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SUITABLE RENDERINGS FOR THERMAL INSULATING SINGLE-LEAF CLAY MASONRY WALLS

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Abstract

Rendered single-leaf clay masonry walls are a very common construction method for exterior walls in many parts of Germany. The development of thermal insulating clay units with an improved thermal resistance raised the question if special measures on site concerning the application of the render are necessary.

The Arbeitsgemeinschaft Mauerziegel as the research association of the German clay unit producers together with some major German mortar producers initiated extensive investigations into the relevant properties of clay masonry units, renders and their combination. The results that are reported below lead to an improved manual (Arge Mauerziegel et al. 2002) for the building site.

Key Words

Clay unit masonry, lightweight rendering

1 Introduction

The development of thermal insulating clay units raises from time to time the question if the renderings available on the market are still suitable for that type of masonry or if additional measures have to be taken to prevent the renders from cracking.

In the early 1990s, there was a need for the development of lightweight renders for thermal insulating masonry, described in the German standard DIN 18550-4 (1993) as the then available renders had insufficient deformation properties and lead to severe cracking problems on site. The relevant requirements for lightweight renders were more or less transferred to EN 998-1 (2003).

The development of clay units for single leaf walls with thermal conductivities as low as λ_R = 0,11 W/(mK) raised that question again in 1999. Investigations (Zeus and Knödler 2001) were carried out to clarify the relevant properties of the rendering mortars and to give hints to the mortar industry for necessary improvements.

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2 Test programme

The material properties most relevant for the crack resistance of rendered masonry were identified as the tensile strength and modulus of elasticity of the unit shells, the water absorption of the shells, the modulus of elasticity of the applied renders on the wall, which is in most cases related to their compressive strength and the time dependent shrinkage of the renders on the wall.
The test programme in (Zeus and Knödler 2001) covered in addition a number of other properties that might be taken into account. It covered three different thermal insulating clay units – two optimised units and one standard unit, see fig. 1 -, six rendering mortars – two mortars according to DIN 18550-4 and four new “super lightweight” developments of different producers - and their combination. Table 1 gives some basic properties of units and rendering mortars. Table 2 gives an overview of the tests.

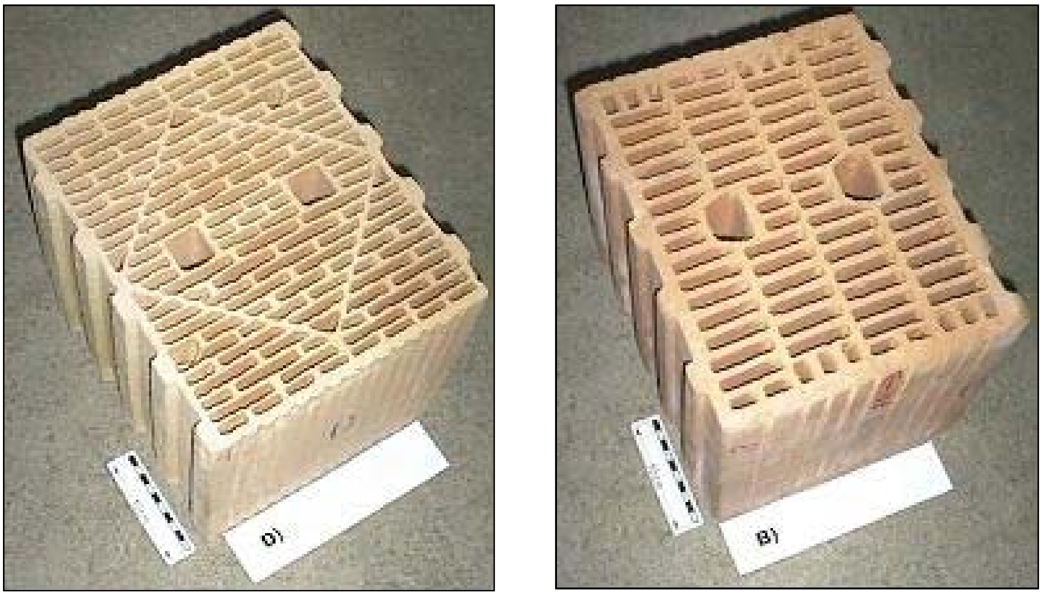

Figure 1 Thermal insulating clay units; left λ_R = 0,11 W/(mK), right λ_R = 0,16 W/(mK)

