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Advancing Timber for the Future Built Environment

DURABILITY: MEMBRANES AND TAPES FOR WOOD PROTECTION

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ABSTRACT: Protecting wood in timber construction is crucial to ensuring long-term durability and structural integrity. To address this challenge, vapour control and breathable membranes are essential to regulate vapour passage and prevent air infiltration. If protection is not properly implemented or the material cannot withstand normal ageing associated with a modern building's life, issues such as mould formation or wood rot due to air and moisture penetration at critical points can arise. Therefore, these materials must protect wood during the construction phase and ensure long-term resistance during the life of the building.

In recent years, Rothoblaas has participated in various projects focused on analysing the durability of building materials, particularly waterproof membranes and adhesive tapes. The main objective was to evaluate both material quality and the effectiveness of their applications within an integrated system, through both laboratory ageing tests according to different norms and real exposure in the outside environment. Exposing materials to various combinations of degradation sources has allowed us to identify those with the greatest impact on product resistance and understand the best techniques to ensure products start their useful life in the best conditions. Results showed that the main degradation source comes from the exposition to UV light, that is capable of altering the chemical structure of the polymer much more compared to high or low temperatures or the presence of extraordinary levels of humidity. However, the tests confirmed that the selected tapes and membranes maintain their adhesion properties and mechanical resistance over time, with some variations depending on their specific composition. Reinforced tapes, for example, exhibit a loss in elongation at break after ageing, whereas non-reinforced tapes maintain more stable deformability. These insights allow us to refine our selection of materials and improve their application in construction, ensuring long-term reliability.

KEYWORDS: durability, UV ageing, thermal ageing, tests, membranes

1 – INTRODUCTION

The degradation processes affecting the polymeric materials used in membranes and tapes for wood protection are diverse and can significantly impact product integrity and functionality. Understanding these factors and their effects is crucial to ensuring long-term performance. In some cases, degradation is visibly apparent and can be assessed without specialized instruments, whereas in others, advanced material analysis techniques are required to quantify the extent of aging and its impact on functionality.

In construction, materials are constantly exposed to environmental and mechanical stresses that can compromise their effectiveness over time. Factors such as UV radiation, temperature variations, humidity, and mechanical loads can accelerate degradation, potentially leading to a reduction in protective performance. If not properly accounted for, these aging effects can result in failures that jeopardize the durability of the entire structure. Therefore, accurately identifying the sources of degradation and evaluating the aging resistance of materials is essential for selecting products that can provide long-term protection.

This study stems from the need to better understand the long-term durability of membranes and tapes used for wood protection. The projects presented in this paper focus on this issue from multiple perspectives, employing various methodologies to accelerate aging and evaluate material performance. By exposing products to different combinations of degradation sources, we have identified the most influential factors affecting resistance and

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assessed the best strategies to ensure optimal product longevity.

The analysis covers membranes and adhesive tapes, both individually and as integrated systems, to evaluate their respective contributions to overall durability. Depending on the type of product, different properties were examined: for acrylic adhesive tapes, mechanical and adhesive strength were assessed; for vapor control and breathable membranes, the focus was on mechanical resistance and the effectiveness of the non-woven layer in protecting the functional film; and for combined systems, the strength of the connection was evaluated. All properties were compared between fresh and aged samples, with aging induced through either natural environmental exposure or accelerated techniques based on established standards.

2 – CASE STUDIES

2.1 CUT - CRACOW UNIVERSITY OF TECHNOLOGY

This work was carried out within the MEZeroE project, a European initiative aimed at providing an open ecosystem for the development, testing, and upscaling of smart, bio-based, human-centric envelope products. Within this project, we had the opportunity to collaborate with the Cracow University of Technology to test various products from our waterproofing & airtightness lineup. Thanks to their material analysis laboratory, we were able to characterize the mechanical properties and the durability of one breathable monolithic membrane, the TRASPIR EVO UV 115, and the membrane-tape-membrane connections composed of the combination of the same membrane and the universal single-sided adhesive tape FLEXI BAND UV, and the one composed of another breathable monolithic membrane, the TRASPIR EVO 160, and the universal single-sided adhesive tape SMART BAND.

