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2 / 2021

Czech Academy of Sciences

ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

EDITORIAL

Dear readers,
the second issue of the 2021 ITAM newsletter again brings news from theoretical and applied research, prepared by the staff of our Institute on the basis of various projects. You will learn, for example, about the construction of a unique snow generator, created in the Department of Dynamics and Aerodynamics, which can be used, among other things, for the production of load models. The climate influence is also related to a paper on aggressive chemicals that interfere with the strength of concrete and cause its degradation.

Above: Opening remarks by the ITAM director, Prof. S. Pospíšil. Below: Christening of the new book by the President of the Czech Academy of Sciences, Prof. E. Zažímalová. Photo: J. Bryscejn.

I don't mention concrete by accident. Research on this key building material was actually at the beginning of the existence of our Institute, which was founded a hundred years ago and was called "Research and Testing Institute of Building Materials and Structures at the Czech Technical University in Prague". Yes, you read it right; this year the Institute celebrated the 100th anniversary of its founding!
We duly celebrated it at a gala evening in the presence of the President of the CAS, Prof. Eva Zažímalová, the Vice-Presidents of the CAS, Dr. Ilona Millerová and Prof. Jan Řídky, and many other distinguished guests from the academic and professional sphere. As you can see from the pictures, the celebration was a success. It was full of speeches, discussions, music and good wine. But above all, a book entitled "The Clue to Structures" was also christened. This truly engaging work, compiled on the basis of the long-term detective work of a team of authors led by Dr. Věra Dvořáčková from the Masaryk Institute and Archives of the CAS, is definitely worth reading. It deals not only with buildings and joints, but also describes the history of society while using the example of an important scientific institution. And that is definitely not to be ignored!

Stanislav Pospíšil, ITAM director

SHATIS'22 - INTERNATIONAL CONFERENCE ON TIMBER STRUCTURES IN PRAGUE

The Institute of Theoretical and Applied Mechanics CAS will host the international conference on timber structures SHATIS´22 - International Conference on Structural Health Assessment of Timber Structures in September 2022.

The main topics are:

- The basis of timber structure design
- Timber properties
- Monitoring and survey of timber structures
- Structural interventions
- Case studies / research & practice

The first SHATIS conference was held in Lisboa in 2011 and since then it happens regularly. The success of the conference lies in the meeting of researchers from all around the world with practitioners and in the freedom that they feel in discussions on current topics related with timber structures, both modern and historical.
You are all warmly invited to the upcoming event that will take place in Prague. More on shatis22.itam.cas.cz

H. Hasníková

SHATIS 22
structural health assessment of timber structures

INVESTIGATION OF THE CROWNED VIRGIN MARY PAINTING FROM MUSEUM IN TELČ

In 2021, ITAM CAS carried out a survey of a panel painting of the Crowned Virgin Mary from the museum in Telč (inventory no. Te-25/C/195, Museum of Vysočina, Jihlava). It is a uniquely preserved regional monument of panel painting of not yet fully explained provenance, dating from around 1500. Thanks to the loan of the painting for research using non-invasive imaging methods, it was possible to obtain documents for a more detailed technological evaluation of the work and to examine the modern modifications that were made to the painting after its inclusion in the collections of the Telč Museum. In addition to a thorough description of the painting, ascertainment of the technology of the painting's execution, and an assessment of the extent of secondary interventions, the follow-up research completed this year was also able to focus on completing the context of the creation of this remarkable monument thanks to close cooperation among the specialisations of the Department of HeritageScience.
During 2021, the work was analysed by X-ray imaging and computed tomography in the X-ray tomography laboratory in Telč. The staff of the Department of Diagnostics and Conservation of Monuments then monitored and evaluated the reaction of the object to a thermal stimulus and to irradiation in the infrared spectrum. The synthesis of the findings enabled a study of the composition of the painting's substrate, which – as it turns out – was made of two planks connected by four thorns, as well as defects in the wood and the way the creators of the painting dealt with them in the 16th century. Furthermore, it was possible to trace the contemporary technology of preparing the wooden support and, based on the different properties of the materials, to determine the exact degree of its damage and secondary behaviours. The research has also made it possible to describe some aspects of the creation of the scene by studying the engraved and brush underdrawing partly covered with colour pigments. The findings support the assumption that the work was created by adapting graphic models of foreign origin, linked to the environment of the Rosicrucian Brotherhoods. A radiographic survey, which was used to compare the technique of the painting manuscript at the sites of the supposed retouchings, helped to verify the extent of the modern interventions in the painting.
Although determining the exact origin of the painting from the Telč museum without direct source references remains a task of further research for the time being, as does confirming the considered links to the members of the family of the Lords of Hradec, the discovery of the technological aspects of the creation of the painting can be considered significant progress in the adequate appreciation of this exceptional work, and is a concrete result of the "digital humanities" approach that is contributing to the expansion of knowledge of social sciences by means of physics and digital technologies.