Table 1: Material properties from *(Zeus and Knödler 2001), Compressive strength and dry density (DIN 105); thermal conductivity(DIN 52611); compressive strength and dry density of rendering mortars (DIN 18555-3); free shrinkage (DIN 52450)*

Units	Compressive strength [N/mm²]	Dry density [kg/m³]	Thermal conductivity [W/(mK)]	Thickness of shells [mm]
Optimised 011-1	8,4	0,60	0,11	10
Optimised 011-2	10,7	0,59	0,11	10
Standard 016	21,7	0,81	0,16	14
Rendering mortars	Compressive strength [N/mm²]	Dry density [kg/m³]	Free shrinkage – end value [mm/m]	
LW (LP-M)	3,5	1,20	1,4	
LW (LP-I)	4,3	1,21	1,2	
SLW (SLP-I)	1,9	1,10	0,9	
SLW (LP-F)	1,2	0,86	0,7	
SLW (SLP-M)	2,2	0,87	2,3	
SLW (SLP-T)	3,6	0,81	1,9	

Table 2: Test programme (Zeus and Knödler 2001)

Clay unit properties	Rendering mortar properties	Properties of rendering mortar hardened on the wall	Properties of masonry
dimensions, dry density, compressive strength in vertical and horizontal direction, thickness of webs and shells, flatness and plane parallelism, tensile strength, shear strength, modulus of elasticity of the unit, modulus of elasticity and tensile strength of shells, deformation due to moisture and temperature, water absorption	bulk density, grading curve, fresh mortar density, consistency, dry density, flexural and compressive strength, modulus of elasticity, initial rate of absorption, water vapour permeability, deformation due to moisture and temperature	shrinkage, adhesive tensile strength, compressive strength, modulus of elasticity, tensile strength	compressive strength, modulus of elasticity, shear strength

3 Test results

3.1 Tensile strength of the shells of vertically perforated clay units

The tensile strength of the shells, tested in vertical direction is given in fig. 2. The values from (Zeus and Knödler 2001) are compared to values determined at the beginning of the 1990s (Schubert and Schmidt 1990). The comparison shows that, due to continuous improvements in production technology, the tensile strength of the shells of optimised thermal insulating clay units is in the same range as the values from the early 1990s. Nevertheless, the value for the 2001 standard unit was significantly higher.

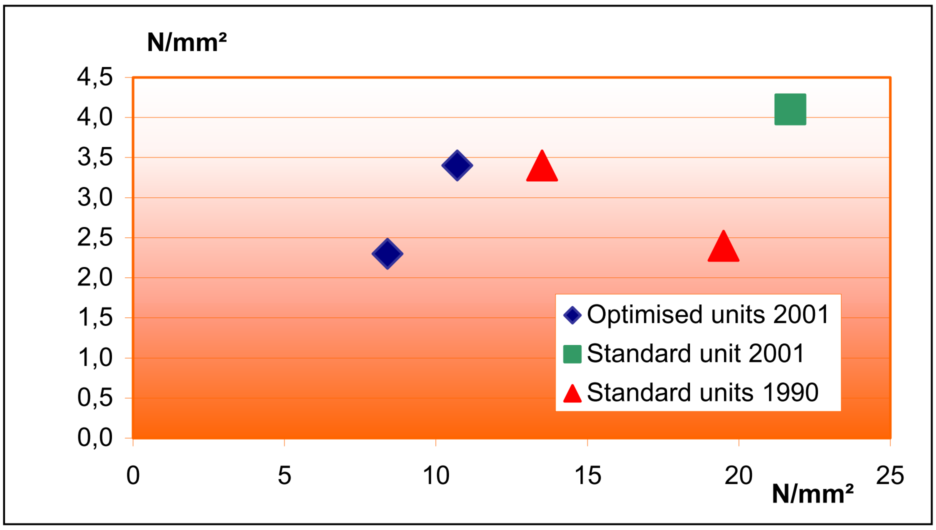

Fig. 2: Tensile strength of the shells of vertically perforated clay units over compressive strength of these units

3.2 Compressive strength of rendering mortars on the wall

Although the requirements in the standards are related to tests acc. to EN 1015-11, where the mortar is tested without contact to the unit, the relevant strength is the one on the wall. It can be determined with the test method described in DIN 18555-9. This strength can be significantly influenced by the water absorption of the unit. The compressive strength of the different renders on the wall was significantly different, but all renders met more or less the requirement for lightweight renders in the German standard, see fig. 3. A significant difference of the compressive strength on optimised units (011) and the standard unit (016) was not observed.

