Final Report Summary - HIFIVENT (High durability and fire performance WPC for ventilated façades)

Executive Summary:
HIFIVENT project started in 1st of October of 2013 and concluded in 31st of March of 2016. During this period, the main objectives of the project have been achieved with minor deviations in terms of personnel effort, resources and time.

A complete study of the feasibility of using WPC based composites for the construction of a ventilated façade has been carried out in several steps:

1.- Modification of raw materials: Natural fibers and Nanoparticles has been modified in the first period of the project in other to improve the durability and the fire performance of the composite.
2.- Compounding: Different approaches were followed based on the interest of the companies for the formulation of the compounds. Two types of natural fibers were selected (TMP and rice husks) and polypropylene was used as main plastic component, taking into consideration PVC as reference material.
3.- A complete study of the durability, fire performance and mechanical properties of the formulations (more than 60) was done and 5 formulations were selected for upscaling.

4.- The procesability and the recyclability of the compounds were also studied and some modifications in the formulations were necessary for the production of good quality profiles.

5.- Based on the standard of reference for ventilated facades (ETAG 034) the viability of using WPC was studied based on mechanical and thermal simulations. Different alternatives were proposed based on wood, aluminum and WPC structural profiles and WPC cladding. A design of the WPC ventilated façade was proposed.

6.- The proposed design and components has been characterized according to ETAG 034 and EN 15534. A very good results were obtained for the most important parameters: fire reaction performance (B-s2,d0) and wind load test (3000 Pa for suction and pressure).

In parallel to the developments, a market analysis, life cycle analysis, business plan and commercialization roadmap of the system has been carried out.

Project Context and Objectives:
Retrofitting is currently one of the major activities within the construction sector in Europe. The majority of actions are related to either recovering aged facades or solving insulation deficiencies. In these cases, ventilated facades are considered one of the most efficient systems.

Wood is a sustainable material that can be used for ventilated facades, but it lacks the necessary durability for outdoor exposition and intensive maintenance is required. This drawback can be addressed by new technological materials which combine durable polymers with high contents of wood (Wood Plastic Composites/WPCs). WPCs offer better thermal and acoustic isolation than aluminium and better durability than wood, however other problems arise that have to be addressed like for example their poor fire performance.

HIFIVENT project develops a new family of WPC compounds, especially suitable for ventilated facades by facing the challenges of their fire performance and durability issues.

HIFIVENT project has joint experienced European companies in the field of natural fibres, flame retardant nanoparticles, WPC compounding, WPC construction products as well as ventilated facades specialist (respectively BAVE, PROLABIN & TEFARM, BEOLOGIC, PLASTICOS ESCANERO and UXAMA). Additionally, those companies have been assisted by three relevant Research Institutions: Fraunhofer-WKI, Università degli Studi di Perugia and TECNALIA Research & Innovation (Project coordinator).

Project Objectives

Scientific objectives

Use of nanotechnology to improve mechanical and fire properties of composites.

.- Flexural stiffness and strength: at least 10% higher than current commercial WPCs.
  Reducing the amount of traditional fire retardant (never halogenated) in at least a 50%.
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Fire performance of ventilated façade in a reaction to fire test, Euroclass B-s3,d0

Improve mechanical performance of WPC by using long fibres for structural parts: 10% increase in stiffness and strength compared to traditional WPCs.

Wood fibre modification to improve weatherability: Good surface aspect after 2000 hours in accelerated weathering conditions (UV light + water spray) and 30% lower water absorbance and dimensional change than for traditional WPCs.

Industrial objectives

HIFIVENT aims to develop a ventilated façade system easy for assembly (reduction of 30-50% in weight with respect to ceramic and stone) that fulfils the following properties:

• Watertightness of joints (EN 12865:2002) = 2.000A
• Wind load resistance (ETAG 034) = 3000 Pa (Pressure) – 2.500 (Suction)
• Airborne noise transmission (EN ISO 140-3:1995) = 40 dB
• Thermal Behavior (EN ISO 10077-2:2008) = 2 W/m2·K
• Reaction to fire (EN 13501-1) = B-s3,d0

Social/Environmental objectives

This project contributes to the development of sustainable production patterns in the field of construction. It increases the use of non-hazardous materials and uses leading edge technologies developing more effective and lower embodied energy materials.

HIFIVENT promote better indoor quality due to the application of the ventilated façade system and improvement on citizen’s safety by reducing the risks caused by the fire in buildings.

