Grassification

D 2.4.3

Use of biocomposites of biopolymers and roadside clippings for prototype products (e.g. landscape infrastructure)

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Contents

The GRASSIFICATION project

Roadside grass clippings are a problem fraction throughout the 2 Seas Programme area due to their high volume, subject to high processing costs. The industrial sector, however, is interested in the possibility of using roadside grass clippings as an alternative resource (as opposed to fossil sources or dedicated agricultural produce, e.g. isolation material). The common challenges for applying roadside grass clippings as a renewable feedstock in industrial processes are currently threefold:

• the supply chains are not yet optimal, resulting in higher costs;

• a highly variable and heterogeneous quantity;

• an unsupportive institutional framework leading to legal and political challenges.

The overall objective of the Grassification project is to apply a multi-dimensional approach to roadside grass clippings refining in order to optimize it into a viable value chain for the biobased and circular economy. The project commits itself to optimize logistics and technical aspects of the grass clippings supply chain and processing, demonstrate its market potential as well as formulate policy and legal recommendations to create a more supportive framework for the recycling of this renewable resource. These actions will increase the volume of usable material, lower costs, and generate a higher added-value for this so-called 'waste' streams. In this way, the use of roadside grass clippings as a renewable resource for the production of biobased products and hence the circular economy will become more attractive.

Context of the document

In WP2, PP6 (Hogeschool Gent) – lead partner, PP2 (Provincie West-Vlaanderen), PP3 (Pro Natura), PP9 (Millvision), PP10 (Delphy), PP11 (Stichting Avans) and PP12 (Innec) are jointly developing, testing and demonstrating several bio-composite products using fibres from roadside clippings. These products will be tested and demonstrated in lab and real-life demos. In order to improve service life, the use of fibre blends (e.g. addition of raspberry fibre) and/or biobased coatings will be taken into account. Target groups are the fibre processing industry, (local) governments and (nature & recreational) organizations with landscape infrastructure.

The (bio)polymer composite materials tested and designed within D2.4.2 were now used in D2.4.3 for landscape infrastructure applications and/or simple building applications. In this report, the design development and the making of a prototype are described for a circular/biobased picnic set of Millvision (PP9), a jetty board plank by Avans (PP11), and different biocomposite prototype products by HOGENT (PP6). The work of Millvision has been performed in close cooperation with the company Stapper Duurzaam Advies, supporting the development of the design of the picnic set, including delivery of artist impressions of these sets together with a first setup of the rating table for the final selection of the circular/biobased picnic set. Both Stichting Avans and HOGENT also interacted with industrial stakeholders in view of prototype upscaling and value chain development activities.

The developed biobased construction and landscaping products can be categorized at Technology Readiness Level (TRL) 4 or 5, bridging on 6 to 7. They are at the transition between small scale and large scale prototypes or larger scale production. The next steps are further upscaling, validation and testing in close to expected performance in real environments. TRL 6 to 7 and enhanced visibility may inspire market participants to lift the products to the commercial level (TRL 8-9). There are however still a number of hurdles to be taken for upscaling and automating some of the pre-processing steps that will allow for a continuous production of these biocomposite products. The fibre quality should be consistent and reliable, and should correspond to stakeholder expectations. For this purpose, Stichting Avans and HOGENT developed two online fiber quality surveys aiming for feedback from potential collectors and processors in the grass clippings value chains. These surveys were filled in by 13 different stakeholders and have yet to be analysed (raw responses in Excel are provided as images in annex 5).

1. Picnic set - Millvision (PP9)

This chapter describes which steps have been taken to develop the prototype picnic set.

1.1 Material composite development

Figure 1: 10x10 profile

In the research in D2.4.2, different types of roadside grasses (from Delphy, ProNatura and VanHeede) were examined in a circular/biobased basic composite compound recipe from Millvision. This resulted in a recipe that has good mechanical properties for making a prototype picnic set. This recipe was compounded on a pilot/semi-works scale at a partner of Millvision and it has been processed via extrusion technique in a 10x10cm profile, as seen in figure 1.

1.2 Sketches of picnic set families

To develop the best design of the picnic set, different sketches were first made of potential prototype families of picnic sets. These can be seen in figures 2 up to 4. In family 1 (figure 2), the visitor sits sideways along the picnic table for a simple meal. In families 2 and 3 (figure 3 and 4), the table can be set to dine a little longer by the visitor.

