BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF CIVIL ENGINEERING

AdMaS®
ADVANCED MATERIALS, STRUCTURES AND TECHNOLOGIES

Annual Report on the Activities of the AdMaS Centre 2021

Foreword by the Director

Dear colleagues,

The AdMaS (Advanced Materials, Structures and Technologies) research centre is a regional research centre in the field of construction which focuses on research, development and the application of advanced building materials, structures and technologies. However, its scope far exceeds the area of the construction industry. For instance, it conducts research focused on transport systems, urban and municipal infrastructure, and the circular economy.

During the seventh year of its full operation, the AdMaS Centre had to deal with the COVID-19 pandemic and the fact that the contractor´s warranty for their construction work on the premises of the Centre expired, which will mean increases in operating costs in the future.

In 2021, the Final Report for the AdMaS project was submitted concerning the reinforcement of the Centre´s research capabilities. The final monitoring report also included information on the fulfilment of all planned monitoring indicators.

In 2021, the activities of the Centre were in full accordance with its professional focus, concerning research projects awarded by the Czech Science Foundation, the Technology Agency of the Czech Republic, and the Ministry of Education, Youth and Sports, alongside contract research. It also prepared the ground for the development of new research activities, e.g. in the field of additive technologies and 3D printing.

Researchers at the AdMaS Centre focused on innovations in the construction industry, the improvement of existing technologies, materials and processes, the circular economy, water and waste recycling within the green infrastructure of cities, and the investigation of individual research projects at the CAMEB centre of competence, which is the main research project of the AdMaS Centre.

Thanks to the efforts of all the researchers at the AdMaS Centre, research activities continued in 2021 with a similar quantity of outputs as in previous years despite the complications associated with the COVID-19 pandemic. At the same time, preparations began for the CAMEB II project, which will be crucial in the coming period.

A big challenge for the AdMaS Centre is posed by the preparations for entrance to the National Centre for Construction 4.0 platform, which aims to employ synergies in the implementation and optimisation of digitisation and automation, as well as in the application of the principles of sustainable environmental behaviour. The AdMaS Centre is preparing to become one great construction testbed for these purposes.

The AdMaS Centre is a reliable research partner and a recognised arbitrator in the construction industry. This is mainly thanks to our researchers and technicians, but I also must not forget the administrative and maintenance staff who create the conditions that all of us work under. I would like to thank all of my colleagues, as without them we would not have achieved the results we have and the AdMaS Centre would not be what it is today.

Ing. Zdeněk Krejza, Ph.D., Director

Contents

1. Organizational structure

Headquarters

Director	Ing. Zdeněk Krejza, Ph.D.
Deputy Director, Facility Manager	Ing. Michaela Ulbrychová
Administrative Manager	Assoc. Prof. Ing. Jiří Zach, Ph.D.
Secretariat	Ing. Andrea Běhálková

Advanced Building Materials Interest Group

Group Coordinator	Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.

Advanced Building Structures and Transport Constructions Interest Group

Group Coordinator	Assoc. Prof. Ing. Pavel Schmid, Ph.D.

Economics and Environment Interest Group

Group Coordinator	Prof. Ing. Petr Hlavínek, CSc., MBA.

2. Activities in the area of management and monitoring

Since 1st January 2021, the Director of the AdMaS Centre has been Ing. Zdeněk Krejza, Ph.D., who replaces Assoc. Prof. JUDr. Ing. Zdeněk Dufek, Ph. D. in this position.

At the end of January 2021, the Final Report for the AdMaS project was submitted – it concerned the reinforcement of the Centre´s research capacities. The final monitoring report also included information on the fulfilment of all planned monitoring indicators.

The traditional Horizontal Integration of the AdMaS Centre research teams took place, including the involvement of Prof. Václavek´s research team (CEITEC, RICAP project).

Cooperation with industrial entities was developed further, both in the field of contract research and with regard to applied R&D projects.

Despite the complications resulting from the COVID-19 pandemic, 3 meetings of the AdMaS Centre board took place, resulting in a decision on the future use of free space P3, the transfer of the 3D printing laboratory (3DCP) to the hall in building P1, and the offices of researchers from the Economy and Environment Interest Group to building P1. A new use was found for the offices in building P4 which will strongly increase the efficiency of the use of space and significantly increase the revenues of the AdMaS Centre.

Only one traditional meeting of the employees of the AdMaS Centre took place, and, unfortunately, the Night of Scientists was not held this year due to restrictions related to the pandemic.

3. Events, training and seminars

In 2021, activities at the AdMaS Centre were severely restricted due to the epidemiological situation, although quite a few activities still took place notwithstanding. These were the following:

- Due to the restrictions on the undertaking of trips abroad, meetings with a Norwegian project team were held in September and November online. During these meetings, the conditions for a prepared joint study programme between the Norwegian University of Science and Technology and Brno University of Technology were discussed. In October, the conference Urban Waters 2021 took place, at which researchers Dr. Žižlavská and Dr. Macsek presented information about an ongoing project as well as a future joint doctoral study programme.
- On 18. 8. 2021, a new frame-mounted 3D printer was ceremoniously presented at the AdMaS Centre premises in cooperation with the Faculty of Mechanical Engineering, enabling the use of 3D printing in the construction industry. In only 10 hours, a team of researchers led by Dr. David Škaroupka made 14 elements for a parkour playground. The mixture which the obstacles are made from resembles concrete, but it isn´t that material because it doesn´t contain coarse particles. The mixture is based on a combination of cement, water, aggregate and polypropylene fibres. The parkour playground will be used for leisure activities in the Prague 11 city district. The playground project features several interesting aspects, such as sustainability and the uniqueness of 3D printing, as well as the connection with the active enjoyment of leisure time. It is the first 3D printing construction project in the Czech Republic that will be used by people in a public space.
- GasNet employees, together with AdMaS Centre representatives from the Faculty of Civil Engineering at BUT, organised the first conference in the Czech Republic on the use of LNG in transport and the power industry on 26.5.2021. The event took place under the auspices of the Dean of the Faculty of Civil Engineering, Prof. Bajer. Assoc. Prof. Zdeněk Dufek presented a global view of the options offered by the greater use of LNG in freight transport, and Ing. Beneš presented issues concerning fire safety in relation to Czech standards.
- On Monday, 3rd May 2021, filming of the robotic 3D printing of concrete took place at the 3D construction printing (3DCP) laboratory in connection with a prepared Czech Television documentary with the working title “Toulky Českou Budoucností” (“Strolls through the Future of the Czech Republic”).
- At the end of 2020, together with its partners, the AdMaS Centre commenced research on the project “For healthier and better water in Brno”, whose contracting authority is the municipal authority of the City of Brno. During 2021, monitoring and evaluation of water quality took place in Brno. The aim of the project was to gain up-to-date information about the quality of drinking and wastewater in Brno with a focus on micropollutants such as drugs, pesticides and microplastics.
- Assoc. Prof. Tomáš Apeltauer, the Head of the Institute of Computer Aided Engineering and Computer Science and the main investigator of the National Competence Centre project “Rebuild - a virtual environment”, which has been underway at the AdMaS Centre for 3 years, prepared a simulation of the operation of vaccination centres in the South Moravian region. Together with his colleagues from the Institute of Computer Aided Engineering and Computer Science, the South Moravian Innovation Centre and University Hospital Brno, he collected data for the simulations and tested the Vaccination Centre at the Brno Exhibition Centre, all with the support of the South Moravian Region. The aim was to get the most from the process and optimise the operation of other regional centres. We are proud that among our colleagues there are people who are willing to dedicate their leisure time to such important projects for free.

4. Research staff mobility and cooperation with institutions abroad

The extent of the coronavirus pandemic also affected AdMaS Centre staff mobility. The majority of business trips to cooperating institutions as well as visits from institutions abroad to the AdMaS Centre were cancelled or postponed indefinitely.

Despite this, some of the planned meetings took place in the form of conference calls or online seminars. Detailed information and examples of visits to and from institutions abroad are provided for the individual interest groups below.

5. Research staff mobility with regard to industrial entities

Research staff mobility for the purpose of collaboration with industrial entities took place throughout the year, but with regard to the worldwide situation, only a limited amount of such visits occurred. In the majority of cases they entailed one-day trips made in order to conduct specific experiments or to take measurements, or for consultation, etc.

Detailed information and examples of such visits are provided for the individual interest groups below.

6. Compliance with the monitoring indicators and benchmarks for 2021

In 2021, all research activities continued in accordance with the scientific research focus of the AdMaS Centre, just as in previous years.

The majority of the planned monitoring indicator values were fulfilled, and in some cases, the annual planned values were significantly exceeded.

The fulfilment of the targets of monitoring indicators occurred as follows:

Table 1: Financial and personnel indicators

Indicator	Value for 2021
Volume of contract research	**52,941**
Volume of funds for R&D obtained from foreign sources	**4,083**
Volume of funds obtained from public tenders for the targeted support of R&D from national resources	**144,508**
Number of employees (HC) – total	**105**
Number of women of total (HC)	**27**
Number of employees (FTE) – total	**86,39**
Number of women of total (FTE)	**17,99**

7. Research activities

7.1 Interest group: Advanced Building Materials

7.1.1 Activities of the IG in the area of management

Fulfilment of the goals of the Advanced Building Materials interest group took place fully in accordance with its professional focus in 2021. As part of the planning and coordination of research activities in 2021, quarterly meetings took place (in person or online) with the participation of the group head, key researchers, and also other employees. During the meetings, concise information was presented about current activities, including the acquisition of financing from public funds (coordination of the preparation of projects for tenders currently announced by the Czech Science Foundation, the Technology Agency of the Czech Republic, the Ministry of Education, Youth and Sports, etc.) and contract research projects with industrial partners, as well as other information with regard to current needs.

Social gatherings and other activities were significantly curtailed by the coronavirus crisis and the restrictions associated with it.

7.1.2 Training and seminars

- On 16. 5. 2021, ČEZ a.s. staff underwent laboratory training via a basic preparatory course which entailed approximately 7 hours of tuition, most of which took place in laboratories. During the course, issues related to the design, preparation and quality control of fresh and hardened concrete were presented. Destructive and non-destructive concrete tests were presented and then conducted on fresh and hardened concrete. Attention was given to the inspection and remediation of the concrete structures of nuclear power stations, surface finishes of materials, and the pore structure and internal structure of materials. Another part of the course involved familiarisation with the most modern laboratory methods for the evaluation of building materials. The theoretical foundations of X-ray diffraction analysis, electron scanning microscopy and computer tomography were presented.
- 4. 9. 2021 – Training of employees from the company ČESKOMORAVSKÝ CEMENT, a.s. - The theme of the training was Concrete and Mixed Cements. All topics related to the design, preparation and testing of fresh and hardened concretes were discussed during the training. Another significant topic was the option of using mixed Portland concretes for prefabrication. The training also included a practical demonstration of tests and of the properties of fresh and hardened concretes in laboratories.
- On 15. 9. and 23. 9. 2021, staff training was conducted for the Road and Motorway Directorate of the Czech Republic - the theme of the training was Concrete and Departmental Regulations. All topics related to the design, preparation and testing of fresh and hardened concretes in the area of road structure quality control systems were discussed, as well as road structure quality policies. Another significant topic was the monitoring of the properties of concretes, and the requirements placed on them from the point of view of individual departmental regulations of the Ministry of Transport, particularly the technical quality conditions TKP 18 RMD.
- 24. 9. 2021 – Training of employees from the company MAPEI a.s. - The training concerned the testing of fresh and hardened concretes and also covered requirements for the properties of repair mortars (mortars for the protection of concrete structures, impregnations, coatings, etc.). The training was divided into two parts, one of which

dealt with the design and production of concrete in detail, as well as the testing of fresh and hardened concrete, including the use of non-destructive testing methods. The second part, dealing with repair materials, concerned a detailed description of the properties and testing of repair mortars in both fresh and hardened conditions. Another part focused on the in situ testing of these materials.

7.1.3 Research staff mobility and cooperation with institutions abroad

In 2021, due to the coronavirus crisis, employee mobility to institutions abroad was significantly curtailed. This trend continued from 2020, when the amount of staff mobility from foreign universities to the AdMaS Centre decreased. New partnerships in the area of international cooperation thus emerged rather sporadically and were deepened via remote communication (e.g. with Kalashnikov Izhevsk State Technical University, Fels Vertriebs and Service GmbH & Co. KG, TU Wien, Bauhaus University Weimar, the Faculty of Civil Engineering in Košice, Universität Rostock, Germany, etc.).
One notable example of important cooperation with entities abroad is the three-year international grant project GA20-09072J undertaken with Prof. Dr. Ing. Grigorij Yakovlev from the Kalashnikov Izhevsk State Technical University, who, together with his colleagues Irina Polyanskikh, Igor Pudov and Zarina Saidova, took part in joint experiments, analyses and particularly consultation concerning the interim results of the joint project at AdMaS from 8 - 12. 11. 2021.
Another example of cooperation with institutions abroad is our joint research with the company Fels Vertriebs und Service GmbH & Co. KG, which is focused on the development of new mixtures for the production of autoclaved aerated concrete. As a part of this cooperation, the joint experimental verification of new raw material variants took place at the AdMaS Centre during the periods 23-27.8.2021, 30.-3.9.2021 and 18.-22.10.2021.
Last but not least, the fourth visit to VUT by staff from TU Vienna in the period from 30.8. 2021 to 5. 9. 2021 should be mentioned. Three members of the research team from the Austrian side took part in the visit, including the project leader Azra Korjenic from Austria. During their stay at BUT, a plan for fulfilling the goals of the project was discussed. Minor experiments and simulations of the behaviour of green buildings were carried out. At the same time, the results from previous project investigations were evaluated and research tasks were set for the next period of 2021. The joint research project is project No.7AMB 8J19AT014, with the title “Study of the Internal Microclimate of Buildings with Green Walls and Their Effect on Human Health”.

As far as student mobility is concerned, the following examples can be named:

- Bc. Vojtěch Uher, 2nd year nM - Universidade do Minho, Portugal, Erasmus + study visit
- Ing. Mizerová Cecílie, 4th year. nD - Karlsruhe Institute of Technology, Germany, Erasmus+ internship
- Ing. Sklenářová Dorothea, 4th year nD - Hochschule Wismar, Germany, internship, financed from RP

As regards staff mobility, the following can be named:

- Assoc. Prof. Ing. Jiří Zach, Ph.D. - University of Žilina, Slovakia, Erasmus+ educational stay
- Assoc. Prof. Ing. Jiří Zach, Ph.D. - University of Ljubljana, Slovenia, Erasmus+ training
- Ing. Vítězslav Novák, Ph.D. - University of Ljubljana, Slovenia, Erasmus+ training
- Ing. Lenka Nevřivová, Ph.D. - Reykjavik University, Iceland, Erasmus+ training
- Assoc. Prof. Ing. Nikol Žižková, Ph.D. - Reykjavik University, Iceland, Erasmus+ training

7.1.4 Researchstaff mobility with regard to industrial entities

Research staff visits to industrial entities took place throughout the year. In the majority of cases, this entailed one-day trips for the purpose of carrying out specific experiments, taking measurements, verifying jointly produced functional samples or verified technologies, training, consultation, etc.

7.1.5 Researchactivities conducted by the IG

The fulfilment of the goals of the Advanced Building Materials interest group took place fully in accordance with its professional focus and expected goals in 2021. One of the key projects of the year 2021 was sub-project No. TN01000056/ 04 with the title “Advanced Materials and Technologies”, which was investigated within the framework of the National Centre of Competence “Centre for Advanced Materials and Efficient Buildings”. 2021 was the first year of the investigation of the extended part of the sub-project, which was expanded by 6 new results with the completion date 31.12.2022. All activities conducted during the investigation took place according to the approved schedule.