Development of eco-friendly and fully recyclable system (facing and structure): Reduction of fossil fuel resources through the usage of biomass based fibres. Maximum of 40% of polymer (recycled origin) and natural fibre content equal or higher than 40%.

Project Results:
The main results of HIFIVENT project are summarized as follows:

1.- Modification of raw materials.
   - The selection of more adequate raw materials for WPC compounding has been carried out. This selection included natural fibres, polymers, fire retardants and additives.
   - Nanoclays have been successfully modified with phosphorous based moieties for improvement of thermal stability and fire performance. Four nanoparticles have been selected for compounding.
   - Natural fibres hydrophobation method has been study and optimized.

2.- Compounding and extrusion of WPC
2.- Compounding and extrusion of WPC.
- Basic formulation for WPC compounding has been defined.
- First compounding test has been carried out including thermomechanical treated fibres (TMP) modified with flame retardants. Phosphorous derived FR has been successfully applied to the fibres.
- A laboratory method for WPC formulation development based on TMP was successfully developed.
- Optimization of formulation for WPC compounding has been carried out.
- Fire retardancy of compounds has been implemented. Addition of fire retardants, TMP fibers treated with FRs and nanoparticles have been studied.
- A laboratory method for WPC formulation development, based on TMP, has been implemented.
- Compounding trials have been carried out including rice husks.
- Regarding hidrophobicity, the method of TMP treated with AKD developed was no applicable for extrusion proposes.
- Co-extrusion approach was not successful and was substituted by the use of inorganic additives.
- A complete characterization of the formulations was done mainly fire and mechanical properties.

3.- Development of WPC based ventilated facade.
- The requirements for ventilated façade has been evaluated according to different EU Building’s regulations and standards for construction works. General characteristics to be considered in the design of the new ventilated façade have been identified.
- An economic feasibility assessment of the ventilated façade system to be developed within HIFIVENT project has been carried out.
- The upscaling of the formulations was implemented for the production of profiles (structural and cladding). Different types of profiles were analyzed.
- Conceptual design of the façade has been defined based on mechanical and thermal simulations with the input data of the properties of the components.
- A LCA analysis has been reported analyzing different façade configurations and materials.
- Fire performance characterization of the profiles was carried out by SBI tests.

4.- Validation of the new ventilated facade.
- Different prototypes were made based on the design and profiles produced in WP4.
- The facade was characterized according to the most relevant tests: Mechanical, fire and wind load tests (ETAG034 for system and EN15534-5 for components)

1.- Modification of raw materials.

Lamellar nanoparticles modification
The use of modified nanoparticles were estudied to improve the fire performance of the WPC by synergistic effect with traditional fire retardants. Two approaches were considered for the modification of the lamellar nanoparticles:
1) Functionalization of lamellar nanoparticles with organic modification to make them more organophilic. In order to test in WPC the synergist effect of an exfoliate clay with traditional FR, such as ammonium polyphosphate (APP), some long chain aliphatic derivatives have to be tested as MMT modifiers.
2) Functionalization of lamellar nanoparticles with fire retardant moieties to improve the fire performance of the composites. An intumescent system based on phosphorous and nitrogen was proposed in which...
The composites. An intumescent system based on phosphorous and nitrogen was proposed in which nitrogen and phosphorous bearing molecules deputate for charring and ceramifying effect are intercalated in MTT clays. The obtained organo-modified clay will act as a micro or nano composite. Hence, the organo-modified nanoparticles obtained in approach 1 (as a first attempt montmorillonite), was considered for further modification with Phosphono-N,N-bis(phosphonomethyl)methanaminium (PN3PM) and derivative chemicals, that have high phosphorous content (of primary importance to obtain satisfactory FR properties in a halogen free fire retardant formulation). In the framework of the project, the intercalation of three different acids with a different length of the alkyl chain was done.

The required modifiers and the Organically Modified nanoparticles (14 products) were produced and characterized at lab scale by SEM, TGA and Cone calorimeter. 4 Modified nanoparticles were selected based on fire and thermal properties: MMT-DMDT and MMT-C4P2; ZrP-Oct and LDH-Stearate. All the selected products were stable in the processing range of PP (190-230ºC).