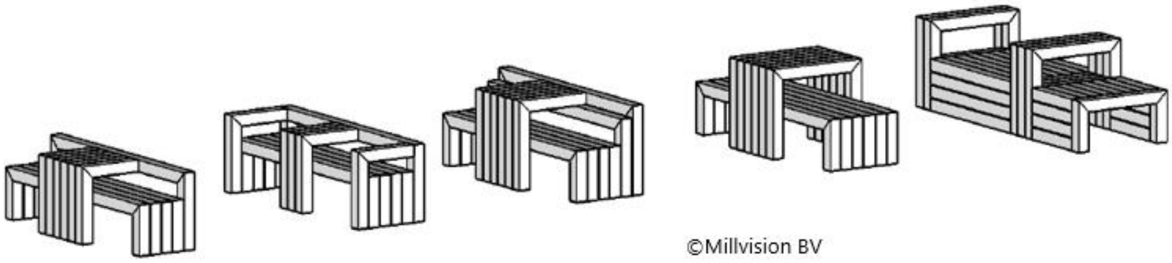

Figure 2: Family 1 biobased cycle route banks

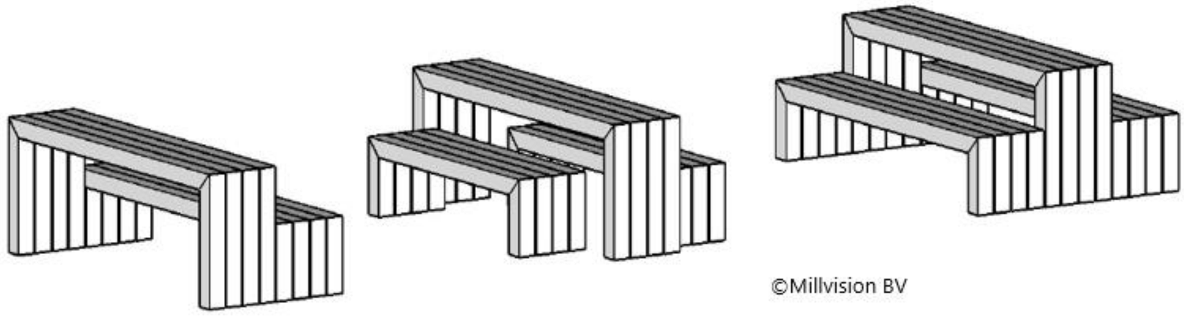

Figure 3: Family 2 biobased service area / car route banks

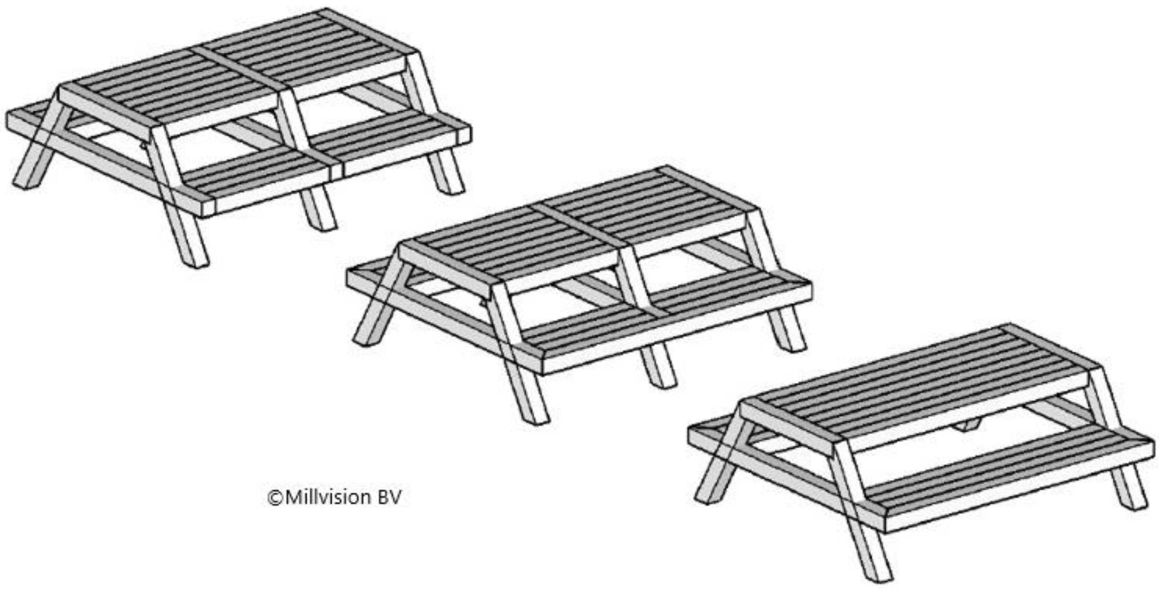

Figure 4: Family 3 biobased variant of current picnic sets

1.3 Artist Impression

Based on these three families, it was decided to process two types of picnic sets into an Artist Impression: the single and double set cycle route and care area picnic set. These can be seen in figure 5 and 6. Due to the Covid-19 pandemic, an extra option has been added for a picnic set in view of the 1.5 meter society. An Artist Impression for this picnic set is presented in figure 7. To get a first good impression of these designs, some examples have also been made using 3D printing.