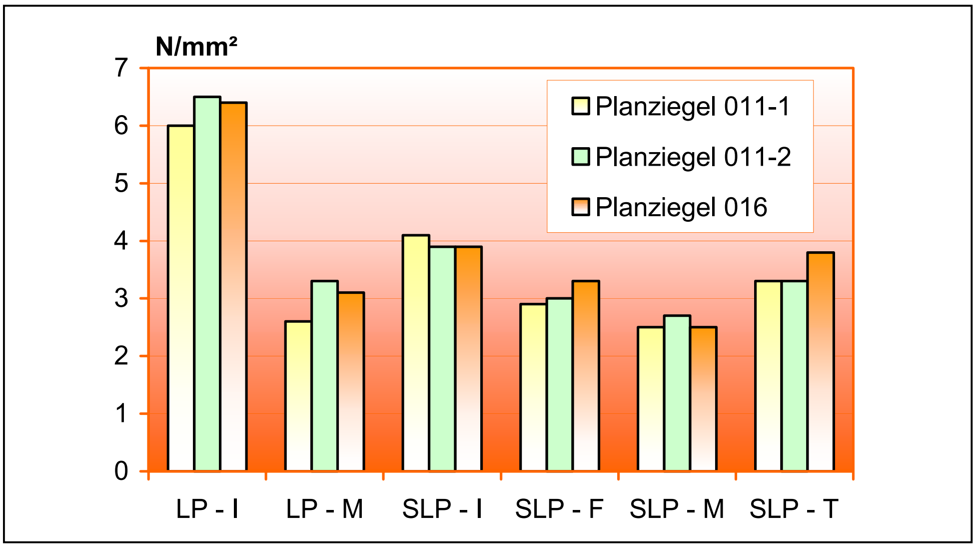

Fig.3: Compressive strength of rendering mortar hardened on the wall

3.3 Modulus of elasticity of rendering mortars and unit shells

A basic rule in the German Render Standard DIN 18550-1 requires that the modulus of elasticity of renders has to be lower than the values of the unit, in case of vertically perforated clay units the value for the unit shells. Figure 4 shows the determined relationships between render and shell values. For the basic combination of the standard unit 016 with mortar LW (LP-M) the relation is just below 50%. For this combination, long time experience of a sufficient crack resistance exists in Germany. As all other relationships determined in (Zeus and Knödler 2001) were in that range or – in the case of the new “Super” Lightweight renders even much lower – it can be concluded that modulus of elasticity of renders is not negatively influenced by clay units with optimised thermal conductivity.

