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Polyamide-Based Adhesive Lascaux 5350 in Textile Conservation—Properties, Stability and Use

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Abstract: Lascaux Polyamid-Textil-Schweisspulver 5350 is a hot-melt adhesive with promising properties for applications in textile conservation. The study presented aims at examining the properties and long-term stability of this adhesive. It also deals with the possibilities of its use for bonding proteinaceous and cellulosic textiles and describes particular methods of using the adhesive either in the form of powder or as a prepared adhesive film. The adhesion techniques are compared with conventional sewing methods commonly used to consolidate damaged textile objects. In addition, the study also deals with the reversibility of the adhesive treatments.

Keywords: adhesive technique; adhesive treatment; hot-melt adhesive; Lascaux 5350; copolyamide; textile conservation; consolidation; long-term stability; reversibility

Citation: Krejčí, J.; Škrdlantová, M.; Drábková, K.; Bureš Víchová, J. Polyamide-Based Adhesive Lascaux 5350 in Textile Conservation—Properties, Stability and Use. *Heritage* **2023**, *6*, 164–176. https://doi.org/10.3390/heritage6010008

Academic Editor: Diego Tamburini

Received: 14 November 2022
Revised: 18 December 2022
Accepted: 19 December 2022
Published: 22 December 2022

1. Introduction

In the field of conservation of textile materials, especially if they are at an advanced stage of degradation, adhesion can be a highly advantageous alternative to more conventional sewing. Alternatively, both techniques can also be combined in an appropriate manner. In addition to the correct choice of the base material, the selection of a suitable adhesive and an optimal method to create an adhesive joint are crucial in the process of adhesion [1,2].

Adhesion of textiles is a term referring to the mechanical stabilization (securing) of the fabric by bonding it to a new base material using a suitable adhesive. The specialised literature provides information on the use of adhesives from various material groups being applied in the conservation of textiles [1–17]. Over time, a visible shift has occurred in the selection of these adhesives. Originally, the adhesives were mostly polysaccharides (starches and gums) from plant sources, or proteins obtained from tissues of various animals (gelatine, animal glues, etc.). Subsequently, the advent of modern times saw applications of polyvinyl acetate or acrylate copolymers (in the form of solutions or aqueous dispersions), polyvinyl alcohols, polyvinyl acetates and various cellulose derivatives. Also, a range of adhesives activated by increased temperature occurred, various wax mixtures or polyamide-based hot-melt adhesives being typical examples [1,3–11].

Adhesion techniques may use various ways of applying an adhesive and creating adhesive joints. Here, a principle of solution drying may be utilized, but it is much more convenient to create a bond using methods that employ the additional activation of the adhesion layer—typically working with an increased temperature or the application of solvents (mostly in the form of vapours). The latter-mentioned methods do not cause adhesives to penetrate excessively into the historical and sensitive part of textiles, but the bond created can still achieve optimal properties [1,4,7,12].

One of the advantages of adhesive techniques is that it allows for flat reinforcement with the minimal manipulation of the object. In contrast, sewing always applies a point/spot reinforcement, which typically requires a considerable extent of manipulation with the object conserved. In the case of textiles at an advanced stage of degradation, the cohesion of an object may be so low that needle punctures and fixing the object with stitches may prove fatal to it [2]. The use of adhesion is particularly suitable in the case of flat textiles or in such cases where a textile needs to be attached to a different kind of material. Furthermore, adhesion is well suited for fixing fabrics that have broken into individual fragments and for attaching floating threads. It can also be very advantageous for painted objects where needle punctures and stitches would be particularly distracting. However, it is always necessary to consider the state of the object meant for intervention and also all the aspects such an intervention may have [1,14–16].

A separate segment is represented by the objects that have already been bonded by adhesion in the past and require conservation intervention. Here, in addition to the choice of a suitable intervention, the removal of the original adhesives must also be taken into account [14,16,17].

Our study builds on extensive research of different adhesive types and their potential applications in the textile conservation. During the research, the advantages of hot-melt adhesives have become apparent as they meet the demands put on them in this field. Obviously, the requirements primarily entail the creation of a sufficiently strong adhesive joint while minimally affecting the appearance of the given object. Moreover, it is essential to preserve the properties and characteristics of the original fabrics as much as possible, i.e., to minimize the increase in rigidity as a result of adhesion, to preserve sufficient flow, and to prevent any significant changes in the feel of the object. Another principal requirement generally desired for the materials applied in conservation is the reversibility of the intervention. Last but not least, it is important for the adhesive used to be sufficiently stable in the long-term as well. Based on the experience of the authors of this article from the entire range of tested adhesives and processes, it was the Lascaux Polyamid-Textil-Schweisspulver 5350 (hereinafter referred to as Lascaux 5350) hot-melt adhesive which best met all the requirements mentioned. The application of this adhesive allows the adhered object to achieve rigidity and flow comparable to those reached by sewing. In addition, the adhesive provides great application variability and thus the intervention can always be tailored to the needs of the specific object. Lascaux 5350 also displays good adhesion to cellulosic and proteinaceous materials and as well as to common synthetic textiles (PAD, PES).

The study presented aims to examine the properties and long-term stability of Lascaux 5350 adhesive in relation to its applications for making adhesive joints. It also describes in detail the issue of intervention reversibility.

2. Materials and Methods

Lascaux 5350 is a hot-melt adhesive based on a polyamide copolymer. It also contains a minor content of fillers of less than 5 wt.%. The adhesive comes in the form of white powder with a fairly wide particle size distribution (up to 500 µm).