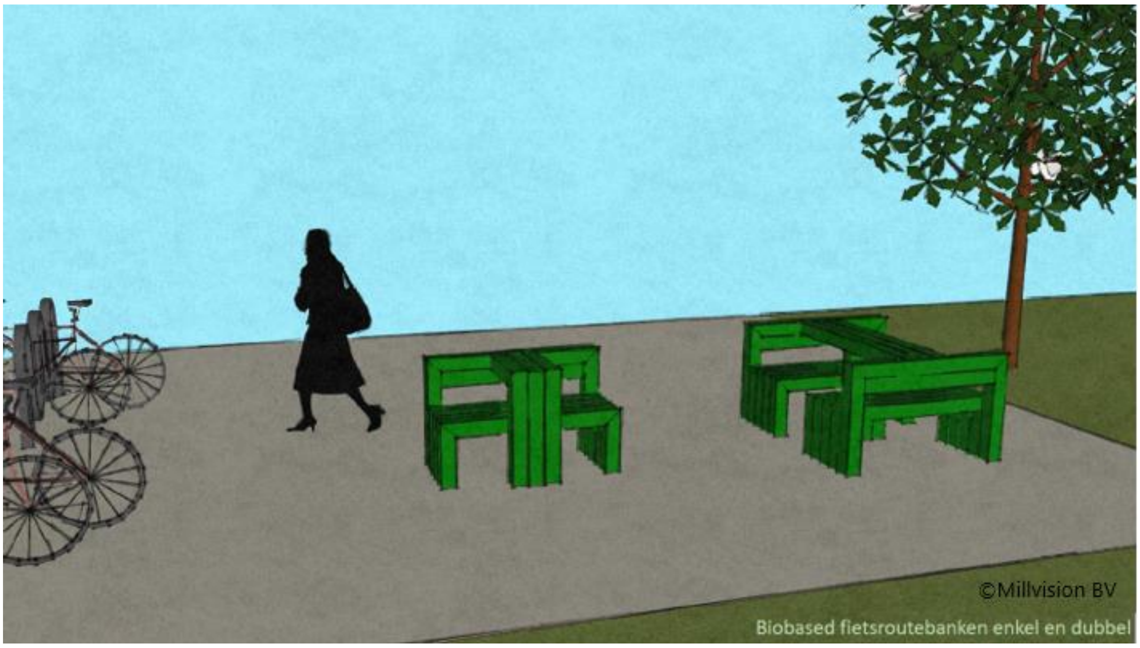

Figure 5: Artist Impression biobased cycle route benches

Figure 6: Artist Impression biobased service area/car route benches

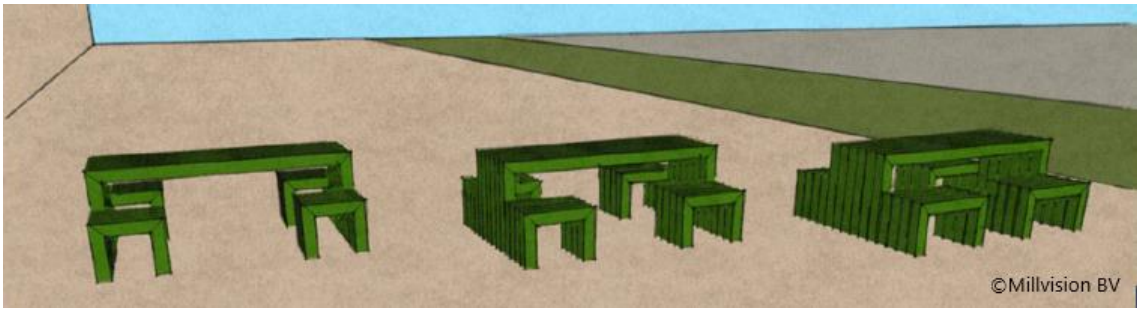

Figure 7: Artist Impression biobased 1.5 meter bench

1.4 Review picnic set

In order to test the functionality and design of these picnic set impressions, contact was made with the Observer partner Rijkswaterstaat (potential end-user) and contractor Mourik Groot Ammers as another partner in the chain and buyer of picnic sets on behalf of Rijkswaterstaat. Important factors that influence the choice of picnic sets are manufacturability, replaceability of parts, price, fast delivery time, easy to install, safe in use, and maintenance. Sustainability is also an important factor and increasingly a selection criterion in tenders, but less relevant for a relatively small object such as a picnic set. Besides these factors, Millvision also has added criteria like sit comfort of the user, vandalism-proof and eco-cost per seat.

To select the best picnic set option, the factors stated in the paragraph before have been put in a matrix (table 1) for the designs given in figures 5 to 7, respectively. A maximum score of 5 points can be achieved on each factor given, rating 1 point in case of unsatisfactory and 5 points in case of excellent. The assessment of the eco-cost per seat is rated as 1 point per 3 euros with a maximum of €15. In this case, an eco-cost per seat of 0-3 euros equals 5 points, 3-6 euros equals 4 points, 6-9 euros equals 3 points, 9-12 euros equals 2 points and 12-15 euros equals 1 point. Because it is less relevant for the customer (Rijkswaterstaat), the eco-costs per seat counts for half in the matrix below.

Table 1: Rating matrix selecting the best option prototype picnic set

Type / Factor	Single / bicycle	Double / bicycle	Single / car	Double/ car	1.5 meter picnic set
Manufacturability	4	2	4	4	4
Replaceability of parts	3	1	4	4	4
Price	3	2	4	4	4
Easy to install	3	2	4	3	3
Vandalism proof	2	2	3	3	3
Safe in use	3	3	4	4	4
Maintenance	3	3	3	3	3
Comfort of user	4	3	3	4	4
SUBTOTAL	**25**	**18**	**29**	**29**	**29**
m1 roadside clippings profile/seat	16 / 2 = 8	32 / 4 = 8	24 / 2 = 12	34 / 4 = 8,5	20 / 4 = 5
Ecocost/seat*	€ 8,48	€ 8,48	€ 12,72	€ 9,01	€ 5,30
Ecocost assessment	1,5	1,5	0,5	1	2
TOTAL	**26,5**	**19,5**	**29,5**	**30**	**31** ©Millvision

* Based on first approach MKI calculation Millvision May 2020

Based on this table, the best option for a prototype picnic set is the 1,5m picnic set (see column 5 in table 1).

1.5 Prototype

Based on input from Rijkswaterstaat and Mourik Groot Ammers, technical drawings (views and details) were made for the prototype picnic set selected. Due to the 'new normal' caused by the COVID-19 pandemic, it was decided to further develop the 1.5 meter picnic set.

A carpenter was consulted to discuss the technical drawings and to check whether the picnic set could be produced from a manufacturability point of view. During the practical implementation, the carpenter came up with feedback that the bench should be built up with a “U” shaped profile. It would be easier if the picnic set consists of separate elements, for example 4 separate benches and a table.