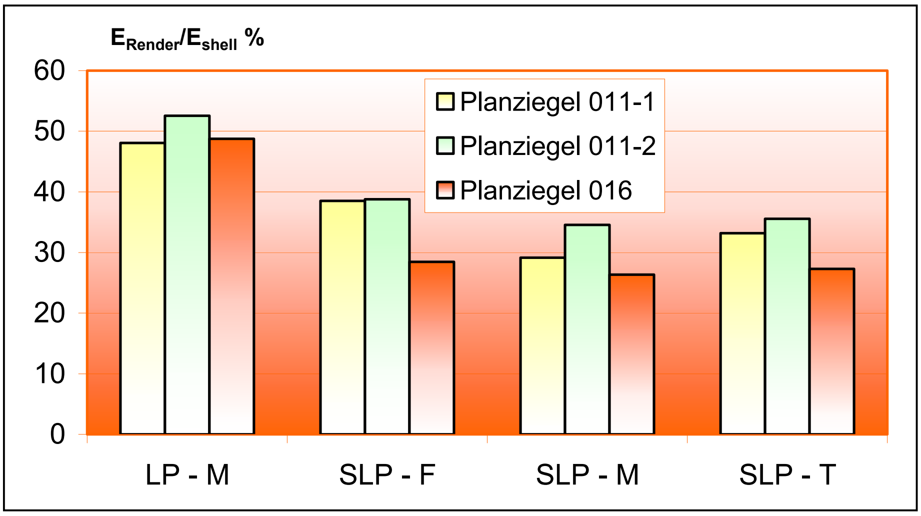

Fig.4.: Relation of E-module Rendering mortar vs. shell of the units

3.4 Shrinkage of rendering mortars on the wall

The shrinkage of the rendering mortars on the wall reached more or less an end value after approx. three months. A significant difference of the total shrinkage values was observed between mortars on standard units and mortars on optimised units, see fig. 5. This difference can be explained by the reduced reinforcing or restraining function of the optimised units and is especially relevant for the new renders. As all values are higher than the usual cracking strains of lightweight renders, which are in a range of 0,2 to 0,3 mm/m (Schubert and Schmidt 1990) this point has to be taken seriously into account.

The German building tradition for single leaf masonry foresees a two layer rendering with a first layer of render of 15 to 20 mm thickness and an additional layer of approx. 3 to 5 mm thickness, which is applied after a certain shrinkage time for the first layer. As the overall shrinkage values of the renders are rather high, a sufficient time between the application of the two layers has to be foreseen to avoid cracks on the wall surface.

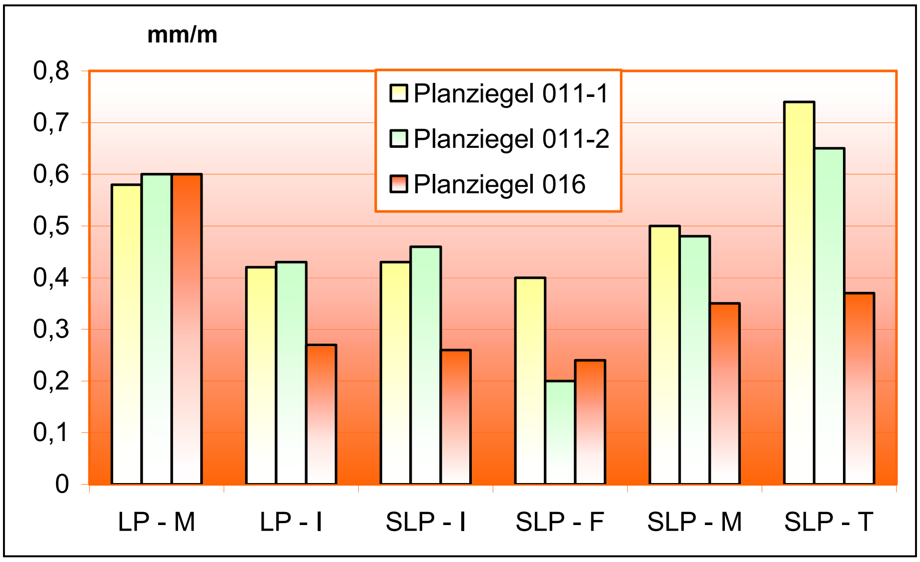

Fig.5: Total shrinkage values of rendering mortars on the wall

The existing experience over the last decades has lead to a rough estimate of 1 day waiting time per mm thickness of the first layer and by no means less than 14 days. Fig. 6 shows the shrinkage values for renders on the wall with the first measurement made at an age of 14 days. It is obvious that all values are significantly reduced compared to the total shrinkage in fig. 5 and in addition below the range of the cracking strain of lightweight renders. A second, very important aspect is the very small difference of the shrinkage values for the same render applied on different units. This means, that the effect of the reinforcing action of the units exists mainly in the first 14 days. If the second layer is applied after 14 days, no difference between standard unit masonry and optimised thermal insulating masonry can be found.

