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Wallpapering earth walls – (Not) a good idea?!

Motivation

Pragmatism was the starting point for this research project undertaken by two medium-sized companies and two research institutes. How can one save at least one work step, and thus costs, when executing the final surface finish of drywall earth surfaces?

In conventional earth drywall construction, earth building boards are mounted on a wall or supporting studs, earth plaster mortar is applied to the joints, and sometimes also the entire surface, and plaster reinforcement mesh or fabric is worked into the still fresh plaster mortar. Once this base coat with embedded mesh has partially dried, a top coat of earth plaster is applied. If the final surface needs to have a specific colour, the surface may be painted with a clay-based paint. This multi-step process, which is important to ensure that drywall earth surfaces do not crack along the joints between the boards, makes earth drywall construction more labour and cost-intensive than conventional plasterboard walling. The research project therefore looked at alternative surface finishes that can be applied in one go to earth substrates and can compensate for cracking stresses in the joint areas as well as provide an attractive final surface – for example, wallpaper or non-woven wall coverings.

The idea of wallpapering earth walls is for many a sacrilegious proposition. An internet search for wallpapering earth walls (in German: "Lehm tapezieren") turns up a wave of indignation:

"That completely misunderstands the point of earth walls!"

"Wallpaper on earth walls? For God's sake NO!!"

"You shouldn't wallpaper earth walls. A horrible idea."

"A crime, but possible!"

"You can't wallpaper earth walls."

"Wallpaper won't stick to earth."

"Wallpapering an earth wall will rob it of many of its positive qualities."

"It'd be such a pity to cover earth plaster with wallpaper!"

"Wallpapering clay plaster is possible, but paradoxical!"

"Wallpapering earth surfaces impedes the properties of the clay plaster!"

"The positive characteristics of earth – regulating air humidity or binding odours – are, unfortunately, minimised by wallpaper."

"In general, wallpaper paste is applied liberally to clay plaster – 'the more the merrier'. The sealing effect is, however, correspondingly 'thorough'."

"Clay plaster walls should not be wallpapered as that prevents the clay plaster from having a beneficial effect."

"Normal plastic dispersions hinder the moisture-equalising properties of the clay plaster." (Ökotest/Volker Lehmkuhl)

Alongside these opinions from the ranks of earth building users, the idea of wallpapering earth walls is equally frowned upon in architecture circles. However, a few constructive viewpoints are put forward by earth building professionals:

"... as with any plaster, it is also possible to wallpaper over smooth, low-texture earth plasters. Prior to wallpapering, a primer or paint should be applied to the earth plaster surface." (conluto)

Table A.1 from DIN 18947:2018-12 – Water vapour sorption classes of earth plaster mortars

Water vapour sorption class	Water vapour sorption according to A.2.2 after				
	½ hour g/m²	1 hour g/m²	3 hours g/m²	6 hours g/m²	12 hours g/m²
WS I	≥ 3.5	≥ 7.0	≥ 13.5	≥ 20.0	≥ 35.0
WS II	≥ 5.0	≥ 10.0	≥ 20.0	≥ 30.0	≥ 47.5
WS III	≥ 6.5	≥ 13.0	≥ 26.5	≥ 40.0	≥ 60.0

"Earth plaster walls are not usually wallpapered. In most cases, users wish to maximise the sorptive effect of the earth plaster for regulating air humidity and choose earth plaster for its aesthetic appearance. But if wallpaper is desired, normal wallpapers should be used, not plasticised vapour-retardant wallpapers." (DVL Consumer Information)

The project partners were, of course, also aware of these various arguments, and cited them in their application for research funding, albeit as a challenge that needed to be overcome: *"... conventional wallpapers hinder the sorption process [...] Wallpaper paste and plastic dispersions seal the pore structure [...] and noticeably reduce the positive moisture-regulating effect of earth building materials."*

Objective

The aim of the research project was, therefore, to develop textile wallpapers that are specifically designed for applying to earth substrates. These should act simultaneously as a flat final wall covering and a reinforcement system that can bridge any cracking in underlying surfaces (e.g. walls and ceilings) made of earth building materials. This approach has the potential to save several work steps, especially by obviating the need for a reinforcing plaster layer on drywall earth substrates. At the same time, the material and its application should impact as little as possible on the sorption properties of the earth substrate.