Its pH is in the neutral range (6.5–7) and the lowest activation temperature required to form an adhesive joint is around 105 °C. However, for the activation and subsequent bonding to occur, this temperature must be reached directly in the adhesive layer and sufficient pressure must be applied. Generally, to create a high-quality adhesive joint the rule is that the lower pressure is applied, the higher the temperature is needed. While a heated restoration spatula can be used to activate the adhesive as low as 105–110 °C, a higher temperature setting (>120 °C) must be considered when using an iron or other alternative means (heated table, etc.) that are unable to achieve sufficiently strong pressure. The thickness of the fabric must also be taken into account when selecting the appropriate temperature. The time required for the elevated temperature to activate the adhesive is usually so short (in the order of seconds) that heat damage to the historical object treated should not occur.

Solubility testing in a wide range of common solvents has shown that Lascaux 5350 adhesive (except for the insoluble fraction of fillers) is largely soluble in alcohols. In methanol, the solubility of the polyamide at laboratory temperature is approximately 10 g/100 g of solvent. At increased temperature and pressure, solubility up to approximately 40 g/100 g of solvent can be achieved. Although such a solution can solidify after a rather long period after cooling, it remains workable in its liquid form for the first few hours after preparation even at laboratory temperature. However, its solubility in ethanol is significantly lower, by about half, and in other alcohols it decreases even further as their chain length grows.

2.1. Sample Preparation and Artificial Ageing

2.1.1. Samples of Adhesive

In order to test the properties and long-term stability of Lascaux 5350 adhesive, model samples were prepared by melt casting into moulds, which had been adapted in shape to the testing methods.

For colorimetric determinations, the samples were disc-shaped with a diameter of 30 mm and a thickness of 5 mm. For the measurement of the Young's modulus and determination of glass transition temperature (T_g), specimens were prepared in the form of strips with dimensions of 30 × 5 × 1 mm.

To determine the long-term stability of the adhesive, the samples were subjected to three types of artificial ageing—dry heat (65 °C, 7% RH, 8 weeks), moist heat (55 °C, 65% RH, 8 weeks) and artificial daylight enriched with UV component (5.2 klx, 13 $W \cdot m^{-2}$, 38 ± 2 °C, 16% RH, 2 weeks).

The properties examined were subsequently measured before and after artificial ageing. Prior to each measurement, samples were conditioned at 45 ± 2% RH and room temperature for 48 h. If several separate measurements were made within one sample set, the resulting value is always presented as the arithmetic mean of the measurements and the errors are expressed as standard deviations.

2.1.2. Samples of Bonded Textiles

The variability of the adhesive tested allows it to be used either directly as original powder or by further processing it to form an adhesive film. In the first case, the powder in excess is applied evenly (e.g., using a sieve) onto silicone paper. Subsequently, the excess powder is more or less removed until only a uniform thin layer of the finest adhesive particles remains on the paper. The amount of the powder trapped/settled on the paper determines the final properties of the fabric bonded. Just by tilting the paper and spreading the powder, we achieved powder consumption of approx. 25 $g \cdot m^{-2}$. After shaking the paper sheet, the powder consumption dropped to approximately 5 $g \cdot m^{-2}$ and by brushing off the excess powder it, reached ca. 2 $g \cdot m^{-2}$. Next, a base fabric is spread out on the silicone paper coated with the layer of the powdered adhesive and levelled. Then, the layer is briefly ironed over an additional sheet of silicone paper (approx. 120 °C). On cooling, the base material is peeled off together with the adhesive layer and transferred to clean silicone paper with the adhesive facing upwards. Afterwards, the adhered fabric is aligned on the prepared base material and again ironed briefly over the clean silicone paper from the side of the adhered fabric. After cooling, the top and bottom silicone paper sheets are removed and the adhesion process is complete. Now, the fabric adhered can be manipulated, its edges can be cleaned, and adhesive residues can be removed from places where the original fabric was not preserved, etc.

The second method of using Lascaux 5350 adhesive takes advantage of its solubility in alcohols, as described earlier. The adhesive is first dissolved in a large amount of a solvent (preferably methanol) to allow the filtration and removal of the insoluble portion. A 10% solution of the adhesive is prepared by completely drying and then re-dissolving it. The solution is poured on a prepared polyethylene mould, where it is immediately spread with a brush to form an even layer. To prepare a film with the final thickness of 10 μm, ca. 1.3 $mL \cdot dm^{-2}$ of the solution were used, while ca. 4 $mL \cdot dm^{-2}$ were needed to produce a film 30 μm thick.

The evaporation of the solvent, which should be aided by a stream of warm air, produces a transparent film, which is non-adhesive at laboratory temperature. The film thus prepared is carefully peeled off the polyethylene mould and spread on thoroughly cleaned silicone paper. The base fabric is then applied to it and the rest of the procedure is analogous to the method using powder (see above).

In order to test the properties and long-term stability of textiles bonded by adhesion, several sets of model sandwich specimens were prepared consisting of two textile layers bonded with Lascaux 5350 adhesive. Their adhesive joints were formed by different variations of the methods described above. The identical material was always selected to serve as the top and base fabric, which was either silk cloth (43 g·m^{-2}, supplied by Zdeněk Volf, CZ) or linen cloth (310 g·m^{-2}, supplied by Sartor Bohemia, CZ). Table 1 shows a list of the used variants of the adhesive procedure. Produced samples of 150 × 100 mm were subsequently cut into strips 150 × 15 mm in the weft direction.

Table 1. Methods of Preparing Model Sandwich Samples by Adhesion.