Based on the discussions with the carpenter, the prototype picnic set was built. The final result of this prototype picnic set is presented in figure 8. The prototype picnic set will be put into use in the spring of 2021 at the location of Millvision and it will be visually monitored (i.e. discoloration, cracks in profiles, creep of profiles) until the end of the Grassification project.

Figure 8: Developed prototype picnic set by Millvision

2. Board planks - Stichting Avans (PP11)

This chapter describes which steps have been taken by PP11 to develop a prototype of a roadside grass biobased composite plank as a tropical hardwood replacer.

2.1 Introduction

One of the products directions for roadside grass from regional authorities is to use it as reinforcement in biobased composites. This can in theory a) facilitate sustainable disposal of the roadside grass and b) offer an alternative construction material to replace or substitute tropical hardwood. Tropical hardwood has widespread use in many outdoor applications because of its mechanical properties and its durability under moist conditions.

Figure 9: Example of a "knuppelpad" (Jetty Board)

A lot of tropical hardwood is currently used in the Netherlands and Belgium, so much that tropical hardwood is becoming scarce and biodiversity is under pressure. With 760.000 m^3 of tropical hardwood use every year, the Netherlands are within the top 4 importers in the world, which is not something to be proud of. Next to the reasons mentioned above, the low price of tropical hardwood might be the biggest challenge to tackle and, therefore, material, product and production optimisation for a roadside grass based composite plank is key.

2.2 Requirements of the jetty board plank

When replacing a tropical hardwood jetty board plank, some requirements have to be fulfilled:

- Measures:

- The length per plank depends on the path to be installed and varies between 1m (standard) and 1.5m
- Width: 160 or 190 mm
- Thickness: 30 mm

- The strength and stiffness of the plank must be comparable to the current hardwood plank.
- The durability (lifespan) must be at least as good.
- Assembly: the boards are mounted on 2 underlying beams of at least 5 cm thick. These are on average 60 cm apart (span) and protrude 20 cm over the underlying beams on the side.
- Operations required: sawing, drilling, screwing
- The biobased board must also be strong enough when wet (similar to the properties of the hardwood plank)

Wishes

- Anti-slip: is not always done because the surface is more subject to wear / aging. From time to time, grooves of 10 mm wide and 2 mm deep are added and filled with a mixture of epoxy and sharp sand. However, this does result in microplastics production.

2.3 Mechanical properties

The basic property that must be achieved for the use of biocomposites instead of tropical hardwood will be the design of the jetty board plank. The mechanical properties in combination with the freedom of shape can result in an optimal design in which the amount of material is minimized.

Table 2: Mechanical properties of hardwood and chemically modified wood planks and new biocomposite board planks

Material[1]	Bending strength [MPa]	Bending stiffness [GPa]
Azobe	70	20
Heavy oak	20-95	10
Accoya	39	8.8
Roadside grass furan vs 1.0	44.9	5
Roadside grass polyester vs 1.1	45	10

Possible advantage is that biocomposite has only little shrinkage, while tropical hardwood (azobe) has a strong radial shrinkage of 4.8%.

2.4 Prototype

The technique we used for producing the prototype is the BMC (Bulk Moulding Compound) process. In this process, fibers, fillers and a resin are mixed to a dough, which then can be pressed into a mould into the wished form.

We used grass fibers as fibers, milled Japanese knotweed as a filler and a furan resin as a binder,

[1] https://www.houtdatabase.nl/?q=hout/gww/25

resulting in a 100% biobased composite material. As only a simple flat plate mould was available, several plates had to be used to build up the prototype.

In the next phase, a special mould will be developed.

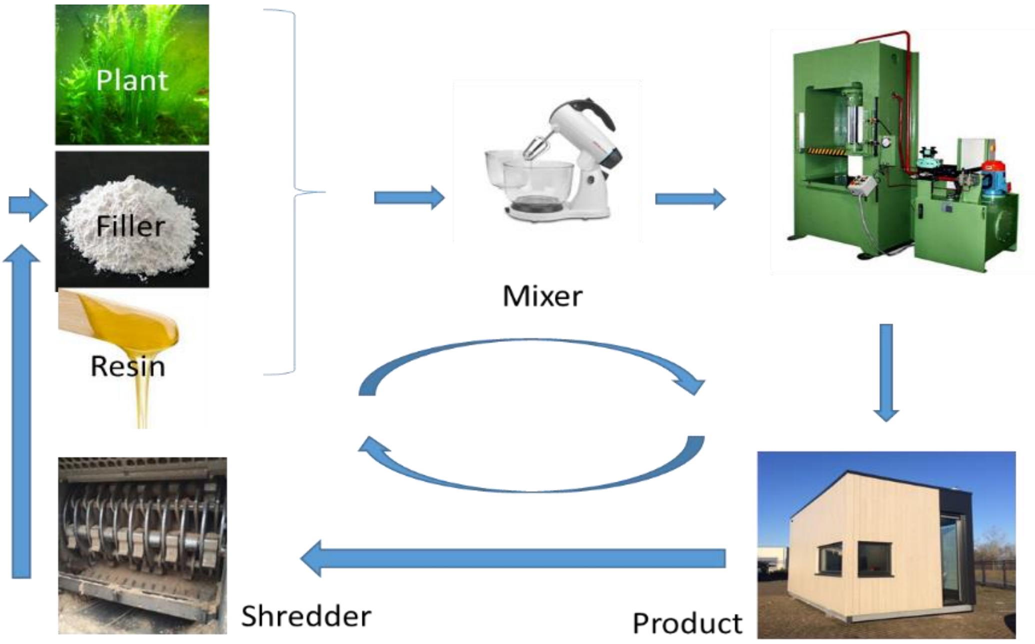

Figure 10: BMC production process and end of life possibility

Figure 11: Photo of the resulting prototype of a jetty board plank

3. Patio construction - HOGENT (PP6)

This chapter describes which steps have been undertaken to develop a demonstrator patio construction showcasing various integrated prototype grass clipping plates and beams.

