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AMBIANCE - Biobased products for outdoor use: durability against external agents

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This CEN Workshop Agreement (CWA 18367:2026) has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid way to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop CEN "AMBIANCE" Advanced Manufacturing of Biobased products for urban outdoor applications through iNnovative CharactErisation, digital technologies, and circular approach", the secretariat of which is held by "UNI" consisting of representatives of interested parties on 2025-06-24, the constitution of which was supported by CEN following the public call for participation made on 2025-05-19. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

The whole society is on a critical path of transition to a circular economy. New innovations are needed to facilitate this transition, such as using a broader range of renewable raw materials as well as developing resource- and cost-efficient production methods to substitute fossil-fuel based products. As the adoption of biomaterials is still low, much technical effort must be put in product and process development, to design and produce the most suitable bio-based material for each application.

AMBIANCE is an ambitious initiative dedicated to the development of innovative bio-based products designed for urban outdoor applications. The project leverages cutting-edge characterization techniques, advanced digital technologies, and a circularity-by-design approach to create sustainable solutions that align with modern environmental and societal needs. By integrating these elements, AMBIANCE aims to set new benchmarks for the durability, functionality, and mechanical properties of outdoor materials, such that they become a valid substitute of traditional, fossil fuel-based, products.

The overarching goal of AMBIANCE is to minimize the environmental footprint of urban infrastructure and promote the widespread adoption of sustainable and recyclable products across European cities. To achieve this, the project emphasizes the transition to greener manufacturing models by optimizing production processes, enhancing resource efficiency, and ensuring that developed solutions can be scaled and replicated across different regions and industries. This holistic approach not only supports the European Green Deal’s sustainability objectives but also fosters innovation and competitiveness within the bio-based sector.

AMBIANCE concentrates its efforts on three key manufacturing value chains, each representing significant areas of urban outdoor application:

1. Sports Facilities – The project is developing bio-based and bio-degradable high-quality artificial turf suitable for sports infrastructure such as running tracks, playgrounds, and sports courts. The product will be a sustainable alternative to traditional fossil-fuel based thermoplastics products, which have high environmental impact and low degradability and recyclability.

2. Outdoor Furniture – AMBIANCE aims to create high-quality, weather-resistant, and aesthetically appealing bio-based materials made through large-scale additive manufacturing processes for benches, tables, and other pieces, enabling the possibility of rapid fabrication of highly customised and sustainable furniture for public urban spaces.

3. Construction Bricks and Decorative Panels – By integrating sound insulating, decorative, moisture resistant, bio-based wall panels into buildings such as shelters or storage rooms for toys or bikes in the park or the town square, the project will enhance the sustainability and resilience of architectural elements used in urban environments, promoting eco-friendly construction practices.

Through these targeted efforts, AMBIANCE seeks to transform urban outdoor applications by demonstrating the viability and benefits of bio-based solutions, ultimately fostering a more sustainable and circular economy in European cities.

1 Scope

This document aims to provide comprehensive information regarding the key characteristics of biobased products intended for recreational outdoor applications, with particular attention to synthetic turf, urban furniture and construction materials. This agreement focuses on evaluating their performance in terms of durability when exposed to various external environmental factors and assesses their resistance to degradation. In particular, the aim is evaluating the resistance of biobased products for recreational outdoor applications against physical wear and tear caused by external forces, and against man-made vandalism, such as graffiti.

By addressing these factors, this document aims to support the development and selection of high-quality biobased products that offer enhanced sustainability, reliability, and longevity in outdoor environments.