The project

When we started our research, it was very evident that everyone agreed that wallpapering earth wall surfaces is taboo but that there was very little actual literature or references to reliable data to back up this assertion.

To investigate the validity of the many, unanimous claims, the MFPA Materials Research and Testing Institute in Weimar set out to develop new methods for characterising the structural behaviour of the material, especially at the interfaces between earth, paste and wallpaper. In addition, existing methods for characterising sorption behaviour, and thus for investigating sorption barriers, were to be developed further to improve the reliability of their findings and substantiate or refute the claims made. Alongside these material investigations, the participating project partners also focused on practical problems of the application, use and usability of textile and paper-based wallpapers.

The project investigated the influence of four commercially available wallpaper pastes:

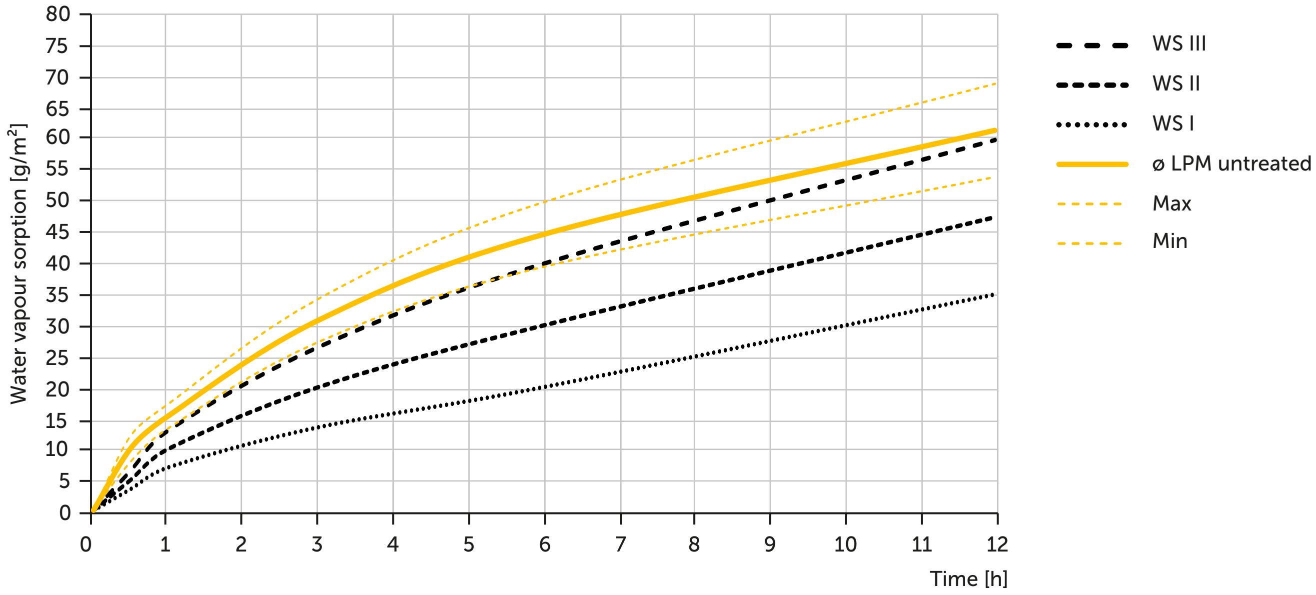
a) Wallpaper paste with methyl cellulose
b) Wallpaper paste with methyl cellulose, additives and synthetic resin powder
c) Wallpaper paste with methyl cellulose, starch ether and synthetic resin powder
d) Synthetic resin dispersion textile adhesive

In terms of wall coverings and application systems, three commercially available products were examined:

e) Medium grain woodchip wallpaper
f) Non-woven renovation fabrics
g) Professional non-woven renovation fabrics

In addition, various textile fabric developments devised as part of the research project with and without a backing coating were also investigated. For all investigations, a clay plaster mortar – DIN 18947 – LPM 0/2 f – S II – 1.8 was used as the substrate.