	Variant of Adhesive
Lascaux 5350	prepared film (thickness 30 µm) prepared film (thickness 10 µm) powder (consumption 25 g·m^{-2}) powder (consumption 5 g·m^{-2}) powder (consumption 2 g·m^{-2})

In order to compare the properties of the adhered textiles with the usual methods of sewing consolidation, an experienced textile conservator also used different variations of sewing techniques to prepare several sets of model samples from the same textiles used in the adhered samples, including the variant of covering the object with silk crepeline (Figure 1). For the sewing of the model samples, a thread drawn from silk organza or a cotton thread was used. The sewing techniques were selected on the basis of the methods used in conservation practice. The dimensions of the samples used were identical to those produced by adhesive techniques, i.e., strips with dimensions 150 × 15 mm in the weft direction.

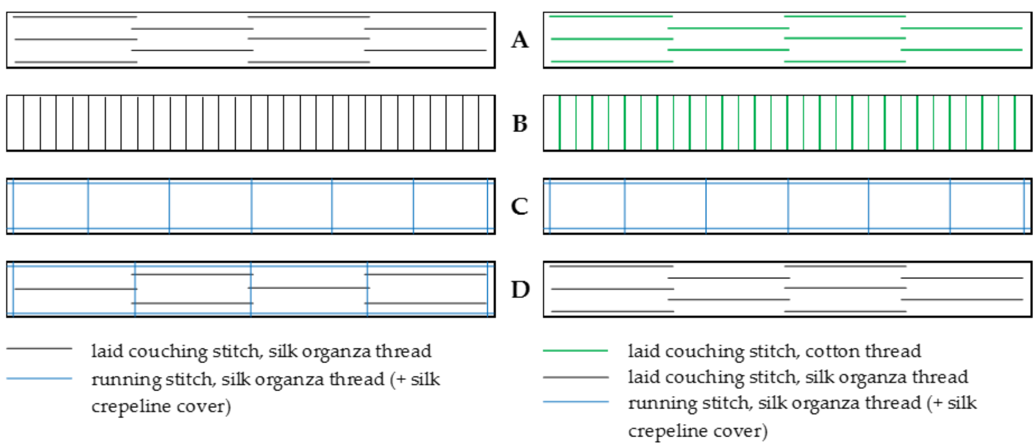

Figure 1. Methods of Preparing Comparative Samples Using Sewing Techniques (A–D).

To evaluate the long-term stability, the samples (both adhered and sewn) were subjected to three types of artificial ageing under the same conditions as in the case of testing the stability of adhesives.

All the properties were measured before and after artificial ageing. Prior to each measurement, samples were conditioned at 45 ± 2% RH at room temperature for 48 h. If several separate measurements were made within one set, the resulting value is always presented as the arithmetic mean of the measurements performed and the errors are expressed as standard deviations.

2.1.3. Samples for Reversibility Testing

Reversibility is one of the basic requirements for the procedures intended for the use in textile conservation. Therefore, our research also looked into the possibility of additional targeted dismantling of adhesive joints and removal of adhesive residues from the previously adhered fabric, e.g., for the purpose of future conservation interventions.

Model sandwich samples were prepared in a manner similar to the previous experimental part using powder (5 g·m^{-2} variant) and a prepared film (10 μm thickness). Samples were artificially aged at 80 °C and 65% RH for 3 weeks. Subsequently, they were treated with different solvents (water, methanol and ethanol) using a compress (30 min) and subsequent rinsing (150 mL per 1 dm^2) performed on the suction table, each time at laboratory (25 °C) and elevated temperatures (50 °C).

The removal efficiency was assessed based on the course and ease of the removal as well as the resulting fabric properties. The feel and flow of the fabric were assessed organoleptically. Flexural rigidity was measured, and the amount of adhesive residues was evaluated by optical microscopy and FTIR. The results of individual methods were marked with grades ranging from 1 (best) to 5 (worst).

2.2. Test Methods Applied

The following table (Table 2) presents an overview of the test methods used for the prepared sets of samples. A detailed description is provided further in the text.

Table 2. Test Methods Applied.

Type of Sample	Test Method
Samples of Adhesive	Colorimetry, Young's Modulus, Dynamic -Mechanical Analysis
Samples of Textiles Bonded by Adhesion	Colorimetry, Flexural Rigidity, Adhesive Joint Strength
Samples using Sewing Techniques	Colorimetry, Flexural Rigidity
Samples for Reversibility Testing	Flexural Rigidity, Organoleptic Evaluation, Microscopy, FTIR Spectrometry

2.2.1. Colorimetry

Colorimetric determinations were conducted on a Konica Minolta CM-700d spectrophotometer with diffusion geometry using a D65 light source and an 8 mm measuring aperture. The measurements were performed on a white light-stable tile. Colour changes were evaluated using the CIELAB colour system (CIE1976) consisting of three orthogonal axes—the specific lightness (L*) and two chromatic axes (a*, b*). The so-called total colour difference (ΔE^*_{ab}) determining the distance between two colour points in space was calculated according to the following formula,

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + \left(a^*_2 - a^*_1\right)^2 + (b^*_2 - b^*_1)^2} \quad (1)$$

where L* is the specific lightness, a* is the colour axis between green and red and b* is the colour axis between blue and yellow.

The values were measured for all the individual colour parameters (L*, a*, b*). For the adhesive samples (3 mm thick), 6 separate measurements were taken. As for the sandwich samples (both adhered and sewn), 10 separate measurements were made.

2.2.2. Young's Modulus

The measurement of the Young's modulus for the adhesive samples followed the ISO 527-1 standard for determining mechanical properties of polymers. The Young's modulus is calculated from the beginning of the tensile curve,

$$E = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \quad (2)$$

where σ_1 is the stress during relative elongation ε_1 = 0.0005 a σ_2 is the stress during relative elongation ε_2 = 0.0025.