M. Ramešová, J. Valach

The painting of the Virgin Mary in the TORATOM device in Telč. Photo: J. Novotný.

Lamp set with thermal imager and IR camera for image documentation at the Optical Methods Laboratory in Telč. Photo: J. Valach.

TOMOGRAPHIC IMAGING OF UNIQUE MESOLITHIC FOSSILS

The laboratory of X-ray tomography in Centre Telč, in cooperation with the Biological Centre of the Czech Academy of Sciences in České Budějovice, performed a pilot tomographic scan of unique Mesozoic fossils. More concretely, the fossilized objects are the nymphal stage of the extinct insect order Coxoplectoptera. This winged insect, related to today's mayflies, lived around 100 million years ago in what is now Brazil. Coxoplectoptera nymph fossils are unique in that, among other things, only about twenty have been documented, all from the Crato site in the Araripe Basin. The aim of the experiment was to find out whether tomographic scanning in our unique TORATOM device could provide images of different parts of the fossil with sufficient accuracy and contrast. In September of this year, a joint article by British and American scientists was published in the Journal of Arachnology, in which a tomography of spiders from the same Brazilian site, taken by an FEI precision tomograph at the University of Kansas, was presented. The fossil samples themselves are in the form of flat sediment sections about 100 x 100 mm in dimension and about 10 mm thick. On one side, there is the uncovered fossilized specimen of Coxoplectoptera, which is approximately 20 mm long and 10 mm wide. As it was figured out later, fossilized insects penetrate only a very shallow depth of the sediment. The thickness of the sediment is thus significantly higher than the thickness of the fossilized insects, which of course has a negative effect on the

achievable contrast, so it was not clear in advance whether it would be possible to obtain satisfactory data for tomographic reconstruction. Thanks to the variable geometry of the TORATOM tomograph, it was possible to perform the measurement using a detector located near the X-ray source which, in combination with a large number of projections, sufficient X-ray power and the use of advanced tools during reconstruction enabled obtaining a 3D model of the fossilized nymph of a considerable quality. Portions of the nymph's body that are preserved on its side facing the sediment are clearly visible in the corresponding sections. The initial results are therefore very promising. The tomographic model is now being investigated by a team of experts from the Biological Centre of CAS, and both workplaces have preliminarily agreed on further cooperation. The TORATOM tomograph, developed at ITAM CAS, can thus make a significant contribution to primary research in the field of paleontology.

M. Vopálenský

Fossilized nymph of an insect of the order Coxoplectoptera. Photo: M. Vopálenský

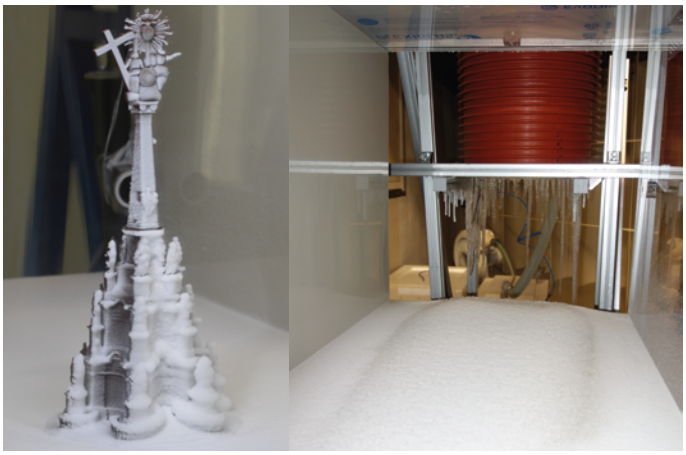
SNOW GENERATOR IN THE CLIMATIC TUNNEL AT THE TELČ CENTRE

In the climatic wind tunnel "Vincenc Strouhal" at the Telč Centre (ITAM CAS), a new device developed within the framework of the ending project of the Czech Technology Agency "Research of a parametric snow generator" is already fully operational. It is an advanced snow generator with an integrated measuring device for determining the parameters (size, quantity) of the produced snowflakes, which enables experimental testing inside wind tunnels in conditions close to real winter conditions.