Natural fibers modification
Complete study (more than 30 formulations analyzed) of the conditions for the treatment of wood fibres were done focusing on the influence of: Method of application, % of reactive, Temperature, pre- and post-treatments, Catalysts, Pressure and pH. The improvement of the hydrophobicity of the fibers were measured by contact angle method and promising results were found. The best conditions were optimized and applied to the other selected natural fibres (wood flour, Rice husks, Hemp and Flax).

The process was upscaled for the production of treated woodfibers for the compounding. The following figure shows the aspect of the fibers during and after the treatment and the contact angle compared with untreated fibers.

2.- Compounding and extrusion of WPC.

After some previous work, two approaches were selected for the compounding process. The use of thermos mechanical pulp (TMP) for structural profiles and Rice husks fibers for cladding profiles. 30 TMP based formulations and 25 Rice husks based formulations were prepared and analysed. The influence of the modified nanoparticles and treated fibers in the formulations were also analysed. The main conclusions of this work were:

Structural
Results obtained using lab-scale processing and small-scale samples indicated that tensile strength was slightly decreased when TMP was pre-treated with FR and further decreased when FR was added during compounding. In contrast, tensile MOE was increased when FR was used. Water uptake and swelling of WPC were increased with the addition of FR, however, the values obtained with pre-treated TMP and with APP added during compounding are still below the threshold value according to EN 15534-5 (maximum of 7% water uptake).

Up-scaling of the TMP treated fibers.
The compounding of the TMP based composites was upscaled by pelleting of TMP and further extrusion and compounding.
Regarding the compounding of Wood fibers treated with hydrophobitation agent, the influence of the processing was studied by direct hot pressing and by injection moulding. In the two cases, the treated fibres improved the performance of the composites by 3.4%. The absolute value of the water uptake is...
fibres improved the performance of the composites by 3-4%. The absolute value of the water uptake is inferior in the case of injection moulding. The best result was the injection moulding samples treated. We could conclude that two effects play a significant role in the process:

- Shear effect: An excessive shear destroys the hydrophobation effect of the treatment.
- Pressure effect: In injection moulding, the pressure effect increases the protection of the fibres by encapsulation with the matrix (PP), decreasing the water uptake.

Analysing the results, the effect of the pressure is higher than the shearing because the injection moulding (T) was the best result (13.33%). This procedure could be perfect for the technology of pelletizing the long fibres and direct injection in which the shearing is minimum, so a positive effect could be observed. However, for extrusion processes, the effect is destroyed by the excess of shearing.

Synergistic effect of nanoparticles
The prepared nanoparticles were evaluated with different commercial fire retardants (PAXYMER, EXOLIT, UNI, ADK). The main conclusions are:

- ZrP showed a synergistic effect with PAXYMER by reducing the maximum of the HRR and the THR.
- Only DMDT showed a synergistic effect with EXOLIT by reducing the maximum of the HRR and delaying the time to ignition.
- No improvements were observed for UNI system with nanoparticles.
- No improvements were observed for ADK system with nanoparticles.

Recycling and reprocessability of the end product obtained

Recycling and reprocessability of the produced end product has been studied. In general, subsequent processing steps give rise to decreases in the materials’ performance. So, it is necessary to know how many times a material can be reprocessed before losing its applicability in the required application. Thus, we studied three repeated extrusions and how the mechanical properties (tensile) can be affected by the repeated processing steps. Moreover, another important property that has been analyzed is the thermal stability of the produced materials: specifically, TGA test, both in nitrogen and air atmosphere, have been performed.

Few differences were found between the virgin material and the recycled one from the point of view of processing, despite changes in the material color occurs between the given processing stage and the subsequent one: the material color became darker after any injection moulding stage, at the point that was decided to stop the cycles at two, being the color of the material quite dark at the third cycle (due to filler/polymer induced degradation). The mentioned changes indicate that degradation phenomena occur and mainly they may regard the natural filler.

Mechanical characterization (tensile tests)
Tensile tests of reprocessed samples (up to 2 cycles) were performed by using a Lloyd LK30 dynamometer following the ISO 527 standard. In particular, the values of tensile strength, elastic modulus and elongation at break were measured at cycle 1 and cycle 2 of recycling.

