Water Repellent Treatment of Building Materials
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# Hygric Dilatation of Hydrophobic Treated Stones

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## Abstract

The maintenance of hygric properties is an important goal within the conservation of natural stones. The stones have to be able to adsorb and evaporate water after treatment with hydrophobic agents. The swelling and shrinkage of the stones must neither be increased nor reduced excessively. At ibac´s natural stones are investigated which are treated with a hydrophobic protective agent according to the Aachen Concept of Stone Preservation [1]. The prisms treated with the hydrophobic agent show swelling and shrinkage after water storage to a much lower degree than the untreated stones. The difference of dilatation between the treated area and the bordering untreated area is a factor two at maximum. These conditions can not be regarded as realistic stresses. The investigations also carried out during change of air humidity. After storing in low humidity again the dilatations of the treated and untreated area reach the zero point again within sufficient time to dry [2, 3].

**Keywords:** swelling, shrinkage

# 1 Introduction

The maintenance of the hygric properties is an important goal within the conservation of natural stones. The stones have to be able to adsorb and evaporate water after treatment with hydrophobic agents. The permeability of water vapour should not be decreased. The swelling and shrinkage of the stones must neither be increased nor reduced excessively.

# 2 Experimental

In this paper investigations of the behaviour of swelling and shrinkage of hydrophobic treated natural stones are reported.

## 2.1 Substrates and treatments

The substrates used are common German sandstones. The types are fine to medium grained and have swelling segments in the main chain.

The treatment for the main investigations is carried out according to the Aachen Concept of Stone Preservation. It is a polyurethane-based system (PUR) with hydrophobic properties [4]. One commercial treatment is used as a comparison. It can be classified as a hydrophobic silica ester.

## 2.2 Samples and Application

The stone samples used are prisms with the dimensions of 50 x 50 x 100 $mm^3$ and slices with a diameter of 44 mm and a thickness of 4 mm. The prisms' lateral faces are sealed by a standard epoxy-resin to prevent water or solvent from evaporation, whereas the front faces remain free. The prisms are treated by capillary forces. The duration of treatment is between 10 minutes and 2 hours because of the different suction of the investigated substrates. The application is carried out in a way that about 2 $kg/m^2$ of the protective agent are taken up. The penetration depth is about 20 mm.

After treatment the samples are cured for more than 4 weeks.

Cylinders with a diameter of 44 mm are drilled from some of the samples and afterwards sawn into slices. The thickness of the slices is 4 mm.

### 2.3 Test methods

Two different measurement methods are used for the two sample geometries (prisms and slices).

The prisms are investigated in a special apparatus for dilatation measurement. The probes are arranged in a way that the treated and untreated areas can be measured at the same time. The water uptake or the adsorption of humidity is possible from both front faces or, after special preparation, only from the treated front face. Figure 1 shows the measurement of the prisms schematically.

The measurement devices used for the slices are strain gauges (type LY41-20/120). The strain gauges are glued on the front and back surfaces of the slices. Plasticine over the strain gauges works as a protection of the measurement devices during the hygric stresses. Figure 2 shows a photography of the test arrangement for the slices.