Snow formation under controlled laboratory conditions is one of the very challenging problems in weather simulation. It depends on a number of environmental factors. Typically, special climatic wind tunnels with a working section of 40 metres or more are used to create snow. Such a long working section is necessary to ensure that the flight time of the water droplet is long enough for crystallisation to occur.

The snow generator developed in the TAČR project uses air jets and guided (oriented) water and the cyclone principle to keep water/snow particles in the core of the generator for the time needed for crystallization. Deeply supercooled air (down to -35/-40°C) produced in a heat exchanger located in a container with technical alcohol and dry ice is injected into the generator inlet, which significantly reduces the time for particle crystallization without cooling the entire volume of air circulating in the tunnel. Thus, the device enables the desired parameters of the produced snow to be achieved in relatively small climate tunnels/climate chambers and with significantly lower energy consumption.

The developed instrument expands the portfolio of the climatic wind tunnel at the Telč Centre by studying, for example, snow drifts in urban areas, snow loads on roofs, frost on metal and the possibility of testing products of the automotive and aerospace industries.



Accumulation of generated snow on models of monuments - Holy Trinity Column, Olomouc. Photo: A. Trush.

A. Trush, S. Pospíšil

NEW GACR PROJECT DEALS WITH CAPACITY OF NOTCHES IN TIMBER BEAMS

The project "Experimental and numerical assessment of the bearing capacity of notches in timber beams at arbitrary locations using LEFM", supported by Czech Science Foundation, started in 2021. As leading organization, ITAM CAS cooperates with the University Centre for Energy Efficient Buildings CTU in Prague and The Faculty of Forestry and Wood Technology at Mendel University in Brno. Jiří Kunecký from the Department of Applied Mechanics and Structures serves as the responsible project leader.

The aim of the project is to predict the bearing capacity of timber beams with notches at arbitrary locations. A numerical model of crack onset will be made using a combination of FEM and LEFM, which uses material characteristics to assess the bearing capacity of real-scale beams. The values taken from the previous steps will be used for verification of the whole approach. Significant size effect is expected. Mainly the experimental part of the project has been under way in 2021 - the assessment of values for opening, shear and mixed modes.

Experimantal set up for mixed mode is labeled by aruco markers for stiffness assessment by optical methods.

H. Hasníková

CONSEQUENCES OF AGGRESSIVE ENVIRONMENT ON THE STRUCTURE OF CEMENT STONE

One of the most commonly used building materials, concrete, is in many cases exposed to chemically aggressive environments that cause its degradation. Such environments are found in the vicinity of deep concrete foundations of buildings, as well as in cement concrete pavements exposed to de-icing salts, or in mortars of masonry structures exposed to aggressive groundwater.

A group from the Department of Materials Research, in collaboration with the Laboratory of X-ray Tomography (Department of Heritage Science), performed a detailed study regarding microstructural changes that occur in hardened Portland-limestone cement pastes during magnesium sulfate attack at low temperature.