This document does not apply to safety requirements for outdoor use of biobased products, and it also does not apply to synthetic turf surfaces for sport applications that are covered by CEN/TC 217, and to wood products that are covered by CEN/TC 112.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 14836:2018, *Surfaces for sports areas — Synthetic surfaces for outdoor sports areas — Test method for artificial weathering*

EN 13672, *Surfaces for sports areas — Determination of resistance to abrasion of non-filled synthetic turf*

EN 13744, *Surfaces for sports areas — Procedure for accelerated ageing by immersion in hot water*

EN 20105-A02, *Textiles — Tests for colour fastness — Part A02: Grey scale for assessing change in colour*

EN ISO 4892-1:2024, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance and requirements*

EN ISO 4892-3:2024, *Plastics — Methods of exposure to laboratory light sources — Part 3: Fluorescent UV lamps*

EN ISO 13864, *Surfaces for sports areas — Determination of tensile strength of synthetic yarns*

ISO 178, *Plastics — Determination of flexural properties*

ISO 4919, *Carpets — Determination of tuft withdrawal force*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp/
- IEC Electropedia: available at http://www.electropedia.org/

3.1
recreational surface
materials used to create areas for various leisure activities (excluding sport applications)

3.2
landscaping
all the visible features of an area of land, often considered in terms of their aesthetic appeal such as public and private gardens, parks, road vegetation including lawns and turfed recreational areas

3.3
bio-based
wholly or partly derived from biomass (3.4)

[SOURCE: ISO 8217:2024, 3.5]

3.4
biomass
material of biological origin excluding material embedded in geological formations and/or fossilized

[SOURCE: ISO 16559:2022, 4.32]

3.5
in-field weathering
outdoor weather conditions including temperature, humidity, UV

3.6
durability
capability of a structure or any component to satisfy, with planned maintenance, the design performance requirements over a specified period of time under the influence of the environmental actions, or as a result of a self-ageing process

[SOURCE: ISO13823:2008]

4 Materials, durability requirements, methodology and characterization

4.1 Materials

4.1.1 General

The materials considered in this CWA are exclusively bio-based products developed within the AMBIANCE project, intended for outdoor recreational applications. These include:

- Synthethic turf filaments composed of bio-based thermoplastics for recreational field/areas;
- Outdoor furniture manufactured by large-scale additive manufacturing using bio-based polymeric feedstocks;
- Construction bricks and decorative panels, produced with bio-based composites designed for enhanced fire and moisture resistance.

4.1.2 Synthethic turf

The filament is produced from bio-based plastics derived from renewable feedstocks, selected for its high mechanical strength, flexibility, UV resistance, and extrusion processability comparable to conventional fossil-based polyethylene. Special attention is given to optimizing the thermal behaviour of the polymer to ensure stable melt flow during filament extrusion and consistent dimensional stability during cooling and tufting operations.

To ensure sustainability and traceability, the bio-based polymer complies with internationally recognized certification schemes [1], guaranteeing that the renewable feedstocks are verifiably sustainable and that the final product is certified by independent third-party audits. In addition, the design considers recyclability at end-of-life by enabling separation and mechanical reprocessing of the filament material without loss of key mechanical properties. The filament shall meet requirements such as tensile strength, colour fastness, and resistance to ageing, ensuring equivalent performance and service life to conventional petroleum-based alternatives while significantly reducing environmental impact throughout the product's life cycle.

4.1.3 Outdoor furniture

Biopolymers used in this context must balance processability, mechanical performance, and long-term durability under outdoor conditions. Urban furniture components are typically exposed to mechanical loads, temperature fluctuations, UV radiation, and moisture; therefore, the material must exhibit sufficient structural integrity, dimensional stability, and resistance to environmental ageing.

Blending different grades of a biopolymer, such as combining predominantly amorphous and semicrystalline phases, can be an effective strategy to optimise performance. Amorphous fractions generally improve processability, interlayer adhesion, and dimensional accuracy by reducing internal stresses during cooling. Semicrystalline fractions, in contrast, contribute to enhanced thermal resistance, stiffness, and durability in outdoor environments.

In addition, the incorporation of reinforcement agents such as natural or mineral fibres can further enhance mechanical strength, reduce shrinkage and warping, and improve long-term stability. These reinforcements are particularly relevant in large format printing, where thermal gradients and material deposition rates can otherwise lead to residual stresses and deformation.