The sample aging process was carried out in accordance with ANNEX C of the EN 13859-1 standard, with a modified UV exposure duration of 5000 hours instead of 336 hours, a modification typically applied to membranes intended for use on open joint facades. The mechanical properties of fresh and aged membranes were assessed following the EN 13859-1 standard. Surface properties of fresh and aged membranes were analysed through SEM imaging and FTIR spectroscopy. The mechanical properties of fresh and aged membrane-tape-membrane samples were evaluated in accordance with the EN 12317-2 standard.

2.2 FLORIDA

This project was aimed at understanding the behaviour of two of our tapes, FLEXI BAND and SPEEDY BAND, when exposed to the environment for an extended period of time. The samples were placed in the Q-LAB facility in Florida and left exposed to the outside for a total of 2 years. The samples were collected at fixed intervals to assess the mechanical properties, following the EN ISO 29864, and the adhesion properties, following the EN ISO 29862.

2.3 SINTEF

In Europe, there is no harmonized norm to assess the performance of construction tapes. However, at Rothoblaas, we are always on the hunt for promising procedures that could one day become the reference for construction tape regulation. Regarding durability and aging resistance, we found that the Durability Evaluation of Adhesive Tapes for Building Applications [1] is a complete and robust method to evaluate the quality of a construction tape based on the Building Technical Regulations (TEK) [2].

The method involves assessing the adhesion properties on various common construction substrates, both before and after aging. The aging process consists of two phases: in the first phase, the tape undergoes a cycle according to NT BUILD 495, while in the second phase, the sample is placed in an oven at high temperatures.

2.4 ROTHOBLAAS FACADE

During the renovation of our headquarters that began in 2020, part of the east/southeast façade was dismantled to allow for the addition of our self-supporting, fully automated timber warehouse. We decided to take advantage of this opportunity to test the membrane used in the original construction in 2015, the TRASPIR EVO UV 210, which had been protecting the building for five years. Both impermeability and mechanical properties are assessed during the CE marking process, where minimum guaranteed values are provided. We took the opportunity to conduct this test to evaluate whether artificial ageing is an effective method for understanding ageing behaviour. By comparing the data from the CE marking tests with those obtained from tests on the membrane in its intended use, we were able to gain insights into how the material performs under real-world conditions over time, beyond the minimum thresholds defined in the CE marking process. This allowed us to assess the membrane's long-term durability and its ability to withstand environmental stresses beyond the standard requirements. The test methods used were the same as

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those applied for CE marking, following the EN 13859-1 standard [3].

3 – MATERIALS AND METHODS

Here will be presented a quick intro on the methods that have been used in this paper.

3.1 AGING

As previously mentioned, the experimental setup varies from one project to another. They can be divided into two main groups: real exposure and lab-controlled exposure.

3.1.2 LAB CONTROLLED AGING

For the lab-controlled exposure, two different methods have been used:

a. ANNEX C of the EN 13859-1 standard, with a modified UV exposure duration of 5000 hours instead of 336 hours.
b. NT BUILD 495 aging process in combination with a high temperature exposure.

The aging according to the ANNEX C from the norm UNI EN 13859-1 involve the exposition of the sample to an array of fluorescent UV lamp of type I (340 nm) and the BST (Black Standard Temperature) shall be of 50 °C for a total time of 336h. as previously mentioned, we decided to extend this timeframe to 5000h, the amount of time that is suggested for the aging of membranes intended for use on open joint facades. The UV exposure is then followed by a staying at 70 °C for 90 days. The instrument used for the UV exposure was the Q-Lab, QUV/spray/rp - Accelerated Weathering Tester, while for the exposure at high temperature, a thermostatic oven from MEMMERT was used.

b. The ageing process according to the SINTEF method is divided into two phases. In the first phase, the samples undergo a 14-day climate ageing cycle following NT BUILD 495 [4] in a vertical climate simulator. This cycle consists of four alternating climate conditions:

- UV light and infrared radiation, with a black panel temperature of 63°C
- Water spray, at a rate of 15 $dm^3/(m^2 \cdot h)$
- Freezing, at -20°C
- Ambient laboratory conditions

Each condition lasts 1 hour per cycle, and the cycle repeats over the 14-day period.