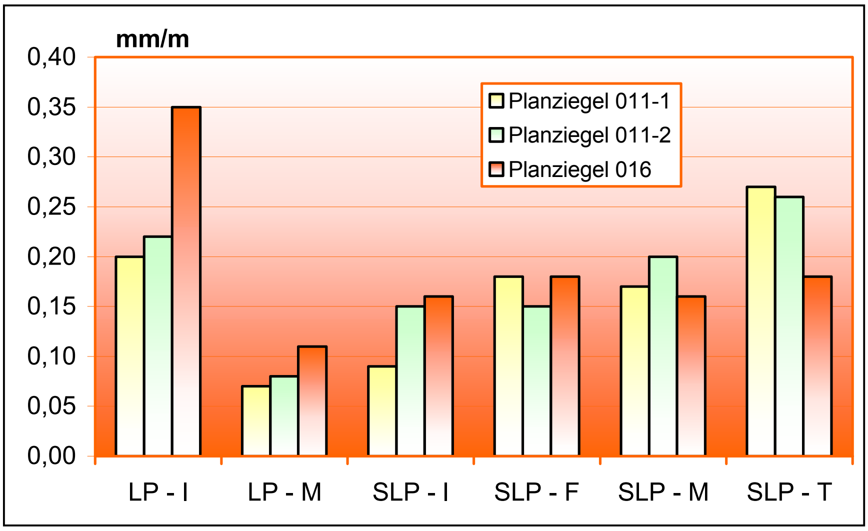

Fig.6: Rest shrinkage of rendering mortars after 14 days of hardening on the wall

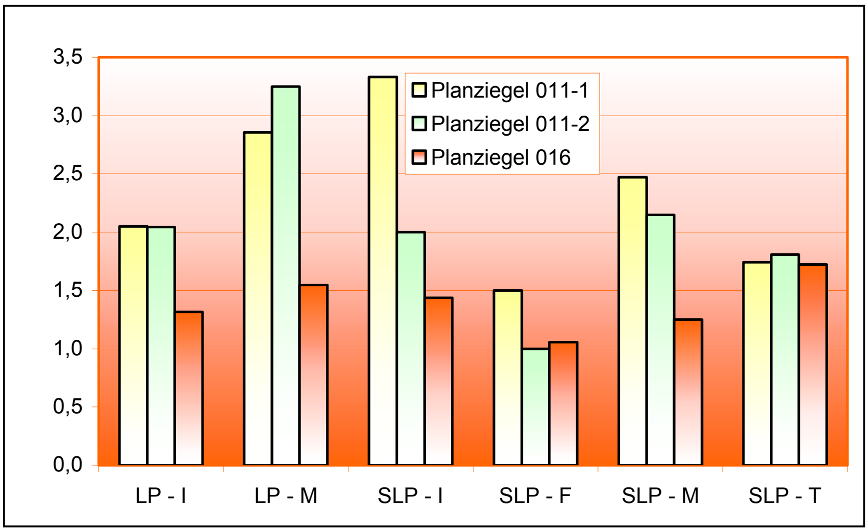

Fig.7: Relationship of shrinkage values of rendering mortars on the wall; measurement starting after 7 days vs. measurement starting after 14 days

Due to the aims to reduce construction time, this valuable experience has in some cases been ignored in the past. A reduction of the waiting time from 14 to 7 days has nevertheless a significant influence on the shrinkage values as well as on the effect of the unit type on these values. Fig. 7 shows that for the tested products, the shrinkage values were significantly increased, in most cases in a range between 50 and 300%. This obviously leads to an increased probability of crack formation on rendered walls, and should therefore be avoided unless improved renders are available.

3.5 Deformation due to moisture and temperature changes

Some so far unexplained crack patterns on rendered masonry may occur in very few cases after some years, at a time, where the shrinkage of the mortar has definitely reached its end value. This problem might be caused by inappropriate deformation properties of rendering mortar and units in multiple natural wetting and drying cycles. Tests have therefore been carried out to determine thermal and moisture deformation coefficients. The values for thermal deformation determined in a range between + 20°C and + 60°C at a constant relative humidity of 65 % are given in fig. 8 for the different units and mortars. All values were in the known range of properties, without significant differences between units and rendering mortar. The moisture deformation was determined for a range between 30 % rH and 90 % rH at a constant temperature of 20°C. The values given in fig. 9 show a significant difference between unit and rendering mortar properties. While unit values are rather negligible, mortar properties vary in a wide range and reach in some cases significant values. A reduced value for this property should be one additional factor to be taken into account in future mortar developments.