4.1.4 Decorative panel and bricks

To create 100% bio-based self-bonded composite panels without synthetic adhesives, underutilised agricultural side streams are used, in particular barley straw and reed canary grass. This approach aims to enhance sustainability, reduce environmental impact, and improve recyclability.

Barley straw and reed canary grass are chosen for their local availability in Sweden and favourable fibre properties. Reed canary grass, a high-yield perennial, thrives in boreal climates and contains high levels of cellulose and silica, with lower hemicellulose and ash content compared to wheat straw. These characteristics make it particularly suitable for structural applications. Barley straw, commonly used for animal bedding and fertilizer, also offers valuable fibre content.

The panels are tested [2] for mechanical strength, moisture absorption, and recyclability. The results demonstrate the feasibility of producing high-performance decorative panels from agricultural residues, supporting a circular value chain and promoting sustainable construction practices.

4.2 Durability requirements

4.2.1 General

Bio-based products for outdoor recreational applications shall demonstrate:

- Resistance to environmental ageing, including solar radiation, temperature fluctuations, and moisture;

- Mechanical stability, ensuring maintenance of tensile, flexural, and impact strength after ageing;

- Surface integrity, withstanding abrasion, graffiti cleaning, and other forms of man-made wear and tear;
- Aesthetic stability, maintaining colour, gloss, and texture over prolonged exposure;
- Biological durability.

These requirements are intended to ensure that bio-based materials perform at least equivalently to conventional fossil-based alternatives in outdoor conditions.

4.2.2 Synthethic turf

4.2.2.1 Tensile strength of the fibres that constitute the pile of synthetic grass

When tested in accordance with EN 13864, the minimum tensile strength of the yarns used to form the pile of the synthetic turf shall be greater than 30 N for fibrillated yarns and 8 N for monofilament yarns. Monofilament yarns shall be tested as individual ribbons.

4.2.2.2 Resistance to artificial ageing of the fibres that constitute the pile of synthetic grass

4.2.2.2.1 Tensile strength

When tested in accordance with EN 13864, following artificial weathering in accordance with EN 14836 Method 1, the tensile strength of the pile yarn(s) used to form the synthetic turf pile shall be within 50% of the tensile strength of the unaged pile yarn and no lower than the minimum values detailed in 4.2.2.1.

4.2.2.2.2 Colour fastness

When tested in accordance with EN 20105-A02, following artificial weathering in accordance with EN 14836, the colour fastness of the weathered synthetic turf, compared with an unaged test specimen of the synthetic turf sample, shall be grey scale 3 or greater.

4.2.2.3 Bonding of the synthetic grass tuft

When tested in accordance with ISO 4919, the tuft withdrawal force shall be ≥ to 30 N.

Following immersion in hot water, in accordance with EN 13744, the tuft withdrawal force shall be at least 75% of the tuft withdrawal force of the unaged test specimen and ≥ 30 N.

4.2.2.4 Abrasion resistance of non-filled short pile synthetic turf surfaces

When tested in accordance with EN 13672, the percentage mass loss after 2 000 cycles shall be ≤ 2%.

4.2.3 Outdoor furniture

4.2.3.1 General

A service life of two years has been defined as the durability target for the outdoor furniture. At the end of this period, the material is expected to remain reprocessable while exhibiting only a marginal decline in mechanical performance. Preserving reprocessability is considered a critical factor in maintaining both the economic and environmental competitiveness of the material.

Within this framework, durability requirements are defined in the following subclauses.

4.2.3.2 Resistance to environmental ageing

The bio-based plastic shall demonstrate adequate resistance to solar radiation (UV exposure), temperature variations, and moisture. Ageing behaviour will be evaluated through accelerated climatic chamber tests. In parallel, real outdoor exposure tests are being conducted under representative service conditions. These real-exposure trials aim to validate and correlate the observations obtained from the climatic chamber, ensuring the relevance and reliability of the accelerated ageing methodology. After ageing, the material shall not exhibit excessive embrittlement, cracking, delamination, or loss of structural cohesion that would compromise functionality or safety.

