newsletter

NEWS
AWARDS
RESEARCH

1 / 2021

Czech Academy of Sciences

ITAM ARCCHIP
INSTITUTE OF THEORETICAL AND APPLIED MECHANICS

WIND FLOW MODELLING IN URBAN AREAS

Within Strategy AV21 - programme no. 23 “City as a Laboratory of Change: Buildings, Cultural Heritage and Environment for Safe and Valuable Life”, the Department of Dynamics and Aerodynamics of ITAM CAS in cooperation with the Institute of Computer Sciences CAS (ICS CAS) is preparing local measurements of wind flow directions on physical models of a part of Prague-Dejvice and the historic centre of Telč. The Prague-Dejvice model covers the area between Jugoslávských partizánů, Terronská, Verdunská streets and Interbrigády Square. The Telč model covers the historic core of Telč around Zachariáš Square from Hradec to Svatoanenská and Na Baště streets. Both models were made using 3D plastic printing technology in a scale of 1: 300. The provider of digital data for the Prague-Dejvice model was the company Operátor ICT, a.s. using data from the Institute of Planning and Development of the City of Prague (IPR Prague).
The planned measurements of local wind flow directions at selected points on both models will take place in the Vincenc Strouhal Climate tunnel at the Telč branch of ITAM CAS. Experimental modelling of wind flow in a wind tunnel using physical models is called physical wind flow modelling. The measurement results will be used for validation and verification of the results of a mathematical model dealing with climate in urban development, which is being developed in Dr. J. Resler’s environmental informatics group at ICS CAS. This mathematical model makes it possible to model climatic parameters in urban areas over time, namely wind flow, temperature, heat fluxes, emissions from traffic and other parameters. A disadvantage of mathematical models is the verification of the correctness and accuracy of calculated values with limited input data (initial and boundary conditions). In this situation, the role of physical modelling in wind tunnels is still irreplaceable, as it is possible to measure local velocities and flow directions as well as other parameters at selected points on the physical model under controlled simulation conditions (wind speed and direction, turbulence intensity, etc.). The cooperation between ITAM CAS and ICS CAS is contributing to the development of a climate model, enabling an examination of the impact of climate change, the effect of the so-called urban heat island, the spread of emissions from transport, and other phenomena that negatively affect urban life.

P. Michálek

EDITORIAL

Dear readers,
In the last somewhat sleepy half year, the staff of the Institute of Theoretical and Applied Mechanics, CAS worked on a number of interesting tasks. Some of them are covered here in the issue of the newsletter you are holding.
An interesting project that falls within the activities of the AV21 Strategy program “City as a Laboratory of Change: Buildings, Cultural Heritage and Environment for Safe and Valuable Life“ is the modelling of wind flow in urban areas. Two urban development models were selected for this purpose, one of which is historical. It will be used to monitor the flow of wind in terms of its possible impact on the spread of fires that have affected life in the city in the past.
At its detached workplace in Telč, ITAM uses its unique TORATOM tomographic device with adjustable geometry, allowing for the examination of a wide range of objects, whether historical artifacts or materials under load. Researchers from the Department of Biomechanics, together with the Department of Monument Care, have made further improvements to this device and designed an additional module that improves imaging of the interior of larger objects.
Bernard beer is objectively a high quality drink. It is produced at a family brewery in Humpolec, whose chimney towers above the city and the surrounding landscape. Engineers from Excon a.s. designed a lookout tower whose steel lattice structure and stairs encases the chimney. The problem, however, was that the lookout tower vibrated in the wind. Researchers from the Department of Dynamics and Aerodynamics designed a special damper that absorbs the vibrations. But more in the newsletter.
This summer reading will, hopefully, once again be informative...

Stanislav Pospíšil, ITAM director

ST. WENCESLAS ROTUNDA IN THE LESSER TOWN OF PRAGUE – SURVEY OF INTERIOR PLASTER WITH WALL PAINTING

In 2004, archaeologists from the National Heritage Institute made an exceptionally valuable discovery while working on preserving historical terrain in the Prague Lesser Town: they discovered the foundation and above-ground masonry of a rotunda built at the end of the 11th century. Early medieval rotundas were exceptional buildings even in their time, and the circumstances of their origin often remain obscure as is the case with the Lesser Town rotunda where written reports on its founding have not been preserved. Archaeologists determined the time of construction of the rotunda based on dating of the Vyšehrad-type paving in the floor. The founding of the rotunda was related to the reign of Wroclaw II. The construction, carried out according to the project of an unknown elite mathematician, corresponds to his ambitions encouraged by obtaining the royal title in 1085 and subsequent coronation in 1086.