The measurements were performed at laboratory temperature (25 °C) with a LabTest 5.030-2 testing machine (Labortech, Opava, Czech Republic) measuring 10 samples within each set.

2.2.3. Dynamic-Mechanical Analysis

Dynamic-mechanical analysis was used to identify the glass transition temperature (T_g) of the adhesive and its possible shift due to ageing. Measurements were performed on a DMA DX04T machine (RMI, Lázně Bohdaneč, Czech Republic) and the temperature gradient was set to 1 °C per minute. The evaluation was made on the basis of the loss modulus values. From each set, one sample was subjected to dynamic mechanical analysis.

2.2.4. Flexural Rigidity

According to DIN 53362, the flexural rigidity is a parameter characterizing the materials flexibility. It is calculated based on the area density of a strip and the length required to bend the strip of the material tested by gravity.

$$G = m_F \cdot \left(\frac{l_0}{2}\right)^3 \cdot 10^{-4} \cdot g_n \quad (3)$$

where G is the flexural rigidity per unit width in mN·cm; m_F is the area density in $g \cdot m^{-2}$, l_0 is the length of the strip in cm required to bend it by 41.5° due to gravity, and g_n is the acceleration due to gravity in $m \cdot s^{-2}$.

The measurements were carried out with an automated flexural rigidity measuring device (Polymertest, Otrokovice, Czech Republic) on both adhered and sewn sandwich samples. For each sample set, five strips were measured from both sides, i.e., 10 measurements were conducted in total. Again, the result is the arithmetic mean value of the measurements with the measurement errors expressed in the form of standard deviations.

When testing the reversibility of selected adhesive methods, rigidity was measured as one of the properties to characterize the extent of the adhesive removal. The lower the rigidity of the fabric after the adhesive removal by the particular method, the more effective the method was considered to be. At this stage, six separate measurements were taken for each of the removal methods examined.

2.2.5. Adhesive Joint Strength

The tear strength, i.e., the stress in the direction perpendicular to the plane of the adhesive joint, was measured on the basis of standard ISO 36. The measurements were carried out for adhered sandwich model samples using a LabTest 5.030-2 universal testing machine (Labortech, Opava, Czech Republic). The joint was first severed at one end of the strip in the length of about 1 cm and fixed in clamps by the separated parts. Measuring was initiated, and gradually, due to the clamp thrust, the layer was separated in the length of 100 mm, and the curve of the force required to split the joint was recorded.

The subsequent calculation was performed according to ISO 6311. First, the initial and final parts of the force curve were removed due to possible imperfections in the peripheral parts of the adhered area. The local maxima were then identified on the remaining central part of the curve, which was used to calculate the median force required to break up the adhered textiles. Afterwards, the resulting force value was correlated to the width of the strip and the joint strength values were expressed in $N \cdot m^{-1}$. For each set, the strength of the adhesive joint was measured in five separate samples.

2.2.6. Organoleptic Evaluation

Complementing the exact measurements performed, organoleptic evaluation was conducted for the samples for reversibility testing, namely for the originally adhered fabrics from which the adhesive was removed by several different methods. The evaluation considered aspects such as how readily the layers could be separated, and the resulting feel and flow.

Concerning these samples, the evaluation of the removal process with the given method can also be included in the category of organoleptic evaluation.

2.2.7. Microscopy

Optical microscopy, specifically an Olympus BX60 microscope with a Canon EOS 1100D camera, was used to monitor adhesive residues in the textile samples for reversibility testing. In fact, the efficiency of adhesive removal by each method was clearly visible on microscopic images.

2.2.8. FTIR Spectroscopy

The method was used to monitor the adhesive removal efficiency in the samples prepared for reversibility testing. The Nicolet iZ10 spectrometer was used in an ATR mode (diamond crystal), i.e., with the attenuated total reflection method. The number of spectrum accumulations reached 64 at the resolution of 4 cm^{-1} using an MCT-A detector cooled with liquid nitrogen. To quantify the content of adhesive residues, an area of 1800–800 cm^{-1} was selected, and automatic baseline correction was performed. Furthermore, the ratio of the intensity of the band characteristic of Lascaux 5350 adhesive at position 1537 cm^{-1} and the characteristic linen band at position 1107 cm^{-1} was calculated. Owing to the overlap of the bands typical of the tested adhesive and silk cloth, infrared spectroscopy could not be used to evaluate the reversibility of the adhesive in silk sandwich samples. Therefore, the method was only applied to linen samples with a total of six spectra measured for each sample of this type.

3. Results and Discussion

3.1. Properties and Stability of Lascaux 5350

The adhesive itself is translucent and whitish, almost transparent in a thin layer. Based on colorimetric determinations conducted before and after artificial ageing of the samples, the sufficient colour stability of the adhesive can be confirmed. The colour changes caused by ageing (regardless of its type) were most evident in an increase of parameter b*, i.e., yellowing. The shift in the other axes was not as significant as in parameter b*. Considering the general principles for storing the collection objects and their common display conditions, where the values of illumination and the UV component of light are regulated to a minimum, the increased sensitivity of the adhesive to light ageing is not seen as limiting (Figure 2).

