Influence of the size and amount of cork particles on the toughness of a structural adhesive

Ana Q Barbosa,
Lucas FM da Silva,
Ricardo Carbas
Juana Abenojar,
Juan Carlos del Real
Contents

- Objectives
- Introduction
  - Methods to improve toughness
  - Cork as an reinforcement material
- Experimental procedures
  - Specimen manufacture
  - Surface treatment and density
  - Toughness impact test and SEM
- Results and discussion
  - Surface properties
  - Cork particles characterization
  - Toughness impact properties
  - Cork particles in resin
  - Density of toughness impact specimens
  - SEM surface analysis
- Conclusions
Objectives

• Cork particles should create obstacles to the propagation of cracks, thus improving the toughness of the adhesive.

• This technique allows a new application of a natural product with an important impact in the Portuguese economy.

• The evaluation of this solution is made by:
  • powder characterization,
  • production of specimens to evaluate adhesion between resin and cork and good particle distribution;
  • mechanical tests.
Methods to improve toughness

Structural adhesives are known for their high strength and stiffness but also of their low ductility and toughness.

There are three main methods to improve the toughness of adhesives:

- Polymer with phase separation
- Polymer without phase separation
- Inclusion of particles

Micro particles of cork powder to increase the toughness of a brittle epoxy adhesive
Cork is a biological material with unique properties.

Cellular structure:
- Similar to a honeycomb
- Without empty spaces between contigous cells
- Closed cells could work to absorb impact
Cork as reinforcement material

- Cork is a biological material with unique properties

- Composite properties depend on:
  - interfacial adhesion between cork and resin
  - size and amount of cork particles
  - mixing conditions
Specimens manufacture

• **Materials**
  - Cork powder (38-53 μm and 125-250 μm)
  - Epoxy resin – Araldite 2020
  
• Mixing with a centrifuge mixing machine (90 seg. at 1500 rpm)

• **Types of specimens:**

  **Without cork**

  - Surface treatment - Plasma
    - 5%
    - 38-53 μm
    - 125-250 μm

  - untreated
    - 1%
    - 38-53 μm
    - 125-250 μm

  **With cork**

  - Surface treatment - Plasma
    - 5%
    - 38-53 μm
    - 125-250 μm

  - untreated
    - 1%
    - 38-53 μm
    - 125-250 μm
Surface treatment and density

• Atmospheric plasma
  • Distance of torch – 8 mm
  • Velocity – 5 m/min

• Density
  • Cork particles – Helium picnometer;
  • Specimens – Archimedes principle (water)

Used to modify cork particles surface
Toughness impact test and SEM

- Toughness impact tests

- SEM analysis
  - Cork particles
  - Composite fracture surface
## Results and discussion

### Surface properties

<table>
<thead>
<tr>
<th>Section</th>
<th>Treated specimen</th>
<th>Untreated Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial</td>
<td>30 ± 4</td>
<td>101 ± 11</td>
</tr>
<tr>
<td>Tangential</td>
<td>33 ± 7</td>
<td>99 ± 18</td>
</tr>
<tr>
<td>Axial</td>
<td>37 ± 2</td>
<td>103 ± 7</td>
</tr>
</tbody>
</table>

[Contact angle images]

Treated with plasma

Untreated
Cork particles characterization

Objectives

Introduction

Experimental

Results and discussion

- Honeycomb cell structure damaged
- Opens cells
- Single cells

- Honeycomb cell structure with several cells
- Opened and closed cells
Cork particles characterization

• Density is influenced by:
  • Size
  • Structure integrity

Results and discussion

Density decreases with plasma treatment

Plasma increases the surface roughness but leads to a weight loss

Objectives  Introduction  Experimental  Results and discussion  Conclusion
Toughness impact properties
Toughness impact properties

![Graph showing force over time for untreated and treated samples.](image)
Density of toughness impact specimens

If resin penetrates the cork cells, specimens density increases.

Density variation is not substantial, so this interpretation may be regarded with caution.
Cork particles in epoxy resin

Cork has good impact behaviour due to its cell structure disposition, giving a pillow effect.
SEM Surface analysis

Results and discussion

Without cork particles

Direction of crack propagation
Results and discussion

SEM Surface analysis

1% cork (38-53 μm)

Untreated

Plasma

Objectives
Introduction
Experimental
Results and discussion
Conclusion
Results and discussion

SEM Surface analysis

5% cork (38-53 μm)

Objectives
Introduction
Experimental
Results and discussion
Conclusion

Untreated
Plasma
SEM Surface analysis

1% cork (125-250 μm)

Results and discussion
Results and discussion

SEM Surface analysis

5% cork (125-250 μm)

Untreated

Plasma

Objectives
Introduction
Experimental
Results and discussion
Conclusion
Conclusions

• Atmospheric plasma surface treatment increases the contact angle and wettability of cork, but treated particles in the composite had an unexpected behaviour;

• SEM and OTM analysis show that most cells are not filled with resin and randomly distributed in the matrix and specimens with these properties show better results;

• The influence of the amount and particle size is notorious.
Acknowledgements

• Financial support by Portuguese Foundation for Science and Technology (PTDC/EME-TME/098752/2008)

• Professor José Pissarra and D. Helena from Biology Department from Science Faculty of Porto University are greatly acknowledged.