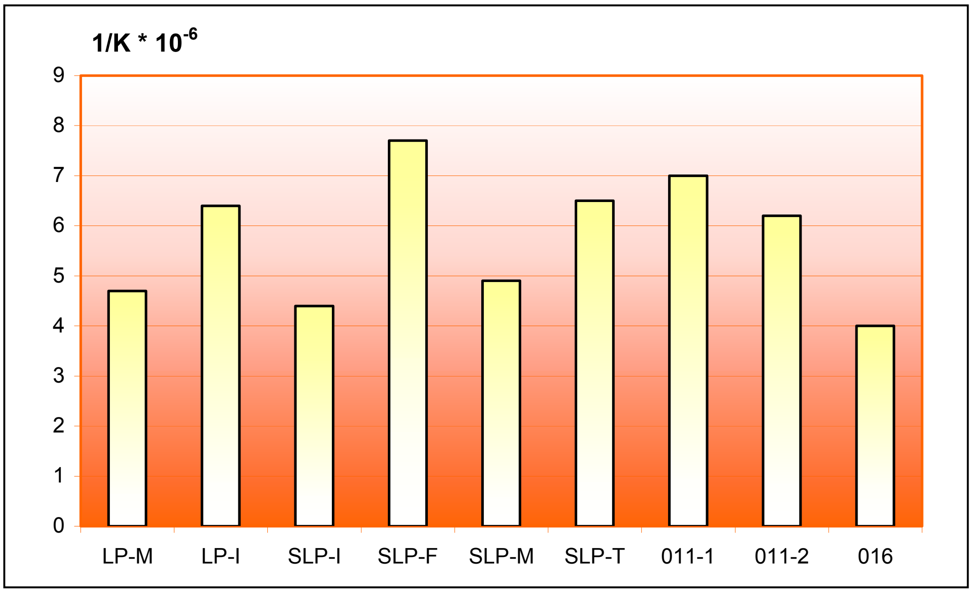

Fig. 8: Coefficient of thermal deformation determined at 65 % rH

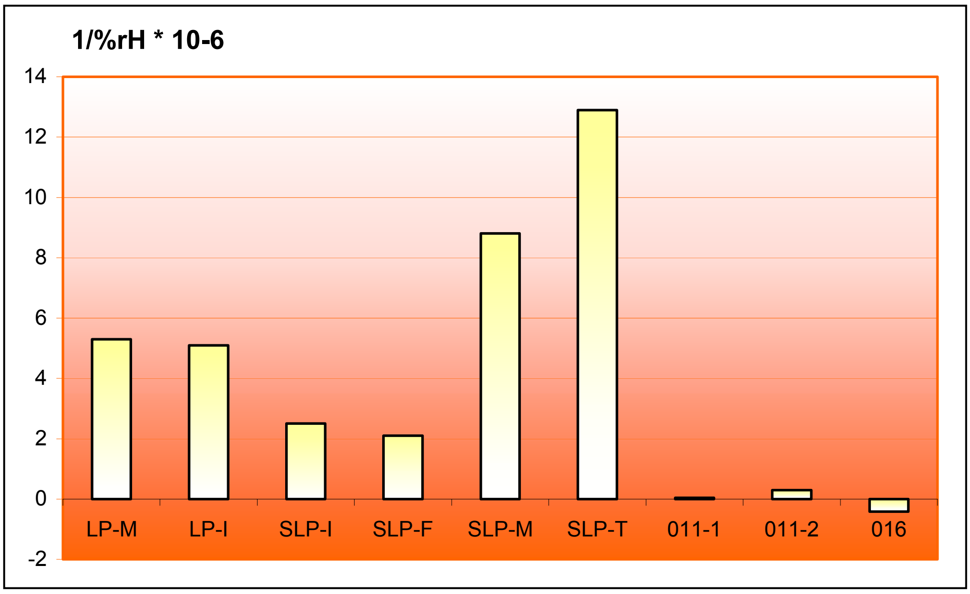

Fig. 9: Coefficient of moisture deformation determined at 20°C

4 Conclusions

The extensive test programme in (Zeus and Knödler 2001) verified that common lightweight renders acc. to the requirements in DIN 18550-4 are still suitable to produce a crack resistant single leaf clay unit masonry wall without any additional measures. The German Mortar Industry has nevertheless provided in the meantime optimised lightweight rendering mortars that fit the requirements for these walls even better. In any case, the application rules, especially the necessary waiting time between the application of the first and second layer have to be followed strictly for the currently available rendering mortars for optimised thermal insulating clay unit masonry. These findings were published in a manual (Arge Mauerziegel et al. 2002) for the building site, which is widely spread in Germany. An extended version of the test results has been published in (Knödler, Meyer and Zeus 2002).

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