In 2021, researchers also studied processes involved in the formation of the structure of silicate composites with organic fillers and their behaviour under specific stress conditions. Another subject of study was issues concerning the controlled modification of the mineralogical composition of ceramic shard in order to improve its useful properties. Another interesting area was the study of the impact of mechanochemical activation on the structural formation process and stability of selected clinker materials.

The field of ceramics is focused on the controlled modification of the mineralogical composition of ceramic shard in order to improve its useful properties, as well as the heat-resistant properties and corrosion resistance of forsterite-spinel ceramics using high-temperature fly ash, or, for example, the characterisation of porosity and cavity defects in ceramic objects manufactured via extrusion additive production.

2021 saw the completion of projects focused on the use of waste from the production of cement-bonded particleboard during the manufacturing of competitive building materials, and also a project concerned with polymer materials employing secondary raw materials and hazardous waste for chemically highly aggressive environments. Additionally, some research concerned a formwork system with a protective anti-corrosion function, while another project focused on a waste-free technology for high-performance aerated concrete production using renewable resources. Other projects that were successfully completed in 2021 included Comprehensive system for the rehabilitation of chemically attacked and stressed building structures, Advanced materials improving grounding in lightning and surge protection systems and the application of laser and radar road measurements in cement-concrete highway pavement, Use of microscopic and chemical analyses of concretes to reduce the degradation processes in concrete that reduce the lifespan of highway pavement.

The use of secondary raw materials is a very important topic for the Advanced Building Materials IG, and in 2021 research focused on a technology used for the processing of residues left after ore mining for the stabilisation of excavated areas and for the underlying layers of linear structures. There was also research into new advanced materials for the rehabilitation of utility infrastructure using secondary raw materials, and mention should also be made of work done in the area of the interaction of cement composites with superabsorbent polymers in order to increase the incorporation of secondary raw materials.

In the field of insulation materials, researchers participated in the development of a technical line for the recycling and material utilisation of waste from insulation materials, and also in studying the internal microclimate of the interior of buildings with green walls, and its impact on human health. Last but not least, they investigated the hygrothermal properties of advanced biologically based insulation materials.

One of the very important areas of research of the Advanced Building Materials IG is concrete technology. Staff were involved, for example, in the development of lightweight structural concrete using foam glass-based aggregates, and the study of the effect of consistency on resistance to abrasive concrete, the use of the sol-gel method for the production of cement-free refractory concrete, the effect of the type of dispersed reinforcement on the properties of concrete at high temperatures ,and also the area of influence of crystallisation additives on the resistance of self-compacting concretes exposed to aggressive gases.

In 2021, several specific research projects were investigated with the heavy involvement of Ph.D. and master´s students. One of the areas concerning the use of secondary raw materials was the use of waste diatomaceous earth as a secondary raw material for the production of modern inorganic insulation materials, and the properties of chemically resistant silicate-based repair material containing secondary raw materials was also investigated. Last but not least, vacuum insulation technologies employing secondary raw materials were developed. Furthermore, projects were undertaken involving concrete, focusing on the investigation of lightweight concretes at high temperatures and the assessment of the resistance of a concrete composite in a chemically aggressive environment using non-destructive methods, and also investigating the effect of the aeration rate of concrete on its volume changes and resistance to mechanical abrasion. The projects also studied, for example, the corrosion resistance of amorphous refractory materials, the crystallisation kinetics of various polymorphs of tricalcium silicate, and the structure of electrically conductive silicate composites containing carbon-based fillers. Also worth mentioning is an investigation into the influence of the microstructure of refractory forsterite-spinel ceramics on their high-temperature behaviour and physico-mechanical properties, and a study of repair and adhesive materials with a higher content of secondary raw materials with increased resistance to extreme loads for cladding elements and concrete structures.

The Advanced Building Materials IG staff constantly and actively publish achieved results at significant scientific conferences and in important international journals, and thus present not only the latest findings from the area of research and development but also the AdMaS Centre itself. This activity also involves acquiring new contacts for future cooperation in the area of R&D and sub-contracts. The achieved results are also verified in the form of functional samples and verified technologies, and registered in the form of utility models and patents. It is not only important research workers in senior researcher positions that are significantly involved in the activities, but also (and indeed mainly) young people in junior researcher positions, who additionally cooperate closely with bachelor´s, master´s and Ph.D. students and pass on their experience to them.

The following results of research activities in 2021 were achieved:

- 29 articles in journals in the Web of Science, Jimp,
- 5 articles in journals in Scopus, Jsc,
- 6 journal articles - others, Jost,
- 77 articles in proceedings in the WoS or Scopus,
- 19 utility models,
- 3 verified technologies,
- 4 utility models,
- one certified methodology,
- one prototype.

Basic research primarily entailed the investigation of Czech Science Foundation projects such as:

- 21-20645S - Characterisation of the properties of modified isocyanate-based adhesives for special adhesive applications of timber elements (investigator at BUT - Assoc. Prof. Ing. Jan Vaněrek, Ph.D.)
- 18-25035S – A study of the effects of flowing fluids on the erosive wear of cement composites, and the subsequent modelling of mechanical corrosion (investigator at BUT - Assoc. Prof. Ing. Lenka Bodnárová, Ph.D.)
- 19-00291S - Analysis of processes in the formation of the structure of silicate composites with organic fillers and their behaviour under specific stress conditions (investigator - Ing. Tomáš Melichar, Ph.D.)
- 20-00676S – Effects of mechano-chemical activation on the process of formation, structure and stability of selected clinker minerals (investigator - Assoc. Prof. Ing. Karel Dvořák, Ph.D.)
- 20-01536S– Controlled modification of the mineralogical composition of ceramic shard in order to improve its useful properties (investigator at BUT - Assoc. Prof. Ing. Radomír Sokolář, Ph.D.)
- 20-09072J - Structural formation of advanced silicate composites with reduced impedance (investigator - Ing. Vít Černý, Ph.D.)
- 21-25813S – Study of the influence of organic fibres on the properties of cement composites under extreme loading (investigator - Ing. Martin Sedlmajer, Ph.D.)
- 21-29680S - Influence of the interaction of cement composites with superabsorbent polymers on the increase in incorporation of secondary raw materials (investigator - Ing. Jindřich Melichar, Ph.D.)

Cooperation with project partners (the Ministry of Industry and Trade, the Technology Agency of the Czech Republic and the Czech Science Foundation) as well as contractual research partners took place at an excellent level and the activities of the individual cooperating organisations complemented one another efficiently. This involved collaboration with producers of raw materials, manufacturers of materials and parts, organisations planning to apply for research funding in the future, and other research organisations. The key project of 2021 was the continuation of sub-project No. TN01000056/04 with the title “Advanced Materials and Technologies”, upon which the Advanced Building Materials IG cooperated with the companies INFRAM a.s. and Wienerberger s.r.o.

As far as other projects are concerned, the following can be named:

- MIT FV20530 – Unique formwork system with a protective anticorrosive function, with FEVA, s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV20149 – Comprehensive system for the remediation of chemically attacked and stressed building structures, cooperation with BETOSAN s.r.o., (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV20303 – Progressive polymer materials utilising secondary raw materials and dangerous waste for use in chemically highly aggressive environments, in cooperation with Redrock Construction s.r.o., (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV30325 - Application of laser and radar measurements of roads in the diagnostic analysis of cement-concrete covers of motorways; implementation of physical and chemical analyses of concretes in order to limit degradation processes in concretes which lower the lifespan of highway pavements, cooperation with CONSULTEST s.r.o., (investigator at BUT - Prof. Ing. Rudolf Hela, CSc.)
- MIT FV30072 - Effective optimisation of the use of waste from the production of cement-bonded particleboards in the production of competitive building materials, collaboration with CIDEM Hranice, a.s. (investigator at BUT - Assoc. Prof. Ing. Jiří Bydžovský, CSc.)
- MIT FV30327 - Advanced waste-free technology for high-performance porous concrete utilising renewable resources, cooperation with PORFIX, CZ a.s. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV30239 – Advanced materials improving earthing in a lightning and overvoltage protection system, cooperation with BETONCONSULT, s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV40081 – Advanced technologies for the establishment and restoration of structural layers of railway track beds with the efficient use of secondary raw materials, in cooperation with INFRAM a.s. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- MIT FV40343 - Silicate-based structural systems of paved surfaces and roads for ecological rainwater management, cooperation with Lias Vintířov, lehký stavební materiál k.s. (investigator at BUT - Prof. Ing. Rudolf Hela, CSc.)
- TAČR TH04020378– Development of new technologies and products for sustainable construction in the area of masonry structures, cooperation with Wienerberger s.r.o. (investigator at BUT - Assoc. Prof. Ing. Jiří Zach, Ph.D.)
- TH04030425- REIZO - Development of a technical line for the recycling and material use of wastes from insulating materials, cooperation with VIA ALTA a.s. (investigator at BUT - Prof. Ing. Stanislav Šťastník, CSc.)

- TAČR FW01010061– Comprehensive technology for the processing of ore mining residues for the stabilisation of excavated areas and for the base layers of linear structures, cooperation with TVAR COM, spol. s r.o. (investigator at BUT - Assoc. Prof. Ing. Karel Dvořák, Ph.D.)
- TAČR FW01010579 - Innovative construction and manufacturing technology for massive solid wooden panels, cooperation with MATRIX a.s. (investigator at BUT – Assoc. Prof. Ing. Milan Šmak, Ph.D.)
- TAČR FW01010197 - Development of and research on new advanced materials for the rehabilitation of utility networks using secondary raw materials, cooperation with IN-CHEMIE Technology s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)

In 2021, new cooperation began not only in the execution of basic and applied research projects but also within contract research. The newly started projects include:

- TAČR FW03010107 – Development of and research into new materials for polymer remediation sprays, cooperation with IN-CHEMIE Technology s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- TAČR FW03010074 - Advanced system for the remediation of defects and failures in basalt sewerage systems, cooperation with Redrock Construction s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- TAČR FW03010073 - Silicate smart autonomously heated composites 4.0, cooperation with BETOSAN s.r.o. (investigator at BUT - Prof. Ing. Rostislav Drochytka, CSc., MBA, Dr.h.c.)
- Czech Science Foundation 21-25813S - Study of the influence of organic fibres on the properties of cement composites under extreme loading (investigator - Ing. Martin Sedlmajer, Ph.D.)
- Czech Science Foundation 21-29680S - Influence of the interaction of cement composites with superabsorbent polymers on the increase in incorporation of secondary raw materials (investigator - Ing. Jindřich Melichar, Ph.D.)
- Czech Science Foundation 21-20645S - Characterisation of the properties of modified isocyanate-based adhesives for special adhesive applications of timber products (investigator - Assoc. Prof. Ing. Jan Vaněrek, Ph.D.)

Selected photographs documenting the verification of materials from a system for the remediation of chemically attacked and stressed building structures:

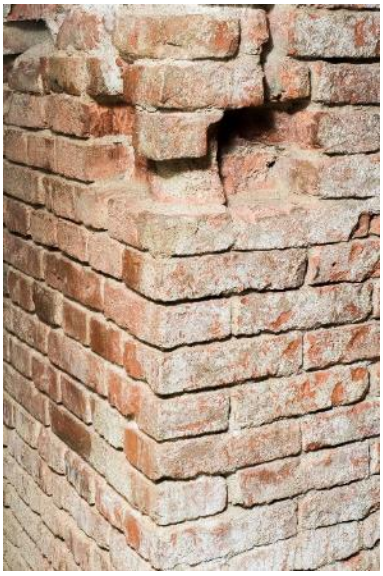


Fig. 1 Masonry prepared for the application of remediation materials

Fig. 2 Preparation of masonry elements

Fig. 3 Laying of the bottom row

Fig. 4 Masonry

Fig. 5 Walled-up opening

Fig. 6 Application of repair mortar

Fig. 7 Renovated wall

Fig. 8 Masonry grouting

Fig. 9 Renovated wall

Fig. 10 Preparation of openings for parks

Fig. 11 Injection

7.2 Interest group: Advanced Building Structures and Transport Constructions

7.2.1 Activities of the IG in the area of management

Basic structure of the IG

MODELLING	MAT-ADMAS	12537	Prof. RNDr. Josef Diblík, DrSc.
	STM-ADMAS	12594	Prof. Ing. Drahomír Novák, DrSc.
	AIU-ADMAS	12546	Assoc. Prof. Mgr. Tomáš Apeltauer, Ph.D.
CONSTRUCTION	GTN-ADMAS	12566	Assoc. Prof. Ing. Lumír Míča, Ph.D.
	BZK-ADMAS	12534	Prof. RNDr. Ing. Petr Štěpánek, CSc.
	KDK-ADMAS	12535	Prof. Ing. Marcela Karmazínová, CSc.
	SZK-ADMAS	12536	Assoc. Prof. Ing. Pavel Schmid, Ph.d.
BUILDING STRUCTURES, ARCHITECTURE	PST-ADMAS	12574	Prof. Ing. Miloslav Novotný, CSc.
	ARC-ADMAS	12539	Assoc. Prof. Ing. Arch. Juraj Dulenčín, Ph.D.
	TST-ADMAS	12575	Assoc. Prof. Ing. Vít Motyčka, CSc.
TRANSPORT STRUCTURES	PKO-ADMAS	12544	Assoc. Prof. Dr. Ing. Michal Varaus
	ZEL-ADMAS	12545	Assoc. Prof. Ing. Otto Plášek, Ph.D.

Operations at individual laboratories in terms of the laboratory work schedule and the ensuring of trouble-free operation (the necessary servicing, maintenance and calibration of equipment) is guaranteed by the heads of the individual laboratories.

As far as health and safety at work is concerned, each laboratory has declared binding Operating and Safety Rules approved by the Faculty of Civil Engineering's safety technician. Only trained persons listed on the list of Authorised Persons are authorised to work in the laboratories with individual devices, including handling equipment (gantry cranes, mobile mechanical lifting and transport equipment). The training and listing of persons is the responsibility of laboratory managers. Operational logs are kept for key pieces of equipment.

Heads of Laboratories at the AdMaS Centre

Head of Laboratories, Construction section (*P1 left, Hall H, storage and workshop facilities P1*)
Assoc. Prof. Ing. Petr Daněk, Ph.D.

Head of Laboratories, Road Structures section (*P1 right hall*)
Ing. Pavla Nekulová;

Head of Laboratories, Railway Structures section (*Hall H*)
Assoc. Prof. Ing. Otto Plášek, Ph.D.

Head of the Outdoor Test Polygon (*in front of Hall P4*)
Ing. David Bečkovský, Ph.D.

Head of Laboratories of the Radiation Defectoscopy Centre (*Hall P1–basement, monitored zone approved by the SUJB – the State Office for Nuclear Safety*)
Ing. Ondřej Anton, Ph.D.

Head of the Fire Resistance Testing Laboratory (*Hall H - test polygon near Hall H, mobile furnace*)
Ing. Martin Zlámal, Ph.D.

7.2.2 Training and seminars

International workshop *Description of the SŽ network and its relevant surroundings 2021.* Správa železnic (SŽ - Railway Network Authority), Directorate-general, Prague 1, Dlážděná 1003/7, meeting room Rytířský sál (The Knights' Hall), 26. 10. 2021. The workshop followed on from a similar event focused on the description of the SŽ railway network which took place at the same place on 9th January 2019. Those interested in attending this year's event could apply in person or online. The workshop was attended by 23 participants in person and 26 online. It featured a total of 13 papers focused on the digitisation of railway infrastructure, for which the description of the railway network and its components is absolutely essential. The papers provided information on the layout and use of the network description not only in various areas dealt with by the SŽ, but also its use in the description of the road network from the perspective of public administration and the Ministry of Transport. With regard to their topicality, the papers were accompanied by lively discussion involving direct participants as well as those online.

