LONG-TERM BEHAVIOUR OF PUR-GLUED CLAY BLOCK MASONRY

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SUMMARY

Because of inexistent experience regarding the evaluation of long-term impacts on PUR-glued clay block masonry newly conceived tests on mini-specimens are accomplished. Resistance against hydrolysis, ageing and alternating climate is investigated by destructive testing methods. Storage in water and alternating climate seems to have a negligible influence on flexural strength perpendicular to the bed joint and initial shear strength. With regard to ageing no definite conclusion is possible due to high scattering and an insufficient number of samples probably.

PREFACE

Traditional thick or medium bed brickwork, usually a hand-made conglomerate of clay blocks and cement-lime mortar, involves some inherent disadvantages. Its manufacture is time-consuming. Building moisture in combination with a too short drying-up period may cause building physical damages. Grouting at low temperatures is restricted. Accuracy depends on the mason's proficiency. Last but not least bricks-and-mortar-built prefabricates have still not achieved a breakthrough primarily due to their long curing time. A reduction of joint thickness to a couple of millimetres and an increase in the size and geometrical precision of blocks led to thin bed brickwork. In spite of this further development still some unfavourable characteristics remain, for example the long hardening time.

Precision clay blocks and the substitution of mineral cement-lime mortar with organic joint components like one-component polyurethane foam (1C PUR) and two-component polyurethane adhesive (2C PUR) have resulted in glued masonry (see Figure 1). For purposes of identification, these combinations are termed "alternative clay block wall systems".

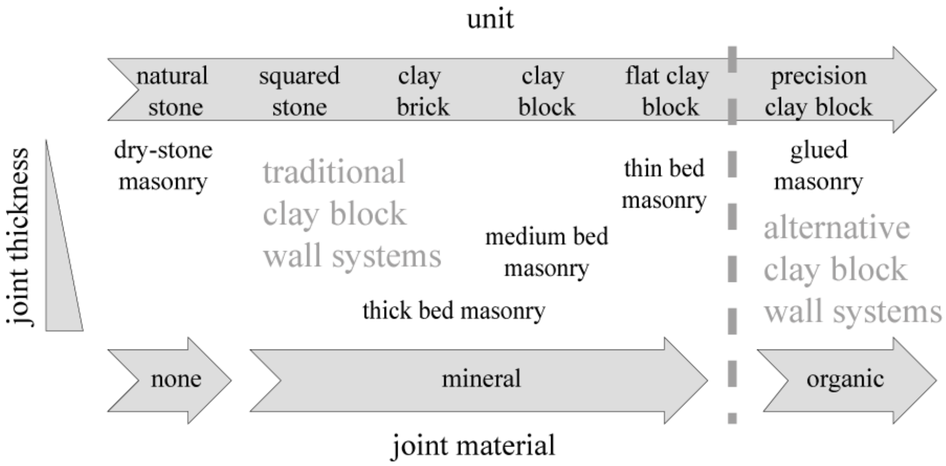


Figure 1. Evolution matrix of brickwork

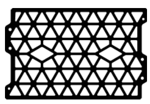
Long-term tests are not as usual within masonry testing as they are in the context of plastics testing. With organic joint components like 1C PUR and 2C PUR such examinations become essential. The present contribution is focused on these experiments.

A SHORT INTRODUCTION TO THE SYSTEM ITSELF

Block components

Dimensional stability – especially as to height, evenness and plane parallelism – is the outstanding property of precision clay blocks and a basic necessity for the quality of glued joints. Therefore some attributes of both commonly used units for PUR-glued clay block masonry are shown in Table 1. Whereas RB 25 VZ FW PLAN is used for in-situ masonry as well as for prefabricated masonry walls, the use of PTH 25-38 M.i PLAN is restricted to site masonry.