4.2.3.3 Mechanical stability after ageing

The material shall maintain sufficient flexural strength to ensure structural integrity throughout the service life. Any reduction in mechanical properties after ageing shall remain within acceptable limits.

4.2.3.4 Rheological stability after ageing

Rheological characterization shall be used to assess changes in the material following environmental exposure. The material shall be tested to evaluate variations in viscoelastic properties, including storage and loss moduli as well as complex viscosity. Changes in these parameters shall remain within acceptable limits to ensure continued processability and compatibility with LSAM (Large Scale Additive Manufacturing) and reprocessing routes.

4.2.3.5 Aesthetic stability

Minor aesthetic changes are acceptable, provided they do not negatively impact user perception or functional performance.

After the two-year service period, LSAM-manufactured components shall be reprocessed without significant degradation of their mechanical or processing performance. Reprocessing may include the controlled addition of virgin bio-based material to restore or enhance properties for reuse in equivalent applications. Alternatively, the material may be directly reused in less demanding or secondary applications, thereby extending its overall life cycle and maximizing resource efficiency.

4.2.4 Decorative panel and bricks

For bio-based materials resistance to moisture absorption and soil contact represents a significant challenge, particularly in outdoor applications. To determine the water absorption capacity of self-bonded composite panels manufactured from processed agricultural resources~~,~~ the specimens (plates and/or bricks) shall be exposed to an environment with a relative humidity close to 100 % for a prolonged period.

For this purpose, the products shall be placed on a grid positioned above a water surface inside a sealed container, for a maximum duration of 350 hours. At regular time intervals, the mass and dimensions of the specimens shall be measured in order to monitor their variation as a function of exposure time.

To enhance the moisture resistance of the panels, a protective coating shall be applied. A linseed oil–based coating, commonly used in the boatbuilding industry, is employed as a bio-based protective solution.

To verify its effectiveness, the coated panels shall be subjected to outdoor exposure and visually inspected to assess structural integrity. Thickness measurements shall be performed at fixed intervals to confirm the absence of swelling or other dimensional instabilities.

4.3 Durability testing methodology

4.3.1 Self-bonded agro-fibre decorative panels

4.3.1.1 General

The purpose of this methodology is to assess the durability of decorative panels manufactured from underutilised agricultural resources (i.e. barley straw after harvesting and reed canary grass) consolidated by compression moulding without added synthetic resin adhesive or binder, intended for outdoor decorative use.

The methodology addresses the main degradation agents relevant for outdoor service: moisture and hygrothermal cycling, UV/weathering, temperature cycling (including freezing), surface integrity and cleanability, and resulting changes in dimensions, mass, appearance, and mechanical performance.

Unless otherwise stated, tests shall be performed on uncoated and coated panels (where a bio-based protective coating, e.g. linseed oil–based, is applied).

4.3.1.2 Test specimens and conditioning

Specimens shall be conditioned at (20 ± 2) °C and (19 ± 3) % RH.

The following minimum set of specimen geometries shall be prepared (or equivalent dimensions suitable for the available test equipment):

- Moisture uptake / dimensional stability: ≥ 5 specimens, nominally (50 × 50) mm (or similar), full panel thickness;

- Mechanical property retention: ≥ 5 specimens for bending; specimen width shall be (20 ± 1) mm and thickness (2,5 ± 1) mm, span shall be 16 times of thickness.

4.3.1.3 Moisture uptake at ~100 % RH (screening of moisture sensitivity)

This screening test evaluates moisture uptake and dimensional stability under near-saturation humidity (without direct water immersion).

Then proceed as follows:

a) Specimens shall be placed on a grid above a water surface inside a sealed container to generate a relative humidity close to 100 % (no direct contact with liquid water).

b) Exposure duration shall be up to 350 h.

c) At defined intervals (e.g. 1 h, 4 h, 24 h, then every 24 h), specimens shall be removed briefly, wiped free of visible surface condensate (without pressing), and mass and thickness shall be measured.

d) The following shall be reported:

   1) mass change (%) vs. time;

   2) thickness change (%) vs. time;

   3) observations (edge swelling, warping, surface changes, odour, microbial growth).