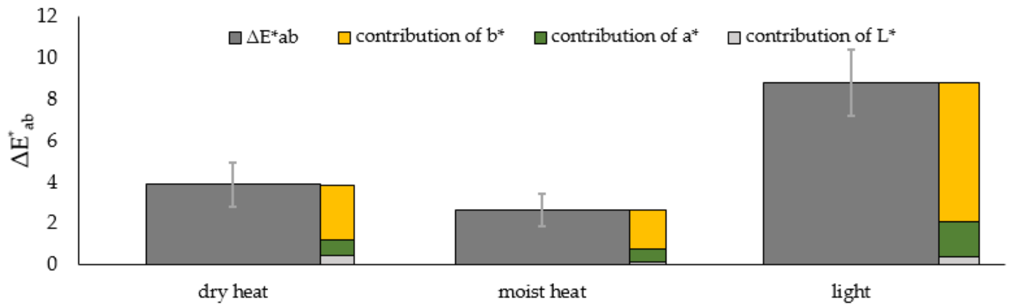

Figure 2. Colour Changes of Lascaux 5350 Adhesive Specimens after Artificial Ageing; Individual Parameter Contributions Indicated as L*, a*, b*.

The Young's modulus of the unaged Lascaux 5350 adhesive was found to be around 200 MPa and the T_g value was determined by dynamic mechanical analysis at 2.7 °C under the given measurement conditions. Similar trends were observed for both of the characteristics measured. In particular, an increase was evident in the Young's modulus (i.e., embrittlement) after moist heat ageing, and an upward shift in the glass transition temperature was observed. For other types of ageing, the changes were less distinct (Figure 3).

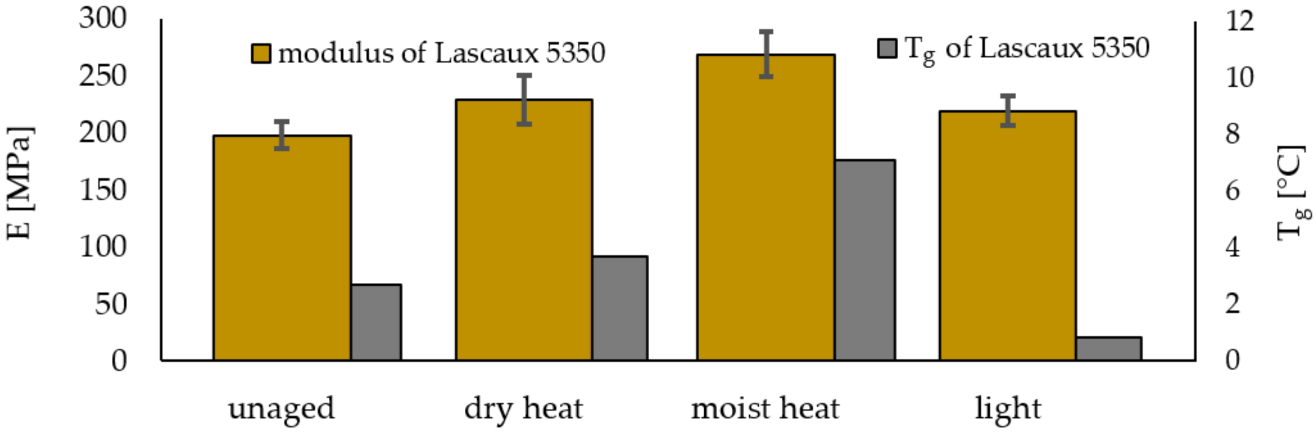

Figure 3. Comparison of Young's Modulus with T_g Values of Lascaux 5350.

3.2. Properties and Stability of Adhesive Joints

Concerning silk, the effect of the adhesive presence was evident in terms of colour changes depending on powder quantities. The application of the powder in quantities of 2 g·m^{-2} and 5 g·m^{-2} did not produce visible colour changes ($\Delta E^*_{ab} < 0.5$). On the other hand, when a larger amount corresponding to 25 g·m^{-2} was applied, the effect of the adhesive layer on the colour of the sandwich could already be seen with the naked eye ($\Delta E^*_{ab} > 1$). In the case of linen, however, the effect of the presence of the adhesive was not apparent, which was probably due to the higher weight of the fabric and thus its lower transparency.

Compared to the reference samples using sewing techniques, Lascaux 5350 adhesive was found to have a lower impact on the appearance of the object. This phenomenon could especially be observed in silk model samples. The explanation is that, when using sewing techniques, small holes are inevitably created in the fabric. Another problem with sewing is the presence of a sewing thread. Sometimes, the visual side of the object may even be covered with a layer of fabric as a result of the sewing technique applied, so the effect of sewing on the appearance of the objects treated cannot be denied.

In terms of the long-term effect, the presence of the adhesive layer seems to display a negligible impact on the colour of the fabric bonded by adhesion. In fact, the colour changes of the adhered samples follow the trends shown by the standard sample consisting of two layers of fabric without any adhesive, both for silk and linen especially (Figure 4). This is true thanks to the good colour stability of the adhesive selected and also owing to the fact that just small amounts of the adhesive are needed to create a high-quality joint. In comparison with sewing, adhesive techniques performed very well. Regarding the sewing techniques, the colour change of the sewing thread, which is also subject to degradation, contributes to the overall colour change of the sample after ageing and, unlike the adhesive, it cannot be completely hidden within the layer.

The amount of adhesive also has a significant effect on the flexural rigidity of adhered textiles. This phenomenon could be well observed by comparing the rigidity of the powder-bonded samples. In the cases where a larger quantity of powder was used, solidification occurred. The trend was more pronounced in finer silk fabrics, but it was also evident in linen, although to a lesser extent. However, this trend was not detected in the methods using the adhesive in the form of a film in varying thickness (Figure 5). Concerning artificial ageing, no changes were observed in the rigidity of the samples.