In the second phase, the specimens are subjected to 24 weeks of heat ageing at 70 °C in a heat chamber, according to NS-EN 1296 [5]. This temperature range (60 °C - 70 °C) is considered the upper safe limit for accelerated ageing of polymers, although higher peaks, up to 90 °C, can occasionally occur in extreme conditions, such as under dark-coloured roof tiles [1].

3.1.2 NATURAL AGING

Regarding natural ageing, this was conducted in two different ways:

a. Direct exposure to the environment in Florida at Q-LAB facility
b. In-use exposition on the open joint façade at our HQ in Cortaccia ssv

We decided to expose two tapes from our product line in Florida because it is the only truly subtropical location in the Northern Hemisphere. The site is characterized by high temperatures, high humidity, and intense UV exposure year-round, making it one of the most challenging environments for testing product durability [6].

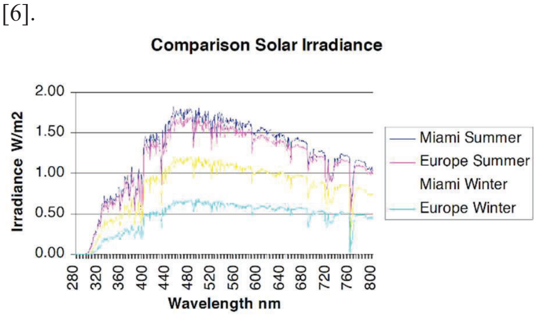

Figure 1 - comparison of average UV exposure during winter and summer between Florida and Europe [4]

The exposition was managed by our partner Q-LAB. The samples for the peeling adhesion properties were let adhere on a plexiglass surface, while the samples for the breaking strength and elongation at break were stapled onto a CLT panel, as can be seen in Figure 2. When our headquarters in Cortaccia sulla Strada del Vino, in the province of Bolzano, Italy, was expanded to accommodate the construction of our fully automated timber warehouse, the east/southeast-facing façade that was dismantled had been protected by our TRASPIR EVO UV 210 membrane. We took this opportunity to compare the membrane, which had been installed following our guidelines and had been in service for five years (from 2015 to 2020), with a new, unused sample. The façade featured open joints 20 mm wide, exposing the membrane to additional environmental stress.

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Figure 2 - Preparation and exposition of samples

3.2 MECHANICAL AND ADHESION TESTING

For the tensile properties of membranes, the standard EN 12311-1 was used. For the evaluation of the mechanical properties of tapes, the standard used was the EN ISO 29864. B method was used for the tested samples, since the tapes were fibre reinforced.

The adhesion values, both before and after ageing, were measured following the method described in standard EN ISO 29862. The substrate and angle may vary between studies, but fresh and aged samples were always compared under consistent substrate and angle conditions.

3.3 SURFACE CHARACTERIZATION

Scanning Electron Microscopy (SEM) is a highly flexible and advanced analytical technique widely used for studying the surface properties of materials. In this case, it was employed to obtain images with magnifications of up to 1000x.

3.3.1 SEM - SCANNING ELECTRON MICROSCOPE

The tests were conducted in variable pressure (VP) in pressure range 80-120 Pa. The samples were glued on stubs using a carbon glue. The samples were then placed in the microscope chamber and the observation started when the column pressure reached below 10^{-4} Pa. EHT accelerating voltage was 20kV while the working distance WD was around 10 mm ± 1 mm. The observations were carried out using BSD detector. The machine used was a ZEISS EVO MA 10.