4.3.1.4 In-field weathering and coating performance

In-field weathering shall be used to assess panel integrity and to screen coating effectiveness (e.g. colour, cracking, erosion).

Exposure duration shall be measured to represent the intended service (e.g. intermediate and final checkpoints at a maximum of 3 months).

At each checkpoint, the following shall be assessed and reported:

- visual inspection (cracking, chalking, fibre raise, erosion, delamination, blistering);

- moisture content measured with terahertz (THz) or sub-terahertz (Thz);

- colour and gloss change, where equipment is available (instrumental preferred; otherwise, photographic documentation under controlled lighting);

- thickness/warpage changes;
- coating integrity and any local defects (edges, cut faces, fastener zones if applicable).

4.3.1.5 Surface integrity and cleanability (including graffiti removal) — optional screening

Where decorative panels are exposed to public-access areas, an indicative cleanability/graffiti-resistance screening may be performed on the panel surface (coated and uncoated):

a) Apply representative "graffiti" agents (e.g. permanent marker, acrylic spray paint) to defined areas; allow to cure/dry (e.g. 24 h).

b) Remove markings using a defined sequence of cleaning agents (e.g. water with mild detergent; ethanol; a biodegradable graffiti remover compatible with bio-based coatings), with controlled wiping cycles and pressure.

c) Rate: residual staining, surface damage, gloss/colour change, and coating loss after cleaning.

NOTE A structured approach and rating system for coating graffiti resistance is described in ASTM D6578 and can be adapted for this purpose.

4.3.1.6 Mechanical property retention after in-field weathering and reporting (optional)

Mechanical testing should be performed on unaged reference specimens and on specimens after in-field weathering (4.3.1.4).

The test report should include at least:

- panel formulation (fibre type, processing conditions, density/thickness range), and coating type/application (if used);
- specimen dimensions, conditioning history, number of replicates;
- exposure weather conditions;
- measured changes in mass, thickness, warpage, and appearance;
- mechanical results (mean, standard deviation) and retention vs. unaged reference (%).

4.3.2 Outdoor furniture

4.3.2.1 General

Durability tests are designed to evaluate the resistance of bio-based products to external environmental agents. The following approaches are adopted.

4.3.2.2 Accelerated ageing under controlled laboratory conditions, including UV exposure, temperature cycles, and humidity stress

For outdoor furniture applications, accelerated weathering tests shall be performed on representative 3D-printed specimens of the selected materials in order to evaluate their resistance to environmental ageing. Testing shall be conducted using a controlled UV-weathering apparatus in accordance with internationally recognized standards for accelerated exposure of plastics, such as ASTM D4329 or equivalent.

The exposure cycle shall simulate outdoor conditions through alternating periods of ultraviolet (UV) radiation and moisture condensation. A representative cycle may consist of UV irradiation at controlled irradiance and temperature, followed by a condensation phase at controlled temperature, repeated continuously without interruption. UV-A lamps with emission centred around 340 nm are commonly used to reproduce the most critical portion of the solar UV spectrum responsible for polymer degradation. Irradiance levels and chamber temperatures shall be defined according to the selected standard and intended severity level.

Specimens shall be exposed for predefined durations (e.g. 500 h, 1 000 h and 2 000 h), allowing evaluation of the evolution of mechanical, physical, and aesthetic properties over time.

To establish equivalence between accelerated testing and natural outdoor exposure, the relationship between radiant exposure and time shall be considered. Radiant exposure is defined as irradiance integrated over time:

$$\text{Radiant exposure (J/m}^2\text{)} = \text{irradiance (W/m}^2\text{)} \times \text{time (s)}$$

For practical purposes in accelerated testing:

$$\text{kJ/m}^2 = \text{irradiance (W/m}^2\text{)} \times 3{,}6 \times \text{exposure time (h)}$$

The expected annual UV radiant exposure for the intended installation region shall be determined using reliable meteorological data.