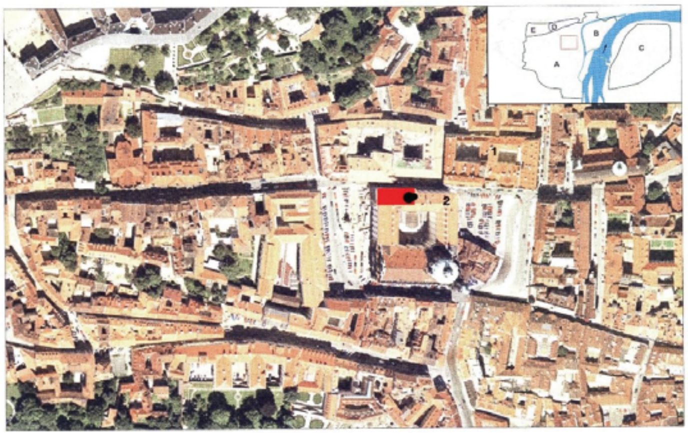


Fig. 1. Location of the rotunda in the building of the professional house (Malostranské nám. no. 2 / III, baroque church in red, rotunda in black)[1].

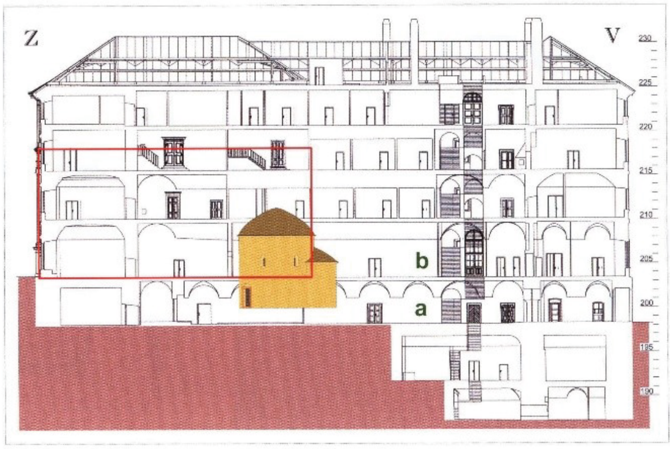
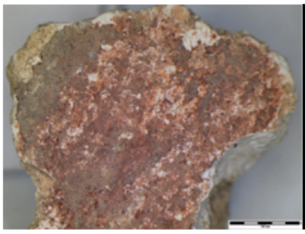


Fig. 2. Section of the building No. 2 / III with the marked height positioning of the rotunda masonry. Reconstruction by J. Čiháková and M. Müller[1].

A fragment of the plaster containing red-brown paint, which represents a unique document of the original surface treatment of the building interior has been preserved on a part of the above-ground masonry. Due to the documentary value of the building material and its decorative treatment, the decision was made to investigate its chemical composition using a non-invasive XRF method and do a microstructural study by means of methods requiring only a minimal volume of the sample. The aim of the laboratory research was to determine the painting technology and to identify the materials used.



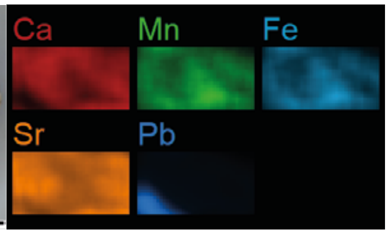


Fig. 3. A fragment of plaster with paint. Optical microscope, reflected light. Photo: P. Mácová

Fig. 4. XRF non-destructive analysis of the painting surface using a Spectro Midex instrument (M. Fikrle). Element maps using a 0.3 mm collimator.

The distribution of chemical elements on the surface was obtained by the non-invasive XRF method. The result of the analysis is a set of surface element maps (Fig. 4). From the small samples taken (a few mm in size), polished sections were further prepared for study under an optical microscope and in a scanning electron microscope with an EDS detector (Fig. 5). The pigments were determined mainly by means of Raman microscopy and spectrometry (Fig. 6).