The analysed images are those of the non-aged samples and the ones aged according to ANNEX C of the EN 13859-1 standard.

Figure 3 - From left to right: EN 12311-1, EN ISO 29864 method B, ISO 29862 at 180° and 90°

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3.3.1 FTIR - FOURIER TRANSFORMATION INFRARED SPECTROSCOPY

The Fourier Transformation Infrared Spectroscopy, usually referred to as FTIR, is a non-destructible technique that is widely used in the characterization of materials thanks to its versatility. This technique is able to analyse a material in a fast and precise way identifying functional groups that have a response to infrared stimulation. The sample is targeted with a mid-infrared radiation which interacts with the molecules of the material. The output is an absorption, or transmission, spectra that gives the molecular fingerprint of the material. FTIR spectrophotometer Jasco FT / IR 6700 with ATR Pro ONE View was used for the tests.

Since this is a very fast analysis, it was possible to examine the membrane surface at 1000-hour intervals up to a total of 5000 hours, following the ANNEX C of the EN 13859-1 standard.

4 – RESULTS AND DISCUSSION

As demonstrated in the use cases, over the years we have conducted various studies that have allowed us to gain a deeper understanding of the behaviour of our membranes and tapes after aging. The ability to perform both natural and lab-controlled aging tests has given us the opportunity to compare the results and better comprehend the processes that occur when the products are exposed to high temperatures, UV light, and water. The analysis of the results will be divided into two main areas: tapes and connections and membranes.

4.1 TAPES AND CONNECTIONS

As shown in the previous chapters, the tapes we tested are the FLEXI BAND UV, the SMART BAND, the FLEXI BAND, and the SPEEDY BAND. Each of them has its own peculiarities and specific uses, but all of them can be used outdoors. This is why it was interesting for us to gain a deeper understanding of their behaviour after ageing. FLEXI BAND UV and SMART BAND were tested in combination with the membranes TRASPIR EVO UV 115 and TRASPIR EVO 160 respectively. Both membranes have a polypropylene non-woven layer protecting the functional film, so the surface where the tapes adhere is comparable.

The first common behaviour observed across all the tested products is that the adhesive is well protected by the carrier of the tapes. This can be seen from the adhesion values from the peel test performed on the FLEXI BAND and SPEEDY BAND exposed to the Florida environment. Below are the graphs showing the adhesion values of the two tapes relative to the months of exposure.

The same trend is confirmed by the CUT analysis, which demonstrated that after UV + heat ageing, the failure of the membrane-tape-membrane connection using the FLEXI BAND UV and SMART BAND tapes was never due to adhesive failure, but rather to membrane failure.

A different behaviour was observed in the work with SINTEF, where the peeling force at 90° on spruce and the TRASPIR 110 membrane decreases after the ageing cycle. The values can decrease by up to -60%, which means that although the adhesion is still considered sufficient for the intended use of the tape, the decrease in adhesion can be substantial. The main difference between the SINTEF ageing cycle and the one proposed by ANNEX C of the UNI EN 13859-1 standard is the presence of liquid water and a freezing phase. Since there is no decrease on steel, we could infer that the wetting-freezing cycle on surfaces that can absorb water may be detrimental to the adhesion properties of the tape. The freezing phase seems to be fundamental to the decrease in performance, as the decrease in adhesion does not occur in the QLAB natural exposure in Florida, where precipitation is consistent throughout the year.