Table 1. Geometrical block characteristics

	RB 25 VZ FW PLAN	PTH 25-38 M.i PLAN
hole pattern		
length l_u	376.5 ± 0.2 mm	372.7 ± 0.4 mm
width b_u	250.5 ± 0.2 mm	249.1 ± 0.5 mm
height h_u	250.1 ± 0.0 mm	249.1 ± 0.1 mm
evenness $\Delta h_{ev,max}$	-0.8 mm	-1.0 mm
Δh_{ev}	-0.3 ± 0.1 mm	-0.8 ± 0.1 mm
plane parallelism $\Delta h_{pp,max}$	0.7 mm	1.0 mm
Δh_{pp}	0.4 ± 0.0 mm	0.5 ± 0.1 mm
quantity n	27	22 ($n_{ev} = n_{pp} = 10$)
level of confidence S	95 %	95 %

Joint components

Generally adhesive are non-metallic compounds that connect two items by adhesion and cohesion. PUR are addition polymers consisting of di- or polyfunctional hydroxyl compounds, for example diols, and di- or triisocyanates (see Figure 2).

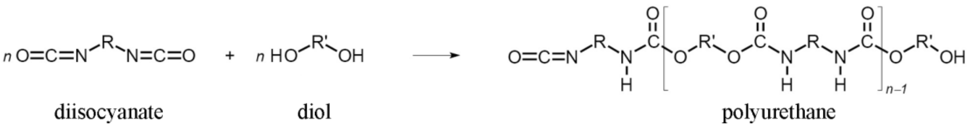


Figure 2. Synthesis of polyurethane (Breitmaier and Jung 2005)

According to (Habenicht 2006) PUR adhesive are classified as reactive adhesive. Depending on the starting substances this reaction produces either linear, ramified or cross-linked chains as shown in Figure 3. Therefore PUR adhesive cover a wide range of mechanical properties.

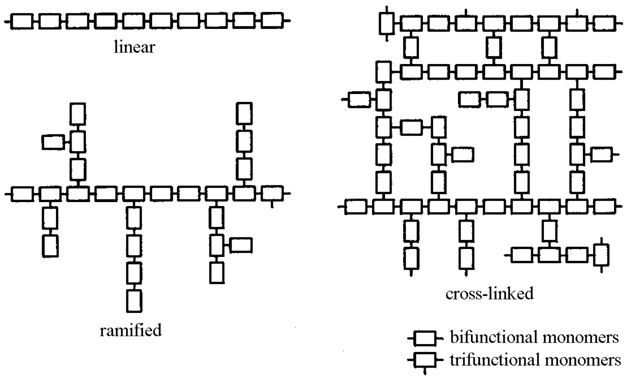


Figure 3. Structures of polymers (Saechtling 2004)

1C PUR foam consists of prepolymers, a mixture of polyurethane chains and still reactive isocyanato-polyurethanes, which prevent premature curing. After evaporation by means of a propellant these prepolymers react with moisture by carbon dioxide emission (see Figure 4).

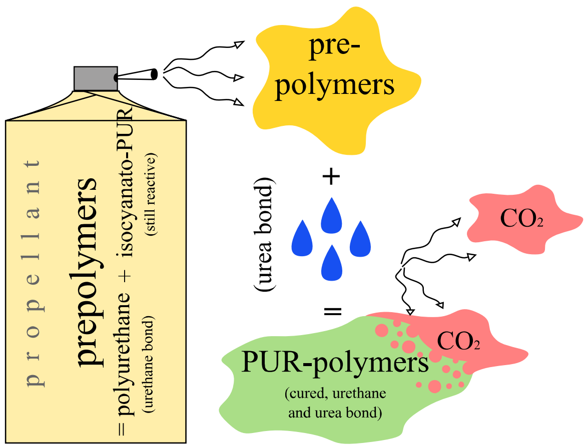


Figure 4. Reaction process of 1C PUR

Figure 5. Application of 1C PUR

The application of 1C PUR with a dispenser works analogous to the marginal strip mortar jointing method, as shown in Figure 5. Within this investigation two types of 1C PUR were used: All Season DRY FIX (DF) and Fischer Austria Winterschaum PUP 750 W (FI).

2C PUR adhesive are primarily used for industrial purposes and consist of a polyol component (resin) and an isocyanate component (hardener). After the assemblage of units by robots the adhesive is applicated by a low pressure pump with a sprinkler head (see Figure 6). Mechanical properties can be controlled by the mixing ratio. Isa-Pur 2607 (resin) and Härter 414 (hardener), both products of H. B. Fuller Austria GmbH and abbreviated with FU, were used within the scope of these examinations.