This approach allows the accelerated ageing protocol to be adapted to different climatic regions in a consistent and reproducible manner, ensuring that 3D-printed biopolymer components for urban furniture meet durability requirements regardless of their installation location.

4.3.2.3 Outdoor exposure tests, assessment of weathering resistance, color stability, and surface degradation after prolonged outdoor use

Natural outdoor exposure testing shall be conducted in parallel with accelerated weathering tests to evaluate the performance of 3D-printed materials under real environmental service conditions. The purpose of this testing is to complement laboratory-based accelerated ageing results and to verify the correlation between artificial weathering and actual outdoor performance.

Test specimens shall be representative of the final printed component and shall preferably feature simple, standardized geometries to ensure reproducibility and comparability of results. The specimens shall be manufactured using the same materials, processing parameters, and layer configurations intended for the final application.

The exposure site shall be selected to represent the climatic conditions relevant to the intended service environment. Environmental parameters to be considered include, but are not limited to, annual and seasonal temperature ranges, relative humidity, precipitation, solar and UV radiation levels, and other relevant environmental stressors such as wind, airborne pollutants, or salt exposure, where applicable.

Specimens shall be exposed outdoors without artificial protection unless otherwise specified in the test protocol. The exposure duration shall be sufficient to capture seasonal variability and cumulative degradation effects and shall typically extend over a minimum period of one year.

At defined inspection intervals, specimens shall be visually examined and, where required, removed for characterization. Post-exposure evaluation shall include assessment of relevant mechanical, physical, rheological, and aesthetic properties, as defined by the performance requirements of the application.

The results obtained from natural exposure testing shall be used to validate and, where applicable, calibrate the degradation trends observed in accelerated weathering tests. The combined analysis of artificial and natural ageing data shall form the basis for durability assessment and service-life estimation of 3D-printed biopolymer components intended for outdoor applications, including urban furniture.

4.3.3 Synthethic turf - Test method for artificial weathering

4.3.3.1 General

Specimens are exposed to ultraviolet (UV) radiation under controlled environmental conditions. Two exposure periods are specified. Method 1 is for assessing products intended for installation in environments where high levels of UV exposure are unlikely. Method 2 is for assessing products intended for installation in environments where high levels of UV exposure might be expected, in accordance with EN 14836:2018.

4.3.3.2 Apparatus

4.3.3.2.1 Artificial weathering cabinet using fluorescent UV lamps and environmental controls having the following features:

a) UVA-340 nm lamps (Type 1A) with a spectrum in accordance with EN ISO 4892-3:2024 and capable of uniformly applying radiation to the test specimen at an irradiance of 0,80 W/m2/nm at 340 nm.

b) Exposure chamber, constructed from inert material and that provides uniform irradiance in accordance with item a), and that includes a means of controlling and measuring the relevant parameters.

c) Condensation wetting mechanism, to wet the exposed face of the specimen, in accordance with EN ISO 4892-3:2024, 4.5.2. The water vapor shall be generated by heating water in a container located beneath and extending across the whole area occupied by the test pieces. Test specimen holders (filled with specimens or blanking panels) shall constitute the sidewall of the exposure chamber, so that the backs of the holders are exposed to the cooling effect of the ambient room temperature.

d) Calibrated radiometer, in accordance with to EN ISO 4892-1:2024, placed alongside the test specimens with the measuring sensor aligned to the same orientation as the test specimens so that it monitors the irradiance and radiant exposure experienced by the test specimens. If test specimens are mounted on the walls of the test chamber and also placed on the base of the chamber two radiometers shall be used.

e) Calibrated black-panel thermometer, in accordance with to EN ISO 4892-1:2024.

f) Specimen holders, made from inert materials that will not affect the results of the exposure.

4.3.3.2.2 Exposure conditions

The exposure cycle shall comprise (240 ± 4) min of dry UV exposure at a black-panel temperature of (55 ± 3) °C, followed by (120 ± 2) min of condensation exposure, without radiation, at a black-panel temperature of (45 ± 3) °C.