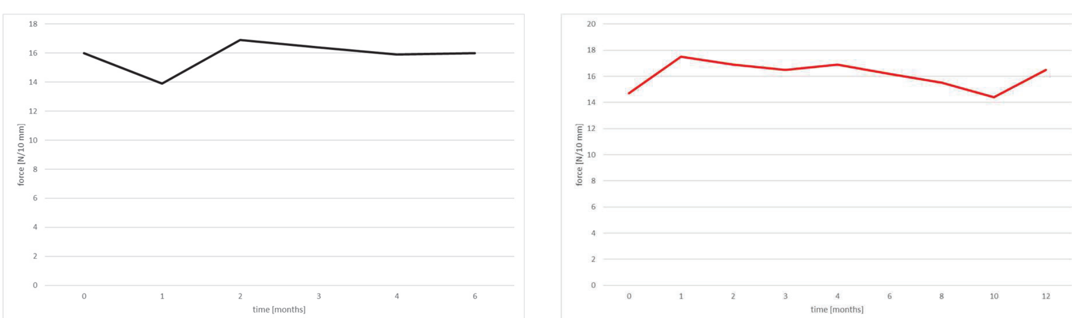

Figure 4 - from left to right: adhesion value of FLEXI BAND and SPEEDY BAND

Another aspect that can be observed in tapes with a reinforcing scrim is the loss of shock absorbance in the carrier after the ageing process. Interestingly, the maximum force measured before ageing is matched by the samples after ageing in all the studies conducted with our partners.

TAPE	FRESH SAMPLE	AGED
FLEXI BAND UV	83.0 N/50mm	81.0 N/50mm
FLEXI BAND (6 months)	16.0 N/10mm	16.0 N/10mm
SPEEDY BAND (12 months)	14.7 N/10mm	16.5 N/10mm

Table 1 – tensile strength values for reinforced tapes before and after aging

On the other hand, the maximum deformation of the tape is significantly reduced after ageing. In both the QLAB and CUT studies, the tape fails immediately after reaching the maximum force, which corresponds to the failure of the reinforcing grid.

On the other hand, the SMART BAND tape, which does not have a reinforcing grid, does not exhibit this more fragile behaviour. This is likely because the maximum deformation is reached with a constant force, applying less stress to the material. This behaviour emerges from the membrane-tape-membrane shear stress test performed on the SMART BAND tape, where the deformation at break is even higher compared to the unaged sample.

It is important to note that the failure mode of the unaged sample is due to the detachment of the tape from the membrane. Therefore, it is reasonable to assume that the maximum deformation would be comparable to that of the aged material.

4.1 MEMBRANES

The behaviour after aging of two of our membranes, TRASPIR EVO UV 115 and TRASPIR EVO UV 210, was analysed thanks to the projects with CUT and the tests we performed on the membrane that was protecting the old façade of our headquarter.

The membranes that have the function of regulate the humidity inside the wall structure, usually are composed of at least two layers: the functional layer, that is the one that actually regulates the passage of water vapour, and the non-woven layer, that is usually protecting the functional layer and gives the mechanical strength to the membrane. A reinforcing grid could be present as well, but these are not the case.

One aspect that was investigated thanks to the collaboration with CUT, was the evolution of the non-woven layer protecting the PA functional layer of the membrane TRASPIR EVO UV 115. As anticipated during the previous chapters, we used a combination of SEM and FTIR analysis to have a clear idea of the changes.

What we could observe is that, even if the non-woven layer was damaged by the exposition to the aging cycle, as can be seen from SEM images, the functional layer was still intact.

We were able to assess the functionality of the functional layer thanks to the FTIR analysis. As can be seen from the graph below, the amin structure of the PA film was maintained, suggesting a conservation of the vapour regulation capabilities of the layer.

The mechanical properties of the TRASPIR EVO UV 210 membrane were evaluated after five years of use on the east/southeast façade of our headquarters in Cortaccia s.s.v. (BZ, Italy). This study was conducted to gain a better understanding of the natural ageing process under real-life conditions during the intended use of the product.