The test method used corresponds to the procedure described in DIN 18947:2018-12 Appendix A.1 for determining water vapour sorption, in which the relative air humidity is increased from 50 (±5) % to 80 (±5) % at a constant temperature and the corresponding increase in mass of the pre-conditioned test specimen is measured over the course of 12 hours. The water vapour sorption classes WS I to WS III – also



01 Water vapour sorption behaviour (mean value of 20 individual measurements) for untreated earth plaster mortar samples with minimum and maximum values (yellow) compared against the water vapour sorption classes WS I to WS III (black dashed lines)

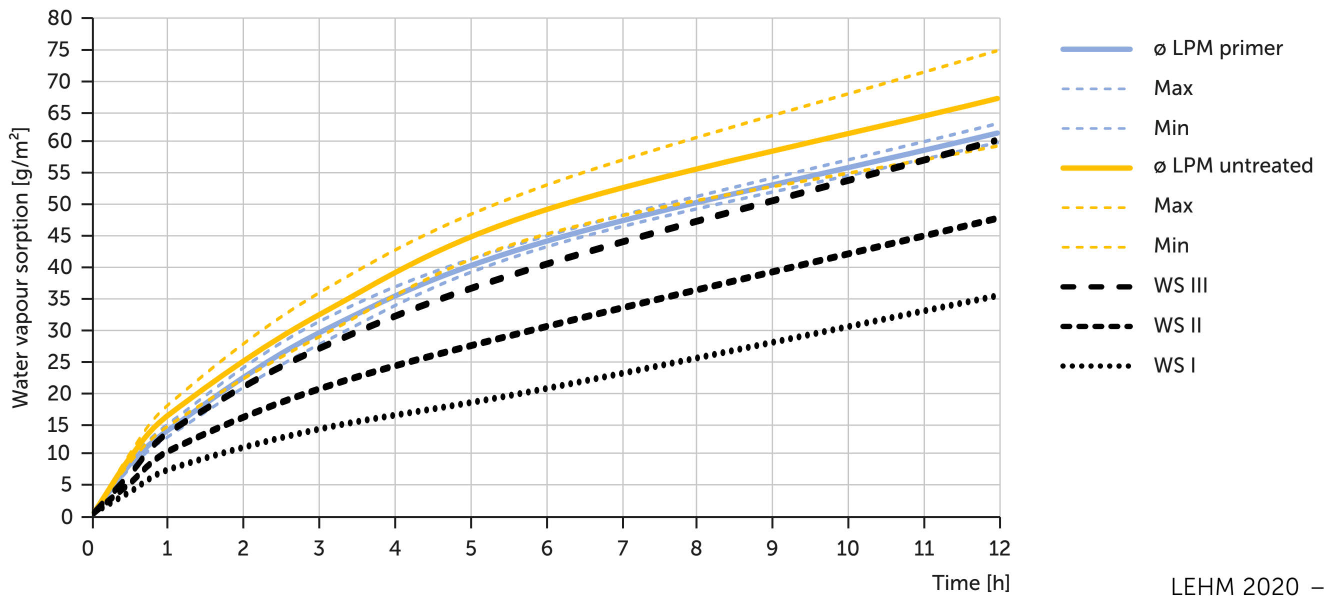
described as requirements in DIN 18947 – were used to classify the test results. Earth plaster mortars that conform to the standard must qualify as at least water vapour sorption class WS I.