3.1 Biocomposite materials development

PP6 has made and tested different grass-based composites (beams, blocks, fibreboards and non-woven mats) with different types and sources of grass clippings (dried fresh clippings, silaged clippings, flail mowed and circular mowed fresh clippings, anaerobically digested (AD) clippings) presenting various dimensions and particle size distributions, combined with different types of binders (biobased resins and mineral-based binders). Combinations of grass clippings with other natural fibres (hemp fibres and shives, hop stems) were also explored. On the non-woven prototypes, a finishing treatment (coatings, impregnations) was tested in order to enhance the strength properties. All the prototype grass composites are to be integrated in the demonstrator patio construction in grass-based beams, blocks, panels, cladding or roof elements.

3.1.1 Prototype biobased grass fiberboards

The main experimental steps and some characteristics of the obtained grass fibreboards are described in Annex 1. In the pressed panel experiments, biobased binders were applied manually (by pouring, spraying or coating) to layers of grass fibres and subjected to hot-pressing. Resin contents ranging from 0% up to 50% (dry mass base) were tested. A resin content of about 5-6% was typically required to achieve an appreciable bonding between fibres. The specific density of the obtained prototyped fibre composite panels varied between 0.333 and 1.268 g/cm^3. The basic density of the prototype panels increased with increasing resin content (see data table and figure in Annex 1). Density usually correlates positively also with mechanical strength; this can also be observed in a broad range of lightweight and high density commercial wood-based panel products (e.g. particleboard, MDF, HDF).

Figure 12: Grass clipping fibreboard prototypes made with varying amounts of biobased binder

Natural fibre-boards could be a (partial) substitute for wood-based panel products used in non-bearing applications (e.g. cladding, backing, space-filling); as an example, the Dutch company Vepa announced plans for construction of a grass fiberboard production plant for interior and furniture applications. Theoretically, about 1 ton of grass fibres could replace about 2 m^3 of wood particles or wood fibres in panel or pulp production. Like wood, grass and other lignocellulosics such as hemp sequester 40 to 55% of carbon (dry weight base), and these renewable resources and fibre panel materials can be considered as potential CO_2-sinks.However, the mechanical properties of grass fibres and lightweight grass fibreboards are expected to be of lower grade than those of wood fibres and wood based panels of comparable density.

3.1.2 Prototype mineral grass-fibre building blocks (“grasscrete”)

Combinations of different fractions of grass clippings, hemp shives and mineral binders (natural lime) were also tested by casting grass-lime mortar into pre-shaped forms and, furthermore, with a self-made modified syringe extruder. These prototypes are equivalent to “hempcrete” and could be labeled “*grasscrete*”, inspired by the hemp-lime building blocks and wall construction methods that are affordable and readily available on the market of eco-friendly building materials and techniques. Grass-lime-(hemp) mortars could potentially be introduced for casting into continuous wall construction applications, as prefabricated building blocks for wall insulation or in non-load bearing flooring applications (e.g. subfloor layers).

Figure 13: “Grass-crete” beam and block made of dried grass clippings and lime. The beam was renforced with “lianas” of hop stems. The block contained hemp shives also.

The wet natural fiber and lime mortar requires quite some time to dry and cure (spanning days or weeks), during which fungal growth and discolorations can be observed. HOGENT experimented with 0.15 x 0.15 x 0.15 m^3 grass-lime blocks (figure 13), and ca. 100-150 cm long beams, with and without reinforcement by integrating hop stems.

These lime-based biocomposite blocks and mineral bioproducts are also considered as promising sustainable building materials, that are capable of storing significant amounts of CO_2 for a longer time (carbon stored in lignocellulosic biomass + carbon stored in the limestone).

3.1.3 Prototype biobased permeable grasstile

The potential of using grass clippings in engineered geotextile products was a third type of prototype explored at the HOGENT FTILab+ (Fashion and Textile Innovations Lab). A medium-scale prototype of a biobased grass-composite roof or floor tile was designed as a series of tubular, netted fabric stuffed with grass clippings (strings or “sausage”), impregnated with a biobased resin and laid out in a layered configuration as depicted in figure 15 (top:

cross-sectional view before and after hot-pressing (150°C) - bottom: top- and lateral view of the resulting flattened tile prototype of approximately 70 cm x 25 cm x 2.5 cm).

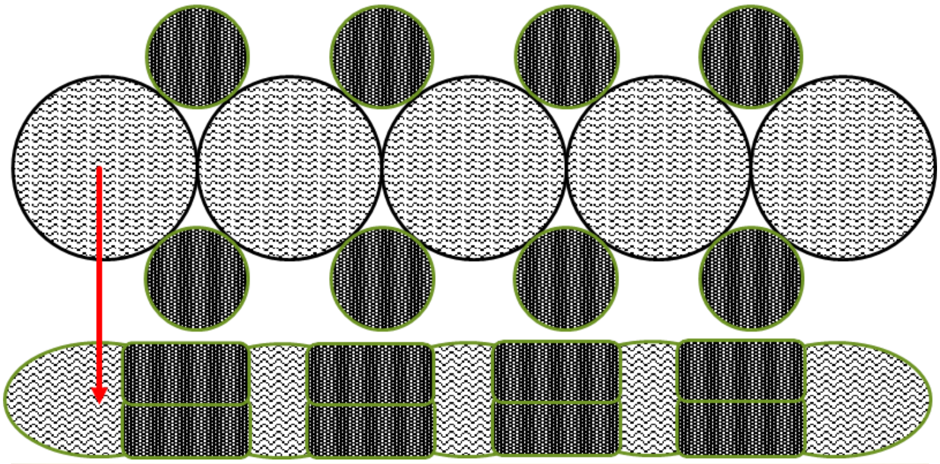

Figure 144: Prototype of grass-stuffed geotextile roof or floor tile (approximately 70 cm x 25 cm x 2.5 cm).