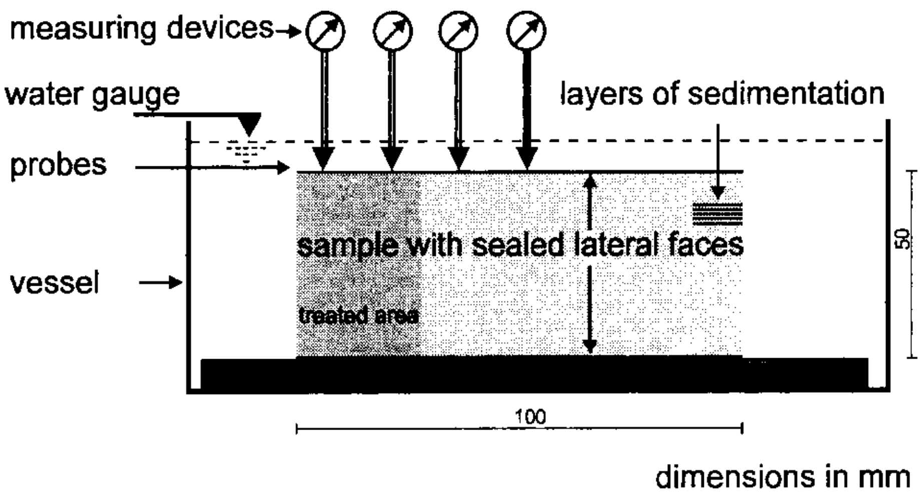


**Figure 1:** Apparatus for dilatation measurement of stone prisms

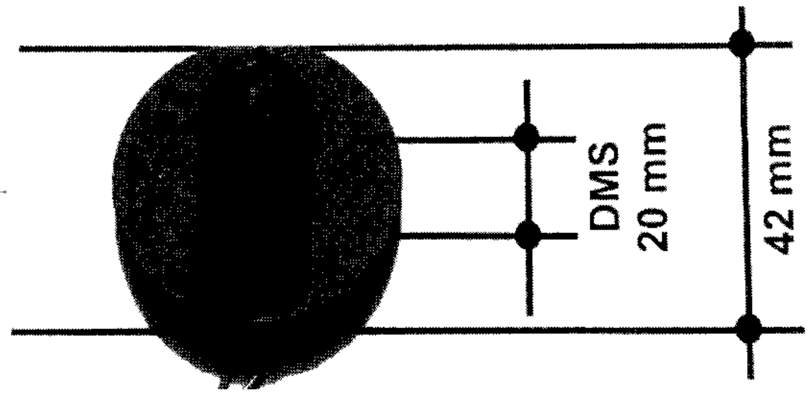


**Figure 2:** Test arrangement for dilatation measurement for slices

# 3 Results

## 3.1 Investigations during storage under water

At first the hydrophobic treatment (PUR) according to the Aachen Concept of Stone Preservation and the commercial treatment (silica ester) were comparatively investigated.

Figure 3 shows the dilatation of two prisms after 2 hours storage under water. The probes (apparatus for dilatation measurement) are in the depths of 2, 18, 34 and 50 mm distance from the treated surface. Thus distances of 2 and 18 mm are acceptable for the probes of the treated area and 34 and 50 mm for the probes of the untreated area. The suction of water can take place from both front faces. The suction of water from the treated surface is prisms show a balanced dilatation into the depth after storage for 2 hours under water.

The data for the same samples after 48 hours storage under water are shown in figure 4. The dilatation of the prism treated with the silica ester is increased to about 750 µm/m in the treated and the untreated areas of the stone. The dilatation of the prism treated with the polyurethane-based system remains up to a depth of 34 mm at about the same level like after a storage of 2 hours. The suction of water takes place from the untreated back face in this case.

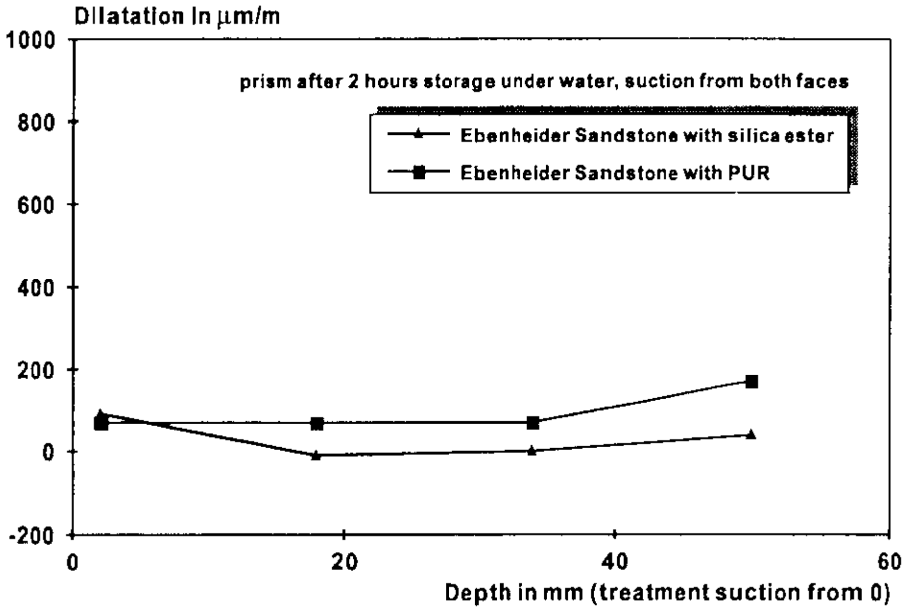


**Figure 3:** Dilatation of Ebenheider sandstone treated with a hydrophobic silica ester and a hydrophobic polyurethane-based system after 2 hours storage under water

In a functional real building structure the suction from both front faces is not possible. The polyurethane-based system protects the stone in the treated area and reduces the motions caused by hygric loads.