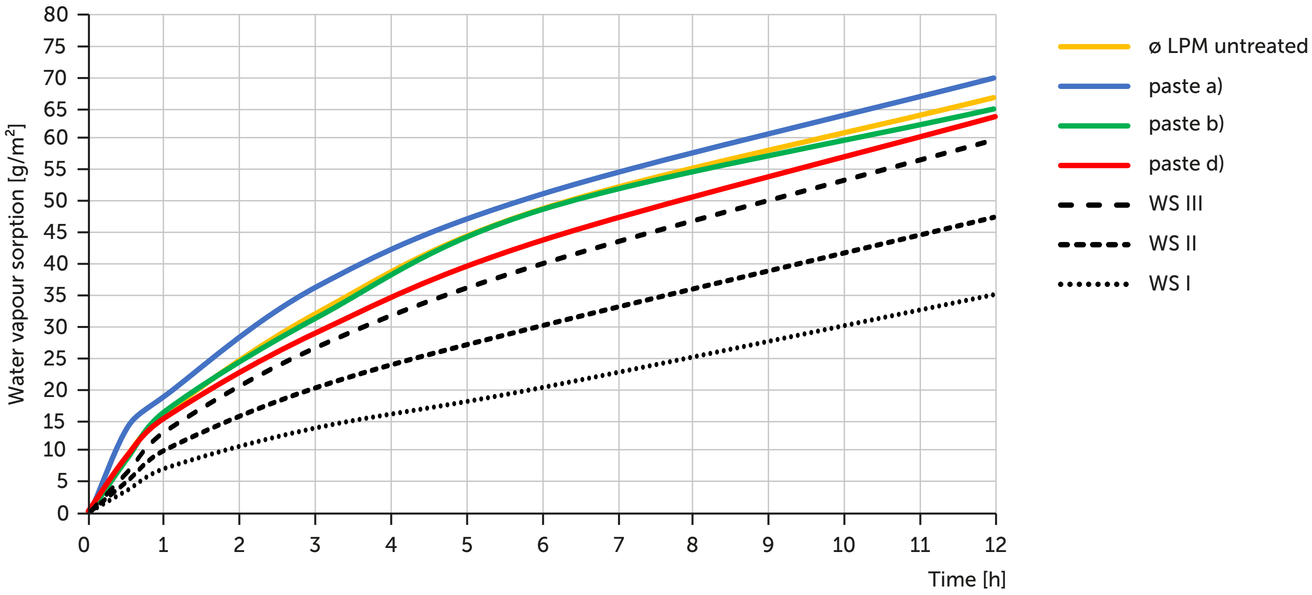
The development of the sorption behaviour was investigated at several stages that correspond relatively closely to the process of applying wallpaper in practice:

1. Investigation of the sorption capacity on untreated earth plaster mortar surfaces
2. Application of diluted wallpaper paste to the earth plaster mortar surfaces (1:1 paste:water dilution)
3. Application of undiluted wallpaper paste on the pre-treated earth mortar surfaces
4. Application of wallpaper/fabric wall covering with paste to the pre-treated earth mortar surfaces

First, the water vapour sorption behaviour of the untreated earth plaster mortar surfaces was determined (Step 1). To this end, 20 individual test surface areas of 20 × 20 cm^2 each were examined according to the above multi-stage matrix.

02 Water vapour sorption behaviour (mean value of 4 individual measurements) of pre-pasted (blue) and untreated (yellow) earth plaster mortar samples with indication of the minimum and maximum values and the water vapour sorption classes WS I to WS III





03 Water vapour sorption behaviour of the test surfaces with pre-glued and pasted (blue, green, red) test surfaces and the untreated (yellow) clay plaster mortar samples as well as the water vapour sorption classes WS I to WS III

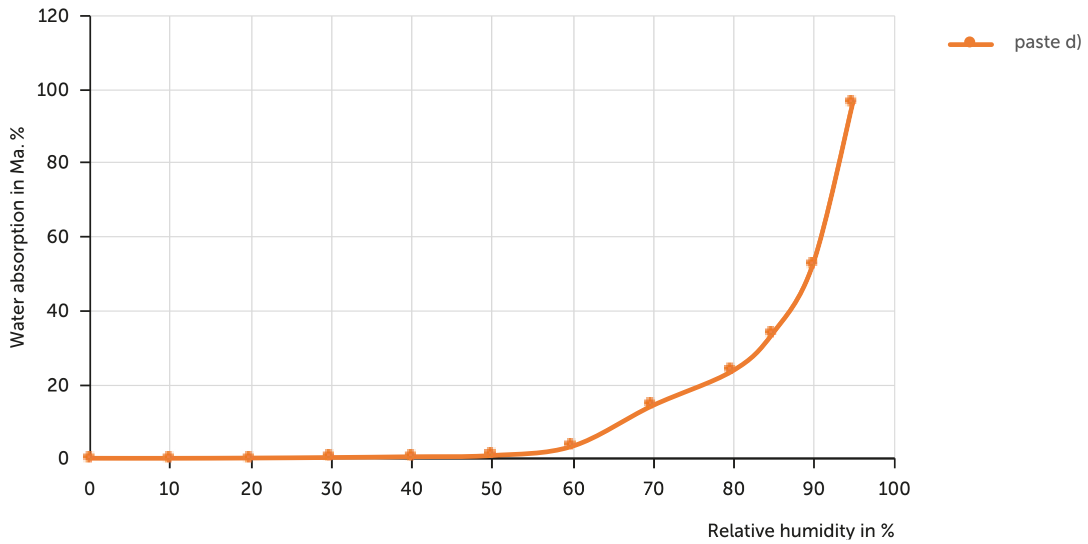
On average, the earth plaster mortar fulfils the requirements of water vapour sorption class WS III, although as the measuring time increases, the values begin to scatter increasingly, falling below the requirements of WS III after approx. 6 hours. The scattering range corresponds approximately to the range of a sorption class. Possible reasons for this include material-related inhomogeneities within the earth plaster mortar itself, the sample preparation and production, as well as the inability to repeat the testing procedure to the same high degree of precision each time (Figure 1).