7.2.3 Research staff mobility and cooperation with institutions abroad

INSTITUTE OF RAILWAY STRUCTURES AND CONSTRUCTIONS - ADMAS

In 2021, the Inbearer sensor project was launched, focusing on the diagnosis of dynamic effects in switches, project investigation period 11/2020 - 10/2021. The project was investigated in collaboration with the University of Birmingham as a subcontract for the research project In2Track2 Research into enhanced track and switch and crossing system 2, led by the Network Rail (UK) railway infrastructure authority. The currently underway follow-up project is Inbearer sensor 2, again focusing on the diagnosis of dynamic effects in switches, project investigation period 11/2021 - 10/2023. The project is again being investigated in collaboration with the University of Birmingham as a subcontract for the In2Track3 Research into enhanced track and switch and crossing system 3, led by the Network Rail (UK) railway infrastructure authority.

The investigation of both projects is taking place as a Shift2Rail joint activity project with the support of the Horizon 2020 research programme.

CONCRETE AND MASONRY STRUCTURES - ADMAS

Person: Đorđe Čairović

Place of stay: Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

Contact person: Albert De La Fuente Antequera <albert.de.la.fuente@upc.edu>

Date of stay: 02. 09. - 17. 09. 2021

Description of work activity:

The main topic of the visit at UPC was internationalisation and future negotiations regarding joint European projects. It included, among other things, the search for a suitable grant programme supporting selected areas of interest. Additionally, an integral part of the stay was a presentation of ongoing research and development activities at the Institute of Concrete and Masonry Structures.

One of the practical aims of the stay was familiarisation with the performance of experimental work at UPC. During the visit, experimental activities occurred related to the use of metal fibres and the behaviour of UHPFRC (Ultra-High Performance Fibre Reinforced Concrete), pilot tests of low-cost wireless sensors for temperature and humidity readings, and the preparation of an extensive experimental study of concrete beams reinforced with pre-stressed FRP (Fibre Reinforced Polymer) reinforcement.

The visit was primarily about getting acquainted with the topic and scope of work in order to expand experience in this area, and also involved specifying areas of common research interests and where cooperation may deepen in the future (e.g. 3D concrete printing, recycled concrete, etc.)

Concrete bench made via 3D printing

UPC Campus

CONCRETE AND MASONRY STRUCTURES - ADMAS

Person: Đorđe Čairović

Place of stay: FH Kärnten, Villach, Austria

Contact person: FH-Prof. DI Dr. Norbert Randl <n.randl@fh-kaernten.at>

Date of stay: 13/10/2021 – 22/10/2021

Description of work activity:

Just as with the previous stay at UPS, the main goal was familiarisation with ongoing experimental activities in order to expand experience in the field, the specification of areas of common research interest and where cooperation may be deepened, which may lead to joint applications for projects funded under international calls, e.g. Horizon Europe, ERA-NET, Interreg Europe, etc.

During the visit, experimental activities were carried out concerning the use of metal fibres and the behaviour of the reinforcement of reinforced concrete structures containing UHPFRC. Loading tests were performed on concrete T-beams reinforced in shear with carbon fabric and high-performance fibre-reinforced concrete with variation in the used anchoring elements. Furthermore, the behaviour of short columns reinforced with a combination of UHPCFRC materials with carbon or basalt textiles was examined.

CONCRETE AND MASONRY STRUCTURES - ADMAS

Person: Dr. Nikola Tošić, (UPC), Barcelona, Spain

Place of stay: FCE, BUT, Brno

Contact person: Đorđe Čairović <cairovic.d@fce.vutbr.cz>

Date of stay: 22/11/2021 – 26/11/2021

Description of work activity:

The visit included lectures both for faculty staff and for doctoral and master´s students on the topics: Ongoing research activities within the working group at UPC; Research intentions at UPC in the future; Long-term behaviour of recycled aggregate structures; Short-term characteristics and behaviour of FRP reinforcements with thermoplastic resin.

Furthermore, specialised discussions were organized on the theme of green buildings - the use of mixed cements and internal FRP reinforcement for the design of ecological and economically sustainable structures, related to future cooperation and the submission of a joint project. The stay also included a visit to the AdMaS research centre.

7.2.4 Researchactivities conducted by the IG

BZK – ADMAS (CONCRETE AND MASONRY STRUCTURES)

Project TH04020431 - Extension of the application area of FRP reinforcement in concrete structures

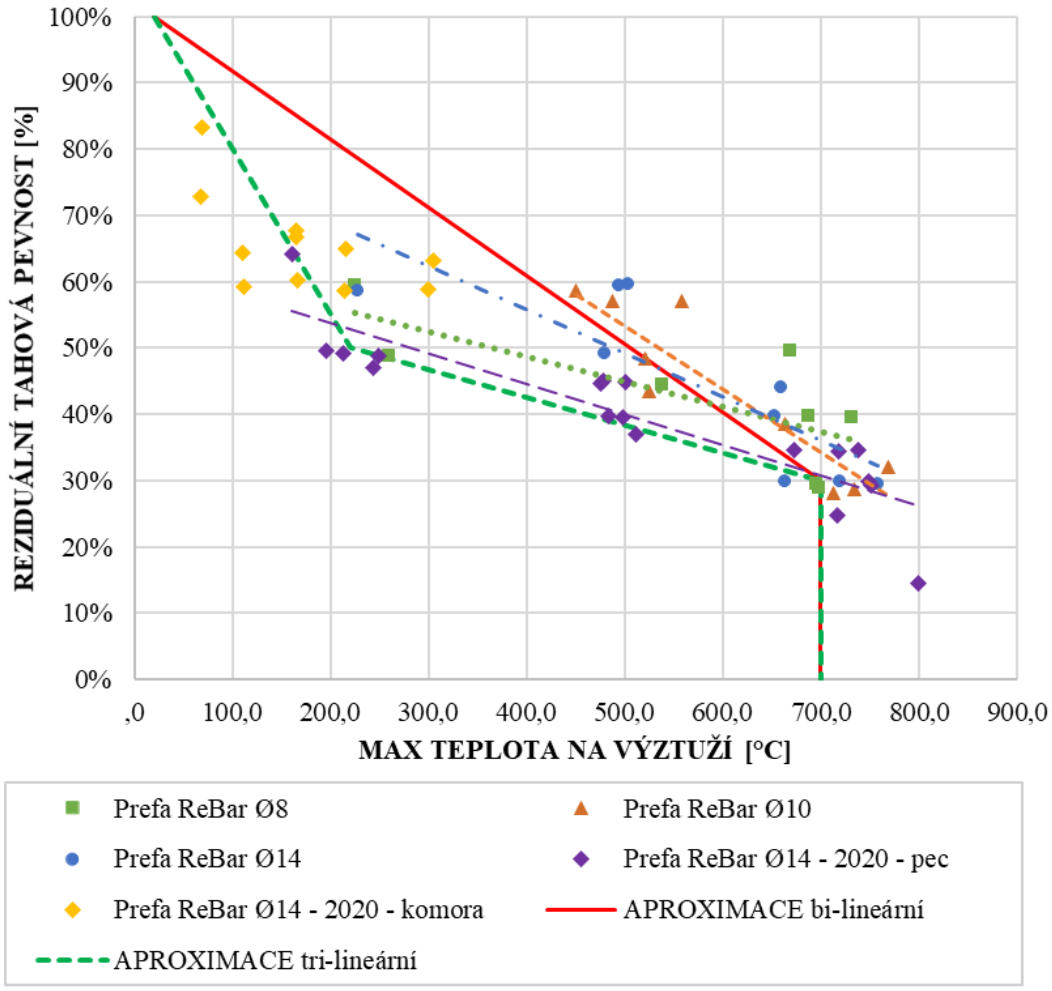
FRP reinforcement tests

As part of the TH04020431 project and in order to determine the influence of reinforcement diameter on the loss of tensile strength caused by elevated temperatures, Prefa ReBar reinforcement bars with diameters of 8, 10 and 14 mm were tested in a fire resistance test furnace stressed by a constant voltage and by temperatures that rise until failure of specimens occurs (variable temperature state). This procedure allows one to approach the behaviour of reinforcement in real structures when the reinforcement is already stressed by the effects of loading at the moment when the fire appears, or even before the structure is exposed to elevated temperatures.

Tensile strength testing of reinforcement at elevated temperatures in a fire resistance test furnace

The samples were tested in a special fire resistance test furnace with a load frame. The total length of the FRP reinforcement was 2 650 mm, with 300 mm long steel ends. In order to maintain conditions corresponding to those present at a real structure under thermal stress during a fire, the tested reinforcement wasn´t exposed to the fire directly, but was protected during the experiment by a layer of protective *Fiberfrax*® *Durablanket*® *S* insulation with a thickness of 19 mm. As is clear from the attached results, there was no difference in the behaviour of the specimens of different diameters exposed to elevated temperatures. Nevertheless, it is important to mention that the main influence of the diameter of the

reinforcement was recorded in tensile tests at normal temperatures, where there was a significant increase in tensile strength and modulus of elasticity with decreasing diameter.



Influence of elevated temperatures on the residual tensile strength of Prefa ReBar GFRP reinforcement

The overall behaviour of the ReBar GFRP reinforcement manufactured by Prefa Kompozity can therefore be simply described with a tri-linear course. Up to a temperature of 200°C, the dependence corresponds to theoretical assumptions, where the tensile strength drops sharply to about 50% of the tensile strength determined without the effect of elevated temperature. This is followed by an area with a mild decrease in strength to about 30% of tensile strength occurring up to a temperature of around 700°C, when a sharp decrease and a complete loss of tensile strength can be observed regardless of the load level.

Anchorage length tests

For the purpose of performing anchorage length tests during exposure to fire, or to increased temperatures resulting from fire, the standard dimensions and shape of the specimens had to be adjusted. The normal shape of a test specimen for the execution of a pull-out test at normal

temperatures takes the form of a cube with an edge length of 200 mm, the reinforcement being placed in the specimen in such a way that cohesion is applied for only 5 times the diameter of the reinforcement from the underside of the specimen, while part of the reinforcement on this unloaded end sticks out of the specimen so as to enable the displacement of the unloaded end to be recorded. Other parts of the reinforcement in front of this area are separated from the concrete.

However, the cube shape is not suitable for the testing of an anchoring area affected by fire, particularly due to the uneven transmission of temperature through the concrete specimen itself. From this aspect, the most suitable specimen shape is a cylinder with a reduced diameter of 150 mm due to the expected heating time of the concrete. For comparison, these specimens were prepared not only for anchorage length tests under fire exposure but also for the comparison of the results with those from standard pull-out tests.

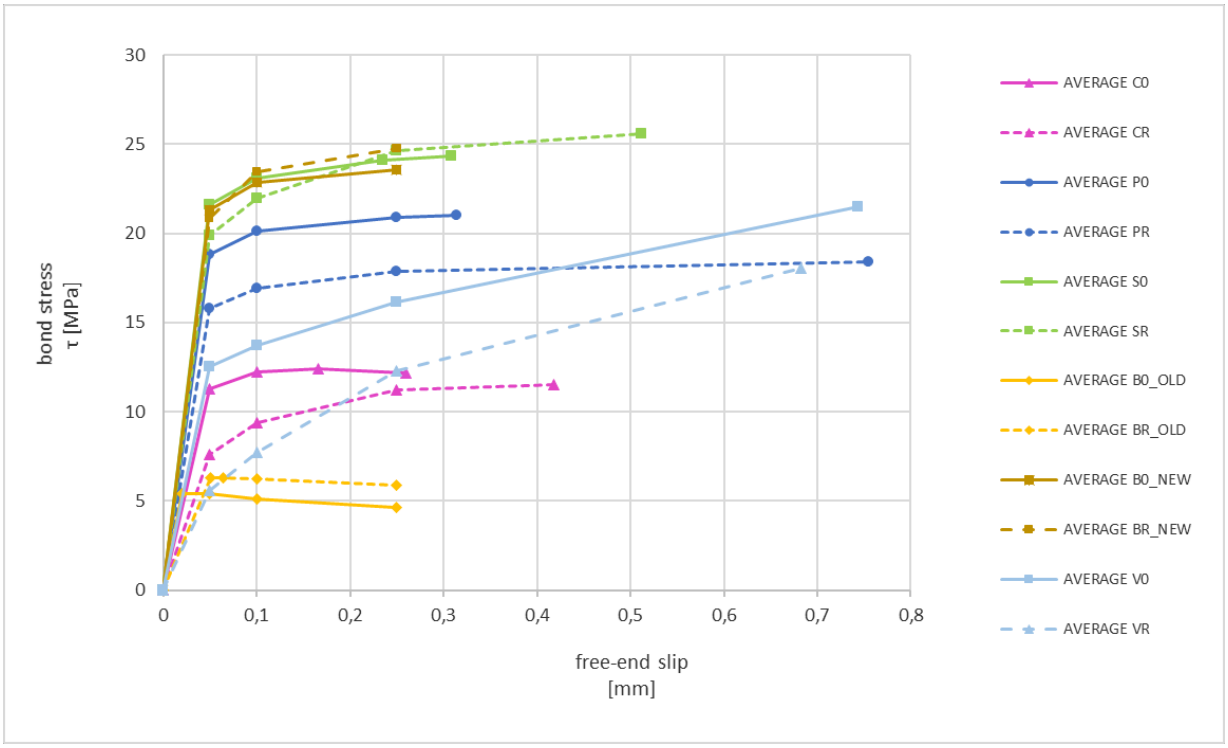
At the same time, the cylindrical specimens were provided with concrete reinforcement with a diameter of 6 mm in the form of a spiral with an outer diameter of 110 mm and a gradient of 60 mm. This was not only to prevent damage to/disintegration of the specimen during the fire test, but also to prevent damage to the specimen due to transverse tension when performing the test at a standard temperature. The specimens for the test at a standard temperature were, again, designed in such a way that cohesion between the concrete and the reinforcement was achieved only for a length corresponding to 5 times the diameter of the reinforcement, and the end of the reinforcement allowed the deformation / displacement of the unloaded end to be measured.

Static tests of anchorage lengths

Static tests of anchoring lengths on standard cube-shaped specimens and on modified cylindrical specimens were performed on a similar load assembly.

Pull-out test of the anchorage length of reinforcement (on a cube and a cylinder)

As a part of the tests at standard temperatures, tests were successfully performed on all of the test specimens, both standard cubic and cylindrical. The aim of the experiments was to obtain basic data on the cohesion of composite reinforcement with concrete which can be further used both in mathematical models and to compare the effect of fire or high temperatures on the determination of anchorage length. We can compare the results obtained during the pull-out tests at a standard temperature in graphic form.

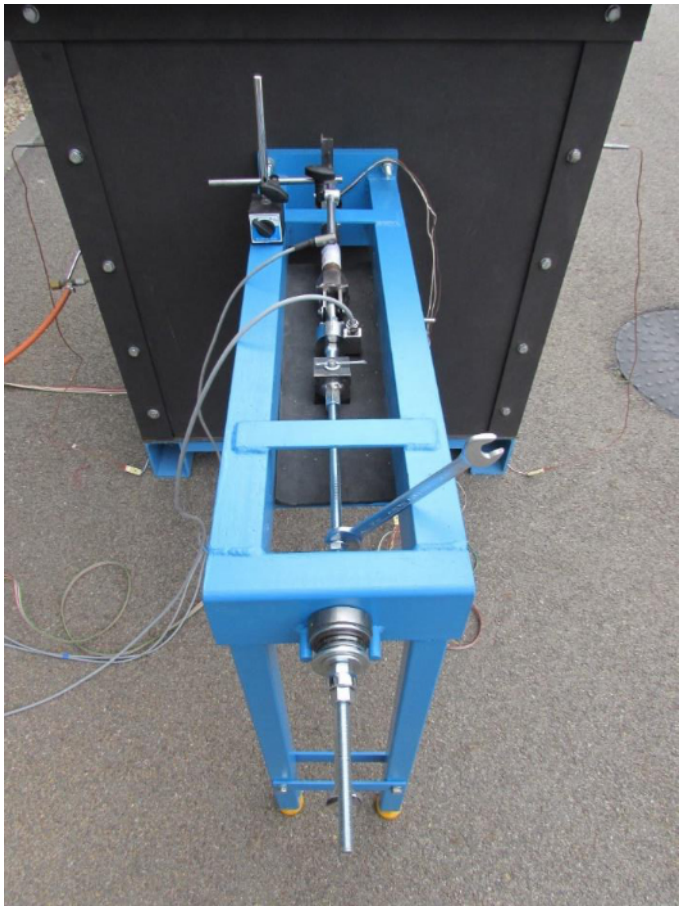


Cohesion stress, average test results

Anchorage length tests at high temperatures

To perform tests on anchoring areas exposed to fire or elevated temperatures, the fire resistance test furnace was slightly modified, and a load frame was manufactured directly connected to the furnace, after which the basic test set was tested. The modification of the furnace allows tests to be performed repeatedly under the same boundary conditions.