Figure 6. Industrial prefabrication of masonry walls by the use of 2C PUR adhesive (Redbloc 2007)

LONG-TERM TESTS

Long-term experience shows, that the proper use of clay blocks makes brickwork to one of the most durable building materials.

However, PUR is a relatively young material with about thirty years of experience. Therefore (Huijben and Maat 2007) investigated the ageing of all cross-linked joint components mentioned above with two different ageing methods:

- constant climate at a temperature of 45 °C and a RH of 95 %
- alternating climate with temperatures between -15 °C and 45 °C and a RH of 95 %

In a nutshell no difference in colour, texture or shape was determined after the ageing process. Bond failure as well as the release of harmful compounds is not expected. If the effect of UV radiation is eliminated by coatings (for example plaster) a limitation to length of service will not be anticipated.

To clarify the question whether mechanical properties of the composite material change during service life or not, following three parameters were tested experimentally:

- resistance against hydrolysis
- ageing resistance (constant climate)
- resistance against alternating climate

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Mini-specimens were used to allow storing in climatic chambers and to cover a wide range of masonry types respectively. Therefore 1,152 mini-bricks with a hole ratio of approximately 30 % were bonded with DF, FI and FU. For the purpose of comparison 36 specimens were made with ordinary thin bed mortar (TB). The geometrical quantities are listed in Table 2.

Table 2. Geometry of mini-bricks

	mini-brick		
hole pattern			
length l_u	51.2 ± 0.0 mm	n_l =	852
width b_u	25.6 ± 0.0 mm	n_b =	838
height h_u	23.4 ± 0.0 mm	n_h =	823
hole length l_{hu}	13.5 ± 0.0 mm	n_{hl} =	544
hole width b_{hu}	9.5 ± 0.0 mm	n_{hb} =	548
level of confidence S	95 %		

Flexural strength perpendicular to the bed joint f_{xu1} (162 samples with five units) and initial shear strength f_{vu} (162 samples with three units) were determined to get information about the joint quality (see Figure 7).

Figure 7. Mini-specimens and test-setup

RESISTANCE AGAINST HYDROLYSIS

Hydrolysis is a splitting process of a chemical compound by reaction with water, which may occur due to water damage or insufficient sealing measures. Specimens were stored in water (pH-value 7.5, electrical conductivity $\sigma = 6.1\times10^{-4}$ S m^{-1}) up to 12 weeks. The time-dependence of f_{xu1} and f_{vu} is shown in Figure 8. Due to low coefficients of determination drawn trend lines should be interpreted carefully. Considering that values scatter over a much wider range, both mechanical quantities stayed approximately constant.

During the storage time the pH-value decreased to 7.0, while the electrical conductivity increased to $\sigma = 6.4\times10^{-3}$ S m^{-1}. A solution of acidic ions, probably chloride or nitrite, is postulated.

Concerning the failure mode of bending tests, about two-thirds of 1C PUR specimens and about half of 2C PUR specimens failed as a result of cohesive and cohesive-near-the-interface fracture. Within the shear tests approximately two-fifths of 2C PUR specimens collapsed due to stone failure, while 1C PUR specimens predominantly showed cohesive failure again.