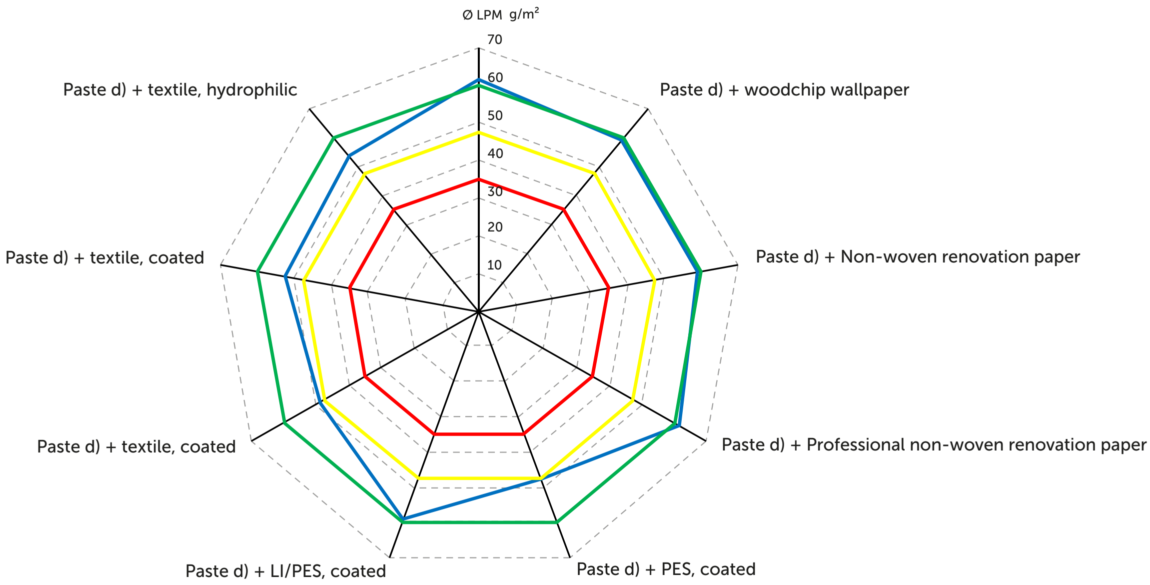
The next step of the investigation (step 2) is the pre-application of diluted wallpaper paste which serves to prime the substrate, reducing and equalising its suction effect. In practice, this helps make the subsequent step more predictable by ensuring that the actual wallpaper paste applied in the next step dries evenly and the wallpaper can adhere equally across the entire surface. At the same time, it consolidates the substrate, especially when it is prone to sanding.

In the following investigations of the step-by-step application of paste and wallpaper to the test surfaces, the measured values of the respective individual samples were compared directly with each other. As a result, the number of measured values is reduced.

By using only four individual measurements, the mean value of the untreated clay plaster mortar sample after 12 hours improves by 5 g/m^2, while the scat-

04 Sorption isotherm of paste d)





05 Comparison of the sorption activity (12-hour values) of untreated earth plaster mortars (above) with different application systems based on paste d)

tering of the measured values remains approximately the same. After application of the diluted paste, two effects become apparent. On the one hand, the sorption capacity is reduced on average by between 1 and 5 g/m² over the course of the test period. And on the other, the scattering of the measured values decreases significantly. The results show clearly that the priming of the surface achieves the desired equalisation of the wallpaper substrate. Here we have used the mean value of all four examined wallpaper pastes (Fig. 2).