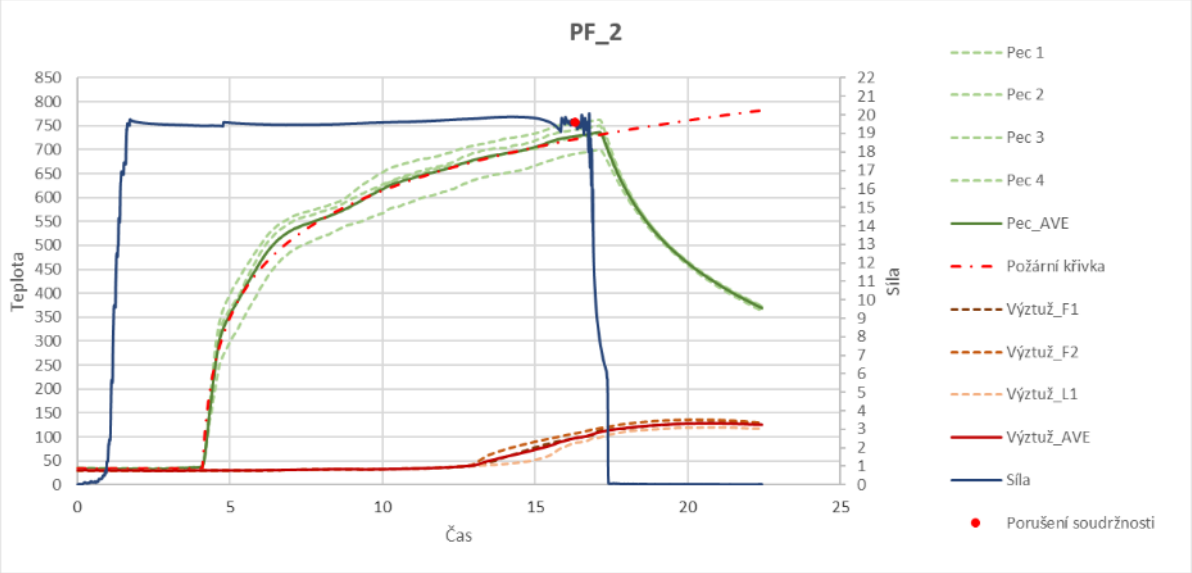
The load frame contains its own loading assembly within it. This is arranged in such a way that the negative influence of bending moments on the results of the experiment is restricted to a maximum degree and only the axial force is applied to the maximum extent. The loading set was supplemented by the continuous measurement of deformations. However, with regard to the test set-up, it wasn´t possible to measure the deformations of the unloaded end and only the deformations of the loaded end on the outside of the combustion chamber of the fire resistance test furnace were measured.



View of the loading frame and loading assembly

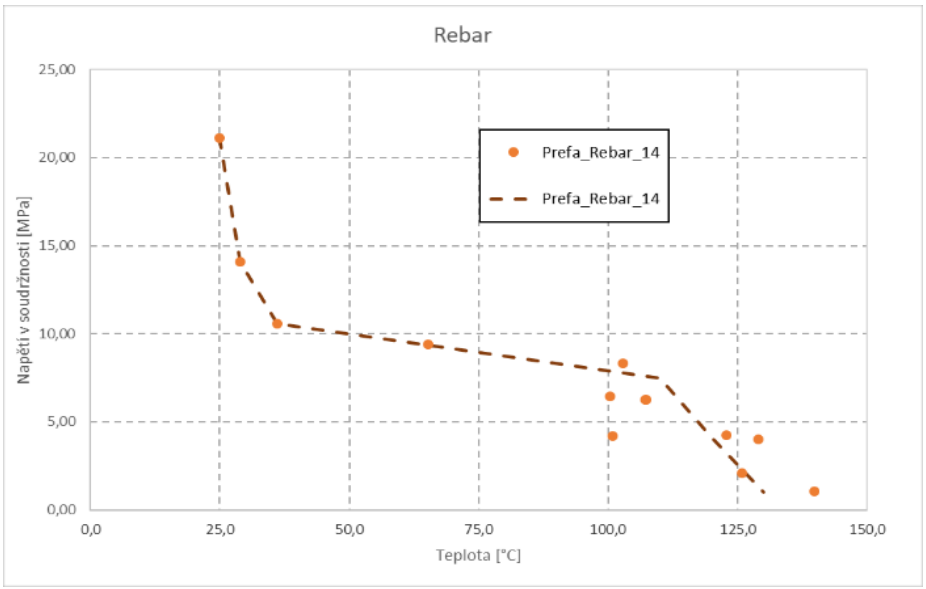
Placement of the specimen inside the combustion chamber of the fire resistance test furnace

The experiments were performed on all of the prepared samples in the same configuration. Since the verification series showed that the position of the specimen and the thermocouples on the surface of the anchor area with regard to the flame source is not significant, and that the temperature distribution in the specimen is uniform, the anchorage areas were fitted with three thermocouples, one on the loaded end and two placed opposite at the unloaded end, while the orientation of all the specimens in the fire resistance test furnace was maintained. In order to maintain the same boundary conditions, the temperature increase in the furnace was restricted to the predefined ISO 834 - 1 fire curve. To illustrate the achievable results, the fire test record is shown in the graph below.



Data from the anchorage area fire test

During the experiment, there was no negative blasting of the surface layer of the concrete and the whole specimen was compact even after the execution of the fire test. An example of the pull-out test results recorded with the influence of elevated temperatures from the effects of fire is shown graphically with respect to the dependence between the stress in cohesion and the maximum temperature at cohesion failure.



Cohesion stress due to elevated temperatures

Static tests of a composite ceiling structure for technical equipment

To verify the behaviour of a structure reinforced by FRP reinforcement, small sets of small-scale test specimens were produced to verify the expected behaviour and compare the experiments with mathematical models in the ATENA program before the actual production of the panels at full scale, which is planned for 2022.

Load test of panels in three-point bending

Failure of a panel with GFRP reinforcement and a span of 1.4 m

The knowledge gained from the static tests was also reflected during the preparation of mathematical models. This was performed in ATENA software, which enables the nonlinear modelling of concrete structures. The results of pull-out tests were also used; they were applied to a model of the cohesion of reinforcement with concrete. With regard to the development of cracks with larger distances, the parameter of the minimum crack distance was also taken into account in the models. When comparing both variants of the mathematical models, i.e. with GFRP reinforcement and with concrete reinforcement, good agreement with real behaviour was achieved. Greater stiffness of the mathematical model generally corresponds to the nonlinear solution in ATENA.

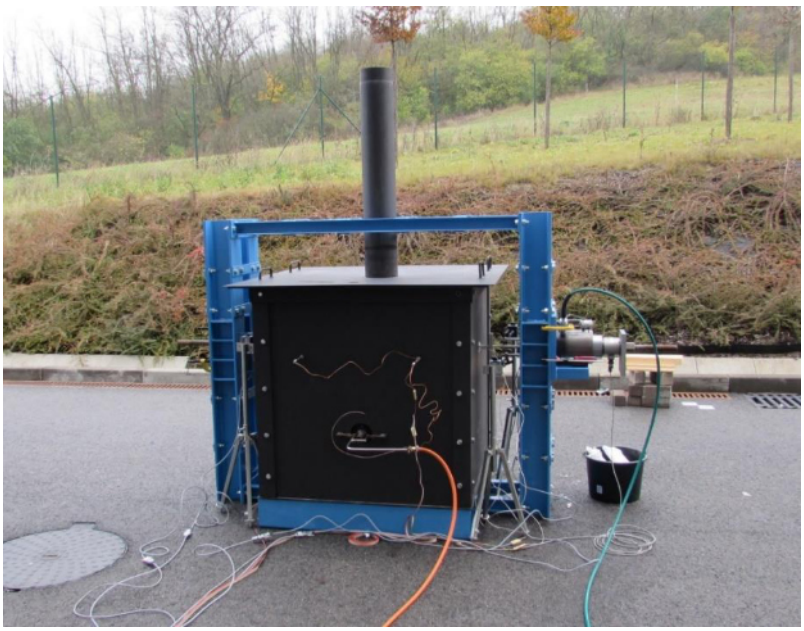
Execution of fire tests in a fire resistance test furnace

The experimental fire resistance test furnace is designed especially for the execution of small-scale tests which would be very expensive and financially inefficient to perform in commercial testing laboratories designed particularly for testing structural elements.

As a part of project TH04020431, a device was developed that will allow performance of the tests necessary to achieve the required project results without affecting the quality of the obtained data. Such tests are mainly tensile tests of reinforcement with simultaneous controlled static loading under given boundary conditions and external load from fire or elevated temperatures according to defined fire curves.

During the project, the furnace was used for:

- Tensile tests of FRP reinforcement exposed to fire or high temperatures and
- Anchorage area tests under conditions of exposure to fire or elevated temperatures.



Fire resistance test furnace with a load frame for tensile tests

Fire resistance test furnace with a load frame for anchorage length tests

KDK- ADMAS (METAL AND TIMBER STRUCTURES)

Overview of results from 2021

(Only outputs linked to the investigated R&D projects listed below are included; DSP student outputs connected with junior SV projects are not listed):

Publications:

ŠMAK, M.; KUBÍČEK, J.; KALA, J.; PODANÝ, K.; VANĚREK, J. The Influence of Hot-Dip Galvanizing on the Mechanical Properties of High Strength Steels. Materials, 2021, vol. 14, No. 18, p. 1- 19. ISSN: 1996- 1944.

WALD, F.; ŠABATKA, L.; **BAJER, M.;** KOŽICH, M.; **VILD, M.;** GOLUBIATNIKOV, K.; KABELÁČ, J.; KUŘÍKOVÁ, M. Component-based finite element design of steel connections. 1. 1. Prague: Czech Technical University in Prague, 2021. 243 p. ISBN: 978-80-01-06861-8.

VILD, M.; CHALUPA, V.; ŠABATKA, L.; WALD, F. Advanced analysis of members with gusset plate joints. In Modern Trends in Research on Steel, Aluminium and Composite Structures. 1. London: Taylor & Francis, 2021, p. 378- 384. ISBN: 9781003132134.

VILD, M.; BAJER, M.; BARNAT, J.; ŠABATKA, L.; WALD, F. Lateral-torsional buckling of a stiffened beam with semi-rigid joints. ce/papers, 2021, vol. 4, No. 2(4). p. 2086 - 2091. ISSN: 2509- 7075.

BARNAT, J.; PROKEŠ, J.; **BAJER, M.**; BEZDĚK, O.; **VILD, M.** Simplified Testing of the Bond Strength of Adhesives Used for Bonded Anchors. Materials, 2021, vol. 14, No. 12, p. 1- 28. ISSN: 1996- 1944.

BUKOVSKÁ, P.; KARMAZÍNOVÁ, M.; ŠTRBA, M. Benefit of Ultra-High Strength Infill in Concrete-Filled Steel Tubular Columns. In 22nd International Conference on Rehabilitation and Reconstruction of Buildings, CRRB 2020. Key Engineering Materials (print): 2021. p. 93- 99. ISBN: 9783035718102. ISSN: 1013- 9826.

BÁLKOVÁ, R.; VANĚREK, J.; **ŠMAK, M**.; DROCHYTKA, R. Time-temperature resistance of transverse stressed lap joints of glued spruce and thermal analysis of adhesives. International Journal of Adhesion and Adhesives, 2021, vol. 104, No. 1, p. 1-12. ISSN: 0143- 7496.

BUKOVSKÁ, P. Limita vzpěrné pevnosti ocelových trubek vyplněných betonem při použití materiálů vysokých pevností. Conference proceedings from JUNIORSTAV 2021. ECON publishing, s.r.o. Brno: Brno University of Technology, Faculty of Civil Engineering, 2021. pp.267- 271. ISBN: 978-80-86433-75-2.

ŠTRBA, M.; KARMAZÍNOVÁ, M.; BUKOVSKÁ, P. Experiences with using of loading tests and the "Design assisted by testing" method for the determination and verification of structural members and details. International Journal of Mechanics, 2021, vol. 15, No. 1, p. 1-11. ISSN: 1998- 4448.

Applied results with legal protection - utility models:

HLADÍK, M.; POFFEL, Z.; **HORÁČEK, M.; KARMAZÍNOVÁ, M.; PEŠEK, O.; BALÁZS, I.** Ceiling structure assembly for the built-in floors of hall buildings, utility model, registered under No. 35134, 2021.

MOCOVÁ, P.; HAVÍŘOVÁ, Z.; SUCHOMELOVÁ, P.; DĚCKÝ, D.; KRAMÁR, S.; PROCHÁZKA, J.; KALOČ, J.; **KARMAZÍNOVÁ, M.; PEŠEK, O.; BALÁZS, I.; BUKOVSKÁ, P.** Supporting skeletal system consisting of timber from a combination of wood species, utility model, registered under No. 34931, 2021.

Products - functional sample:

KARMAZÍNOVÁ, M.; KRONTORÁD, K.; ŠTRBA, M.; PILGR, M.; HORÁČEK, M.; PEŠEK, O.; BALÁZS, I.; DORŇÁK, V.; HAVÍŘOVÁ, P.; KRÁL, P.; MOCOVÁ, P. Reinforced wood-based composite structural element for horizontal load-bearing structures, functional sample, 2021.

Description of R&D activities in 2021

In 2021, several applied R&D projects were investigated at the Institute of Metal and Timber Structures (junior SV projects are not listed):

FAST-S-20-6400 Analysis, experimental verification and possible effective uses of the mutual interaction of materials in composite structural elements, investigator M. Štrba, 2021:

The project dealt with the theoretical and experimental analysis of the possibilities for the use of the interaction of materials in composite structural elements, especially in the case of the combination of steel and concrete, or other materials, with regard to input geometric and material characteristics, or a specific structural design. During the investigation, a method of designing and determining load-bearing capacity on the basis of tests was used, among other things. Emphasis was placed on efficient and reliable design. As part of the investigation, a number of tests were performed on reinforced concrete columns made of steel and higher strength concrete stressed by buckling pressure.

FW01010579 Innovative construction and production technology for solid wood panels, recipient MATRIX a.s., **investigator for FCE BUT M. Šmak**, 2020–2023.

The project focuses on the development of solid wood panels with the possible use of calamity timber. The panel components are connected on a mechanical basis with the optional application of green adhesives. The panel will be part of a modular system of timber buildings.

FW01010443 Advanced next-generation composite materials for construction and automotive applications, recipient GDP KORAL, s.r.o., **investigator on behalf of FCE BUT O. Pešek**, 2020–2022.

The aim of the project is to achieve a significant increase in the useful properties of elements, with a focus on the cost-effectiveness of design, through research into the behaviour of new types of fibre-reinforced composites and their interaction with other materials. The newly developed products are to be verified in automotive/mass transportation and in infrastructure. The products are intended for use abroad, where there are better conditions for the use of the 2nd generation of fibre-reinforced composites.

FW01010392 Advanced design of construction details/elements equipped with machine learning, recipient IDEA StatiCa, s.r.o., **investigator on behalf of FCE BUT M. Bajer**, 2020–2023.