Several of these tiles would be needed to cover the roof or (intermediate) floor of the patio construction. However, the manual development and production of one such tile was time-consuming; the preparation of the strings could be done faster via automation.

Different layering designs could be implemented, offering flexibility and upscaling potential. The service-life of such tiles in outdoor applications (green roofing, temporary green flooring) is expected to be limited, but it could be enhanced by smart finishing applied to the tiles if necessary.

3.1.4 Prototypes of biobased non-woven grass mats (felt)

A last prototype development involved the design and manufacturing of a light, non-woven weed control or green roofing substrate or mat. To achieve this, the needle-punching technique was explored with the help of a leading industrial partner. Combinations of grass-clippings (longer fibre fractions, i.e. straw and hayish material) and hemp were tested on an industrial needle-punching line for which the process had to be tailored to our purpose. Pictures of the obtained non-woven fiber mats, with varying amounts of grass and hemp fibres (0%, 25%, 50% or 100%), are shown in figure 16. The needle-punching technique allowed producing continuous felt mats of approximately 60 cm wide (and unlimited length). Due to limited amounts of test fibres, HOGENT could obtain only short stretches of ca. 80-100 cm long for further analysis (strength, water absorption) and finishing/durability evaluation.

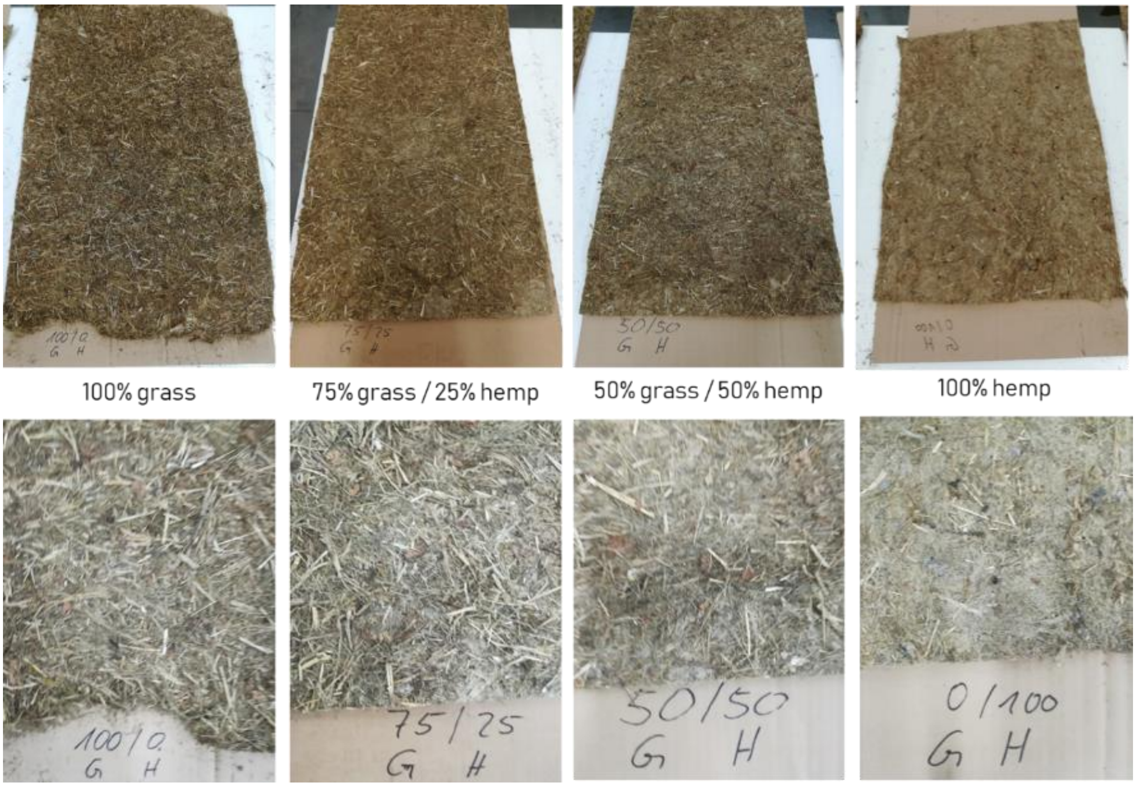

Figure 155: Needle-punched grass and hemp fibre mats of approximately 50 cm x 80 cm (above) and zoomed in (below) - left to right: 100% grass - 75% grass/25% hemp - 50% grass%50% hemp - 100% hemp.

The industrial test service provider proceeded manually for preparation steps prior to the needle punching trials. The dimensions of the grass clippings (mostly straw fraction) were not altered because of brittleness but the moisture content was increased by spraying with water ; hemp fiber length was reduced with a fibre-opener to 50-60 mm.