A prism treated with the polyurethane-based system was investigated during storage under water with suction of water only from the treated face. The probes (strain gauges) are fixed in the depths of 6, 54 and 85 mm. The dilatation of this prism after various durations of water suction is shown in figure 5.

The increase of the dilatation in the treated area (in this case only at the depth of 6 mm) is very slowly. Only half of the maximum dilatation of the untreated area (fig. 4) is achieved after a storage of about 8 days.

The dilatation of untreated slices of Ebenheider sandstone after 48 hour storage under water is about 400 µm/m. This measure is at a much lower level than the dilatation of prisms. Only the slice prepared from near the treated surface of the stone shows a decreased dilatation. Obviously there is a strong influence on the geometries of the samples. The slices can stretch in all di-

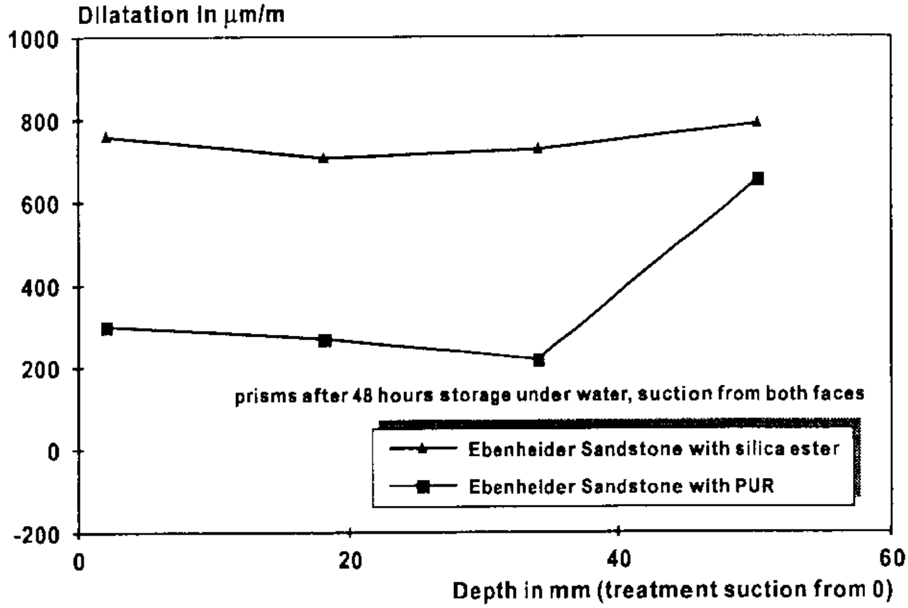


**Figure 4:** Dilatation of Ebenheider sandstone treated with a hydrophobic silica ester and a hydrophobic polyurethane-based system after 48 hours storage under water

rections whereas the movement of the measured areas in the prisms is influenced by their individual viscinity. In figure 6 the dilatation of slices taken from a treated prism is presented.

### 3.2 Investigations during change of air humidity

The investigations during change of air humidity are carried out on 3 types of sandstone: Ebenheider, Sander and Nebraer Sandstone. The samples are slices treated with the polyurethane-based system. The untreated and the treated slices are taken from the same prism after treatment and curing. The following figures always show the mean value of two individuals. The stresses are changing with air humidities between 50 and 95 % r. h. whereas the temperature of 23 °C is constant. One period of constant humidity takes one week.