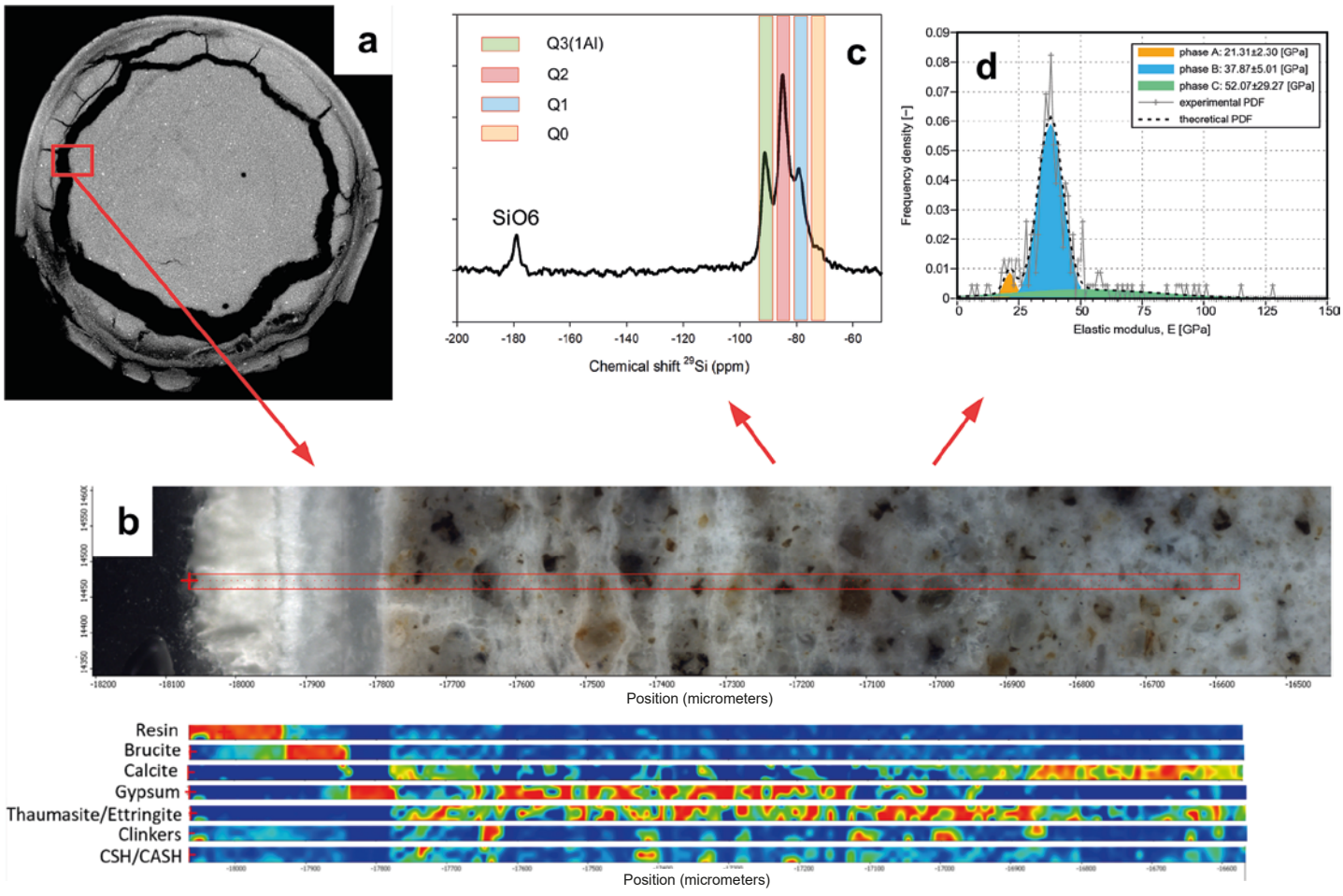
The simulated conditions severely degraded the main binder component in the cement matrix, further leading to the formation of deterioration products which disrupted the structural integrity of the material. The work was performed employing advanced experimental techniques including, among others, X ray micro-computed tomography and solid-state nuclear magnetic resonance (ssNMR) spectroscopy. The chemical changes in phase assemblage of the microstructure were numerically validated using thermodynamic simulations.

This work is the second sequential study associated with the research grant GAČR 18-26056Y that has been published in the most prestigious journal in the field of "Building and Construction" (Cement and Concrete Research). The researchers collected and analyzed a large amount of quantitative data linking the microstructural changes with the macroscopic behavior of the materials. The obtained information will then be used for the development of a micromechanical model for predicting the mechanical performance of Portland-limestone cement paste under similar chemical-attack conditions; the model will be available in the near future.

Related article: K. Sotiriadis, M. Hlobil, A. Viani, P. Mácová, M. Vopálenský. Physical-chemical-mechanical quantitative assessment of the microstructural evolution in Portland-limestone cement pastes exposed to magnesium sulfate attack at low temperature. Cement and Concrete Research 149 (2021) 106566. DOI: 10.1016/j.cemconres.2021.106566.

Figure: The applied analytical approach: (a) Cross sectional tomographic image; (b) phase assemblage (Raman spectroscopy) at the edge of the deteriorated matrix; (c) structure of silicate hydrates (ssNMR spectroscopy); (d) mechanical response – elastic modulus (nanoindentation).

K. Sotiriadis



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