The specific density of these grass / hemp fiber non-wovens was assessed. It ranged from ca. 1200 to over 1400 g/m²:

- 100% grass fiber: 1249 g/m²
- 75% / 25% grass fiber / hemp fiber (L = 60 mm): 1208 g/m²
- 50% / 50% grass fiber / hemp fiber: 1195 g/m²
- 100% hemp fiber: 1403 g/m²

Two benchmarks were selected, commercially available ground cover materials made of flax and hemp:

- 100% flax non-woven felt (Fibrimat T300): 500 g/m²
- 100% hemp felt (ground cover): 645 g/m²

The commercial products were much lighter. The strength analysis of the six materials revealed that tensile strength decreased with increasing grass content; it was highest in the 100% hemp prototype. To improve compactness / cohesion after needle punching, six different finishing products and application methods were screened (a.o. natural latex, lignin-based resins and other biopolymers).

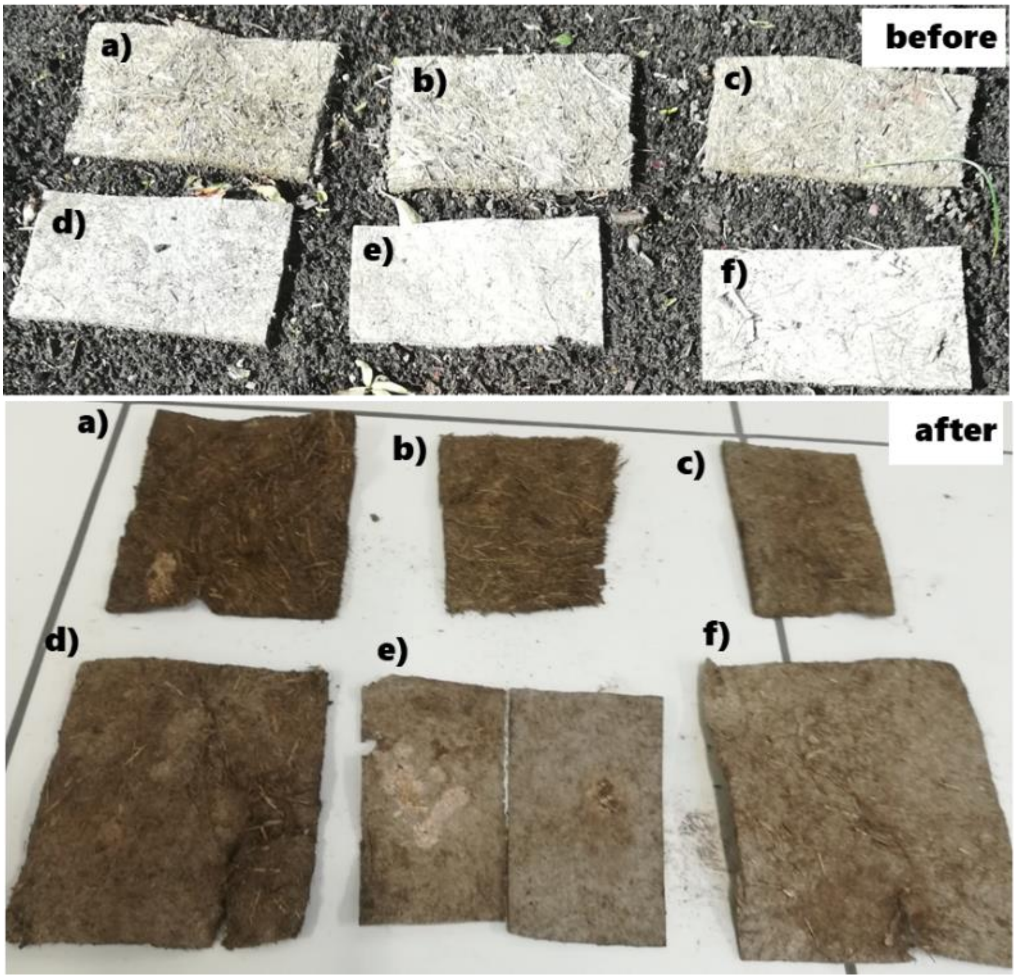

Figure 166: Results of needle-punched fibre mats (uncoated) exposed during three months to outside weathering, with ground contact (between 01.09.2020 and 30.11.2020) a) 100% grass; b) 75% grass/25% hemp; c) 50% grass/50% hemp; d) 100% hemp; e) 100% flax felt (commercial non-woven); f) 100% hemp felt (commercial non-woven). Note: before (above) and after (below) outside weathering and drying - image scales not comparable.

The natural latex applications appeared to provide significant strength improvements to the HOGENT prototype groundcovers. Comparative tensile strength measurements (as those listed in annex 3) were impossible due to earth contaminations introduced during the outdoor weathering. All 6 samples were equally easily shredded by hand after three months outdoor exposure on the ground (including the commercial, purchased alternatives). It is concluded that the prototype non-woven mats coated with natural latex coating maintained sufficient weed suppression or growth substrate functionality after three months of outdoor exposure, which would potentially allow for preferred crops to establish and grow before weeds take over.