The dilatation of the treated Ebenheider Sandstone slices at the end of the period with high humidity is about 400 µm/m. The untreated slices ob-

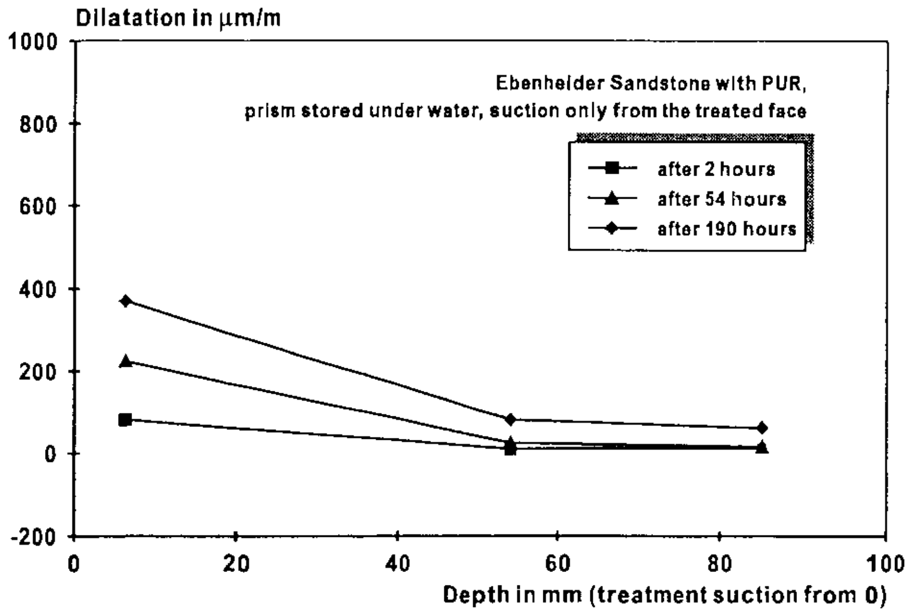


**Figure 5:** Dilatation of Ebenheider sandstone treated with a hydrophobic polyurethane-based system after various durations of water suction only from the treated face

tain only a dilatation of about 200 µm/m. Figure 7 shows the course of the dilatation during the periods with high and low humidities.

The treated as well as the untreated slices do not have reached the maximum dilatation within one week of high humidity. The evaporation from the treated slices is slower than that from the untreated one. This can be seen by the fact that the treated samples do not reach the zeropoint of dilatation in the same time as the untreated samples will do. There is a danger of an increase of dilatation during sufficient time to dry. The untreated slices reach the zeropoint of dilatation after one week of low air humidity.

The investigation with the Sander Sandstone leads to the same levels of dilatation of untreated and treated samples (figure 8). The level of dilatation is about 200 µm/m during the period of high humidity and returns to the zeropoint after one week storage in 50 % air humidity.

A similar effect like the Sander Sandstone is established with the Nebraer Sandstone (figure 9). The dilatation of the untreated slices at the end of the period of high air humidity is about 200 µm/m. The dilatation of the slic-

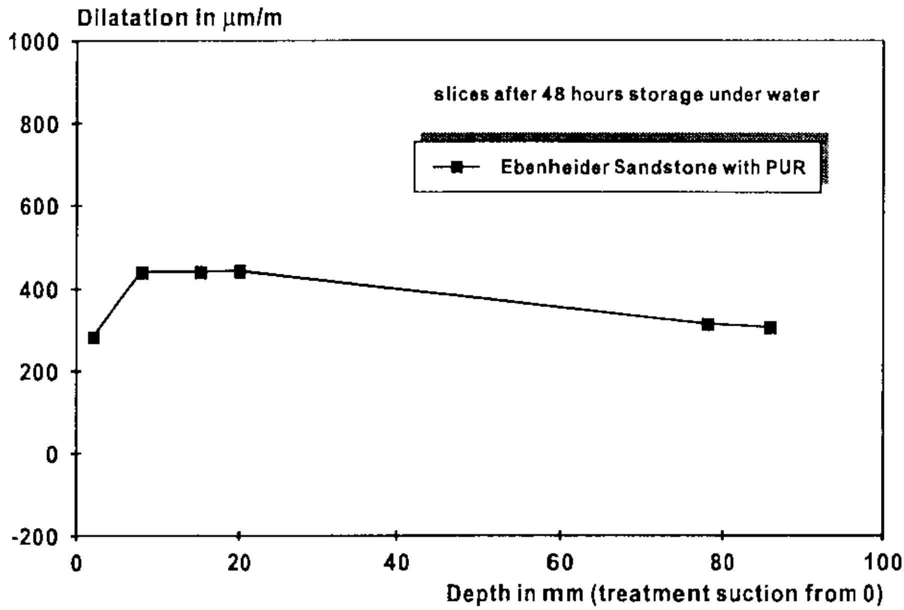


**Figure 6:** Dilatation of slices of a polyurethane treated Ebenheider Sandstone after 48 hours storage under water

es treated with the polyurethane-based system is slightly below that value. The treated slices also reach the zeropoint of dilatation during one week of drying.

