Neutron imaging of stone samples

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The restoration of memorials and historical buildings in Vienna is a continuous challenge. The procedure for restoration is very expensive. The chemical preservation of natural stone surfaces of historical buildings is carried out by the use of stone strengthener agents. As these agents contain hydrogen, they offer good properties for neutron imaging. The main interest in the restoration process is the development of a suitable stone strengthener. In cooperation with the St. Stephans Cathedral and the geologists at The Technical University, Vienna, we are investigating the penetration depth and distribution of different stone strengtheners. These studies are being carried out with different stone samples. Lime stones, lime sandstones and marble. The size of the samples varies from 2 to 5 cm in diameter and up to 20 cm in height.

Fig. 1: A photograph of some samples taken to FRM II for measurement.

These samples were taken to the neutron source of the Technical University of Munich, FRM-II by Fareeha Hameed who is a PhD student at The Atomic Institute, Technical University Vienna. The use of this experimental facility in Germany for a scientist in Austria is possible through a European research project (NMI3). Neutron tomography measurements with good resolution were carried out at FRM-II. Also dynamic neutron radiography measurements were carried out to study the penetration of water and stone strengthener agents.

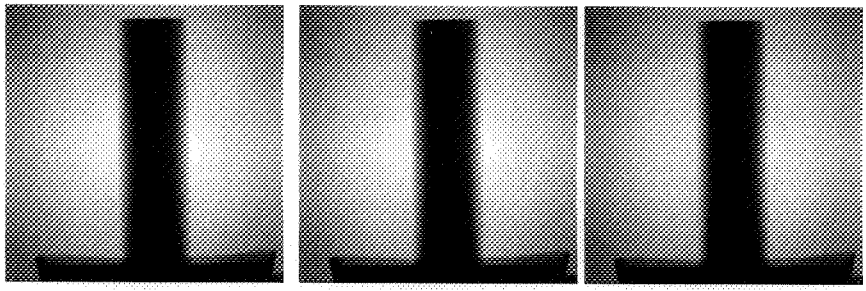
Measurements and Results:

Time resolved neutron radiography measurements were performed. First of all, the dry samples were put into the water bath, and water penetration depths were visualized as a function of time. After drying at 120 °C in an oven, the samples were put into stone strengthener. Again dynamic neutron radiography was performed to see the penetration of the strengthener in the sample. Two different kinds of strengtheners were used, OH100 and paraloid 5 %.

Neutron tomography was employed to the treated samples in order to visualize the distribution of the stone strengthening agents within the samples. In each tomography experiment, 400 projections were taken for 9 seconds exposure time per projection.

The data from the measurements performed at FRM II was analysed at The Atomic Institute, Vienna. During this analysis there were some problems as the data was too large for our computers and softwares to handle. But after some upgrading, the data has been analysed successfully.

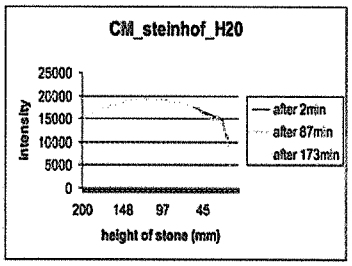
Sample: CM_steinhof – Carara marble sample – used in Steinhof Kirche Vienna.



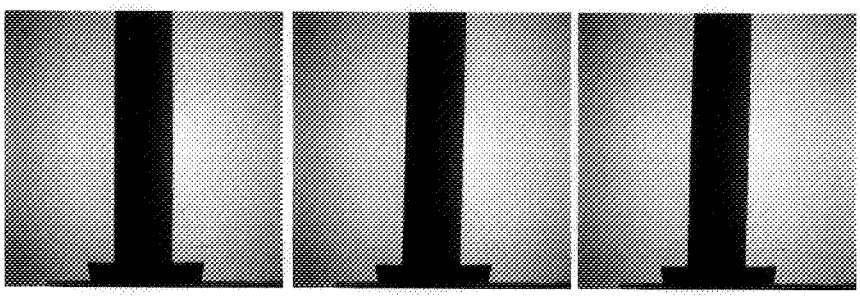
a) 2 min after being placed in a dish containing water.

b) After 87min, no penetration.

c) After 173min, no penetration of H2O.



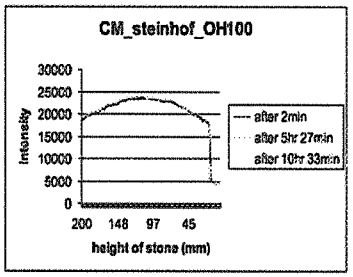
d) line profile showing that there is no penetration of H2O after different intervals of time.



a) 2min after being placed in a dish containing paraloid 5%

b) after 5hr 27min, no penetration of strengthener.