An increase in tensile properties was observed. In WPC composites, the adhesion quality of the components is the most effective factor on the strength. WPC rupture mostly initiates and occurs at the weak interface and thus a good quality of bonding gives rise to an improved stress transfer between wood particle and polymer, resulting in an enhanced strength. Regarding the modulus, it is the composites behavior at the elastic region of small strains, while the other factors such as the individual components...
behavior at the elastic region of small strains, while the other factors such as the individual components properties and homogeneity of the structure could be more important than the adhesion quality. This consequence is because of interactions between two opposite effects of recycling. On one hand, degradation caused by thermal and mechanical stresses in matrix and filler and on the other hand, improved combination and distribution caused by improvement in mixing and wetting of wood flour by polymeric matrix.

Thermogravimetric tests
TGA analysis of recycled samples was performed, both in nitrogen and air atmosphere, to verify how the thermal treatment due to the extrusion could affect the thermal stability of the different samples. In details, it can be observed that no substantial differences can be detected in TG and DTG profiles of the virgin WPC and the recycled material after two cycles.

The material selected for recyclability tests has been reprocessed in extrusion/injection steps up to 2 cycles and the thermal and mechanical properties have been evaluated after each processing step. The results confirmed how the reprocessed materials could show better tensile properties, due to the effect of an improved stress transfer between wood particle and polymer, resulting in an enhanced strength. Thermal stability of the reprocessed samples was also confirmed by means of TGA tests performed both in inert and oxidant atmosphere.

3.- Development of WPC based ventilated facade.

Up-scaling of the preparation of ZrP
The procedure developed at laboratory scale was adapted to the industrial scale and the intercalation was carried out using a turbo emulsifier. The magnetic stirring was substituted with the vigorous stirring of the turbo emulsifier, reducing the time of reaction. The intercalated solid was separated from the mother liquor using and industrial filter press.

Extrusion process:
The processing of prototypes was optimized at three levels; laboratory scale, semi-industrial scale and Industrial scale. The tools designed and made for HIFIVENT have been tested and optimized for the extrusion of PP based WPCs. Some problems were detected in the up-scaling, especially for the extrusion of PP/rice husks composites and reformulation and tuning of the parameters was needed. The prototypes needed for the characterization campaign and for build the façade prototype were produced.

Characterization of composites
A SEM characterization of the nanocomposites was carried out.
A complete fire characterization of the prototypes was done by cone calorimeter and SBI test.
The synergistic effect observed for nanoparticles (ZrP-Oct) at lab scale is not replicated at real scale by the real extruded profiles. Probably the different mixing conditions and the dispersion grade could be the reason for this different performance. The SBI was selected as the fire reaction test taking into account that is the method for the certification of the fire performance of components and facade systems according to EN 15535 and ETAG 034 respectively. The selected composites were evaluated according to this test. Euroclass classification was determined for the WPC prototypes and compared with PVC reference.

PROT I reaches the best classification according to SBI B-s2, d0, even better than PVC reference (C-s3, d0) and surpassing the initial objective of the project (B-s3, d0).
Design of the ventilated façade system.

After an analysis of the requirements for ventilated facades in Europe, the following requirements were defined as targets for HIFIVENT façade:

ER Essential Characteristics

2 Reaction to fire "B-s2,d0" (In the areas required)

Fire resistance NO

3 Water tightness Insulation "water repellent" or EN 12865 Procedure A (600 Pa maximum)

Release of:
formaldehyde NO
asbestos (content) NO
pentachlorophenol NO
other dangerous substances The materials are allowed in all/some countries, but with restrictions, in which case the nature of the materials as well as their concentration/emission rate/etc shall be given.

4 Wind load resistance Wind pressure design of 2600 Pa

Mechanical resistance EN 1991-1

Resistance to horizontal point loads For culture/public buildings this value rates from 5 kN/m - areas susceptible to large crowds- to 3 kN/m – areas without obstacles for moving people. For residential and other buildings, the horizontal live load established is 1 kN/m.

Impact resistance Value rates depending on use categories from 100 to 400 joules for soft body impact and from 0 to 10 joules for hard body impact.

Resistance to seismic actions Depending on building location and national regulation. Avoid part detachment in case of earthquake.

Hygrothermal behaviour Avoid deterioration such as cracking or delamination, detachment and irreversible deformation on the cladding element.