The project focuses on innovation in IDEA StatiCa applications. The research part is under the patronage of CTU in Prague and BUT in Brno. The main desktop applications of IDEA StatiCa are Steel Connection, Member and Detail. In the area of cloud technologies, these are the Viewer and the new Connection Browser. The research at universities was focused on fatigue in steel structures, the fire resistance of steel structural elements and the behaviour of concrete under spatial stress.

After achieving the result "New Connection Generation", all the other results were processed in 2021, with the result "Implementation of 3D concrete reinforcement in IDEA StatiCa analytical models" being completed in particular. In the Member programme, the input of longitudinal and transverse reinforcement was developed, including coverage of bending moments and shear forces along the length of an element. Also, the basic version for the import of reinforcement baskets from CAD programmes, especially Tekla Structures, was also completed.

A more detailed description and information are given in the section Examples of collaboration with industrial entities on R&D and contract research projects.

FW01010206 Improved design of thin-walled cold formed steel beams in terms of load carrying capacity and fire resistance, recipient voestalpine Profilform, s.r.o., **investigator on behalf of FCE BUT M. Horáček**, 2020–2021.

The main purpose of the project was to experimentally investigate the real behaviour of thin-walled cold formed floor beams under the effects of loads corresponding to normal operating conditions and exposure to fire.

The aim of the project was to determine improved design characteristics of floor beams derived from the results of experiments which will lead to their more economical design compared to designs conducted only according to the rules and calculation procedures specified in the relevant standards (Eurocodes). An increase in the efficiency of the design of this type of structure will increase their competitiveness on the domestic and foreign markets.

In 2021, a result was achieved for the project "Ceiling structure assembly for built-in floors of hall buildings" (utility model, registered under No. 35134); fire resistance tests were carried out on a section of a ceiling structure, and the project was completed successfully.

A more detailed description and information are given in the section Examples of collaboration with industrial entities on R&D and contract research projects.

TN01000056/05 Advanced construction elements based on wood and composites for civil engineering projects, a sub-project within the framework of NCK CAMEB, recipient CTU in Prague, **investigator on behalf of FCE BUT M. Karmazínová**, 2019–2022.

The subject of part of a sub-project investigated by the Institute of Metal and Timber Structures is research into and development of wood-based composite structural elements intended for horizontal structures (Task 1) and large-format structural wall elements with improved acoustic properties (Task 2).

The goal of "Task 1" is to discover a reinforcing element for application to the outer lamella or surface of KFH or BSH prisms that will increase their load-bearing capacity and rigidity using suitable reinforcement elements. In 2021, the relationship between the type of adhesive used and the glued material was also investigated. In 2021, among other things, a result was achieved - "Reinforced wood-based composite structural element for horizontal load-bearing structures" (functional sample).

The aim of "Task 2" is to conduct research into the acoustic properties of manufactured elements of Novatop wall structures and modifications made to their structures aimed at achieving higher acoustic values of airborne soundproofing, as well as the verification of fire resistance and static verification of construction details. In 2021, work continued on the experimental verification of Novatop Element panels with regard to their fire resistance and static behaviour.

CZ.01.1.02/0.0/0.0/17_176/0015728 Development of advanced segmental elements for children´s playgrounds, **investigator on behalf of FCE BUT M. Šmak**, 2019–2022.

The main goal of the project is to develop a segmental modular element for children to use while playing (named "ÚL" – "beehive") into the phase of a functional prototype, which will be ready for the start of serial production. This goal will be achieved through the undertaking of industrial research and experimental development activities in three successive stages of the project. The investigation of the project is leading to the development of a functional prototype of the "ÚL" standardized modular play element up to the stage of a verified functional prototype.

TJ02000171 Rod elements of the structural skeleton of a timber house using hard wood, recipient MendelU, **investigator on behalf of FCE BUT M. Karmazínová**, 2019–2021.

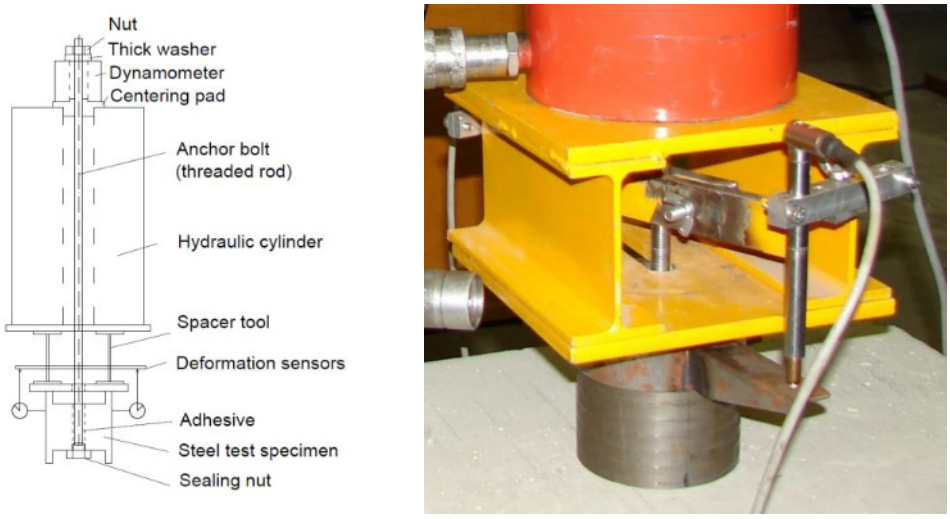
The main goal of the project was to verify the possibility of using deciduous wood in a glued beam, or a combination of different wood species (e.g. beech / spruce), both for columns and for beams to be used in a skeletal system. The possibility of use was verified both in terms of statics and with regard to the fire resistance of the elements. One of the results of the project achieved in 2021 is, among others, a "Supporting skeletal system consisting of timber from a combination of wood species" (utility model, registered 03/2021 under No. 34931).

Examples of R&D activities in 2021

The paragraphs below present two illustrative examples of R&D activities, which resulted in the creation of a major publication in the first case and a utility model in the second.

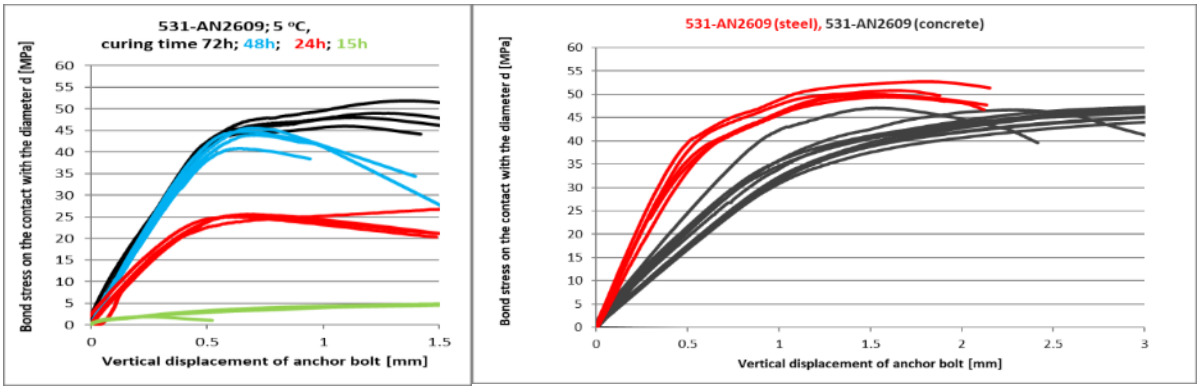
BARNAT, J.; PROKEŠ, J.; BAJER, M.; BEZDĚK, O.; VILD, M. Simplified Testing of the Bond Strength of Adhesives Used for Bonded Anchors. Materials, 2021, vol. 12, No. 14, p. 1-28. ISSN: 1996- 1944.

The experimental analysis presented in the article focuses on the issue of the cohesion of glued anchors in concrete. Cohesion is used as a summary parameter describing the quality of the adhesive-mediated bond. The first part describes issues concerning joint strength as the most important parameter affecting the final resistance of an anchor to tensile loading. Furthermore, a new method for the simplified testing of adhesive strength parameters is described in the text. In this method, use is made of special steel test specimens which allow easy testing and reusability.



Test assembly with a steel specimen

Epoxy resins with special fillers, such as carbon fibres, carbon nanotubes or graphene, were tested during the analysis. The use of these adhesives at temperatures close to zero degrees Celsius was also verified, with the recipe given and a comparison of the tests for concrete and steel elements.



Designed epoxy adhesive mixture and test results

The results of the analysis showed that the use of fillers in the form of carbon fibres, nanofibres or graphene is not very effective in terms of producing improvements in the material characteristics of the adhesive. On the contrary, it causes problems with the workability of the adhesive at increased economic cost. However, it does seem very economically advantageous to replace a considerable volume of adhesive with a cheap filler such as ground limestone. Calcium-type fillers are 25-50 times cheaper than binder per unit weight, or 10-20 times cheaper per unit volume, but a high concentration of fillers can reduce the workability of the adhesive, which can lead to problems during its use in practice.

HLADÍK, M.; PÖFFEL, Z.; HORÁČEK, M.; KARMAZÍNOVÁ, M.; PEŠEK, O.; BALÁZS, I. Assembly of a ceiling structure for the built-in floors of halls, utility model, registered under No. 35134, 2021.

The utility model is the result of experimental and numerical analyses of a ceiling structure assembly made from thin-walled cold-formed profiles (ceilings, beams), which aimed to improve the parameters of a structural system (e.g. the relative height of structural elements with respect to the type of connection) and to achieve an effective solution providing (given the initial conditions and requirements) maximum load-bearing capacity, especially with regard to the local and global stability of construction elements.

Experimental verification of one of the ceiling structure variants - illustration of the assembly arrangement and failure after ultimate strength was reached.

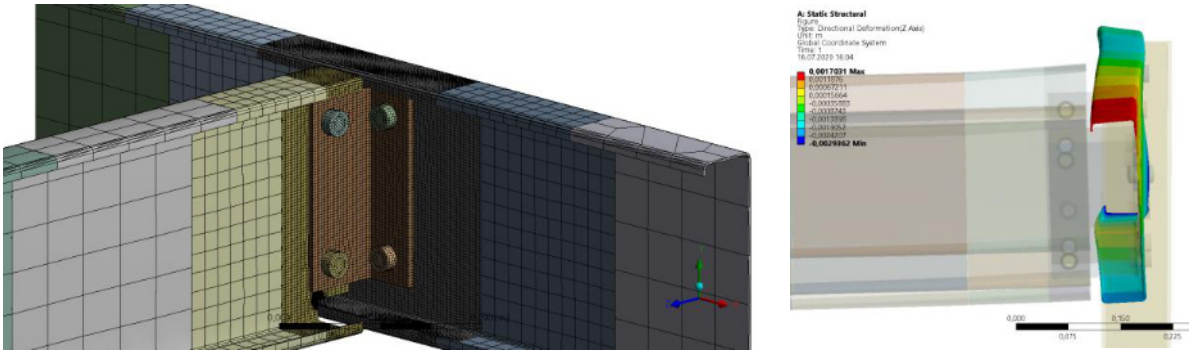


Illustration of joint modelling

As part of the experimental verification, a range of assembly variants were tested (see the illustrations in Fig. 3), and the test results were evaluated and compared with the assumed load capacities determined by calculations and results concerning numerical joint models (see Fig. 4). Based on the test results, the parameters of the structural assembly were adjusted so that the resulting solution provided the greatest possible load-bearing capacity with an economical design.

Examples of collaboration with industrial entities on R&D and contract research projects.

The examples of cooperation with industrial entities detailed below concern two Technology Agency of the Czech Republic (TAČR) projects that demonstrate Brno University of Technology's capacity for effective cooperation. In the first case this was with another university (CTU in Prague) and a software company (IDEA StatiCa), while in the second case, collaboration occurred with a manufacturing and production company engaged in the fabrication of thin-walled steel profiles and the supply of structures of this type (voestalpine Profilform).

TAČR TREND project "Advanced design of construction details/elements equipped with machine learning"

IDEA StatiCa – CTU Prague –BUT

General information

The project focuses on innovation in IDEA StatiCa applications. The research part is under the patronage of CTU in Prague and BUT in Brno. The main desktop applications of IDEA StatiCa are Steel Connection, Member and Detail. In the area of cloud technologies, there is the Viewer and the new Connection Browser. Research at universities focused on fatigue in steel structures, the fire resistance of steel structural elements and the behaviour of concrete under spatial stress.

Project aims for 2021

After achieving the result "New Connection Generation", all the other results were processed in 2021, with the result "Implementation of 3D concrete reinforcement in IDEA StatiCa analytical models" being of particular importance. In the Member program, the input of longitudinal and transverse reinforcement was developed, including coverage of bending moments and shear forces along the length of an element. Also, the basic version for the import of reinforcement baskets from CAD programmes, especially Tekla Structures, was also completed.

Fatigue assessment in IDEA StatiCa Connection software

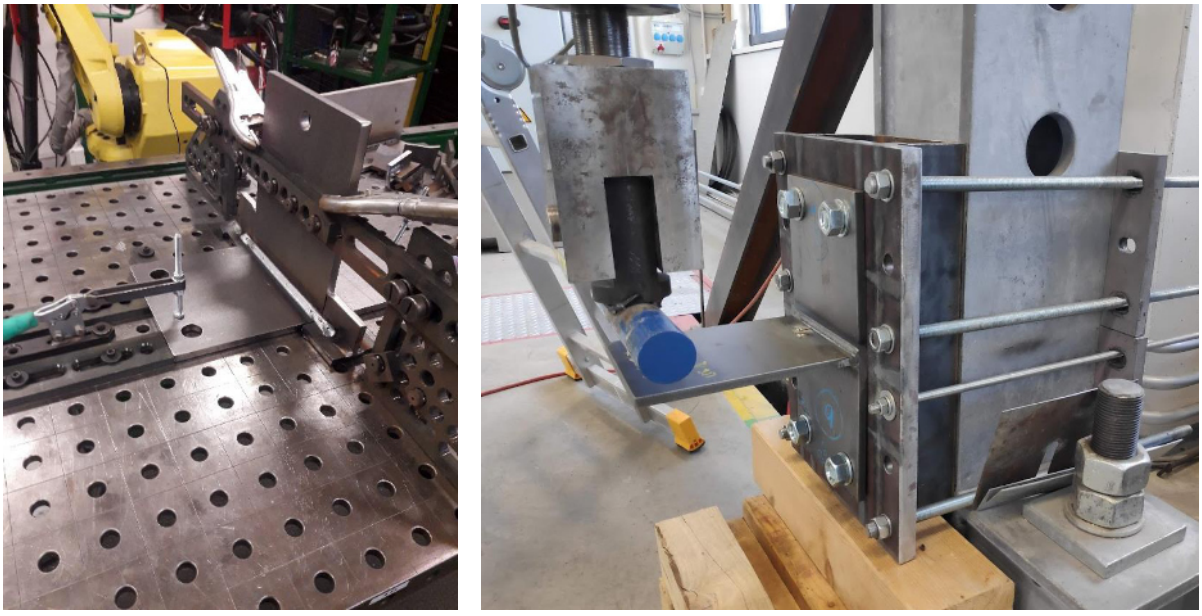
The first fatigue assessment version in the IDEA StatiCa Connection application was developed for version 21.0, which was released in April 2021. Based on testing and user requirements, the functionality was further improved and expanded. Work is continuing on verification examples which will be published on the IDEA StatiCa website and in a forthcoming monograph. Experimental research is also continuing, the aim of which is to validate numerical models as well as to contribute to the general knowledge available regarding the fatigue strength of welded joints from high-strength steels.