In terms of the influence of the various types of paste a) to d), we can see that paste a) based purely on methyl cellulose has either no effect or a slightly positive effect on sorption behaviour, pastes b) and d) with methyl cellulose, additives and synthetic resin powder or a pure synthetic resin dispersion have a slightly negative effect, and paste c) with methyl cellulose, starch ether and synthetic resin powder has a clear negative effect. For this reason, paste c) was not used any further in the subsequent investigations.

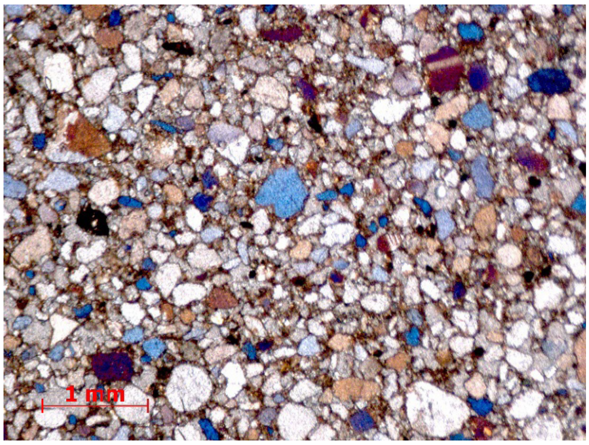
In step 3, the now-primed test surfaces were coated with the respective undiluted paste (prior to application of the wallpaper) in order to show the influence of applying paste. A further deterioration of the sorption behaviour was expected as a product of the paste "sealing" the earth plaster mortar surface.

Contrary to the expectations outlined earlier, the tests on the three pastes after a second application of undiluted paste show that paste a) (methyl cellulose) has an improving effect on the sorption behaviour, while pastes b) and d) (both with synthetic resin) show no to slightly negative effects on the sorption behaviour (Fig. 3). In view of these unexpected test results, the absorption of water vapour over a moisture range of 0 to 95% relative humidity was determined with the help of Dynamic Vapour Sorption (DVS) conducted on the pure paste d) made of synthetic resin dispersion. Glass plates were coated with the paste, which then dried at room temperature and were examined in the DVS apparatus (Fig. 4).

This DVS test shows that even pastes with synthetic resin dispersion are clearly able to absorb water vapour from a relative humidity of 50% upwards, and even as much as 100% of their dry mass at a maximum humidity of 95%. These results, however, only partially explain the minimal effect of pastes on sorption behaviour. The paste sorbs water vapour from a relative air humidity of 50%, which means that on the surface of the clay plaster mortar samples there is a layer of paste enriched with water molecules that can be transported further into the underlying earth substrate. The tests provide no indication, however, of how this happens, whether by capillary conduction or convection.

In the final step, various combinations of pastes and wallpapers or specially developed textile fabrics with and without coatings were investigated. Figure 5 shows the sorption activity after 12 hours using the

06 Polished section of a composite specimen of earth plaster, textile fabric, glued on flat with cellulose paste



07 Thin section, 35 µm thick, showing parallel polarizers, a little binder (clay constituents), high quartz content and high open porosity

example of the synthetic resin-dispersive paste d) in the form of a network diagram.

The network diagram shows the minimum 12-hour values for the water vapour sorption classes WS I (red), WS II (yellow) and WS III (green) according to DIN 18947 in g/m² for orientation. The mean 12-hour value of all tested earth plaster mortar (LPM) zero samples is 61.56 g/m² (Ø LPM). The results show in particular that:

5. All applications with commercially available wallpaper materials, such as woodchip wallpaper and regular and professional non-woven renovation fabrics have little to no effect on the sorption behaviour of the earth plaster mortar.
6. The specially developed textile fabric coverings with backing coatings (to improve the opacity) all have a more obvious effect on the sorption capacity with the exception of the wall covering with natural fibres (paste d) + LI/PES coated). Nevertheless, all the special coverings still fulfil the requirements for water vapour sorption class WS II.