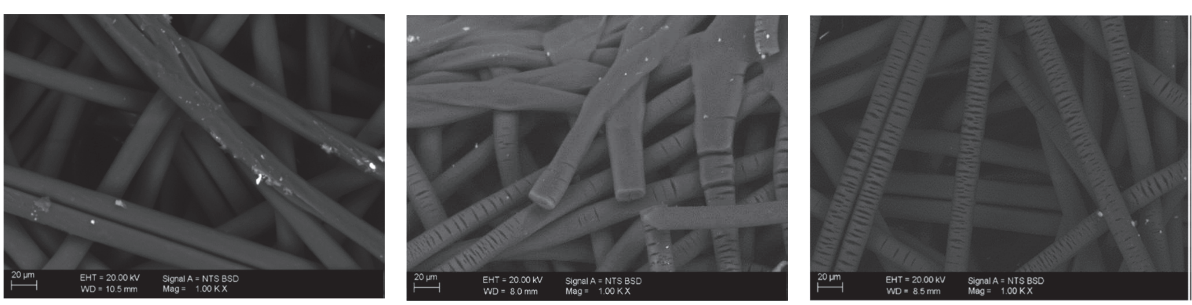

Figure 5 - from left ro right: SEM image of the non-woven surface of the membrane TRASPIR EVO UV 115.

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As shown in the table below, the tensile strength and deformation at failure of the aged membrane remain above the values declared in the DoP, both in the longitudinal and transverse directions.

Value declared in DoP	After 5 years exposure
Tensile force MD	
300 N/50mm	338 N/50mm
Elongation MD	
25%	28%
Tensile force CD	
200 N/50mm	251 N/50mm
Elongation CD	
25%	31%

Table 2 – tensile strength and elongation values before and after natural aging of the TRASPIR EVO UV 210

This confirms that the ageing process prescribed in the EN 13859-1 standard effectively covers at least five years of real-world exposure for this membrane. In fact, the strength values of the naturally aged membrane still exceed those declared for the unaged membrane, demonstrating that the material remains far from the degradation level simulated by the standard ageing procedure used for CE marking.

5 - CONCLUSIONS

The studies conducted on our membranes and tapes, both through natural and accelerated ageing, have provided a deeper understanding of their long-term performance. The results confirm the reliability of the ageing protocols used in EN 13859-1, demonstrating that the artificial ageing process accurately replicates the degradation observed in real-world conditions.

For tapes, the adhesion performance remained largely stable over time, as confirmed by both the CUT tests and the Florida natural exposure study. The failure modes observed indicate that the adhesive remains well protected by the carrier, preventing significant deterioration due to environmental factors. However, in the SINTEF study, where liquid water and freeze-thaw cycles were included, a substantial decrease in adhesion was observed on absorbent substrates like spruce. This highlights the critical role of surface type and environmental conditions in determining long-term adhesion performance.

The mechanical behaviour of tapes with reinforcing grids, such as SPEEDY BAND, FLEXI BAND UV and FLEXI BAND, exhibited a reduction in elongation at break after ageing. While the maximum tensile force remained unchanged, the tapes became more brittle, failing immediately after reaching peak load due to the degradation of the reinforcing mesh. In contrast, SMART BAND, which lacks a reinforcing grid, showed a different response. Its ability to distribute stress more evenly resulted in a higher deformation at break even after ageing, making it less prone to sudden failure.

For membranes, the TRASPIR EVO UV 210 was analysed after five years of exposure on the east/southeast façade of our headquarters. The results confirmed that its mechanical properties remained above the declared values in the DoP, reinforcing the validity of the CE marking ageing process. The membrane retained tensile strength and elongation properties beyond those declared in the DoP of the unaged sample, proving that it is well suited for prolonged outdoor applications.

Finally, Scanning Electron Microscopy (SEM) analysis on the membrane TRASPIR EVO UV 115 provided valuable insights into the surface degradation mechanisms of aged samples. The microscopic observations helped correlate mechanical performance with structural changes, reinforcing the findings obtained through macroscopic testing.

Overall, these studies confirm the durability and performance stability of our tapes and membranes in various ageing conditions. While exposure to heat alone have a limited impact on adhesion, combined factors such as moisture and freezing cycles can significantly influence performance on specific substrates. UV exposure can reduce the mechanical performance of products used for wall protection, but for the products analysed in this study, their functional characteristics are still maintained even after prolonged exposure. These findings will be instrumental in refining our product formulations and optimising recommendations for different environmental conditions and applications.

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