4.3.3.2.3 Specimens

Specimens shall be of the size specified by the test methods for the properties to be measured after exposure, as detailed in the relevant product specification.

If a synthetic turf yarn is produced in several different thicknesses (e.g. 100 µm, 150 µm, 300 µm, etc.) but is manufactured from the same polymer and has the same cross-sectional shape, only the thinnest version of the yarn shall be tested. To validate yarns are from the same family the characteristics of the yarn should be identified using:

a) Differential Scanning Calorimetry in accordance with EN ISO 11357-3. The main points of reference being obtained from the second heating of the polymer sample and comprising the peak temperature, peak area and overall curve shape, all of which should be similar (peak temperature ± 3 °C);

b) Fourier Transform Infrared Spectroscopy (FTIR) in accordance with ASTM E1252-98. The main points of reference to be used when comparing products shall be the peak locations and peak heights;

c) Thickness – measured using the procedure described in EN 14836:2018, Annex A;

d) Shape – recorded photographically; and

e) Colour – assessed using standard colour charts such as RAL Design (www.ral-farben.de).

Fluorescent UV lamps use the emission from a low-pressure mercury arc to excite a phosphor that produces a continuous spectrum in a relatively narrow wavelength interval, which is generally distributed around a peak wavelength. The spectral distribution of the radiation from a fluorescent lamp is determined by the emission spectrum of the phosphor and the UV transmission properties of the glass tube. Fluorescent UV lamps are generally used to expose material to UV radiation in a limited spectral range. The use of alternative artificial weathering procedures, such as those specified in EN ISO 4892-2, might be used when developing products.

4.3.3.3 Mounting of test specimens' procedure

Wrap, without strain, a specimen of the yarn around the specimen holders so that the exposed strands do not overlap and mount in the test cabinet with the test surface facing the lamps. Fill any spaces, using blank panels, to ensure uniform exposure conditions.

Take a single fibre and without applying any lengthways tension, carefully place across the width of the test holder with its extreme ends overlapping onto the adhesive surface of the double-sided tape. Press the fibre ends down onto the adhesive. Leaving gaps between individual fibres to prevent any fibre overlap, mount subsequent fibres in the same manner until a maximum 150 fibres have been mounted. When each holder is full, replace the cover strip of the double-sided tape back into position, to avoid the exposed adhesive sticking to other items or apparatus.

4.3.3.4 Exposure period

Expose the specimen, measuring the irradiance and radiant exposure at the surface of the specimen. After an exposure of (4 896 ± 125) kJ/m^2/nm at 340 nm, carefully remove the specimen from the exposure cabinet and test as required by the product specification.

NOTE An exposure of (4 896 ± 125) kJ/m^2/nm will require approximately 1 700 h UV exposure and takes approximately 2 550 h with cycling to complete.

4.4 Characterization after durability testing

4.4.1 General

To assess the impact of durability tests on material performance, a comprehensive characterization protocol is implemented:

- Visual inspection for surface degradation (cracking, discoloration, graffiti cleaning response);
- Mechanical characterization (tensile, flexural, and impact properties) before and after ageing;
- Microscopic and spectroscopic analyses (SEM, FTIR) to detect changes in surface morphology and chemical structure.

The combination of these methods provides a robust evaluation of the resistance of bio-based materials to external stressors, ensuring that their performance can be benchmarked against conventional fossil-based alternatives.

4.4.2 Urban furniture

4.4.2.1 General

To assess the impact of durability of both artificial and real exposure tests on material performance a comprehensive characterization protocol is implemented.

4.4.2.2 Visual and aesthetic assessment

The visual appearance of the materials after ageing is evaluated through photographs taken at different exposure times. Slight colour variations (whitening or yellowing) are expected and considered acceptable. These changes are attributed to the formation of degradation by-products, including low-molecular-weight compounds and chromophore groups, or to alterations in the crystalline structure, which may affect light absorption and scattering properties. However, samples exhibiting deformation or drastic colour changes are to be discarded. As well, samples showing clear signs of delamination, cracking etc are to be discarded.