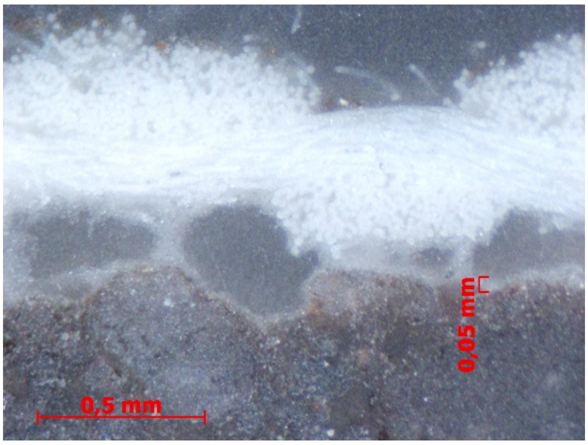
These on the whole positive results with respect to the impact of wallpapers on the sorption behaviour of earth plaster mortars cannot be fully explained, as described above. In particular, the water vapour transport through the individual layers and interfaces between them still requires further investigations.

To this end, a method of thin-section preparation was developed. The production of polished and thin sections is considered problematic because the clay minerals within clay, especially the three-layer minerals (montmorillonite, illite), store water in their structure that is very difficult to expel in "normal" drying processes. The water remaining in the crystal bond could have a structure-destroying effect during water-free preparation with resin. The thin and polished sections obtained with the newly developed method now provide insight into the structural matrix of the earth plaster mortar and, for the first time, into the interfaces and layers of the applications of paste and wallpaper or textile fabrics.

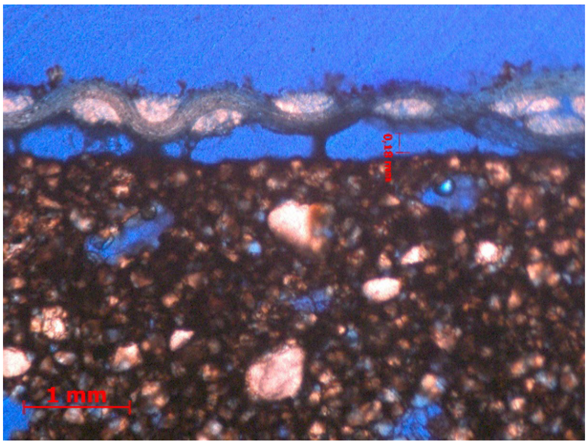
Figure 6 shows the polished section of a composite specimen fixed with resin. Both the earth plaster base as well as the bond with the covering (here a textile fabric) could be prepared non-destructively. Thin sections provide a detailed view of the structural matrix of the base body of clay plaster mortar. Polarisation was used to visually bring out the high aggregate and porosity content and the surprisingly low clay content (Fig. 7). This is of an earth plaster mortar that fulfils water vapour sorption class III.

To identify why the paste has such small influence on the sorption behaviour, the interfaces between the earth plaster mortar, paste and wallpaper or fabric was examined under the microscope.

The images of the polished section and thin sections under the microscope shown in figures 8 and 9 show the structure at the boundaries between the layers and the bond between the earth plaster, paste and wallpaper. In contrast to the assumptions voiced at the outset of the project, the bond between the two layers does not form a flat, continuous barrier layer of paste, e.g. a film on the earth plaster mortar surface. Instead the paste, as it dries, forms finely distributed micro-web bridges between the two interfaces. This explains the continued good sorption behaviour



08 Polished section: Detail of the surface zone showing the textile wallpaper, paste a) and earth plaster mortar.



09 Thin section: Detail of the surface zone showing the textile wallpaper, paste d) and earth plaster mortar.

of the wall even after the application of paste and wallpaper. The paste does not, as originally thought, seal the surface of the highly sorptive earth plaster, but forms finely distributed web bridges between the two interfaces as it dries, which does not hinder water vapour transport from the room to the earth plaster mortar. Furthermore, the hydrophilic behaviour of the paste with increasing air humidity has a further positive effect on the sorption activity of the earth plaster mortar (catalyst effect). Both mechanisms mean that wallpaper and wallpaper pastes do not significantly impede the sorption process of earth substrates.

Conclusion

Contrary to popular opinion, wallpapering earth wall surfaces can be a good idea. Commercially available wallpaper pastes and wallpaper or fabric wall coverings have a negligible negative effect on the sorption behaviour of earth substrates provided they are vapour permeable. The results of the investigations into the sorption behaviour of earth plaster mortars with wallpaper/fabric coverings carried out as part of this research project have helped analyse and shed light on the reasons and underlying mechanisms for the first time.

To conclude, therefore, I would like to share a quotation attributed to the English philosopher Bertrand Russel: *"Even if everyone agrees, everyone can be wrong."*

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