Fatigue experiments

As part of the project, experiments on the welded detail of a T-section are continuing. In previous years, experiments were performed on samples of STRENX 700 MC high-strength steel. It became apparent that high-strength steel specimens have high low-cyclic fatigue strength, but the slope of the fatigue curve is steeper than for conventional strength steels. This finding is not included in the EN 1993-1-9 steel design standards. Therefore, the experimental programme was extended by other samples from different strength classes of

steel - steel of normal strength, S355, and two high-strength steels, STRENX 500 MC and STRENX 700 MC. The specimens were prepared at the CTU welding laboratory and transported to the AdMaS Research Centre at the Faculty of Civil Engineering in Brno. The testing began in December 2021, but as these are long-term fatigue tests, it will continue also during 2022.

A total of 27 samples were welded, 9 samples from steel of each strength. All of the metal sheets were blast cleaned in a chamber before welding. The attachable welding electrodes used were always stronger than the sheet metal material. A double-sided fillet weld with an effective height of 5 mm was applied. During welding, lead in- and lead-out "T" joint plates were used, which were chipped off afterwards and the weld faces ground with a hand-held angle grinder.



Specimen during welding (left); Specimen prepared for testing (on the right)

Conclusion

All of the project results are gradually being implemented into existing IDEA StatiCa applications and released for use by customers. In 2021, releases 21.0 and 21.1 were successfully implemented.

Partner universities will use the new versions of the programmes for their research and tuition. The project helps universities retain post-doctoral students and employ them in interesting applied research. In 2021, IDEA StatiCa established new contacts with universities in Ohio, Tennessee and Alberta, among others.

TAČR TREND project "Advanced design of construction details/elements equipped with machine learning"

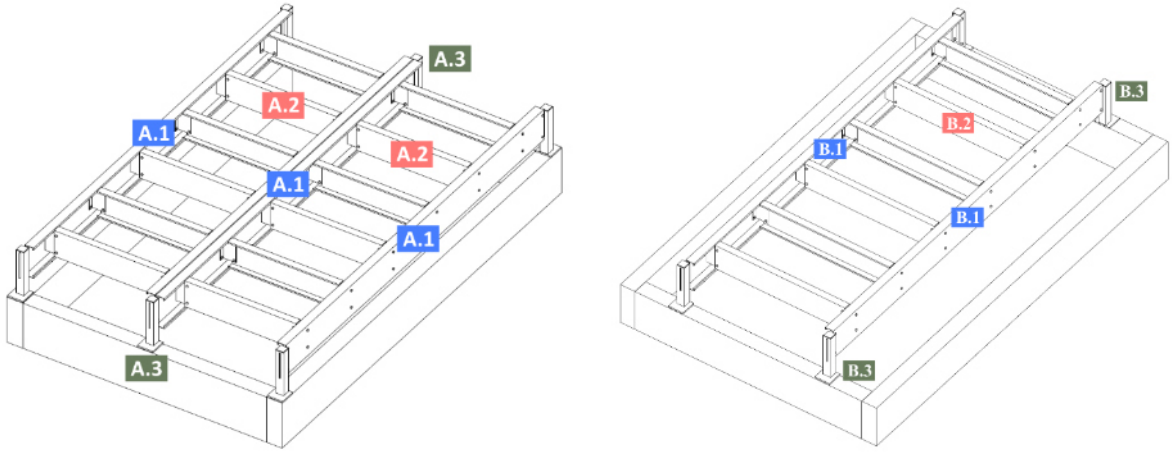
voelstalpine Profilform, s.r.o. – Brno University of Technology

During the project investigation, fire tests were carried out on a section of ceiling structure with the aim of experimentally verifying fire resistance and comparing the results with the expected fire resistance determined by calculations according to the Eurocode.

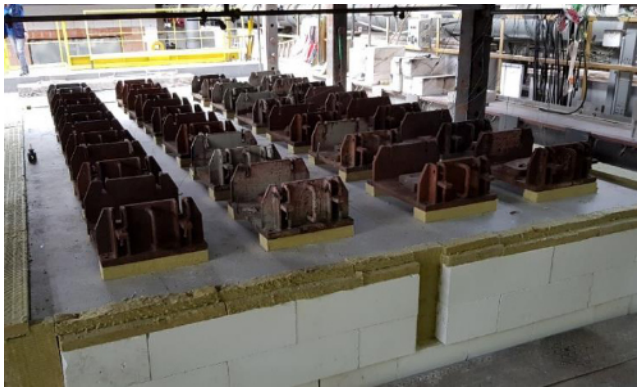
Fig. 6 below shows two variants of the ceiling structure assembly used for the fire tests. After these had been fabricated, the test specimens were installed in a fire resistance test furnace and loaded with steel weights - see the images in Fig 7.

Fig. 8 shows both variants of the structural assembly during the fire test when viewed inside the test furnace during the test (deformation), and when viewed from the outside. Fig. 9 illustrates the temperature profile over time for some selected locations in the structure (for both assembly variants).

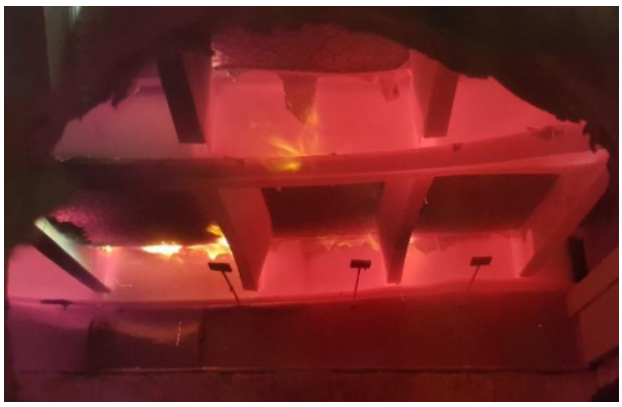
The fire tests verified the real fire resistance and proved that it corresponds to the fire resistance determined by calculations according to the relevant standard. Due to the complexity of the fire tests, both in terms of design and parameter measurement technology and with regard to financial costs, not many tests of this type have been performed so far. This is especially true for fire tests on thin-walled structures, which behave significantly worse at elevated temperatures. Each fire test verification will bring significant findings and a contribution to the body of information and knowledge about the fire resistance of thin-walled structural elements and structures.

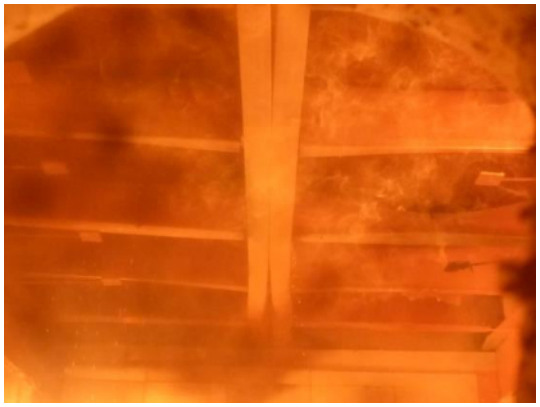


Assembly variants for fire tests



Test specimens installed in a fire resistance test furnace (figure above) and under load (figure below)





Views of a tested structure during a test

GTN – ADMAS (GEOTECHNICS)

Overview of results from 2021

CHALMOVSKÝ, J. *Využití metody přenosových funkcí pro predikci chování hlubinných základů v ČR.* 2021.

CHALMOVSKÝ, J.; KOUDELA, P.: PMpLTO; PMpLTO (Pile Micropile Load Transfer Optimization). https://geotech.fce.vutbr.cz/veda-a-vyzkum/projekty-tacr/projekt-tj02000140-vyuziti-metody-prenosovych-funkci-pro-predikci-chovani-hlubinnych-zakladu-v-cr/. URL: https://geotech.fce.vutbr.cz/veda-a-vyzkum/projekty-tacr/projekt-tj02000140-vyuziti-metody-prenosovych-funkci-pro-predikci-chovani-hlubinnych-zakladu-v-cr/. (software)

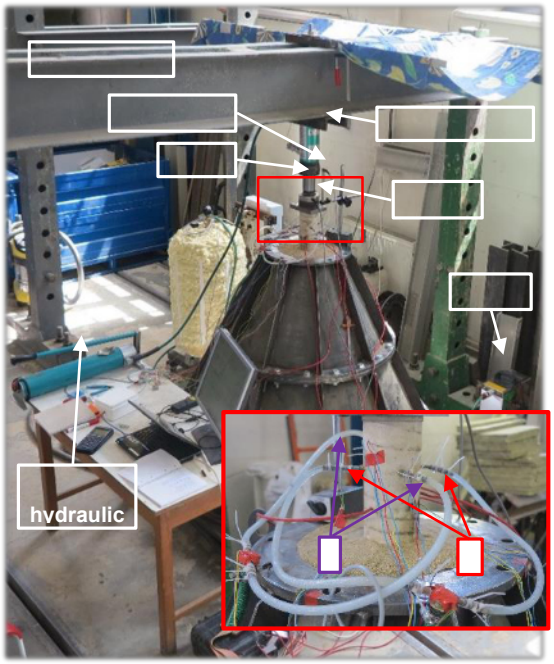
KRAJČÍK, M.; ARICI, M.; ŠIKULA, O.; ŠIMKO, M. Review of water-based wall systems: Heating, cooling, and thermal barriers. ENERGY AND BUILDINGS, 2021, vol. 253, No. 1, p. 1- 31. ISSN: 0378- 7788.

Description of R&D activities performed in 2021

In the monitored period, laboratory soil tests were performed with a focus on determining the initial shear model G_0 as well as the strength characteristics of granitoid rocks of the Moldanubian Pluton. Furthermore, research activities took place within the CAMEB centre and the TJ02000140 project.

Examples of R&D activities

During project TN01000056/06, the experimental part of the research activities was devoted to a physical model of a lone EP loaded both by mechanical axial compressive force with a nominal value of 8 kN and then by temperature. Use was made of a ZFMEpilot 1.0 load cone, upon which structural modifications were made during 2021. During the experiment, the temperature in the EP and in the sand, the force and displacement in the EP head and the axial deformation in the EP were monitored at selected points in the model. A stress-strain diagram of the EP was processed from the data, which also shows the influence of temperature load (the cooling of the EP in this case) caused by a change in the temperature field, as well as the development of the size of the normal force along the length of the EP model obtained from tensometric measurements during its mechanical loading.



Physical model

MAT – ADMAS (MATHEMATICAL MODELLING)

The following research results in particular were published by the institute of Mathematical Modelling:

ASTASHOVA, I.; DIBLÍK, J.; KOROBKO, E. Existence of a solution of discrete Emden-Fowler equation caused by continuous equation. *Discrete and Continuous Dynamical Systems – Series S* 14/12 (2021), 4159-4178. ISSN 1937-1632. IF (2020) 2,425.

BEREZOVSKI, V.; CHEREVKO, Y.; MIKEŠ, J.; RÝPAROVÁ, L. Canonical almost geodesic mappings of the first type of spaces with affine connections onto generalized m-Ricci-symmetric spaces. *Mathematics* 9/4 (2021), 1-12. ISSN 2227-7390. IF (2020) 2,258.

DIBLÍK, J. Representation of solutions to delayed differential equations with a single delay by dominant and subdominant solutions. *Applied Mathematics Letters* 119 (2021), 107236/1-7. ISSN 0893-9659. IF (2020) 4,055.

KOTRECHKO, S.; KOZÁK, V.; ZATSARNA, O.; ZIMINA, G.; STETSENKO, N.; DLOUHÝ, I. Incorporation of temperature and plastic strain effects into local approach to fracture. *Materials* 14/20 (2021), 6224/1-11. ISSN 1996-1944. IF (2020) 3,623.

MIKEŠ, J.; GUSEVA, N.; PEŠKA, P.; RÝPAROVÁ, L. Rotary mappings and projections of a sphere. *Mathematical Notes* 110/1-2 (2021), 152-155. ISSN 0001-4346. IF (2020) 0,673.

MIKEŠ, J.; FORMELLA, S.; HINTERLEITNER, I.; GUSEVA, N. I. Some questions of geodesic mappings of Einstein spaces. *Itogi Nauki i Tekhniki: Sovremennaya Matematika i ee Prilozheniya, Tematicheskie Obzory* 203 (2021), 50-61. ISSN 0233-6723.

ŠPAČEK, P.; KOMENDA, J.; LAHAYE, S. Analysis of P-time event graphs in (max,+) and (min,+) semirings. *International Journal of Systems Science* 52/4 (2021), 694-709. ISSN 0020-7721. IF (2020) 2,281.

VALA, J. On a computational smeared damage approach to the analysis of strength of quasi-brittle materials. *WSEAS Transactions on Applied and Theoretical Mechanics* 16 (2021), 283-292. ISSN 1991-8747.

VALA, J.; KOZÁK, V. Non-local damage modelling of quasi-brittle composites. *Applications of Mathematics* 66/6 (2021), 815-836. ISSN 0862-7940. IF (2020) 0,881.

VALA, J.; KOZÁK, V.; JEDLIČKA, M. Scale bridging in computational modelling of quasi-brittle fracture of cementitious composites. *Solid State Phenomena* 325 (2021), 56-64. ISSN 1012-0394.

VALA, J.; NĚMEC, I.; VANĚČKOVÁ, A. Exact solution of a thick beam on Pasternak subsoil in finite element calculations. *Mathematics and Computers in Simulation* 189/11 (2021), 36-54. ISSN 0378-4754. IF (2020) 2,463.

The Institute of Mathematical Modelling hosted several important foreign experts who gave lectures at the institute:

Prof. Mihály Pituk, University of Pannonia, Veszprém, Hungary, lecture (24. 8. 2021) “Ergodicity in nonautonomous linear ordinary differential equations”.

Prof. M. Galewski, Politechnika Łódzka, Łódz, Poland, lecture (23. 11. 2021) “Hadamard well posedness for nonlinear problems via monotonicity methods”.

Prof. I. Astashova, Moscow Lomonosov University, Moscow, Russian Federation, lectures (11. 11. 2021) “*Mathematical aspects of the control over temperature conditions in industrial greenhouses”* and (15. 11. 2021) “*On uniqueness of solutions to Emden-Fowler type second-order equations with general power-law nonlinearities”.*

TST - ADMAS (Technology, Mechanization and Construction Management)

Fulfilment of goals in 2021

The research goals of the Institute of Technology, Mechanization and Construction Management were set for 2021 in connection with the goals of specific research projects. All of the expected outputs were achieved, in some categories beyond expectations. These projects were:

FAST-S-21-7374: Secondary transport by tower cranes in the construction of high-rise buildings (Investigator: Ing. Rostislav Doubek)

FAST-J-21-7288: Analysis and assessment of the environmental aspects of recycled concrete using the LCA method and its implementation in digital twins of buildings based on an active BIM approach (Investigator: Ing. Michal Brandtner)

FAST-J-21-7378: Analysis of the structural and technical maintenance of the environmentally friendly roofing of buildings (Investigator: Ing. Jan Jílek)

Overview of outputs in 2021

Conference articles according to Thomson Reuters, Scopus (RIV-D):

BRANDTNER, M.; VENKRBEC, V. A data structures for purpose of the BIM-based Life Cycle Assessment: A review and theoretical background. *IOP Conference Series: Materials Science and Engineering*. 2021, 1209(1). ISSN 1757-8981. doi:10.1088/1757-899X/1209/1/012001.

DOUBEK, R.; KURKOVÁ, D.; ŠTĚRBA, M.; KANTOVÁ, R. Analysis of construction sub-processes for the evaluation of the real performance of tower cranes. In *6th World Multidisciplinary Civil Engineering-Architecture-Urban planning Symposium 30 August-3 September 2021*, Prague, Czech Republic. IOP Conference Series: Materials Science and Engineering. IOP Conf. Ser.: Mater. Sci. Eng. 1203 (2021) 022132, doi:10.1088/1757-899X/1203/2/022132.

DOUBEK, R. Comparison of the planned and actual course of construction of reinforced concrete monolithic structures. In *13th International Scientific Conference of Civil and Environmental Engineering for PhD. Students and Young Scientists 13-15 October 2021, High Tatras, Slovakia*. IOP Conference Series: Materials Science and Engineering. IOP Conf. Series: Materials Science and Engineering 1209 (2021) 012011. Košice: IOP Publishing, 2021. s. 1-6, doi:10.1088/1757-899X/1209/1/012011.