5 Airborne sound insulation $RA_{tr} = 60$ dBA

6 Thermal resistance $0.8 - 0.15$ W/m²K

Furthermore, an taking into consideration the final cost of the product and the requirements, the Characteristics of the system were also defined:

- Anchorages to facade of the mullions. Maximum $Lv (max) = 1.3$ m
- Maximum span between mullions $Lh (max) = 0.50$ m
- Maximum Wind load = $3$ KN/m² = $3000$ Pa
- The stresses do not exceed the elastic limit of the material $\sigma_{max} < \sigma_Y$
- Safety factor for the yield strength $= 1.05$
- Coefficient load majorization $= 1.5$

Determining the mechanical and thermal characteristics of the product by means of simulation

The mechanical and thermal performance of the systems were analyzed by simulation. Different components and materials were studied (Aluminium, wood, WPC) in order to find the best solution for the HIFIVENT ventilated façade. Façade formed by decking of WPC and wood vertical profiles is which has the lowest thermal losses (The values for the ventilated façade system entirely made in WPC are better than those made of aluminium. Due to this the system could have multiple configurations each of them for some specific market:

- Demand of eco-materials (WPC and Wood)
- Demand of lower cost systems (aluminium profiles)
Study of economic viability
An economic feasibility assessment of the ventilated façade system developed within HIFIVENT project was carried out. This economic feasibility assessment aims to objectively and rationally cover the strengths and weaknesses of the use of WPCs as cladding and load-bearing structure for ventilated façade systems. Opportunities and threats comparing with market current systems have been studied together with the prospects for success. According with the financial statements performed in this economic viability study, it is clear that, based on the initial conceptual design, we have the possibility to develop an interesting and profitable ventilated façade system that could give important benefits since the fifth year.

Analysis of life cycle of the product
A comparative life cycle assessment of ventilated façades was realized; Wood Plastic Composite and Aluminum. It permitted to obtain a specific and objective ecoprofile for many indicators and on the entire life cycle of the façade; quantify enhancement and degradations on the environmental indicators between products; identify most important factors; give enhancement ways of the modified WPCs regarding the environmental criteria and provide reliable and rigorous communication arguments. LCA provides a holistic approach to evaluate environmental performance by considering the potential impacts from all stages of manufacture, product use and end-of-life stages. For the calculations, real inputs of the materials, methods and processes used by all the companies involved in the value chain were compiled and used for the assessment of the LCA for the final HIFIVENT façade.

LCA Results
The following table presents the potential savings in percent, per functional unit, for the following ventilated façade systems regarding to the traditional ventilated façade system made of aluminium.

- WPC cladding and aluminium profile.
- WPC cladding and WPC profile.
- WPC cladding and wood profile.

Table: Percentage of savings obtained with the alternatives studied compared with the traditional ventilated façade system.

<table>
<thead>
<tr>
<th>POTENCIAL ENVIRONMENTAL IMPACT 1 m2 SYSTEM</th>
<th>WPC + ALUMINIUM</th>
<th>WPC + WPC</th>
<th>WPC + WOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming Potential (GWP 100 years, in kg CO2-Eq)</td>
<td>60,89%</td>
<td>84,84%</td>
<td>89,72%</td>
</tr>
<tr>
<td>Ozone Layer Depletion Potential (ODP, steady state, in kg CFC-11-Eq)</td>
<td>38,23%</td>
<td>74,79%</td>
<td>82,19%</td>
</tr>
<tr>
<td>Acidification Potential (AP, in kg SO2-Eq)</td>
<td>54,21%</td>
<td>74,36%</td>
<td>83,15%</td>
</tr>
<tr>
<td>Eutrophication Potential (EP, in kg PO4-Eq)</td>
<td>57,61%</td>
<td>92,79%</td>
<td>94,85%</td>
</tr>
<tr>
<td>Abiotic Depletion (ADP fossil, in MJ)</td>
<td>52,71%</td>
<td>72,01%</td>
<td>80,71%</td>
</tr>
</tbody>
</table>

As can be seen in table, the WPC-Wood façade system presents the highest potential savings regarding to the traditional ventilated façade system. Therefore, this system presents the best environmental performance with life cycle perspective and whenever possible the use of this solution is recommended against to the other solutions studied.
4.- Validation of the new ventilated facade.

The designed HIFIVENT facade was characterized according to the corresponding standards. The characterization of the components was done according to EN 15534 and the whole system according to ETAG034.

Component characterization

The cladding components were characterized according to EN15534-5. Mechanical properties: The mechanical properties of the cladding elements have been evaluated. For comparison, wood flour and rice husk based formulations has been tested. Wood flour based formulations showed better results. For the design of the facade, these results has been taking into account but they are not restrictive, just impact in the number of anchoring and vertical profiles to be installed. Durability: Ageing test has been carried out with reasonable results for formulations with UV-absorbers and HALs and very good results for formulations with mineral. As expected, the formulations without ageing treatments showed bad results.