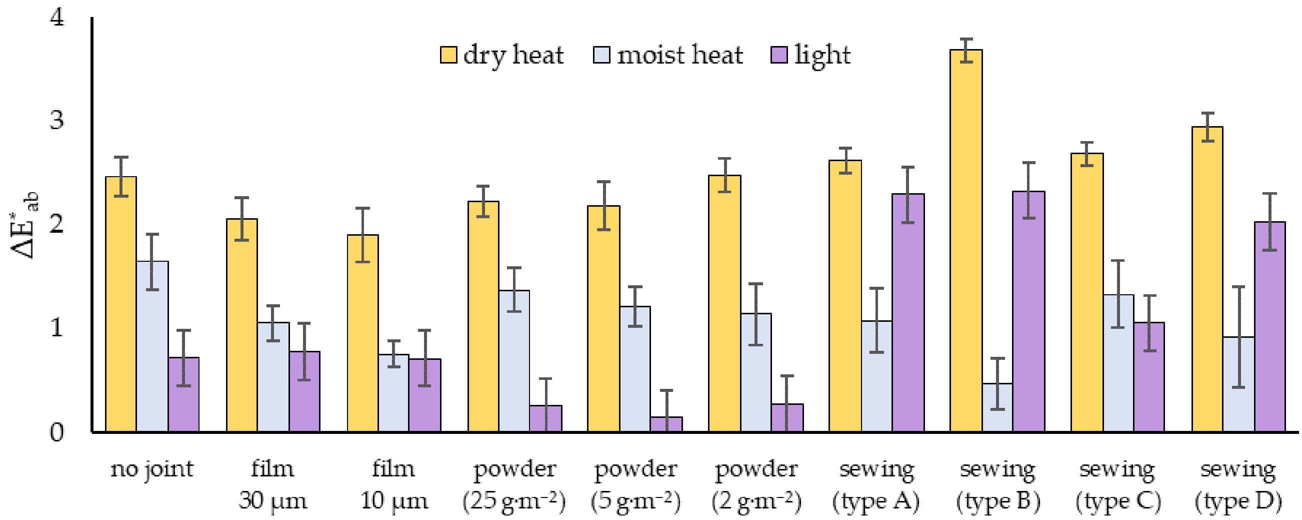

Figure 4. Colour Changes of Linen Sandwich Samples after Artificial Ageing.

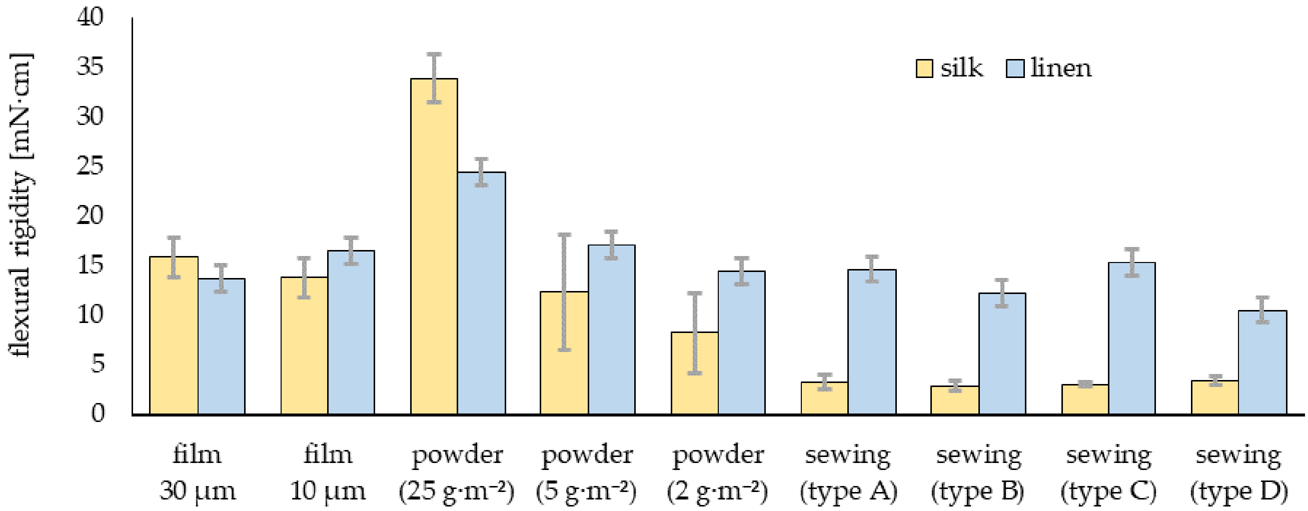

Figure 5. Comparison of Adhesive Methods and Sewing Techniques in Silk and Linen, Unaged Samples.

In all cases, the strength of the adhesive joints measured was found to be sufficient for the needs of textile conservation as confirmed organoleptically. Higher strengths are achieved by the joints produced using prepared films or larger amounts of powder. It can be concluded that all methods using powder provide comparable joint strength for both silk and linen. Better adhesion to silk was observed in the film form (especially 30 μm), but this was most likely due to the nature of the fabric rather than inferior adhesion to cellulosic materials. The 30 μm thick film provided the highest joint strength (in the case of silk). The joint formed by a 10 μm film showed comparable strength to that produced using powder in an amount equivalent to 25 $g \cdot m^{-2}$ and, at the same time, it displayed strength several times higher compared to that resulting from all the other methods using powder (consumption of 2 and 5 $g \cdot m^{-2}$). Still, even the latter methods yielded joint strength sufficient for use in textile conservation (Figure 6).

The strength of the adhesive joints was found not to change profoundly due to ageing. However, a certain trend was observed in silk, where certain samples showed a slight decrease in strength after moist heat ageing. In contrast, a slight increase in strength was observed in linen in several isolated cases after certain types of the ageing. However, the changes were usually within the measurement error, which is why the good long-term stability of the adhesive joints can be concluded for both proteinaceous and cellulosic textiles (Figure 6).