Papers in non-impact periodicals (RIV-Jneim):

DOUBEK, R. Preparation of a simulation model of tower crane performance. In *Buildustry*, 2021, year 2/2021, No. 9772454038007, Nitrianske Rudno, Slovakia. Bria Invenia, s.r.o, Nitrianske Rudno, 2021. p. 168 – 171. ISSN: 2454-0382.

BRANDTNER, M. Negrafická data a jejich struktura pro využití LCA v BIM. *Czech Journal of Civil Engineering*, 2021, year 7, No. 1, pp. 16- 26. ISSN: 2336-7148.

JÍLEK, J.; MOHAPL, M.; LUKÁŠKOVÁ, J. Analýza spotřeby energií při výstavbě bytových domů, porovnání dvou etap výstavby. In *Buildustry*, 2021, year 2/2021, No. 9772454038007.

Nitrianske Rudno, Slovakia. Bria Invenia, s.r.o, Nitrianske Rudno, 2021,pp. 94- 102. ISSN: 2454-0382.

Paper at a specific research conference (RIV-O):

DOUBEK, R. Agenda standardního specifického výzkumu FAST VUT v Brně. *PROCEEDINGS OF JUNIORSTAV 2022 24th professional conference for doctoral studies.* Brno: ECON publishing, s. r. o., 2022. pp. 60 - 64. ISBN: 978-80-86433-76-9.

KURKOVÁ, D. Analýza pracovních cyklů věžových jeřábů. *PROCEEDINGS OF JUNIORSTAV 2022 24th professional conference for doctoral studies.* Brno: ECON publishing, s. r. o., 2022. pp. 71 - 76. ISBN: 978-80-86433-76-9.

BRANDTNER, Michal and Adam BOHÁČEK. Využití metody BIM pro studie LCA a digitalizaci stavebnictví – recherche. In: *PROCEEDINGS OF JUNIORSTAV 2022 24th professional conference for doctoral studies.* Brno University of Technology, Faculty of Civil Engineering, 2021, pp. 65- 70. ISBN 978-80-86433-76-9. Available from: doi:10.13164/juniorstav.2022.65.

BOHÁČEK, Adam and Michal BRANDTNER. Tahové vlastnosti tmelů při tmelení materiálu na bázi cementu. *PROCEEDINGS OF JUNIORSTAV 2022 24th professional conference for doctoral studies.* Brno University of Technology, Faculty of Civil Engineering, 2021, pp. 104-108. ISBN 978-80-86433-76-9. Available from: doi:10.13164/juniorstav.2022.104.

Utility model (RIV-F):

Utility model application "*Equipment for the inspection of green roofs".* Date of submission of the application at the Industrial Property Office (IPO) 24.11.2021

Software (RIV-R):

MOTYČKA, V.; PŘIBYL, O.; DOUBEK, R.: *Časové vytížení stavebních jeřábů 2.0*; Časové vytížení stavebních jeřábů - Crane Occupancy 2.0. On the server of the Institute of Technology, Mechanization and Construction Management, Faculty of Civil Engineering, BUT URL: http://tstsw.cz/vytizeni-jerabu-v2/ (software).

BRANDTNER, M.; VENKRBEC, V.: Envi4BIM 2.0; Envi4BIM. On the server of the Institute of Technology, Mechanization and Construction Management, Faculty of Civil Engineering, BUT URL: http://tstsw.cz/Envi4BIM/v2/ (software).

ZEL - ADMAS (RAILWAY STRUCTURES AND CONSTRUCTIONS)

Articles:

KRČ, R.; PODROUŽEK, J.; VUKUŠIČ, I.; PLÁŠEK, O. Data pre-processing effect on classification accuracy of convolutional neural networks for train type identification. Computational Science and AI in Industry (CSAI 2021). 2021. s. 1 (1 s.).

SMUTNÝ, J.; JANOŠTÍK, D.; NOHÁL, V. The use of the Hilbert Huang transformation in the testing of railway structures. Akustika, 2021, year 40, No. 1, pp. 28- 34. ISSN: 1801-9064. Detail | WWW | Full text in the Digital Library

SMUTNÝ, J.; JANOŠTÍK, D.; PAZDERA, L.; VALENTA, M. ANALYSING ACOUSTIC PROPERTIES OF A SUBWAY TRACK. Akustika, 2021, year 38, No. 1, pp. 9- 18. ISSN: 1801-9064.

VALEHRACH, J. Železnice - příležitost pro přírodu. Conference proceedings for Želva 2021. Prague: Czech Technical University in Prague, 2021. pp.70- 78. ISBN: 978-80-01-06881-6.

Impact factor– RIV Jimp

BOGHANI, H.; AMBUR, R.; BLUMENFELD, M.; SAADE, L.; GOODALL, R.; WARD, C.; PLÁŠEK, O.; GOFTON, N.; MORATA, M.; ROBERTS, C.; DIXON, R. Sensitivity enriched multi-criterion decision making process for novel railway switches and crossings - a case study. European Transport Research Review, 2021, year 13, No. 1, pp. 1- 14. ISSN: 1866-8887.

Important R&D projects with industrial entities and other activities:

CK01000091, Switch 4.0, launched: 01. 04. 2020, completion: 29. 03. 2024. TAČR - 1st public tender Funding Programme for Applied Research, Experimental Development and Innovation in Transport – TRANSPORT 2020+. Recipient DT – Výhybkárna a strojírna , a.s.

TM01000016, Affordable smart sensing system for railways 4.0, launch: 01. 03. 2020, completion: 31.12.2022. TAČR– 1st public tender for the Programme for Applied Research, Experimental Development and Innovation DELTA 2 2019. Recipient BUT, Faculty of Mechanical Engineering.

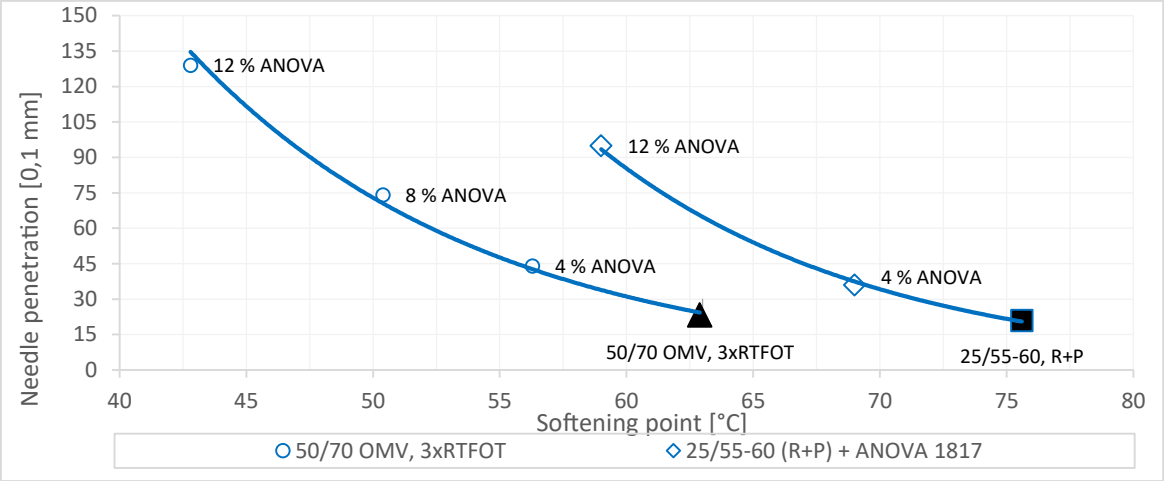
PKP – ADMAS (ROAD STRUCTURES)

At the Institute of Road Structures, several Technology Agency of the Czech Republic (TAČR) research projects are currently being investigated, namely project CK01000022 and project CK01000033.

Research project CK01000022

The investigation of the project “Optimisation of the production of asphalt mixtures with an above-limit amount of R-material at packaging plants with a double-skinned drum” focused in 2021 on the production of ACO 11 + asphalt mixtures with 40% R material at a packaging plant in Dalovice, with optimal dosage of ANOVA 1817 revitalizing agent. The optimal dosage was determined experimentally during the production of the mixture at the packaging plant. At the same time, during the production of asphalt mixtures at the packaging plant, an investigation took place with regard to different mixing times with the aim of achieving the optimal homogenisation of the R-material binder, the newly added 50/70 binder and revitalising additives. In 2021, testing of the rheological properties of bituminous revived binders was completed. The properties of the revived binders were compared in relation to each other, but also with the properties of road asphalts in the 50/70 category.
Another significant achievement in 2021 was the completion of the development of a dosing device for revitalising additives at the Dalovice packaging plant. Based on the performed measurements, another evaluated output will be prepared for the Z_{tech} project “Verified technology for the production of asphalt mixtures with R-material at a packaging plant with a double skinned drum”. An important goal of 2021 was the development of a method entitled “Methods for optimising the production of asphalt mixtures with above-limit amounts of R-material at packaging plants with a double-skinned drum”.

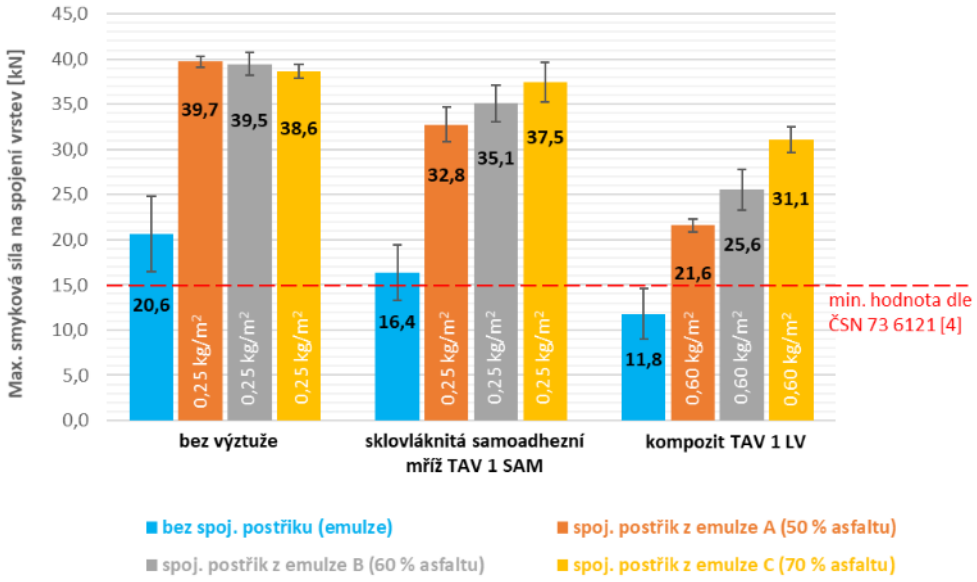
Dosing equipment at the Dalovice packaging plant



The course of revitalisation of long-term-aged binders 50/70 and 25/55-60 with the use of the additive Anova

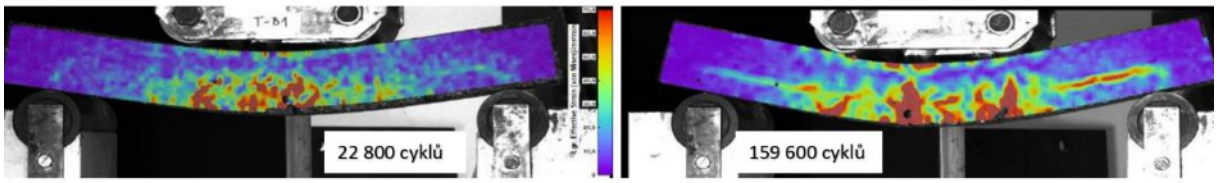
Research project CK01000033

The project entitled “Extending the service life of regional and local roads by means of innovative asphalt layers using high-strength composite materials” deals with research into and the introduction of maintenance and repair technologies for roads (especially regional and municipal roads) using reinforcing fibreglass materials (grilles or composites). In the UPKO laboratory, the testing of reinforced asphalt layers was performed and evaluated using newly developed materials from the co-investigator of the project, SAINT-GOBAIN ADFORS CZ s.r.o. In 2021, extensive research was carried out in the field of joining reinforced or unreinforced asphalt layers in combination with various reinforcing elements or by using bonding sprays consisting of asphalt emulsions with different proportions of asphalt. The planned output of the project was a verified technology entitled “Optimisation of bonding sprays and thin asphalt layers for the maintenance of asphalt roads using reinforcing composites.” The co-investigator of this verified technology, VIALIT Soběslav, spol. s.r.o., developed, prepared and implemented the production of a new asphalt emulsion with a 70% content of asphalt. The effect of the use of this new asphalt emulsion on the quality of the bonding of layers was verified, and it is possible to see the benefit of this emulsion with a higher proportion of asphalt, which manifested itself in reinforced layers, especially when using reinforcing composites. A test section was established on the premises of the VIALIT Soběslav packaging plant, at which staff performed the verification of the use of the new asphalt emulsion in combination with a reinforcing mesh or composite under an abrasive layer of ACO 11 with a thickness of only 30 mm. The co-investigator VIALIT Soběslav spol. s.r.o. was also involved in the development of an emulsion microcarpet containing R-material, and a short test section was established on the premises of the company in Soběslav.



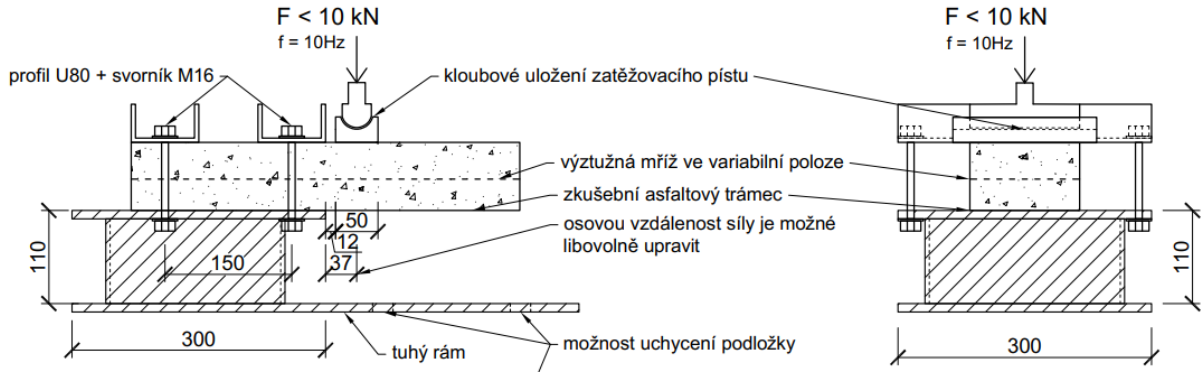
The influence of the type of asphalt emulsion on the shear connection of layers with or without reinforcing elements

In cooperation with the application guarantor Správou a údržbou silnic Jihomoravského kraje, přísp. organizace (The South Moravian Region Road Administration and Maintenance Authority), it was possible to construct test sections using reinforcing materials, namely a section of road III/3983 Přeskače - Tavíkovice (reinforcing elements under an abrasive layer with a thickness of 50 mm) and a section of road III/3978 Slup - Jaroslavice (reinforcing elements under an emulsion microcarpet). The execution of other test sections is being prepared together with the application guarantors of the project in 2022.
In addition to layer bonding tests, functional tests were performed to determine the fatigue resistance and stiffness of asphalt layers with a reinforcement mesh. A four-point bending test with creep was also performed at an AdMaS Centre laboratory using the digital image correlation method (DIC), which enables crack propagation to be detected in a specimen. The following figure shows the relative deformations at the end of the tests of specimens with and without reinforcement (deflection 30 mm). The figure clearly shows the activation of the reinforcing mesh in the reinforced specimen, and it is also clear that the reinforced specimen reached a comparable deflection after a 7 times longer period of loading compared to the specimen without the reinforcing mesh.



