Evaluation of Biocomposite Materials by Test

IIG meeting – 16th September 2014 – Copenhagen
Summary

> Aim of WP 6
> Lab-scale testing
> Full-size test testing
WP 6 - Evaluation of Biocomposite System Performance

**Objectives**

The Aim of this work package is to use small-scale and then full-size test rigs to evaluate the materials and systems developed in the project. The detailed objectives are:

- Lab scale testing of material combinations
- Lab scale testing assemblies of panels, profiles, fixings
- The specification, design and build of full-size test rigs and mouldings
- Evaluation to standards and specifications
- Comparative data generation for comparison with current products

**Tasks**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.6.1</td>
<td>Testing of Lab-Scale Systems</td>
<td>M30</td>
</tr>
<tr>
<td>D.6.2</td>
<td>Manufacture Full-size Test Rigs</td>
<td>M30</td>
</tr>
<tr>
<td>D.6.3</td>
<td>Definitive Testing of Full-Scale Demonstration Installation Test-Rigs</td>
<td>M41</td>
</tr>
</tbody>
</table>
WP6 Evaluation of Biocomposite System Performance

• **Description of deliverables**
  - **D6.1 Interim biocomposite evaluation report** - A report which will evaluate the progress and feasibility of the biocomposite systems, designs and installations. Date: M24 – December 2013

  - **D6.2 Testing of Lab-Scale Systems complete** - The outputs from WP4 and WP6 will be tested for performance (fire retardancy, durability, acoustically, thermally and environmental impact).

  - **D6.3 Manufacture Full-size Test Rigs** - Full sized panels will be mounted on full size rigs to replicate internal and external installations in order to study a wide range of conditions.

  - **D6.4 Definitive Testing of Full-Scale Demonstration Installation Test Rigs** - Full size installations will be subjected to a range of tests to ascertain performance in respect to various European standards and guidelines.
Biobuild products definition (ECK)

Prepared by WP5
# Lab scale tests - External Cladding Kits (ECK)

Material:
- 3 mm furan/flax 2x2 twill prepreg – for open hat profiles (Samples A)
- 5 mm furan/flax 2x2 twill prepreg – for flat profiles (Samples B)

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Samples</th>
<th>Quantity</th>
<th>Partner(s)</th>
<th>Type</th>
<th>Comments/type of testing sample</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination of flexural properties at ambient temperature</td>
<td>EN ISO 14125 ISO 178</td>
<td>Length = 30 x thickness Width = 15 mm for thickness between 1-10 mm</td>
<td>≥ 12 test specimens per material 6 at 90° 6 at 45°</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Determination of tensile properties at ambient and at elevated temperatures</td>
<td>EN ISO 527 ISO 14125</td>
<td>Length ≥ 250 mm Width max 50 mm Thickness any</td>
<td>≥ 20 test specimens per material 10 at 90° 10 at 45°</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Apparent interlaminar shear (ILSS)</td>
<td>ISO 14130</td>
<td>length = 20 x thickness width = 5 x thickness</td>
<td>≥ 10 test specimens per material 5 at 90° 5 at 45°</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Determination of dynamic mechanical properties (storage modulus, loss modulus and tan delta) during a linear temperature scan under heating conditions</td>
<td>ISO 9721</td>
<td>Length 60 mm Width 15 mm</td>
<td>≥ 10 test specimens per material</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>Charpy impact properties or Izod impact strength or tensile impact strength</td>
<td>EN ISO 179-1 EN ISO 180 ISO 3256</td>
<td>Preferred dimensions Length = 20 x thickness Width = 2.5 x thickness</td>
<td>≥ 10 test specimens per material</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>Temperature of deflection under load</td>
<td>ISO 75-3</td>
<td>length = 123 mm Width : 8.8 to 12.8 mm Thickness : 2.0 to 7.0 mm</td>
<td>≥ 2 test specimens per material</td>
<td>LNEC/NMO</td>
<td>Performance</td>
<td>B</td>
<td>2</td>
</tr>
</tbody>
</table>
Lab scale tests

- A: Resin + reinforcement (fibre);
- B: Resin + reinforcement (fibre) + core;
- C: Resin + reinforcement (fibre) + core + coating;
- D: Resin;
- E: Composite profiles;
- F: Core
Request of test samples