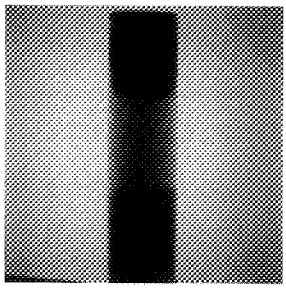
c) after 10hr 33min, no penetration.



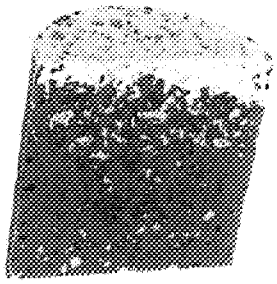
d) line profile showing that there is no penetration of OH100 after different intervals of time.

Fig 2: These are the neutron radiography images of CM-steinhof, which is a Carara marble sample. The first row shows the stone placed in a bath with water. This NR series was made with an exposure time of 2s and L/D = 400. The second row shows the same stone placed after drying in an Aluminium dish containing paraloid 5 %. This NR series was made with an exposure time of 9s and L/D = 800. It was found that there is no penetration of water or of stone strengthener even after ten and a half hours.

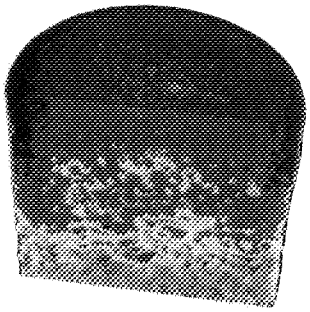
Sample: IV23STM



a) NR showing the same stone strengthened with OH100 on one side and paraloid on the other.



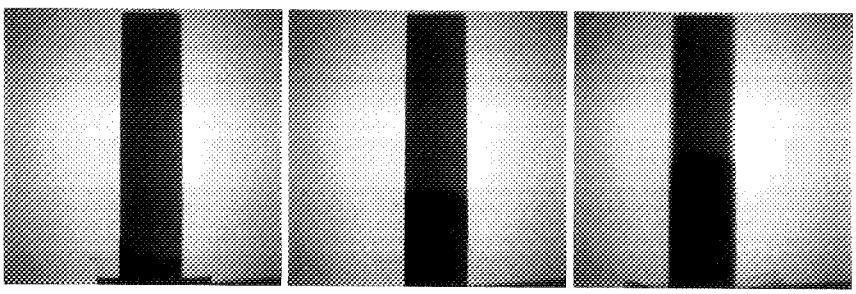
b) This is the NT of the bottom part of the stone showing the distribution of



c) This is the NT of the top part of the stone which has been strengthened with paraloid 5%.

Fig 3: a) shows the NR of the stone. b) Here we see that OH100 is homogeneously distributed. c) In this case we see the top part of the stone which is strengthened with paraloid. In this case we see that the distribution is different from the first case. Here the light blue colour shows low density of strengthener and the dark blue segments represent high density areas. So we see a surface effect. On the surface of the stone there is a high density distribution of paraloid. So we see that the distribution of the two strengtheners in the same stone is different.

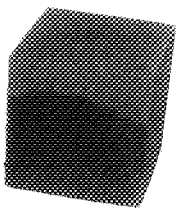
Sample: Biha'c (from Bosnia, used in buildings in Vienna).



a) 2min after the sample placed in a dish containing OH100

b) after 23min, we see the penetration of strengthener.

c) 1hr 35min after the stone has been removed from the bath containing OH100.



d) NT of the stone several hours after strengthening.

Fig 4: the NR has been carried out with an exposure time of 2s and L/D = 400. In a) and b) we see the penetration of strengthener. In c), the sample has been removed from the dish. We see that even after removal the strengthener OH100 penetrates further in the stone for some time. This effect has not been found in case of paraloid. In d) we see the NT of the same stone. We can see that the strengthener penetrates more in the central region of the stone.

Conclusions:

It has been found with the help of neutron tomography that the penetration and distribution of the two kinds of strengtheners used is different. When the same stone was strengthened with the two strengtheners on different sides, it was seen that the distribution of OH100 was homogenous, but in the case of paraloid, there was a surface effect. There was a region of high density on the surface. Dynamic Neutron Radiography showed that OH100 continues to penetrate for some time after the dish containing the strengthener is removed. In the case of marble samples, it was found that neither water nor strengthener could penetrate.