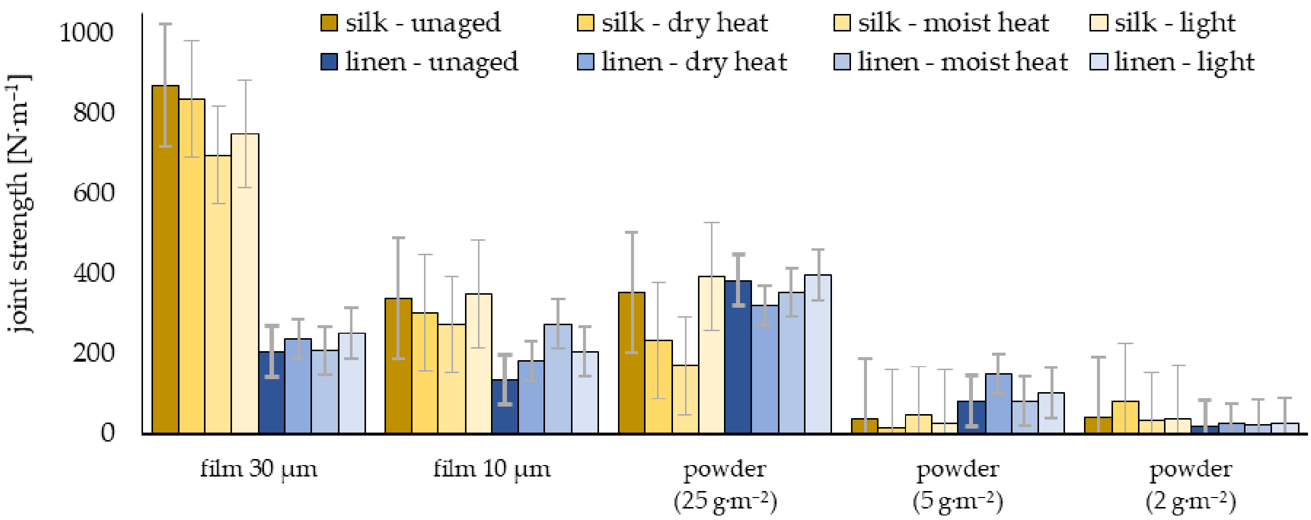

Figure 6. Comparison of Strength of Adhesive Joints Depending on the Methods Applied.

3.3. Reversibility of Lascaux 5350

As can be seen from the graph in Figure 7, a compress followed by a warm methanol rinse (50 °C) was identified to be the most effective method of removing Lascaux 5350 adhesive (both in the form of powder and film). This method offers a gentle way to separate bonded layers posing a minimal risk to delicate and sensitive textiles.

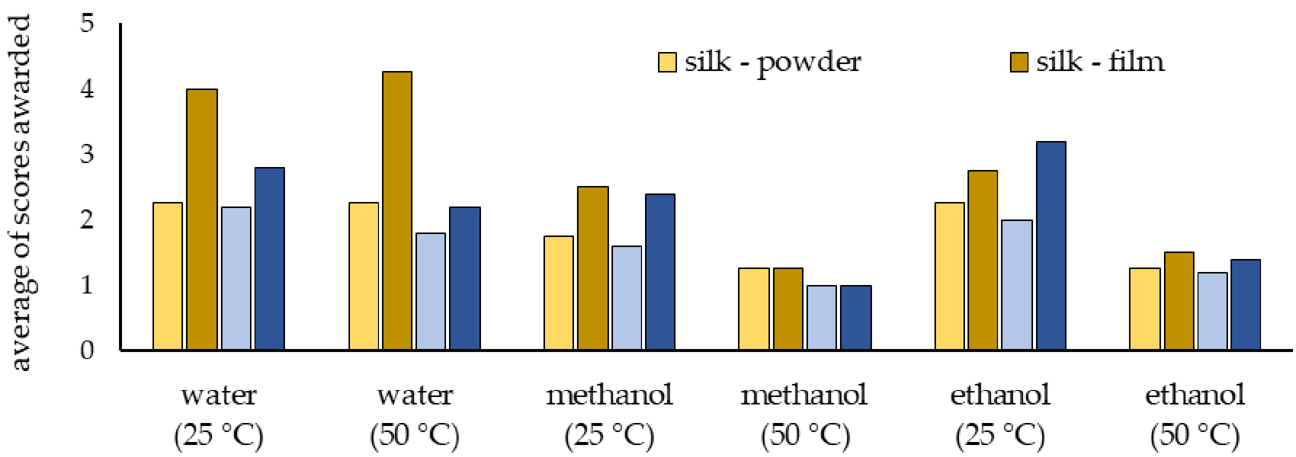

Figure 7. Evaluating Removal Methods for the Range of Samples (Average of the Scores Awarded).

At the same time, it practically allows the residue-free removal of Lascaux 5350 adhesive from the previously adhered fabrics, which was confirmed by all the methods used, including FTIR spectroscopy (Figure 8).

If, for any reason (e.g., toxicological), it is not possible to use warm methanol for the described method of the adhesive removal, it may be substituted with warm ethanol for cellulosic textiles, but then the reduced efficiency of the latter solvent must be taken into account. Our complementary and ongoing piece of research, which is looking into the resistance of textiles in relation to the solvents used, has not identified the effect of warm methanol on the properties of proteinaceous and cellulosic textiles but noted the effect of warm ethanol causing a slight decrease in the strength of silk. Therefore, this substitute cannot be recommended for proteinaceous materials. Before applying the described methods to real historical objects, it is also necessary to carry out a colour stability test in the solvent selected.