3.2 Demonstrator design

An existing timber framework (assembled by HOGENT bachelor students in wood technology) was chosen as a base construction and adapted to become the 100% biobased support for showcasing the different grass biocomposites developed by HOGENT:

§3.2.1 cladding and wall elements: grass with biobased binder (pressed **plate materials**)

§3.2.2 **blocks** and vertical pillars (**beams**): grass with mineral or biobased binders.
§3.2.3 green roof module: permeable grass-**tiles** with biobased binders
§3.2.4 Non-woven grass-fiber **groundcover** with bio-binder and post-treatment (latex)

The original design (see CAD renderings shown in figure 17) has been downsized to allow for easy indoor and outdoor displacement. The following structural features can distinguished:

- The height is now approximately 200 cm, the inside width 80 cm and the depth 100 cm.
- The unit has been made mobile by placing it on 4 heavy duty wheels. It can also be transported by forklift (limited ground-clearance, total height should remain below 201 cm for indoor mobility)
- Roof structure with a slope of 4% (green roof specs)
- Grass/hemp-crete columns (200 x 15 x 15 cm)
- Two timberframe 'mosaic' side walls filled with grass-composite blocks (featuring sound-break, noise–absorption).
- A thinner long sidewall with more/larger plate materials embedded in commercial benchmark products.
- Internal platform (mid-height) and bottom floor: display of grass geotextile and permeable grass tile
- The unit will have limited resistance to outdoors exposure.

To be added:

- Two vertical columns added on the right side (grass-liquid binder trial, partially substituting slaked lime – *at best CO_2 neutral*).
- Block and plate materials with biobased finishing (coating)

The unit is to be showcased at the postponed Grassification demo event in 2021, in a co-created "Living Lab" setting (HOGENT Campus Schoonmeersen, around the T-Building) together with other eco-friendly demo-products (e.g. "insect hotel", "textile dome", ...).

Figure 177: HOGENT demo-unit integrating and showcasing the different biocomposite prototypes of building and landscaping products. CAD design drawings showing the positioning of the mineral beams blocks and biobased plate and sheething materials, and the demo-unit in construction (indoor).

3.3 Recommendations - grass composite market potential

The realized and partly tested prototype products (e.g. groundcover non-wovens in a basic outdoor field-trial) can be categorized as TRL4 or TRL5 products, i.e. they are at the transition between small scale and large scale prototypes. The next steps are further upscaling, validation and testing in close to expected performance in real environments.

With the construction and landscaping products demonstrator (the patio construction showcasing different prototype products), a first step can be set towards TRL 6-7, and enhanced visibility may inspire market participants to lift the products to the commercial level (TRL 8-9). There are however still a number of hurdles to be taken for upscaling and automating some of the preprocessing steps that will allow for a continuous production of biocomposites. The fibre quality should be consistent and reliable.

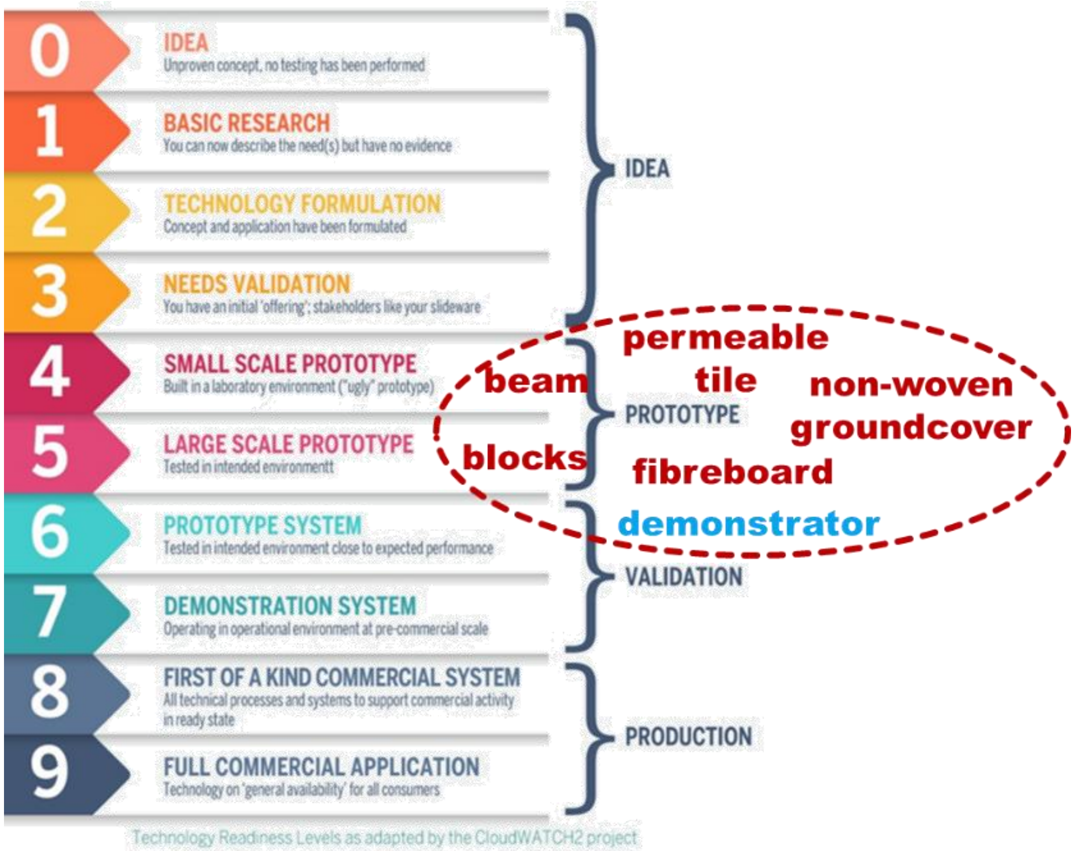

Figure 188: Tentative positioning of the HOGENT biobased prototype products and the demonstration unit, relative to Technology Readiness Levels (TRL) - source: cloudwatchhub.eu

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