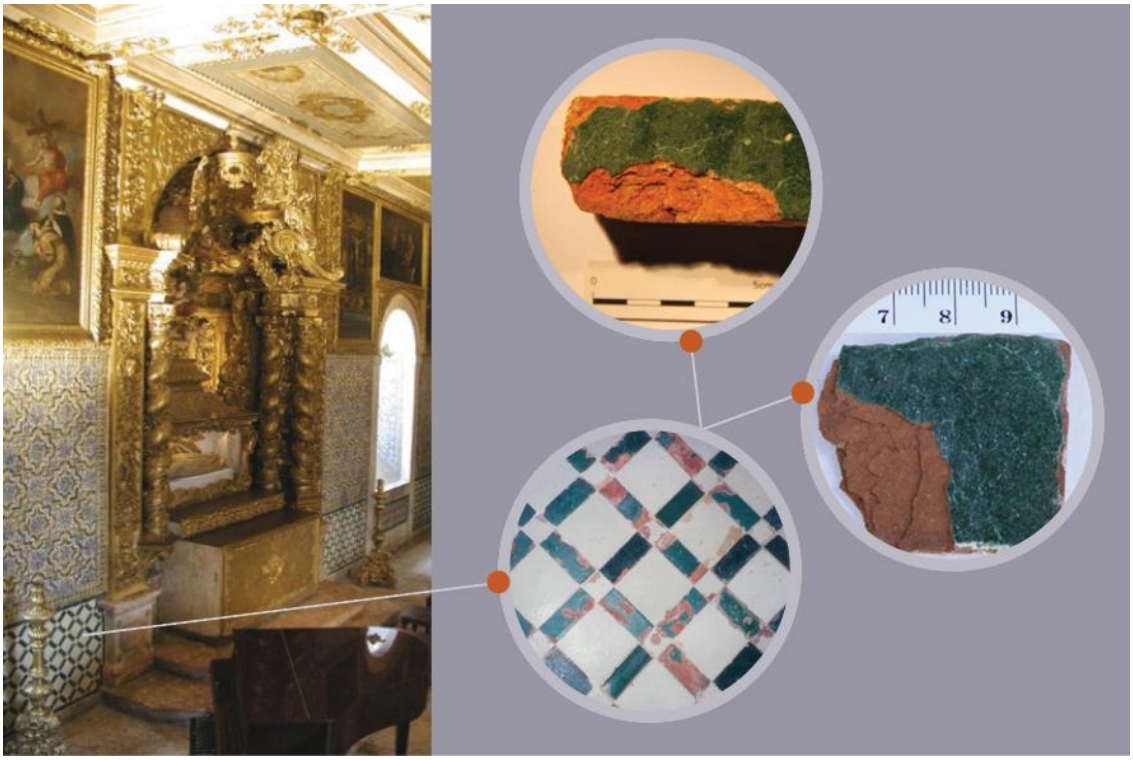
Rescuing ancient glazed tiles using neutron tomography



Left: Madre de Deus Church in Lisbon. Right: Some tile fragments collected.

Glazed tiles are used in many parts of the world to protect building facades, or as decorative art. Iberian countries such as Spain and Portugal have a very strong influence from the Arab tradition of tile making. As the centuries go by, the tiles degrade and action needs to be taken for their conservation and preservation for future generations.

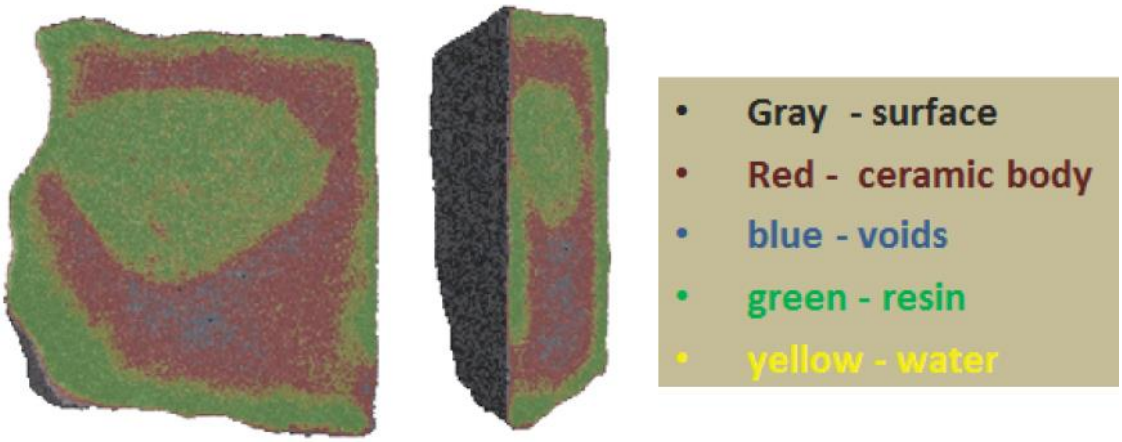
A transparent thermoplastic resin is often used in conservation and restoration of ceramic objects and glass objects as a consolidant of brittle objects. At the Portuguese National Tile Museum, ancient tiles were usually treated by immersion in the resin, diluted in acetone, for some hours in the case of an advanced degradation state. Another method was to brush the tiles, but this was considered less efficient and used only if the tile was well preserved. Thus it was thought that immersion lead to deeper penetration of the resin.