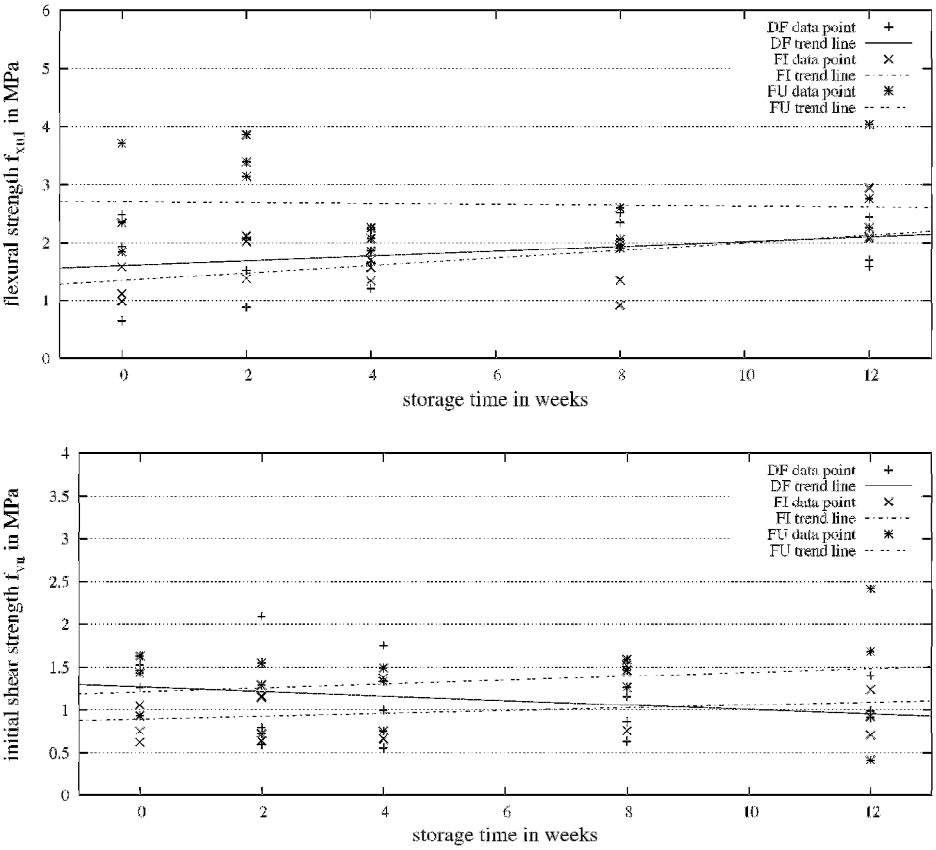

Figure 8. Time-dependence of f_{xu1} and f_{vu} after storage in water

AGEING RESISTANCE

Ageing is the sum of chemical and physical processes in materials during service life. Time-lapsed ageing procedures are necessary to make ageing tests possible for long-lasting substances. One of these is the tightening of surrounding conditions, which is a common test method in plastics testing. In this case specimens were stored for four weeks in a climatic chamber each with a constant climate at a temperature of 90 °C and a RH of 95 %, at a temperature of 65 °C and a RH of 95 % and finally at a temperature of 40 °C and a RH of 95 %. The time-dependence of f_{xu1} and f_{vu} is shown in Figure 9 and Figure 10 respectively.

Considering both, f_{xu1} and f_{vu}, specimens with TB continued hardening, test items with DF decreased, samples with FI showed a divergent behavior and specimens with FU slightly increased. Due to high scattering it is not possible to say if there is a definite dependence of f_{xu1} and f_{vu} on time-lapsed ageing or not.