System characterization

A complete characterization of the facade has been done according to ETAG034 for the whole system. The most important parameters like fire performance and wind load response were tested and the thermal performance was simulated.

Wind load test

A facade prototype of 3mx3m was built for testing

Wind load test is one of the most important test that a ventilated facade must comply with. So and in spite that only pressure test was consider initially, suction test was also studied. The tests procedures were according to the following standards:

- Resistance to wind suction in accordance with ETAG No. 34, 2012, section 5.4.1.1.
- Resistance to wind pressure in accordance with ETAG No. 34, 2012, section 5.4.1.2.

Pressure test

The cladding showed a linear deformation as a function of the pressure load reaching a maximum deflection of 30mm and a medium deflection of 22 mm for the six control points with a load of 2000Pa. The permanent deflections after each application of pressure load are shown in the next figure.

The material showed an inflection point at 1600Pa that is related with the modulus of elasticity of the WPC. The maximum value was 4.5mm and the media about 3.5mm. At this point, it was decided to finish the pressure test and continue with suction test that is more demanding. So, the sample did not fail but the test was stopped in order to avoid issues with the sample for suction test.
Suction test

The values of the deformations were similar to pressure ones. After 2.000Pa the defection increase but with a lower slope reaching a maximum of 35mm for 3.000Pa.

The permanent deflection values reach a maximum of 12mm (media value of 10mm) for 3000Pa suction load.

With this results, the HIFIVENT façade did not fail in the test conditions (no breaks observed) according to the ETAG034 failure criteria. However, the maximum load of the equipment was 3000Pa so we can conclude that the maximum tested load for the façade was 3000Pa.

Fire reaction test:

The fire reaction performance according to SBI test reach better result than requirements: B-s2,d0, for wood flour ignifugated samples. However, a cost effective alternative has been tested (D-s2,d0) for the applications that do not require the maximum performance.

Thermal performance:

The Uef was calculated based in simulations and the WPC façade has reached very good values improving the performance of other alternatives like aluminium and reaching values close to the best requirements. Ueq (W/m2.K)= 0.279

The following table summarizes the results of the HIFVENT Façade characterization compared with the targets defined.

<table>
<thead>
<tr>
<th>ER Essential Characteristics</th>
<th>HIFIVENT TARGET RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Reaction to fire “B-s2,d0” (In the areas required)</td>
<td>B-s2,d0</td>
</tr>
<tr>
<td>Fire resistance NO --</td>
<td></td>
</tr>
<tr>
<td>3 Water tightness Insulation “water repellent” or EN 12865 Procedure A (600 Pa maximum) --</td>
<td></td>
</tr>
<tr>
<td>Release of: formaldehyde NO</td>
<td></td>
</tr>
<tr>
<td>asbestos (content) NO</td>
<td></td>
</tr>
<tr>
<td>pentachlorophenol NO</td>
<td></td>
</tr>
<tr>
<td>other dangerous substances</td>
<td>OK</td>
</tr>
<tr>
<td>The materials are allowed in all/some countries, but with restrictions, in which case the nature of the materials as well as their concentration/emission rate/etc shall be given. OK</td>
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</tr>
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<tr>
<td>Mechanical resistance EN 1991-1 OK</td>
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<tr>
<td>Resistance to horizontal point loads For culture/public buildings this value rates from 5 kN/m - areas susceptible to large crowds- to 3 kN/m – areas without obstacles for moving people. For residential and other buildings, the horizontal live load established is 1 kN/m. OK</td>
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<td>Impact resistance Value rates depending on use categories from 100 to 400 joules for soft body impact</td>
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Impact resistance: Value rates depending on use categories from 100 to 400 joules for soft body impact and from 0 to 10 joules for hard body impact.

Hydrothermal behaviour: Avoid deterioration such as cracking or delamination, detachment and irreversible deformation on the cladding element. OK

5 Airborne sound insulation $R_{A,tr} = 60$ dBA

6 Thermal resistance $0.8 - 0.15$ W/m²K $0.27$ W/m²K

In conclusion, HIFIVENT façade has been characterized according to the current standards and has obtained good results that allow to the first steps of commercialization of the system. As is scheduled in the commercialization roadmap, a complete test campaign will be carried out to obtain the certification of the system.