4.4.2.3 Mechanical properties

Changes in the chemical and morphological structure of polymers can lead to the deterioration of their mechanical properties. The three-point bending test is a well-established method for evaluating the flexural performance of materials manufactured using 3D printing technologies. Flexural testing is performed using a three-point bending configuration in accordance with ISO 178. The support span is set to 80 mm, and the radii of the two supports and the central loading nose are 10 mm. The crosshead speed is maintained at 2 mm/min. For each condition, at least five specimens are tested, and the reported results represent the average values. The target performance criterion is a reduction in flexural strength of less than 20% after ageing, with absolute values remaining above 90 kg/cm^2. This threshold is consistent with the load-bearing requirements defined in ASTM F1561 and ASTM F2467, which apply to outdoor plastic chairs and urban park benches. It should be noted, however, that these standards refer to finished products, whereas the present evaluation is conducted on printed test panels.

4.4.2.4 Rheology analysis

Rheological characterization is performed to evaluate the impact of environmental ageing on the processability of the bio-based polymer. Measurements are carried out on aged and unaged materials to determine changes in key rheological parameters, including complex viscosity, which is a sensitive indicator of polymer degradation. The material is considered to pass the ageing tests if the rheological properties remain within defined acceptable limits, ensuring continued compatibility with processing and reprocessing operations, this ensures that melt flow behaviour remains stable.

Rheological stability, in combination with retained mechanical performance, is therefore used as a key indicator of the material's durability and suitability for circular use after service life.

Annex A
(informative)

Results of accelerated ageing and mechanical testing of artificial turf yarns

A.1 Scope

This Annex presents the results obtained within the project concerning:

- accelerated ageing of artificial turf yarns in a climatic chamber;
- mechanical testing of yarn before and after exposure.

This Annex does not establish product requirements.

A.2 Test Specimens

Artificial turf yarns representative of the project materials are tested:

- in the unaged condition;
- after accelerated climatic exposure.

Specimen preparation and conditioning prior to testing are carried out in accordance with EN 14836.

A.3 Test Specimens

A.3.1 General

Accelerated ageing is conducted in a climatic chamber in accordance with:

- EN ISO 4892-2 or EN ISO 4892-3 (UV exposure), as applicable;
- EN 14836 (thermal ageing).

A.3.2 Exposure conditions

Exposure included controlled cycles of:

- temperature;
- relative humidity;
- ultraviolet radiation.

The ageing programme simulated long-term outdoor exposure conditions in accordance with EN 14836. The total exposure duration and irradiance levels are defined in the test protocol.

A.4 Mechanical Testing

A.4.1 Tensile properties of yarns

Mechanical properties are determined before and after ageing exposure.

Testing is performed under standard laboratory conditions in accordance with EN ISO 13864.

The following parameters are recorded:

- maximum tensile force (N);
- elongation at break (%);
- breaking tenacity.

Mean values and standard deviations are calculated.

A.5 Results

A.5.1 Tensile strength retention

Tensile strength retention after ageing is calculated as:

Retention (%) = (Value after ageing / Initial value) × 100

Results are expressed as percentage retention relative to unaged specimens.

A.5.2 Elongation at break

Changes in elongation at break are determined in accordance with EN ISO 13864.

Variations are analysed to identify potential embrittlement or loss of ductility due to climatic exposure.

A.5.3 Observed degradation effects

Visual inspection of specimens after ageing is performed according to EN 20105-A02.

Where applicable, the following are recorded:

- colour change;
- surface cracking;

A.6 Interpretation of results

The comparison between mechanical properties before and after accelerated ageing allows assessment of:

- resistance to UV radiation;
- resistance to thermal degradation;
- retention of mechanical integrity under simulated environmental exposure.

Results are limited to the specific materials and exposure protocol defined in AMBIANCE project.

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