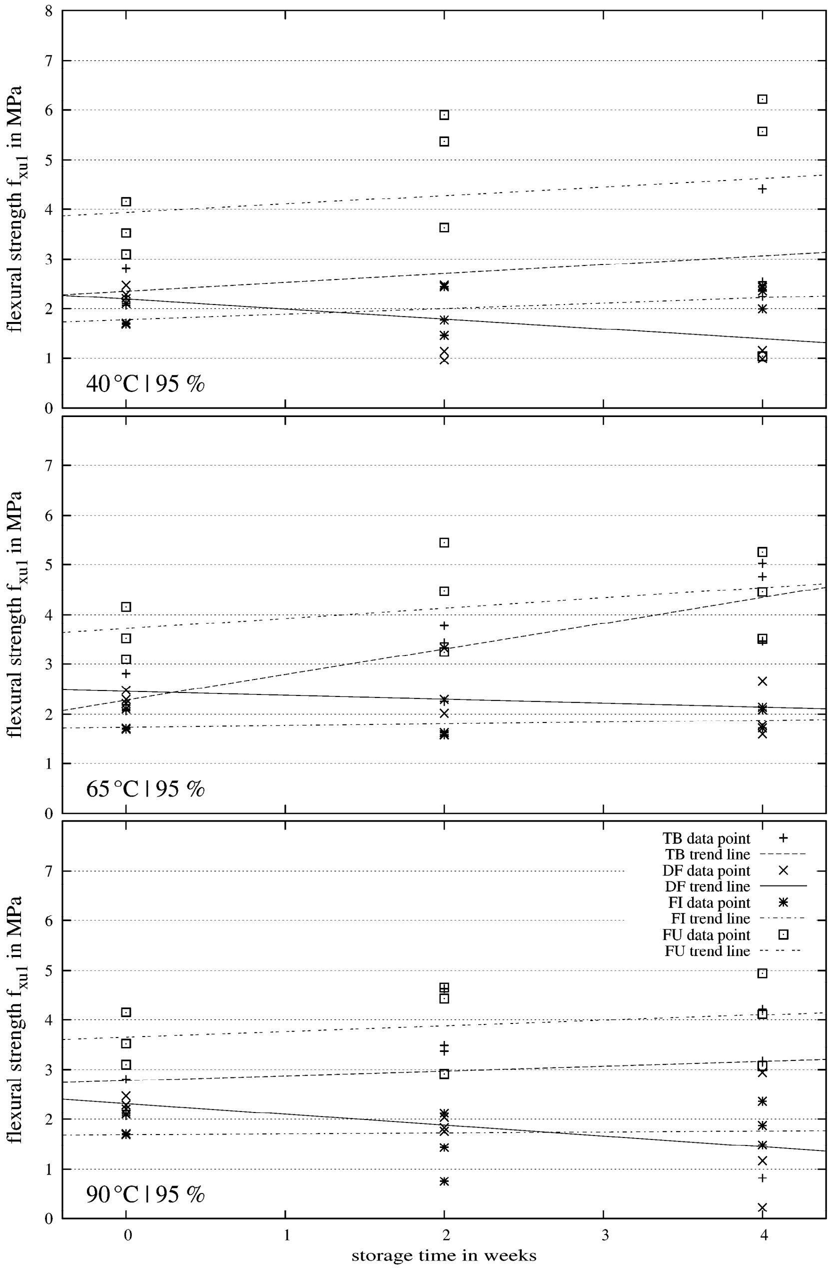

Figure 9. Time-dependence of f_{xu1} after storage in constant climate

Again approximately two-thirds of 1C PUR bending specimens failed due to cohesive fracture. Specimens with FU and TB collapsed in equal shares either due to cohesive, adhesive or stone failure. Concerning the failure mode of shear tests, about two-thirds of 2C PUR and TB specimens failed as a result of stone fracture. 1C PUR specimens showed cohesive and stone failure in equal parts.