<table>
<thead>
<tr>
<th>Partner</th>
<th>D: Resin</th>
<th>F: core</th>
<th>A: Resin + reinforcement (fibre)</th>
<th>B: Resin + reinforcement (fibre) + core</th>
<th>C: Resin + reinforcement (fibre) + core + coating</th>
<th>E: Composite profiles</th>
</tr>
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<tbody>
<tr>
<td>TFC</td>
<td></td>
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<tr>
<td>Net Composites</td>
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<tr>
<td>Amorim Cork Composites</td>
<td>IPK, ECK, SCK</td>
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<td>IPK</td>
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<tr>
<td>EXEL</td>
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<td>IPK, ECK</td>
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<tr>
<td>IVW</td>
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<td>ECK</td>
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<tr>
<td>ACCIONA</td>
<td></td>
<td></td>
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<td>SCK</td>
<td>SCK</td>
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<tr>
<td>Fiber-tech</td>
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<td></td>
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<td>SCK</td>
<td>SCK</td>
<td></td>
</tr>
</tbody>
</table>
1 - Samples description

Compression moulded sheets constituted by furan resin reinforced with flax fibers (0/90º)

Sent by NET COMPOSITES in Set 2013

2 layers flax/furan prepregs - 6 mm NL20 cork - 2 layers flax/furan prepregs

Sent by IVW in Oct. 2013

Compression moulded sheets constituted by furan resin reinforced with flax fibers (0/90º) 8 pre-preg layers (≈ 5 mm thickness)

Sent by IVW/CCMM in June 2014
1 - Samples description

Compression moulded sheets constituted by furan resin reinforced with flax fibers (0/90°)  

Sent by **NET COMPOSITES** in Set 2013

<table>
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<tr>
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2 layers flax-furan prepregs - 8 mm NL20 cork - 2 layers flax/furan prepregs  

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**Description**

Compression moulded sheets constituted by furan resin reinforced with flax fibers (0/90°)

- 8 pre-preg layers (≈ 5 mm thickness)

Sent by IVW/CCMM in June 2014
## 1. Samples description

### Compression moulded sheets

**Materials:** Resin + flax fibers

**Manufacturing:** Compression moulding

**Thickness:** 8 pre-preg layers (~5 mm thickness)

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</tbody>
</table>

**Samples:**
- Sent by **IVW/CCMM** in June 2014
- Sent by **NET COMPOSITES** in Set 2013
- Sent by **IVW** in Oct. 2013
2.1. Determination of Water Vapour Transmission

Results

**Dry cup**

\[
T = 23^\circ C; \\
HR_{\text{inside}} = 0\%; \\
HR_{\text{outside}} = 50\%
\]

**Wet cup**

\[
T = 23^\circ C; \\
HR_{\text{inside}} = 93\%; \\
HR_{\text{outside}} = 50\%
\]

Saturated aqueous solution Ammonium Dihydrogen Phosphate.

Calcium Chloride Anhydrous
## 2.1. Determination of Water Vapour Transmission

### Results

<table>
<thead>
<tr>
<th>Property</th>
<th>NET COMPOSITES</th>
<th>IVW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flax/furan</td>
<td>Flax/furan-cork</td>
</tr>
<tr>
<td></td>
<td>External layer of Flax/furan-cork</td>
<td>External layer of Flax/furan-cork</td>
</tr>
<tr>
<td>WET CUP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>783</td>
<td>3673</td>
</tr>
<tr>
<td></td>
<td>1733</td>
<td>12279</td>
</tr>
<tr>
<td>$S_d$ (m)</td>
<td>1.8</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>16</td>
</tr>
</tbody>
</table>

$\mu$: water vapor diffusion resistance factor

$S_d$: water vapour diffusion-equivalent air layer thickness
2.2. Determination of tensile properties

IVV/CCMM (Jun 2014)

(fibers at 45\(^{\circ}\))