Project Objectives (DoW) Results

Flexural stiffness and strength: at least 10% higher than current commercial WPCs. Reached with TMP formulations (12%)

Reducing the amount of traditional fire retardant (never halogenated) in at least a 50%. No halogenated fire retardants used. Synergestic effect of nanoparticles detected at lab scale but not observed in industrial scale. Further research needed in this field

Fire performance of ventilated façade in a reaction to fire test, Euroclass B-s3,d0 Reached B-s2,d0 by TMP-FR composite

Wood fibre modification to improve weatherability: Good surface aspect after 2000 hours in accelerated weathering conditions (UV light + water spray) and 30% lower water absorbance and dimensional change than for traditional WPCs. Modification of fiber showed good results at lab scale but failed in real scale. An improvement in the durability was observed by the addition of mineral additives but the objective of 30% reduction in water uptake was no reached (10%). However, the composites fullfill the current requerements.

HIFIVENT aims to develop a ventilated facade system easy for assembly (reduction of 30-50% in weight with respect to ceramic and stone) Reached. 60% of reduction in weight (15-20kg/m²; ceramic 30-50kg/m² and stone 80-100kg/m²).

Watertightness of joints (EN 12865:2002) = 2.000A

No evaluated. Substituted by fire tests.

Wind load resistance (ETAG 034) = 3000 Pa (Pressure) – 2.500 (Suction) Reached (>2000Pa Pressure and 3000Pa suction)

Airborne noise transmission (EN ISO 140-3:1995) = 40 dB No evaluated. Substituted by fire tests.

Thermal Behavior (EN ISO 10077-2:2008) = 2 W/m²K Reached. 0.27 W/m²K by simulation.

Development of eco-friendly and fully recyclable system (facing and structure) More than 40% of waste natural material. Material reproccesable minimum 2 times.

Reduction of fossil fuel resources through the usage of biomass based fibres. Maximum of 40% of polymer (recycled origin) and natural fibre content equal or higher than 40%. Reached. 25% of Polymer and 45% of natural fiber used

Potential Impact:

A market analysis was done analyzing the retrofitting market and the competitors at European level. The total European market for ventilated façades shows the idea of the overall market. However, the potential market size is given by the potential of HIFIVENT ventilated façade to gain market share of phenolic ventilated facades. The current quantity of ventilated facades in Europe is 50 000 000m² of
Phenolic ventilated facades. The current quantity of ventilated facades in Europe is 50,000,000 m², of which 22% correspond to phenolic ventilated facades (11,000,000 m²) and the remaining 88% (39,000,000 m²) correspond to different type of ventilated facades, such as aluminium, glass, stone, etc.

In order to calculate HIFIVENT WPC ventilated facade’s potential market different assumptions have been made:
We considered that WPC ventilated facade can gain 5% of market share from HPL (High pressure laminate) ventilated facade in the first year of commercialisation, and up to 15% in the fifth year. This estimation is based on the data provided by the companies participating in the project.
Similarly, we have assumed that WPC ventilated facade will gain 0.50% of market share from other type of ventilated facades in the first year of commercialisation, and up to 0.75% in the fifth year. The estimation has been made based on the data provided by the companies participating in the project.

To sum up, the market volume for WPC ventilated facades in Europe is estimated to amount to 745,000 m² in the first year, and up to 2,250,025 m² in the fifth year.

Exploitation plans

A patent search and a filing of patents was reported to evaluate the patentability of the results obtained during the project. Taking into account these analysis and the results of the project, the following exploitable results were considered:

Category no.// HIFIVENT //SMEs
1. New developments in advanced materials: Modified Nanoparticles ER1 New modified nanoclays to improve fire retardancy of composites. PROLABIN

Functionalized natural fibers ER2 Functionalized agricultural by-products and cellulosic fibres compatibles with plastics for new applications such as WPCs. BAVE
2. New developments in compounder: WPC compounds ER3 WPC compounds with improved fire and weathering performance. BEOLOGIC
3. New developments in process: extrusion process for WPCs. ER4 New extrusion process: to manufacture profiles and facing materials by extrusion of WPC components of a ventilated facade ESCANERO

A calculation of the system cost, sales forecast and benefit description were done. Due to the confidentiality of this data is not reported.

Dissemination of results

In order to structure the external dissemination activities in the dissemination plan and to be able to analyze the impact of dissemination on a comparable basis a more accurate division of the target audience was developed.