The Museum collaborated with the group of Dr. Isabel Prudêncio of Instituto Superior Técnico in Lisbon to develop a visualization tool for the inspection of the resin penetration in the tiles by means of neutron tomography done at the Portuguese Research Reactor. The questions were very simple: is the treatment working? Does the resin penetrate into the ancient glazed tiles? Do the tiles retain their porosity, essential for resistance to changes in humidity? What is the best method of applying the resin?

Several fragments of glazed tiles from the XVI century from the Madre de Deus Church in Lisbon were studied. The figure shows fragments of tiles with green glaze, and with a ceramic body in a very advanced degradation state from the permanent collection exhibited to the public. The fragments were subject to treatment by brushing with the resin or by immersion in the resin.

Photographs of the brushing (left) and immersion (right) techniques for the application of resin in the a green glazed tile from the "Madre de Deus" Church, "Museu Nacional do Azulejo (MNA)" (Lisbon, Portugal). Figure credit: Adapted from M.I. Prudêncio et al., 2012.

Neutron tomography was done on the tiles before and after treatment, to check the penetration of the resin and its distribution inside the tiles. Neutron tomography was also done after immersion of the treated tiles in water, to check their porosity: the neutrons are highly sensitive to the hydrogen in the water, and an actual image of the water distribution inside the tiles can be obtained. If the treatment had diminished the porosity, which is an undesired effect, the neutron tomography would show it.



Neutron tomography image of a green glazed tile from the "Madre de Deus" Church, "Museu Nacional do Azulejo (MNA)" (Lisbon, Portugal). Figure credit: Adapted from M.I. Prudêncio et al., 2012.

The results showed that the brushing treatment lead to an increase in the light element content of the glazed tiles three times higher than by immersion, with a better penetration of the consolidant, and also that the porosity was not affected by the treatment. Voids inside the tiles could also be observed.

These findings helped to improve the conservation strategy at the National Tile Museum, and the conservators are now confident that the public in centuries to come will still be able to enjoy and appreciate these beautiful pieces of history.

Other techniques

Porosity: scanning electron microscopy, water absorption, nitrogen adsorption and helium pycnometry. These techniques provide total or local porosity, not distribution in the sample.

Composition: X-ray diffraction, NAA.

Gamma irradiation for disinfestation of insects and inactivate microbiota.

X-ray radiography and tomography: high energies needed; low sensitivity to light elements. See e.g. the work of Deschler-Erb.

See also:

IAEA-TECDOC-1604. Neutron Imaging: A Non-Destructive Tool for Materials Testing - Report of a coordinated research project 2003–2006, IAEA, Vienna 2008.

International Atomic Energy Agency Coordinated Research Project on Application of 3D Neutron Imaging and Tomography in Cultural Heritage Research. Report of 1st Research Co-ordination Meeting.

What is neutron tomography?

The principle of neutron tomography is the same as for X-ray tomography, used commonly in CAT imaging (computed tomography of the body) devices. A beam of neutrons (or X-rays) crosses an object, where some attenuation of the beam takes place, depending on the materials crossed in each place. An image is formed by on a camera located after the sample - this is a simple radiography. The sample is located on a rotating stage, and so many images are taken, each at a different angle. Based on all the images, a 3D reconstruction of the object is computed.

There are significant differences between neutron and X-ray tomography. X-ray attenuation increases gradually with atomic number, which means that they are sensitive to heavy elements such as metals, and not very sensitive to light elements. On the contrary, most of the light elements, including hydrogen, strongly attenuate neutrons, while most of the technically relevant metals do not. For instance, lead is almost transparent to slow neutrons. This makes neutron tomography an ideal technique to observe hydrogen, or other light elements, inside metallic objects.