## 4 Discussion

The prisms treated with the hydrophobic polyurethane-based system show a much lower degree of dilatation than the untreated stones. The treatment has a protective effect on natural stones with high dilatations caused by hygric stresses. This fact can be propitious in a functional building structure. Hygric stresses do not cause dilatations in the surface area. The durability of the natural stone is improved by the treatment.

The reduction of the swelling and shrinkage proves to be a disadvantage in these cases, where hygric stresses behind the treated area can occur.

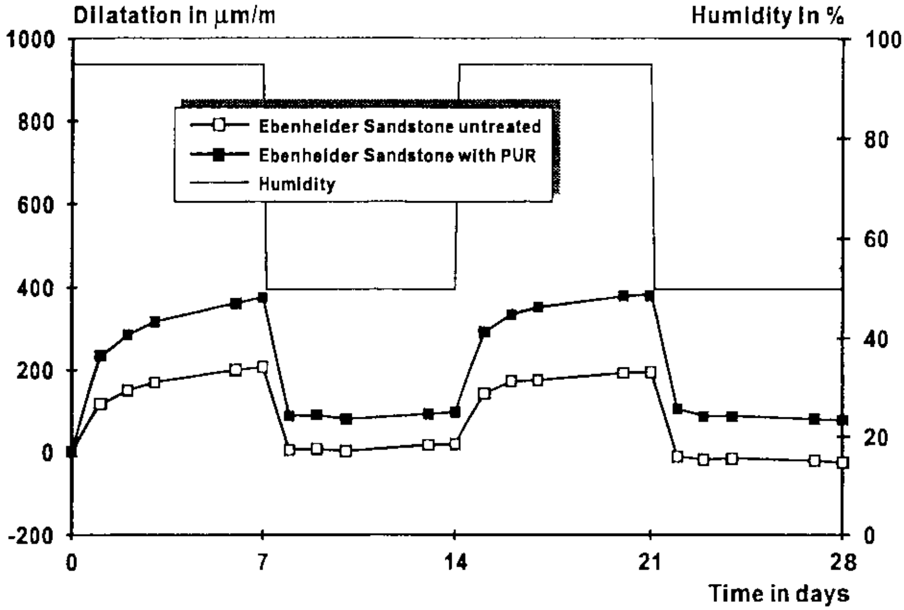


**Figure 7:** Dilatation of slices of Ebenheider Sandstone untreated and treated with a hydrophobic polyurethane-based system during changing with air humidities

The gradient of the dilatation between the treated and the untreated areas may be very steep. The danger of forming high stresses within bordering areas can not be excluded.

The investigated commercial treatment with silica ester does not change the properties of swelling and shrinkage in comparison with the untreated stone. That means that a protective effect relating to the swelling and shrinkage does not exist.

First the investigations were carried out during storage under water. These conditions can not be regarded as realistic stresses. The measurement device was selected because of the short time for investigations. Afterwards the investigations were carried out during changing with air humidities. The changes were chosen with field-situation parameters. The absolute dilatations during periods of high humidity show a lower level than the dilatations during storage under water.