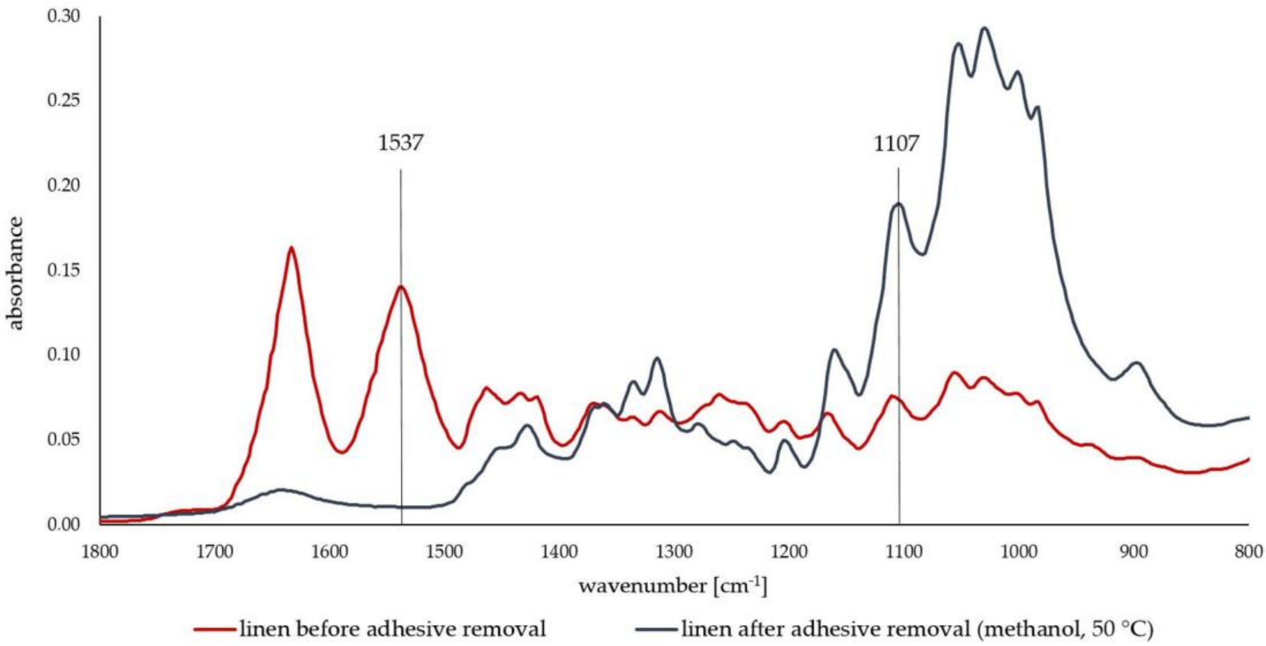

Figure 8. FTIR Analysis of Polyamide Based Adhesive Lascaux 5350 Removal from Linen Cloth with Methanol (50 °C).

4. Conclusions

The use of Lascaux Polyamid-Textil-Schweisspulver 5350 hot-melt adhesive based on a polyamide copolymer appears to be a suitable alternative to the more common sewing techniques, e.g., in the case of heavily degraded textile items where needle punctures, necessary manipulation and the point-limited nature of the sewing consolidation could worsen the cohesion of the item treated.

In the case of adhesion using powder (with consumption of 2 g·m^{-2} or 5 g·m^{-2}), optimal results can be achieved for flowing or sparse fabrics. The resulting adhesive joint achieves exceptionally low rigidity and maintains a pleasant feel and good flow of the fabric bonded by adhesion. The use of this method ensures the sufficient strength of the adhesive joint, which reaches approximately 25–150 N·m^{-1} depending on the type of the textile materials adhered. While the use of excessive amounts of adhesive powder results in the creation of a stronger joint, it has an undesirable impact on the appearance of the object and causes an increase in rigidity. As for stronger joints, it is preferable to use a prepared adhesive film, which allows the conservator to achieve a joint strength of 140–350 N·m^{-1} with respect to the materials used. A good feel, the flow and sufficiently low rigidity of the fabric treated can still be maintained. In addition, when applying an adhesive film, the threads are well fixed in the weave preventing the risk of their possible fraying after cutting the edges of the base fabric. Use of an adhesive film can be complicated in case of large missing areas or sparse fabrics (due to possible gloss).

A high degree of reversibility of the adhesive examined has been successfully demonstrated in removal procedures using a compress followed by the rinsing of the adhered fabric with warm methanol (50 °C) performed on a suction table.

The procedures described in this study have to be carried out in accordance with general principles of occupational health and safety and the organic solvents tested (namely methanol) should be handled in a fume hood. Also, the workplace needs to be kept clean to avoid any unwanted contamination of the visible textile segments with adhesive powder or film residues.

The described methods of bonding textile materials with Lascaux Polyamid-Textil-Schweisspulver 5350 adhesive can be modified in various ways according to the needs of the specific object to be treated. For instance, when covering the front side of the object with crepeline or tulle or when working on finer details, it is advisable to use a heated spatula instead of an iron. Also, it is possible to adhere a textile to a non-textile base material or to prepare an adhesive film thicker than 10 μm if the object treated requires an adhesive joint of exceptionally high strength.

Author Contributions: Conceptualization, J.K.; methodology, J.K., M.Š. and K.D.; validation, J.B.V. and J.K., investigation, J.K., J.B.V., M.Š. and K.D.; data curation, J.K.; writing—original draft preparation, J.K.; visualization, J.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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