Academic and research community

This group targets all research communities interested in the HIFIVENT project’s developments, results and innovation which can be beneficiary for their own research activities.

Scientific contributions of HIFIVENT are particularly interesting for researchers working in the field of wood plastic composites. This includes the following not exhaustive topical areas: Fire retardancy, durability, materials characterization, nano particles, composites advanced materials, incorporating fire retardants to
Materials characterization, nano-particles, composites advanced materials, incorporating fire retardants to bulk materials, natural fibers modifications and outcomes (Life Cycle Assessment).

Several oral communications were done mainly by Dr. Aitor Barrio and Dr. Arne Schirp in Congress and conferences related with the topic of composites and building envelopes.

A reference of the participation of BAVE, BEOLOGIC and WKI is cited in the Compounding World magazine in the March 2016 issue.

Regarding publication of the results in a scientific journals, there are two articles in preparation:

1. Synergistic effect of nanoparticles in WPC (UNIPEG, PROLABIN, TECNALIA): Results out of the scope of the patent in preparation will be included in this publication. Preparation of the modified nanoparticles, characterization and the synergistic effect in WPC at bench scale will be the content of the article.

2. Fire retardancy of WPC products (WKI, TECNALIA). Fire retardancy of WPC at product scale. The influence of the addition of different fire retardants and the results of LOI, Cone calorimeter shaft test and SBI test will be included.

The two articles will be sending to Polymer Degradation and Stability journal for its consideration.

Industrial sector, Professional Associations.

A major objective of HIFIVENT is to address and trigger the active involvement of industrial and user communities. HIFIVENT has already attracted stakeholders from two relevant industrial sectors (Construction and Automotive) whose potential for the exploitation of the Project results has been analyzed mainly in the chapter of exploitation plan. In this field, the HIFIVENT partners have been very active and have participated in a lot of fairs and meetings related with WPC and composites. Three approaches were scheduled taking into consideration the progress of the project:

1. First approach was the dissemination of the project itself by presentation of the flyers and by direct communication of the audiences. The first 18 months of the project.

2. Second approach was the dissemination of results mainly in the last year of the project.

3. Third approach was show the prototype and the results of the characterization of the WPC ventilated façade to demonstrate that the product fulfil the requirements and is an attractive alternative to the current solutions in the market. Last months of the project and planning after the project.

A positive feedback of the customers has been already detected in the fairs that the partners showed this development, especially in Maderalia 2016, when the visitors showed a great interest in the façade taking into account that the competitors in this fairs only had decking and fencing products.

Dissemination materials:
The activities related with these materials are described below:

HIFIVENT logo

A project logo has been created in order to assure to the project an attractive visual identity, and to foster its immediate observer recognition.

Website

Project websites are one of the main communication tools of projects funded under the EU 7th Framework Programme. To ensure maximum visibility to the HIFIVENT objectives and results, it has been set up a project website registered in the “eu” domain and with an intuitive URL to increase hit rates:

http://www.hifiventproject.eu/

Project Videos

Two videos of the project were created.
Two videos of the project were created. One specific of the project that shows the context of the project, partners, objectives and some developments. PESL also include a reference to HIFIVENT project in a promotional video of their tradename Decksystem: https://www.youtube.com/watch?v=bqHdwrlRxWnU

HIFIVENT project flyer

The main objective of the project leaflet was to provide our audiences with an attractive and written project overview and a summary of the main project objectives and characteristics. To assist the dissemination effort, an attractive and professionally made leaflet has been prepared by TECNALIA. The text was designed taking into account not only experts, but also an interested non-specialist. The leaflet presents the goals of the project and the main (expected) findings, as well as its main mission and goals. Furthermore, it includes the website address and provides basic information on HIFIVENT Consortium. All partners’ logos are also displayed. The project flyer has been an excellent way to disseminate the project in fairs and to catch the interest of the future customers.

HIFIVENT poster

The main purpose of the poster is to catch the audience attention. The poster focuses on the visual aspects and it is clear and easily understandable by the target end users. With regard to the layout and design, the poster shows the HIFIVENT project’s logo and the colours emphasizing the link to the project’s graphic. This poster has been mainly prepared for include it in the project prototypes.

List of Websites:

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Project website http://www.hifiventproject.eu/
Related documents

[final1-final-report-hifivent-605891-publisable.pdf]

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