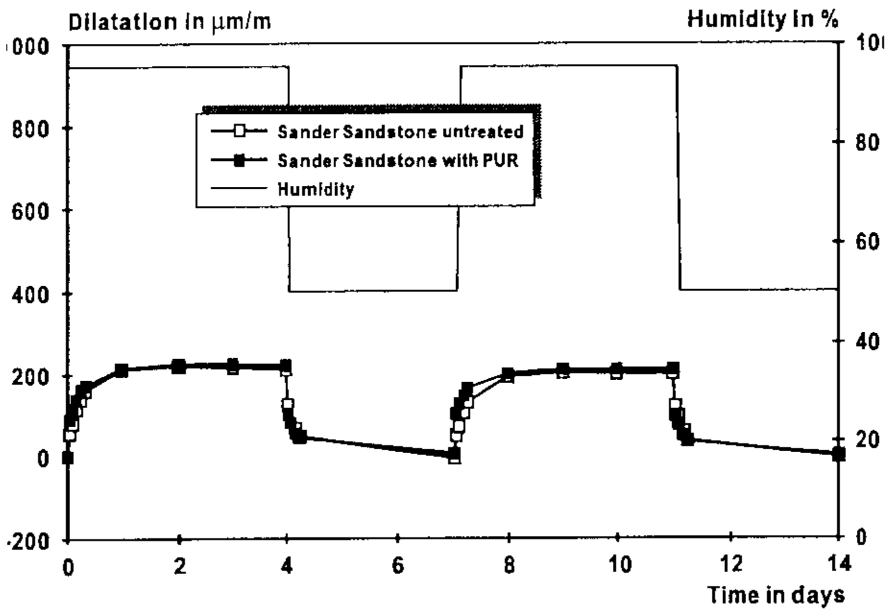


**Figure 8:** Dilatation of slices of Sander Sandstone untreated and treated with a hydrophobic polyurethane-based system during changing with air humidities

Another fact is to be considered: prisms and slices are used as samples. The absolute dilatation of the prisms has to be different from the measure of the slices caused by the geometries.

The results of the investigations during changing with air humidities differ with the different types of natural stones. The dilatation of the treated samples is on a higher level in comparison with the untreated samples in one case. The factor between the dilatation of untreated and treated stones is less than 2. After storage in high humidity the dilatations of the untreated and treated area reach the zero point again within sufficient time to dry. A danger of increasing dilatation with rising cycles can not be established.

## 5 Conclusions

The determination of swelling and shrinkage processes at treated natural stones is a main criterion within the assessment of protective agents.

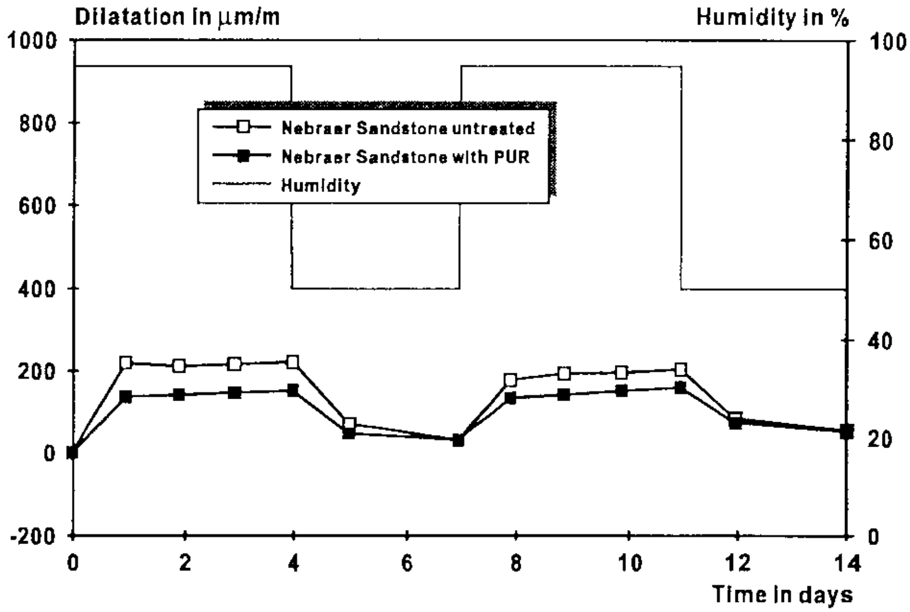


**Figure 9:** Dilitation of slices of Nebraer Sandstone and untreated and treated with a hydrophobic polyurethane-based system during changing with air humidities

The investigations were carried out with following parameters:

- three types of natural stones with different tendencies of swelling,
- two types of samples: prisms and slices,
- two types of test devices,
- two kinds of stresses, storage under water and changing of air humidity.

The influences of the different parameters have to be considered seriously. To sum it up it can be said:

- The investigated treatment according to the Aachen Concept of Stone Preservation results in a protective effect with reference to the swelling and shrinkage. The use of the treatment does not have negative influences to the dilatation behaviour of the natural stones.
- The two measurements show comparative results in their temporal tendencies but not in their absolute values.

- The short-time test with storage under water can be taken as a measure for the maximum dilatation of untreated and treated natural stones.
- The Dilatation tests have to be carried out separately for each individual combination of stone and treatment.

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