THE USE OF CLIMATE CHAMBER SIMULATIONS AS AN PROTECTION ANALYSING TOOL AGAINST MOISTURE AND SALT DETERIORATION PROCESSES IN MONUMENTAL BRICK CONSTRUCTIONS

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1. Introduction

Experience learns that very often the best way to preserve a historical building is to give it an active (re)use. However, it is also observed that this is only true if the conditions for (re)use are controlled to a certain extent. Parameters of control are then humidity, temperature and especially the changes of humidity and temperature.

With respect to the 18th century fortification Tenaille von Fersen , Suomenlinna , Finland (included in the UNESCO World Heritage list) the conditions of the building can be described as follows: the walls and vaults are water – logged and salt contaminated. The building was unused and unheated for a long period of time. Part of the building is nowadays used for several types of activities. Extension of the reuse of the fortification is foreseen in a near future.

2. Previous research

In the 'test room' of the Tennaille von Fersen building several series of tests have been carried out over the last 5 year. The primary goal was to determine the (change of) climatic conditions which create the most severe deterioration of the interior brickwork. The results obtained from the changing climatic conditions of the test room and within the walls will be used to formulate concrete directives to optimising the temperature and humidity of the Tennaile von fersen building. The great hall in the building is generally used for events at weekends, drawing as many as 150-300 people for wedding banquets or concerts. On such occasions the moisture of the hall rises rapidly, especially during hot and humid summers. It was observed that under these conditions the brick surfaces deteriorated badly. From this it was concluded that the study of deterioration mechanisms during brief periods of humidity change was the most effective way to gain more insight into the problem. For this reason a series of short tests was performed in the 'test room': the tests comprised a number of cycles, with 2-4 day changes between each moisture content in the test room

Deteriorated brick power was collected in receptacles after each treatment period. The salts falling from the brick walls during the dry and wet periods were also being analysed. These were identified as predominantly trona on two of the walls and as halite with some nitratine on the others. The first test conclusions were that the brick deterioration during a period of rising humidity, from 60-80% RH, shows the most damage. The deterioration during the drying cycle was about 5 times as low as during the wetting cycle.

1. Laboratory (climatic cabinet) tests simulations

3.1 Introduction

In the climatic cabinet cycles are applied that simulate conditions occurring in practice (Finnish winter and summer cycles) inside the building.

Original samples from the fortification were used in the testing programme. The monitoring of the test specimens during testing was done through continuous observation with: computer camera, microscope and an continuous weighting system. At the end of the testing programme some X-ray diffraction tests were carried out under relevant climatic conditions as applied in the cabinet.

1.1 Sample preparation

One of the first problems to be solved was to obtain samples that really show damage during testing. Preliminary cycling testing with samples from the fortification did not show any deterioration. This meant in fact that the degree of (super)saturation and probably the number of cycles necessary were not sufficient to obtain deterioration.

In order the be sure to get damage during cycling a special preparation method of the test sample was applied. To this end the sample was inserted 1 day in an salt solution (Na_2CO_3-NaCl 20 % w, these salts are already present in the sample) and followed by a two day drying phase and a two day wetting phase on an wet sponge. The cycle of drying and wetting was repeated until a visible deterioration was noticed. Then the sample was ready for testing in the climatic cabinet.

1.1 Computer camera, microscope and continuous weighing system

During the climate chamber cycle tests the deterioration of the samples were continuously observed. In the next diagram the change of humidity (humidity line) and the change in sample weight through absorption/loss of water (weight line) is shown. The critical deterioration points are registered with a camera and marked on the humidity changing line (Loss of material from the sample is not visible from the weight line as the damaged material falls on the balance that as well is weighing the remaining sample material) . The main deterioration occurs during wetting with a maximum at 82% RH. The weight line shows a clear increase of moisture during the wetting especially between 77 % and 82 % RH.

Simultaneously another sample was observed with a computer microscope during the same climatic cabinet cycle. The opening of cracks was clearly visible at 82 % RH.

4. X-ray diffraction

The results of the testing in the “test room” of Tenaille von Fersen as well as the tests in the climatic cabinet show that most of the damage occurs in periods of increasing humidity (especially going from 77 to 82 % RH). The reasons for this phenomenon are unclear.

Therefore it was tried to get more insight through taking X-ray diffractograms under wet and dry conditions. It was supposed that if in the higher humidity region hydration products could be found that were not present under low humidity conditions an explanation for the damage with increasing humidity could be given. With respect to possible hydration products of especially Trona or related modification products were considered.

From the diffractogram it can be concluded that only a considerable change regarding NaCl can be observed: under wet conditions it is dissolved (which is to be expected above 75% RH) and under dry conditions it apparently recrystallises. This dissolving and recrystalisation may explain the (little) damage that is observed during drying. However, no hydration products related to Trona are present. This means that the damage during a period of increasing humidity is not caused by expansion as a result of the formation of hydration products.

The moisture increase of the sample between 77% and 82% RH indicate an absorption of water by the specimen. This may lead to volume changes. This phenomenon combined with a decrease of bond through decrystallisation of NaCl may be the cause of damage. However, this still has to be proven.

5. Conclusions

The test results show that the damage mechanisms as observed in the “test room” of the fortification can be simulated through climatic cabinet testing. For this the sample preparation must be adequate and a proper interval time of the cycles must be applied

The climatic cabinet tests confirm that most of the damage occurs during the wetting period from 77% to 82% RH. Less damage is observed during drying.

On basis of the results the requirements with regard to climatic conditioning, focussed on the prevention of damage in the interior walls of the fortification, are known.

The reasons for the damage of the walls during the wetting period are still unclear. Further research, focussed on the deformation behaviour of the material during wetting may provide an explanation.

6. References

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Fig. 1 The Tenaille von Fersen building to the left and the dry dock

Fig. 2 The sample and the camera inside the Climatic Cabinet.

Fig. 3 The computerised continuous weighing System

Fig. 4a The wet sample before drying phase
Fig. 4b The sample after the drying phase(visible damage with enlarging openings)

Fig 6a Microscope picture at the start of the cycle (50 % RH) cracks at 82 % RH

Fig 6b Microscope picture showing opening of cracks at 82 % RH