(fibers at 90\(^{\circ}\))

specimen after test
### 2.2. Determination of tensile properties

#### Results

<table>
<thead>
<tr>
<th>Fiber orientation</th>
<th>Tensile property</th>
<th>Lamella sandwich</th>
<th>ACCIONA</th>
<th>NET COMPOSITES</th>
<th>IVW</th>
<th>IVV/CCMM (Jun 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45°</td>
<td>$E_t$ (MPa)</td>
<td>-</td>
<td>5089 ± 113</td>
<td>-</td>
<td>5611 ± 326</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\sigma_t$ (MPa)</td>
<td>-</td>
<td>34.6 ± 4.0</td>
<td>-</td>
<td>37.5 ± 2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_t$ (%)</td>
<td>-</td>
<td>2.5 ± 0.1</td>
<td>-</td>
<td>2.4 ± 0.6</td>
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<tr>
<td>90°</td>
<td>$E_t$ (MPa)</td>
<td>3148 ± 196</td>
<td>5926 ± 410</td>
<td>4656 ± 294</td>
<td>7971 ± 255</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\sigma_t$ (MPa)</td>
<td>28.3 ± 1.0</td>
<td>45.2 ± 2.0</td>
<td>28.8 ± 2.0</td>
<td>53.8 ± 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\varepsilon_t$ (%)</td>
<td>1.4 ± 0.1</td>
<td>1.3 ± 0.2</td>
<td>1.2 ± 0.1</td>
<td>1.4 ± 0.2</td>
<td></td>
</tr>
</tbody>
</table>

$E_t$: Elastic modulus  \hspace{1cm} $\sigma_t$: Stress at break  \hspace{1cm} $\varepsilon_t$: Strain at break
Reaction to fire tests

• Purpose
  – The target is to obtain RtF class B (best classification attained by organic products) required by fire safety regulations in some end-uses (and countries).
Reaction to fire tests

• Methods
  – Ignitability test
    • Ignitability tests were performed to assess and screen the combinations with regards to:
      – The degree of ignitability under attack (edge and surface) of a small ignition source (small flame);
      – The speed and extension of flame propagation.
    • Tests were performed according EN ISO 11 925-2 (250 mm x 90 mm).
Reaction to fire tests

• Methods
  – Single Burning Item test
  • Assessment criteria: FIGRA_{0.2MJ} and FIGRA_{0.4MJ} (Fire Growth Rate Index)
  • Tests were performed according to EN 13823 (1.5 m x 1.0 m x 0.5 m)
Ignitability test

• Assessment of basic materials
  – Reinforcement material (flax and jute)
  – Furan-flax prepreg
  – Biopolyester-flax
  – Core material (cork)
  – Pultruded profiles
  – Coatings
Ignitability test

• Assessment of the sandwich
  – Flax-furan-cork
    • Conclusion: relevant contribution of the core and reinforcement materials
  – SCK lamellae
    • Biopolyester-jute-cork
      – Conclusion: needs improvement
    • Biopolyester-flax-cork-coating
      – ECK
    • Furan-flax-cork
      – IPK
    • Furan-jute-cork
SBI test

- Assessment of products
  - SCK
    - Bioplyester-flax-coating
  - ECK
    - Furan-flax-cork
  - IPK
    - Furan-jute-cork
    - Furan-jute-cork-coating

- Assessment of coatings
  - Applyed over reference materials
**ECK PANELS + ENVIROGRAPH INTUMESCENT COATING (SBI #7)**

**ECK case study COMPOSITE LAMINATE**  
(Fire retarded [Bio-PE]/Flax)

Panels manufactured in an autoclave by **IVW**

Panels had dimensions 1800 m x 500 mm and 1800 mm x 400 mm and thickness approx. 5 mm

Panels have been cut into halves (900 mm long) and coated by LNEC’s technicians
Specimen 1 – coated (Envirograf system)
1 coat of intumescent paint + 2 finishing top coats
Acceptable reaction to fire (class B)? (not tested before)
Improved durability under exterior (ECK) applications
(2 topcoats)
Total: 4 coats (incl. primer) – similar cost (?)

Specimen 2 – coated with Envirograf system
2 coats of intumescent paint + 1 finishing top coat
Expected) reaction to fire class B
Durability under exterior (ECK) weathering? (SHR and LNEC)
(1 topcoat)
Total: 4 coats (incl. primer) – similar cost (?)