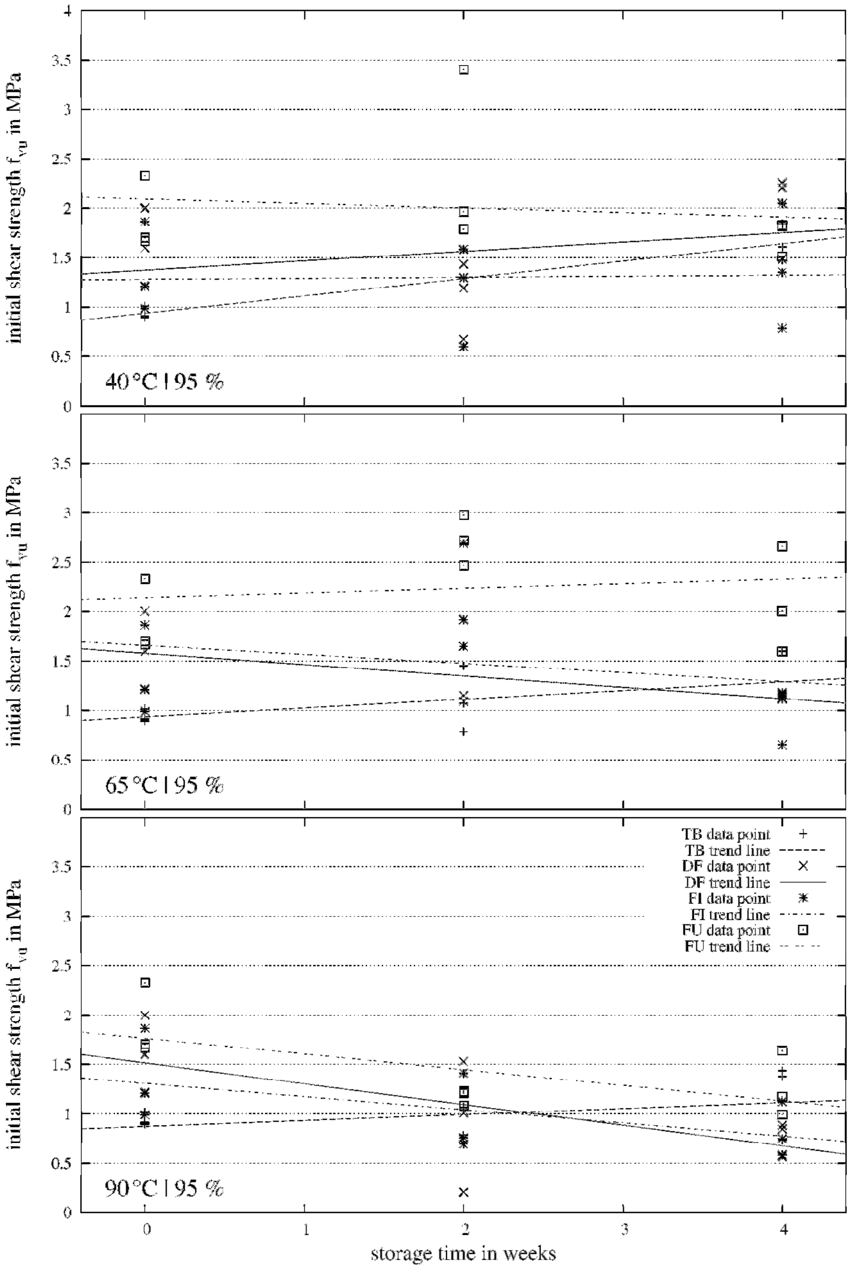

Figure 10. Time-dependence of f_{vu} after storage in constant climate

RESISTANCE AGAINST ALTERNATING CLIMATE

Austria is dominated by the alpine climate. Focussing on built-up areas Austria covers a wide temperature range from about -15 °C in the winter to approximately 45 °C in the summer. Bare brickwork is exposed to the elements, so specimens were stored for 12 weeks in a climatic chamber with an alternating climate as shown in Figure 11. Half a day reflects a seasonal cycle. The time-dependence of f_{xu1} and f_{vu} is shown in Figure 12. Although in an insignificant manner, all types of specimens show a divergent behaviour. With 2C PUR specimens f_{xu1} increases and f_{vu} decreases. 1C PUR specimens show an opposite characteristic.

