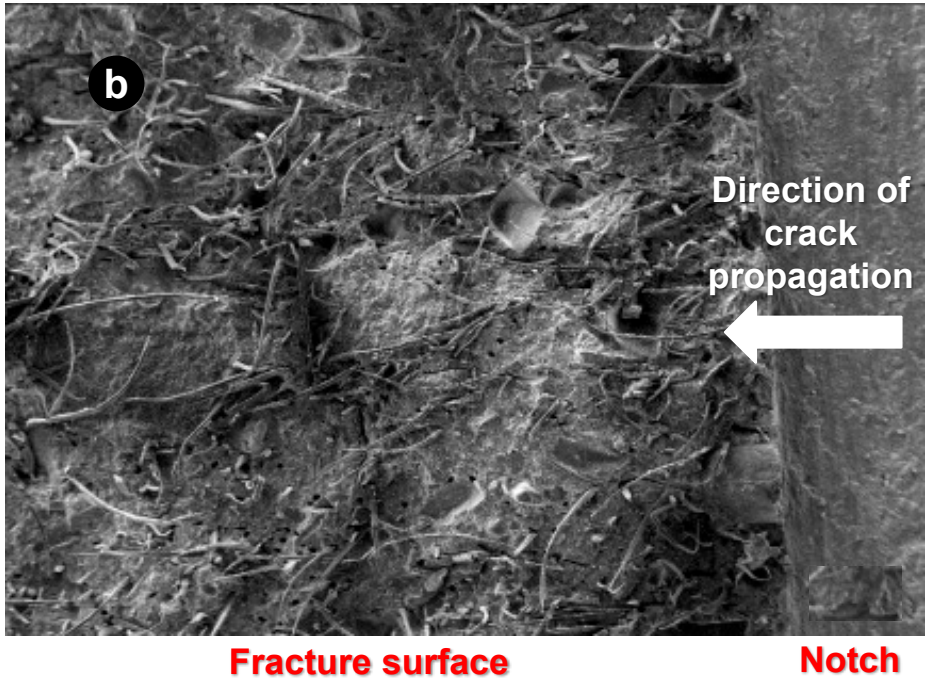

120
100
80
60
40
20
0
γ_{WoF} (J/m^2)
25
20
15
10
5
0
MOR (MPa)
0
2
4
6
8
10
12
Colloidal silica suspension content (%)

Results



✓ 0% - Without toughening mechanisms

✓ 10% - Toughening mechanisms in the fracture process : pull-out.



Thank you for your attention

sergio.francisco-santos@unesp.br