Specimen 3 – uncoated
Evaluate reaction to fire performance of FR BioPE+flax
Previous ignitability results were good
SBI performance still unknown
Finishing protective/decorative coating will always be required
(lower cost)
Test specimen number 1

Probable reaction to fire classification: C-s2, d0

total HRR was too high (extensive combustion of the specimen)
ECK PANELS + ENVIROGRAPH
INTUMESCENT COATING (SBI #7)

Test specimen number 2

The results obtained point to probable B,s2-d0

But this is a small test specimen
ECK PANELS + ENVIROGRAPH INTUMESCENT COATING (SBI #7)

Test specimen number 3
(no intumescent coating)

The results obtained point to probable D,s3-d0

But this is a small test specimen
<table>
<thead>
<tr>
<th>Test</th>
<th>Test method (EN, ISO, …)</th>
<th>Test samples (dimensions – mm/quantity)</th>
<th>Quantity</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Burning Item (SBI)</td>
<td>EN 13823</td>
<td>1500 x 1000 + 1500 x 495 x (200 max)</td>
<td>2 + 2 (minimum)</td>
<td>Annex E (ETAG 034) includes precise, specific information about the SBI-Testing for cladding kits. Asymmetrically composed cladding elements may have to be tested to reaction to fire on back side. The construction details are in preparation.</td>
</tr>
<tr>
<td>Wind load resistance</td>
<td>ETAG 034</td>
<td>Not defined</td>
<td>1+2 if necessary</td>
<td>See Figure 2.</td>
</tr>
<tr>
<td>Mechanical test (Type C) Resistance of slot (Figure 3)</td>
<td>ETAG 34</td>
<td>4200 (height) x 4800 (width) including rigid frame (see note 1)</td>
<td>5</td>
<td>This test is not needed if relevant information is available.</td>
</tr>
<tr>
<td>Resistance to horizontal point loads</td>
<td>ETAG 34</td>
<td>1 panel element (1.8 x 0.5)</td>
<td>1</td>
<td>Test will be performed in the test specimen for wind load test (Figure 2)</td>
</tr>
<tr>
<td>Impact resistance</td>
<td>ISO 7892:1988</td>
<td>1 panel element (1.8 x 0.5)</td>
<td>1</td>
<td>Test will be performed in the test specimen for wind load test (Figure 2)</td>
</tr>
<tr>
<td>Impact resistance</td>
<td>ISO 7892:1988</td>
<td>1 panel element (1.8 x 0.5)</td>
<td>1</td>
<td>Test will be performed in the sample for wind load test (Figure 2)</td>
</tr>
<tr>
<td>Hygrothermal behavior – Resistance to thermal shock</td>
<td>ETAG 34</td>
<td>3.2 m x 1.95 m</td>
<td>1</td>
<td>Test specimen in Figure 4.</td>
</tr>
<tr>
<td>Thermal resistance</td>
<td>EN ISO 6946: EN ISO 10211</td>
<td></td>
<td>0</td>
<td>By calculation.</td>
</tr>
</tbody>
</table>

Note 1 – Usually one specimen representing the large size solutions is enough. If in the course of experimental evaluation some rupture occur these components should be replaced, for instance in the wind load test or impact test.
Full-scale test specimens (ECK)

Figure 2 – Sample for wind load test

Figure 3 – Resistance of slot test

Figure 4 – Hygrothermal behavior (the dimensions of test chamber are also shown)
Hygrothermal test rig
Test rig for air permeability, watertightness and wind resistance tests
Full-scale test specimens (ECK)

Flat panel
Flax/furan pre-preg 5 mm (2x2 twill)
Open- Hat profile
Flax/furan pre-preg 3 mm (2x2 twill)
M8 x 15mm
Aluminium L-profile
50 x 40 x 4 mm
Distance- Clip
Adhesive bonding
(2K epoxy adhesive)
Top hat profile
Systea KU 35 VA, (23/60/50/60/23 mm)
Sliding bracket with bolt
Systea KU 35 VA
U-Bracket, Systea KU 35 VA
(UH 100/55/100-160 Albo)
Mineral Insulation 100 mm
(Rockwool or similar)
Screw

Prepared by WP5
Conclusions

• Testing allowed to compare the performance with benchmark products
• Improvements have been made in order to obtain a better performance of Biobuild products
• Full size tests will be important to fully characterize the Biobuild products
Thank you for your attention