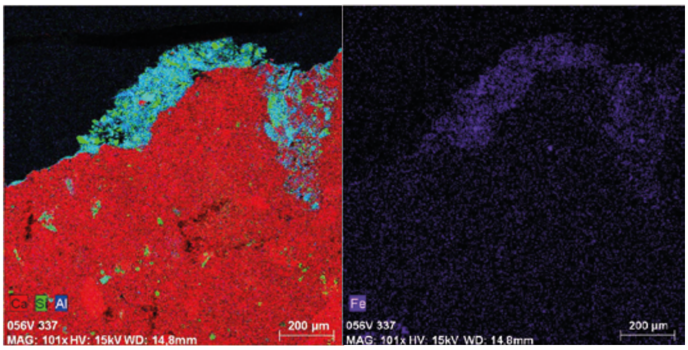
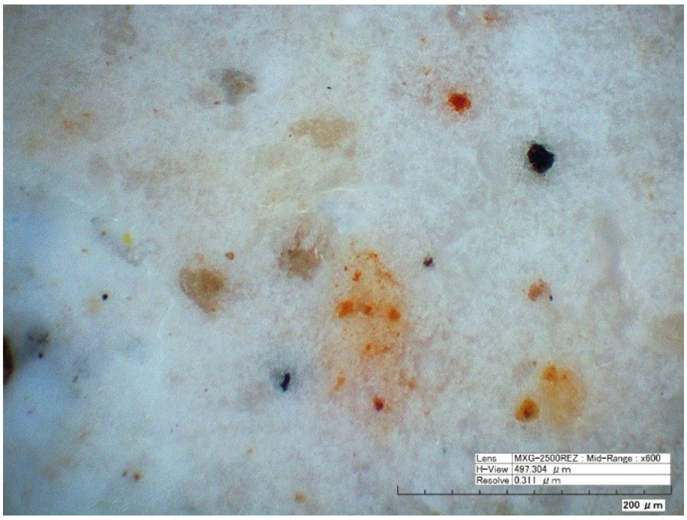


Fig. 5. SEM-EDS element maps showing various chemical elements in the material in cross section (perpendicular to the surface): calcium compounds (lime substrate under the painting) marked in red, silicate compounds (quartz grains) in green, aluminosilicates (feldspar, clay minerals) in blue-green, and pigments based on iron oxides are marked in purple (in the picture on the right).

The analyses showed that the material considered to be a plaster on the masonry consists only of a sand-free lime mass on which a coloured surface layer based on ferrous clay is applied. The lime layer is made of calcium carbonate formed by carbonation of slaked air lime and is up to 8 mm thick. The determined elemental composition of the lime layer based on the SEM-EDS analysis is 96% CaO and 2-3% SiO2, from which we deduce that the limestone used for lime production was highly pure in terms of calcium carbonate content, and minimally contaminated with aluminium, silica or iron admixtures. The microstructure of the calcium binder is inhomogeneous; in the electron microscope images we can observe pieces of lime binder enclosed in a fine-grained lime matrix, as well as sharp-edged limestone grains of various sizes, from small dust particles of 0.05 mm to larger clusters. The limestone grains form a filler of lime mass, however it is probably not an addition of limestone crumb to the lime, but residues of insufficiently burned and quenched raw limestone material which was, in the spirit of the contemporary technology, left in the slaked lime as a component of the product. From the SEM images, the area ratio of carbonated calcium binder and limestone residues can be estimated to be 1: 0.4. The lime mass contains small pieces of clay (we believe that it is a contamination of lime during plastering and painting). The clay contains the following pigments and minerals: hematite, magnetite, maghemite, goethite, perovskite, rutile, albite and muscovite.



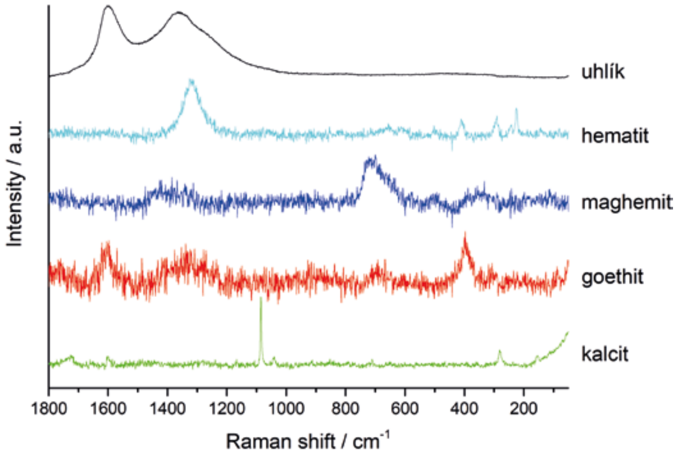


Fig. 6. Pigments observed in the lime substrate under the painting: yellow particles - goethite, red - maghemite, dark red - hematite, black - carbon (carbon black). Left: an image of a section using a Hirox KHX-7700 3D digital microscope, reflected light, magnification 600x. Right: spectra of pigments and calcite (calcium carbonate) measured with a Nicolet DXR Raman dispersion microscope.