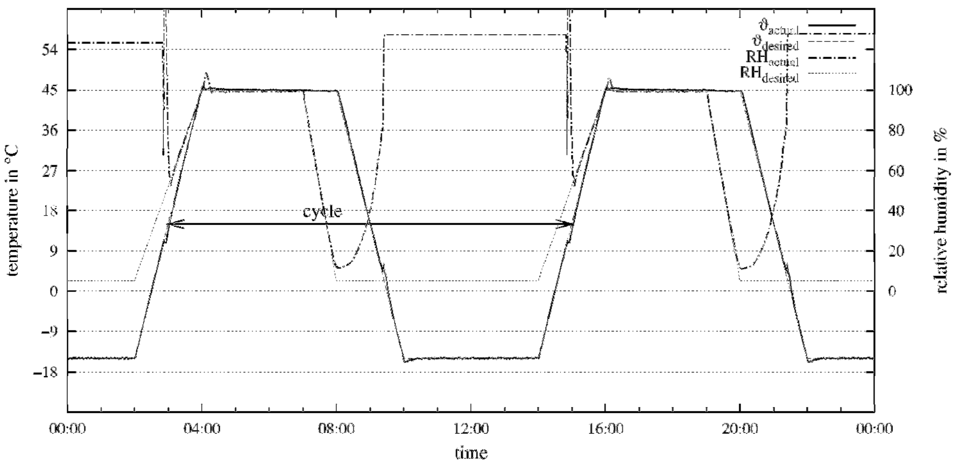

Figure 11. Alternating climate

The storage in alternating climate seemed to have only a marginal influence on f_{xu1} and f_{vu}. Like resistance against hydrolysis, about two-thirds of 1C PUR specimens failed as a result of cohesive and cohesive-near-the-interface fracture. However, stone fracture dominated the failure of 2C PUR specimens. Shear tests showed a different failure mode distribution. Approximately two-thirds of specimens with FI and FU failed due to stone fracture, while specimens with DF showed cohesive and stone failure in roughly equal parts.

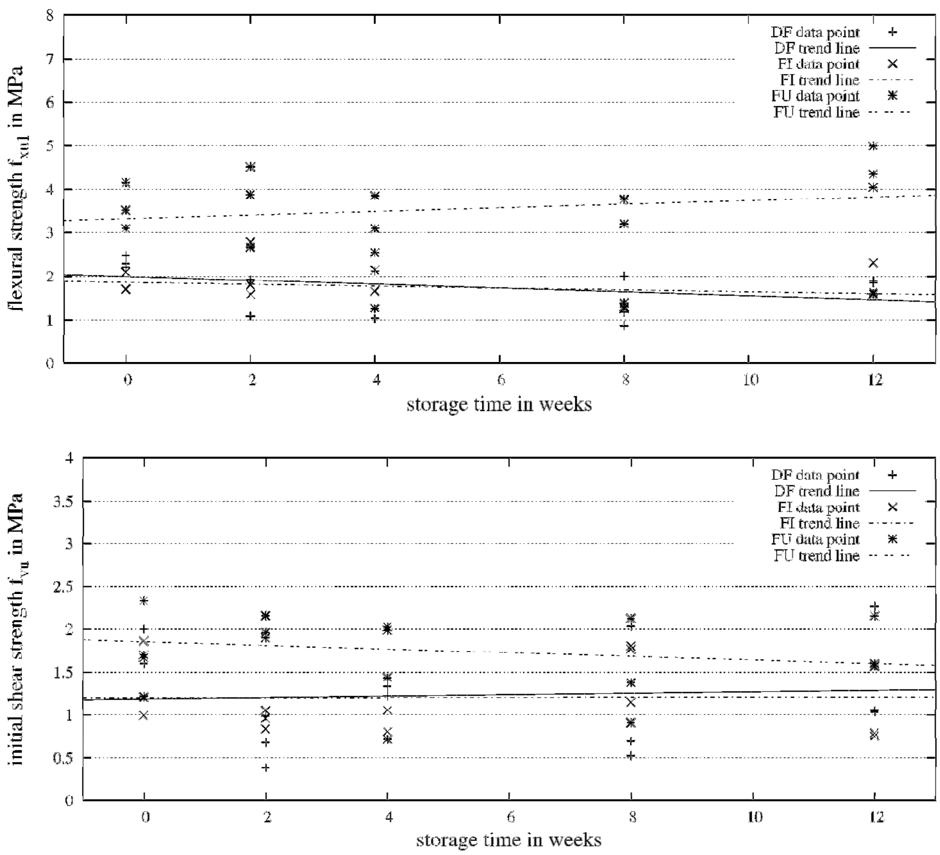

Figure 12. Time-dependence of f_{xu1} and f_{vu} after storage in alternating climate

CONCLUSIONS

Storage in water seems to have a minor influence on flexural strength perpendicular to the bed joint and initial shear strength. Chemical analyses are necessary to explain the decrease of the pH-value and the increase of the electrical conductivity in detail. Concerning storage in constant climate (time-lapsed ageing) no definite conclusion is possible due to high scattering and an insufficient number of samples probably. An enlarged rerun of this part may provide clarity. Alternating climate shows a marginal influence on the outlined composite material.

Concerning the failure mode, cohesive fracture is the dominant one followed by stone collapse. Adhesive fracture or fracture jumping from one interface to the other occurs sporadically. Therefore these testing methods allow conclusions about the joint behaviour as desired.

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