The colour of the painting fragment is shown in Fig. 3.; the shades of the colour are red to brown-red, and in part of the sample there is a dark colour on the surface with a shade of gray-green. Underneath the colour painting, a white layer of lime shines through. Ferrous clay, present in the form of small dispersed impurities in the lime substrate, forms the main component of the painting layer on the surface of the lime layer. The ferrous compounds (pigments) in the clay probably contain a small amount of manganese. Phosphorus was also found in the fragment, which indicates the admixture of bone black in the clay. The material survey thus provided evidence that the plastering of the masonry in the interior of the rotunda was carried out by applying a thick layer of slaked air lime, and the painting was performed on the hardening lime coating using the natural mined earthy pigments called clay and carbon black. The related publication Malostranská rotunda svatého Václava v Praze (The Lesser Town Rotunda of St. Wenceslas in Prague) won the Josef Hlávka Award for 2020 in the field of physical science.

[1]*Čiháková, J.; Müller, M. Malostranská rotunda svatého Václava v Praze. Praha: Národní památkový ústav, územní odborné pracoviště v Praze, 2020 - (Čiháková, J.; Müller, M.), Archeologické prameny k dějinám Prahy, 8. ISBN 978-80-87220-17-7.*

Z. Slížková, P. Mácová, A. Viani, M. Fikrle, J. Čiháková

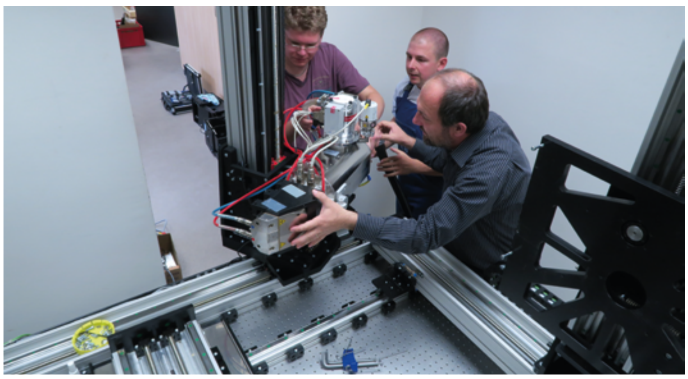
THE PROF. BAŽANT AWARD GOES TO PROF. MIROŠ PIRNER

Every year, the Prof. Z. P. Bažant Award is given by the Czech Society for Mechanics to outstanding personalities for extraordinary contribution to the development of mechanics. A prominent Czech or a foreign scientist who produced his major work in the Czech Republic within the framework of international cooperation may be nominated. This high award for the year 2020 was given on 19 January 2021 to prof. Ing. Miroš Pirner, DrSc., a researcher from ITAM CAS.
Prof. Miroš Pirner is a world-renowned expert with extremely high moral credit. He is the founder of the Czech School of Aeroelasticity in Civil Engineering, which currently has many successful successors. In 1976 he became a member of the editorial board of the then newly established publication (Elsevier) Journal of Wind Engineering and Industrial Aerodynamics. He is the author of several specialized wind tunnels built in the Czech Republic. He was the first to describe a number of aeroelastic phenomena important for the safety of structures.

J. Náprstek

IMPROVEMENTS TO THE TORATOM TOMOGRAPH IN THE TELČ CENTER WILL SIMPLIFY TOMOGRAPHY OF TALL

New X-ray source manipulators, developed at the Department of Biomechanics, were installed on the TORATOM tomograph in the X-ray tomography laboratory in Telč. The TORATOM tomograph is unique, among other things, in that its geometry is adjustable over a wide range. This makes it possible to significantly change the resolution of the tomography as well as create enough space for the insertion of relatively large objects, which is useful, for example, in the X-ray examination of paintings. Until recently, a major limitation was the insufficiently long and robust linear manipulator of both X-ray sources – the stroke was less than 20 cm. However, this problem was solved by installing new manipulators with a stroke of almost 100 cm, called ToraLift by their designer Tomáš Fíla from the Department of Biomechanics. With this improvement, it is now much easier to perform scans of flat objects (e.g. paintings) and create tomography of tall objects (typically swords, small statues, etc.). The development of control software that would allow for so-called spiral tomography is also planned. This would further simplify the study of tall objects by eliminating the need to stack multiple virtual objects created as individual tomograms at different heights into a single final model.



Installation of the ToraLift manipulator onto the Toratom tomograph. Left to right: Václav Rada, Tomáš Fíla, Michal Vopálenský

M. Vopálenský

PENDULUM VIBRATION ABSORBER ON THE BREWERY LOOKOUT TOWER

The chimney of the Bernard Family Brewery in Humpolec in the Vysočina region is a local landmark due to its height of over 30 m. This year, visitors to the brewery will have the opportunity to take advantage of its considerable height and look around from the 32.5 m high platform at the top of the self-supporting metal lookout tower, which encircles the chimney without touching it. From the platform you can see e.g. the ruins of the Orlík Castle, the Lipnice Castle or the highway bridge in Vystrkov.

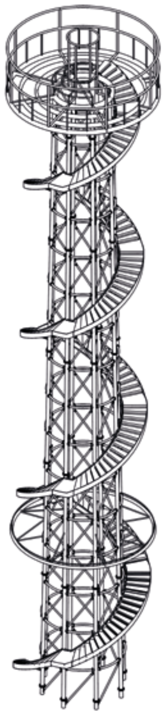


Fig. 1. Self-supporting octagonal lookout tower of the Bernard brewery and its 3D model. Source: S. Hračov (L) and Excon, a.s. (R)

Before opening the tower to the public, it was necessary to test the dynamic characteristics of the entire structure, and, if needed, to design and install a vibration absorber. This was important because high-rise buildings, such as the Bernard lookout tower, can be subject to unwanted vibrations due to wind or the movement of persons which affect the well-being of the people on the structure – standing on a swinging platform 30 m above the ground is not at all pleasant. During the dynamic tests carried out by researchers from ITAM CAS led by Shota Urushadze, it was found that the observation platform of the structure without a vibration absorber shows an above-limit response caused by the movement of persons on the tower structure. It was therefore necessary to install a suitable vibration absorber, which would effectively reduce the level of vibration of the structure. The pendulum absorber designed for the Bernard lookout tower took the form of a large metal ring placed around the chimney, weighs a ton and is attached to the supporting structure of the viewing platform by eight hinges (Fig. 2). With the hinges the absorber can move in all directions. The kinetic energy of the vibrating structure of the lookout tower is transferred to the pendulum absorber, which then also oscillates. It acts "against" the movement of the lookout tower structure, thus dampening its vibrations. Part of the kinetic energy is also absorbed by friction in the hinges.

Fig. 2. Ring absorber with sensors already deployed. Photo: S. Hračov

The vibration absorber was designed by the Head of the Department of Dynamics and Aerodynamics, Stanislav Hračov, and was installed by Excon, a.s. The dynamic characteristics tests, this time with the absorber, were again conducted by our colleagues from ITAM CAS. First they verified the functionality of the suspension elements in the Central Laboratory at ITAM. A total of six sensors (accelerometers) were then installed on the viewing platform which measured the acceleration of the structure during various types of excitation (wind, a person walking on the stairs, moving people on the platform, vandalism – intentional oscillation of the platform, etc.) with an active as well as a blocked absorber. An important part of the tests was to verify the functionality and behaviour of the absorbers during all of these activities. The accelerometers were placed in pairs at different places on the platform, and measured the response in two mutually perpendicular horizontal directions.

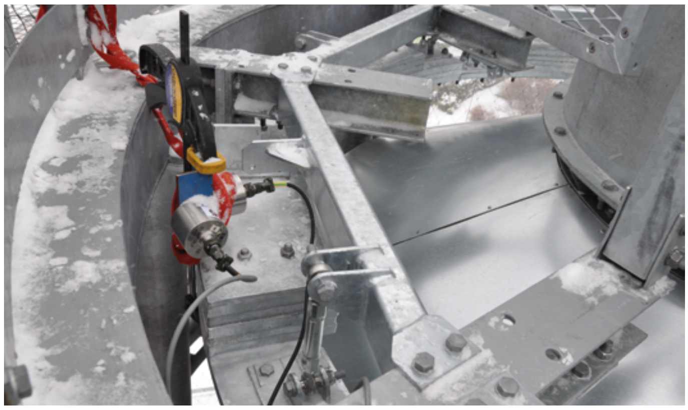


Fig. 3. A detail of the hinges and one pair of sensors. Photo: B. Přechová

The tests showed a slight decrease in the lowest resonant frequency compared to before installing the absorber. At the same time, the installation of the absorber in the construction of the lookout tower led to a significant reduction in the vibration level. When the tower oscillated due to human force, the resistance of the active absorber could be seen to prevent the attainment of the resonant state and its prolonged maintenance. The analysis of the response showed that the effective values in forced oscillations decreased by seven times, and the maximum values by six. It was thus possible to state that, with an active vibration absorber, the lookout tower is suitable for safe operation. The pendulum absorber can be viewed during a visit after climbing all 191 steps.

B. Přechová

Published by: Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, Prague 2021.
year V., graphic and preprint works: Barbora Přechová, Linguistic revision: Marek Eisler