4-point creep test evaluated by the DIC method - unreinforced specimen on the left, reinforced specimen on the right (both samples with the same deflection of 30 mm)

In the second year of project investigation, development and optimisation took place for a test device for determining resistance to shear in reinforced test beams. It simulates in situ conditions during the strengthening and extension of the edges of an asphalt pavement. The layout of the test device is shown in the following figure. Also depicted is a test specimen with a reinforcing glass-fibre mesh during a test.



Layout of the device for testing resistance against shear stress

Testing of the resistance of reinforced layers against shear stress, left: at the start of the test, right: at a deflection under load of 7mm

Supplementary activities

Supplementary activities included the technical measurement of stiffness and resistance to fatigue of asphalt mixtures using a test device for the establishment of a comprehensive modulus of stiffness and fatigue via two-point bending.

ARC – ADMAS (ARCHITECTURE)

The team comprises:
research team leader Ing. arch. Viktor Svojanovský from the Institute of Architecture
team members - students Bc. Ondřej Venclík (2nd yr. master's degree), Bc. Marco Aulisa (2nd yr. master's degree), both from the Institute of Architecture. The team also includes Ing. Eva Frimlová (1st yr. doctoral studies) from the Institute of Building Testing under the supervision of Assoc. Prof. Ing. Pavel Schmid, Ph.D.

Grant SV 2021 was obtained for the research, providing aid in the purchase of equipment required for the processing of prototypes and samples. During meetings, the team focused on a strategy for the efficient manufacture of prototypes. At the interdisciplinary level, cooperation concerned the various possible types of mechanical test for the determination and proving of any changes in the characteristics of materials during repeated recycling.
Small successes were achieved with regard to commercial use, but the search is still on for larger scale applications in the commercial sphere.

The results of the work are presented online (web pages, articles and reports in the media).

Collaborative workshops took place with companies from Holland, Austria and Slovakia. They are companies with a shared area of interest and with overlap into the commercial sphere.

Presentation of research and an article in the proceedings of the international conference Architektura v perspektivě 2021:

SVOJANOVSKÝ, Viktor, 2021. RECYKLACE ODPADNÍHO PLASTU: DESIGN, FORMOVÁNÍ, TESTOVÁNÍ. In: *Architektura v perspektivě 2021*. Ostrava: VŠB - Technical University of Ostrava, s. 259-261. ISBN 978-80-248-4552-4.

Presentations in the media:

https://brnodaily.com/2021/01/28/news/czech-government-enforces-eu-directive-reducing-single-use-plastics/

https://www.startupjobs.cz/newsroom/i-kdyby-uy-nevznikl-jediny-kus-plastu-do-konce-zivota-mame-co-delat-tvrdi-plastic-guys

https://www.vut.cz/vut/aktuality-f19528/nejlepsi-podnikatelsky-napad-z-vut-maji-plastic-guys-z-fakulty-stavebni-d218602

https://www.ceskatelevize.cz/porady/10805121298-gejzir/221562235000006/

Articles in the Dolce Vita and DesignBlok magazines.

The spaces and equipment found at AdMaS are used for the process of scientific testing and the creation of prototypes and specimens.

7.3 Interest Group: Economicsand Environment

7.3.1 Activities of the IG in the area of management

Coordination meetings between all employees at which the work activities of the interest group are discussed took place only once every two months – during the Covid 19 pandemic contact was minimised by using videoconferencing and email communication to the maximum degree.

Working meetings were called according to need, in particular with regard to the current requirements of ongoing projects – in 2021 4 national projects and one international research project were worked on.

For the interest group it remained typical that aside from specific themes there was also a search for interdisciplinary topics and comprehensive subjects relevant to the activities of the AdMaS Centre as a whole. In connection with the diagnostic analysis of the technical state of sewage networks there was close cooperation with the Advanced Building Materials interest group, while with regard to the performance of contract research in the area of green car parks, close cooperation took place with the Advanced Building Structures and Transport Constructions interest group.

7.3.2 Training and seminars

Particularly with regard to the continuing limitations related to the Covid – 19 pandemic, it was necessary to restrict a whole range of activities. Even so, presentations to chosen partners from the construction field, owners of water management complexes, waste disposal companies, etc. took place for the purpose of publicising the AdMaS Centre and the Economics and Environment interest group.

7.3.3 Research staff mobility and cooperation with institutions abroad

Most of the planned staff mobility was cancelled due to restrictions related to the Covid-19 pandemic.

Study visits to foreign institutions included:

1. Learning Academy Bologna – Daniel Rodriguez: 7. – 13. 11. 2021, training in ICT and new technologies
2. Learning Academy Bologna – Veronika Rodriguezová: 7. – 13. 11. 2021, training in ICT and new technologies
3. University of Rijeka – Tomáš Hanák – 4. 7. - 10. 7. 2021 – Erasmus+ mobility, education
4. University of Maribor – Tomáš Hanák – 11. 7. - 15. 7. 2021 – Erasmus+ mobility, training
5. UPC BarcelonaTECH – Dana Linkeschová – 4. 10. - 9. 10. 2021 – Erasmus+ mobility, education
6. STU Bratislava – Radek Dohnal - 26. 9. - 1. 10. 2021 – Erasmus+ mobility, education
7. University of Osijek – Tomáš Hanák - 11. 4. - 17. 4. 2021 – CEEPUS online mobility

8. Cracow University of Technology – Tomáš Hanák - 14. 6. - 19. 6. 2021 – CEEPUS online mobility
9. TU Vienna – Dana Linkeschová - 1. 3. - 31. 3. 2021 - CEEPUS online mobility

Visits by the employees of foreign partners to the Centre in connection with this interest group:

1. The Rzeszow University of Technology – Katarzyna Pietrucha-Urbanik – 12th–16th June 2021 – ERASMUS+ mobility, providing the lecture: "Functional safety to support hazard assessment and risk management in water-supply systems".
2. The Rzeszow University of Technology – Justyna Stecko – 12th–16th June 2021 – ERASMUS+ mobility; providing the lecture: "Presentation of Rzeszow University of Technology. Ethical aspects of management. Applied ethics, i.e. the issue of norms and values in human resource management. Ethical aspects of social responsibility."
3. Cracow University of Technology – Michal Juszczyk – 13. 9. - 12. 10. 2021 – teaching and research stay
4. University of Rijeka – Ivan Marović – 8. 11. - 3. 12. 2021 – CEEPUS online mobility
5. University of Belgrade, Faculty of Forestry – Vesna Đukić – 26. 9. - 30. 9. 2021 – provision of two lectures: "Spatio-temporal analysis of remotely sensed and hydrological model soil moisture in the small River catchment" and "The Benefits of Using Remotely Sensed Soil Moisture for Improving Small – scale Hydrological Models".
6. Bydgoszcz University of Science and Technology, Faculty of Civil and Environmental Engineering and Architecture – Jacek Sztubecki – 8. – 12. 11. 2021 – exchange of experience and teaching methods, modern technology in geodesy, building monitoring, GIS applications, specialised excursion. Exchange of contacts, options for future collaboration.
7. Koszalin's University of Technology, Faculty of Civil Engineering, Environmental and Geodetic Sciences, Department of Geoinformatics – Tomasz Oberski – 13. – 17. 9. 2021 – presentation of specialised activities in the area of GIS, Laser scanning, DPZ. Excursion to selected workplaces at the Institute of Geodesy and the Faculty of Civil Engineering. Specialised excursion to the cartography centre in Velké Opatovice. Consultations regarding possible cooperation between workplaces.

During 2021 the ADMAS – VHO (Municipal Water Management) group and other subgroups of the Economics and Environment interest group engaged in preparations to submit applications for a range of international projects, either in the position of Chief Investigator or as a member of an international team of investigators:

1. Program: COST European Cooperation in Science and Technology; Project proposal: Circular wastewater management; cooperation with universities across COST Countries (21)
2. Program H2020: Call: H2020-LC-GD-4-1-2020; Project proposal: SMART & SUSTAINABLE BUILDINGS OF THE 3RD MILLENIUM - ENERGY-EFFICIENT WAY OF DESIGNING THROUGH LIVING LABS; cooperation with a range of partners, leading partner Technical University of Košice, Slovakia
3. Program: International collaborative activity in research and development for the support of male and female research staff mobility 8J – Czech-Austrian mobility 2022 – 2023; Project proposal: Circular wastewater management - Wastewater as a local source for service water, renewable energy and nutrients; collaboration with the UNIVERSITY OF NATURAL RESOURCES AND LIFE SCIENCES IN VIENNA (BOKU), Austria

4. Program INTER-ACTION 2021; Project proposal: Material transformation of organic waste into building structures with a vegetative layer; cooperation with the Technical University of Košice, Slovakia
5. Ministry of Foreign Affairs, Czech Republic; Strengthening the capacities of public universities in developing countries; Project proposal: USE OF BIOCHAR AS MATERIALLY TRANSFORMED WASTE FOR EXTENSIVE GREEN ROOFS; cooperation with the University of Banja Luka, Bosnia and Hercegovina
6. The Czech Science Foundation (evaluation based on the Lead Agency principle) in cooperation with the Polish National Science Centre (NCN). Title: Socio-economic Evaluation of Development Territories in the Urban Areas of Municipalities, Investigator: FAST – EKR, 2 representatives from KAM, Cracow University.

7.3.4 Researchstaff mobility with regard to industrial entities

In 2021 no significant internships were undertaken, but cooperation with companies did take place primarily in connection with Innovation Vouchers. This included the following firms: VODA CZ, VH Atelier, Sunrise Applied Technologies, ASIO, CAMAXIS and WOMBAT.

7.3.5 Researchactivities conducted by the IG

Subgoals according to the AdMaS Centre TA:

The development of new technologies in the areas of wastewater drainage and treatment, the treatment and distribution of drinking water, waste management, the development of new methods for the use of energy from wastewaters, waste and sludge arising during wastewater treatment.

The achievement of goals according to the AdMaS Centre TA is ensured by the Economics and Environment interest group through a range of research projects conducted particularly under the auspices of the Czech Science Foundation, contract research linked to the Ministry of Industry and Trade's Innovation Vouchers subsidy programme, and direct contract research with technology companies, operators of water management facilities, and other entities.

Also underway are internal standard specific research projects entitled "Management of economic processes in construction" and a total of five junior specific research projects.

With the Economics and Environment group, a notable role is played by the Institute of Social Sciences at the Faculty of Civil Engineering, which provides support services as required primarily in the area of translations into English, or other foreign languages.

In the area of waste and treatment plant sludge management, the most important Czech Science Foundation – Zéta projects (i.e. projects intended mainly for young scientists) that were successfully completed in 2021 are:

- "Conversion of gastro waste into the form of a solid carbonaceous product for material use"; project identification code: TJ02000262

Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies

- "Potential of torrefaction in the processing of wastewater treatment plant sludges for their further use"; identification code: TJ02000261

Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies

In 2021 further work was performed on NCK CAMEB; subsidiary project REVOZIM; work commenced on a Ministry of Industry and Trade Aplikace project, and on the implementation of further projects:

- Technology Agency of the Czech Republic (TAČR) NCK CAMEB, subsidiary project "REVOZIM – Recycling of water and wastes within the green infrastructure of cities"; project identification code TN01000056/03

  Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies; area P3 – experimental polygon with fully instrumented green roofs; Measurement of discharge and automatic sampling; Hall P4 – system with separate greywater acquisition;

- Ministry of Industry and Trade Aplikace, project "KALOMAN – Hygienising of sludge for small-scale sources of pollution", identification code CZ.01.1.02/0.0/0.0/20_321/0024624

  Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies;

- TAČR NCK CEVOOH – Centre of Environmental Research: "Waste and circulatory management and environmental safety", identification code SS02030008
- TAČR – "Design and safe operation of LNG fuelling stations"
- TAČR – "Evaluation of improvements in the safety and reliability of railway infrastructure after modernisation or reconstruction"
- NAZV Země – "The potential for the development of small water bodies in the landscape as adaptive measures for the elimination of hydrometeorological extremes" ID: QK21010328,
- TAČR Epsilon – "Agroforestry systems for the protection and renewal of the function of landscapes threatened by the effects of climate changes and human activities" ID: TH04030409
- TAČR Epsilon – "Development of effective tools for the evaluation and limitation of the negative effects of precipitation drainage processes in the nongrowing season in connection with extremes in climate development" ID: TH04030363
- NAZV Země – " Optimisation of a method of evaluating the wind erosion threat level for a land area and a proposal for protective measures for landscapes experiencing intensive agricultural use" ID: QK1710197

International projects underway in 2021:

- EHP and Norway, "ADAPTAN II – Integrated approaches to the adaptation of landscapes in the Moravian-Silesian Region to climate change"
- INTERREG ATCZ28 "SEDECO - Sediments, ecosystem services and interrelation with floods and droughts in the AT-CZ border region"
- EHP and Norway "Curriculum for the Czech-Norwegian doctoral program in the field of water management and water engineering"

In the area of the development of new approaches to the use of energy from wastewaters, the most significant project is TAČR – Zéta, i.e. again a project intended for young scientists, which was also successfully completed in 2021:

- "Acquisition and use of thermal energy from wastewaters in combination with the use of treated water"; identification code: TJ02000190

Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies; Hall P4; discharge measurement equipment

The Economics and Environment interest group has been involved with a whole range of Innovation Vouchers from the Ministry of Industry and Trade which dovetail well with the topics of goals described in the TA. In 2021 these included:

- Innovation Voucher – specialised study – Evaluation and comparison of different types of sewage program shaft;

  Instrumentation: Hall P2; Accredited testing laboratory (Hubáček)

- Innovation voucher – specialised study – Evaluation and comparison of trenchless technologies and techniques using trenches when constructing water management infrastructure;
- Innovation Voucher – specialised study – Conceptual solution for the blue-green infrastructure of towns and municipalities;
- Innovation Voucher – specialised study – Potential of water treatment sludge and food industry waste treated by microwave torrefaction technology

  Instrumentation: area P3; fully instrumented polygon of green roofs; microwave torrefaction technology; the equipment of a stationary analytical laboratory for municipal engineering technologies;

- Innovation Voucher – specialised study – Performance of analyses on selected samples of various water treatment sludges from different water treatment plants above 2000 EO;

  Instrumentation: the equipment of a stationary analytical laboratory for municipal engineering technologies;

- Innovation Voucher – specialised study – Technical and economic study of sludge management in catchment areas;
- Innovation Voucher – specialised study – Options for the use of water treatment sludge from small pollution sources within green infrastructure, and its use in agriculture;
- Innovation Voucher – specialised study – Performance of tests on biochar with regard to its innovative use as a substrate in green car parks;

  Instrumentation: area P3; fully instrumented polygon of green car parks; the equipment of a stationary analytical laboratory for municipal engineering technologies;

Examples of contract research undertaken for industry partners in 2021 include the following:

- Contract research in the area of the specialised assessment of sludge and waste management on the premises of SAINT GOBAIN ADFORS CZ;

Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies;

- Contract research: preparation of a hydrotechnical proposal for rainwater management within the plan "Development of apartments in Brno-Chrlice";

Instrumentation: SW MIKE URBAN

· overview of results from 2021,

When fulfilling the objectives of the AdMaS Centre's TA, high-quality publishing activities supported by the findings from investigated research projects can be considered to be of fundamental importance. For example, just the EKR subgroup produced five high-impact publications in 2021, all of them in quarter Q2. However, this publishing activity was significantly supplemented by publications in peer-reviewed journals and in conference proceedings included in the WoS or SCOPUS. In the case of journals, four articles were published as Jimp and two as Jost. A total of 34 publications were included in conference proceedings. Twenty of these have already been, or will be, included in the WoS or SCOPUS databases. The other articles are contributions to conferences outside the WoS and SCOPUS, or contributions to PhD-level conferences.

Utility models:

[1] TOMŠŮ, J.; MÜNSTER, P.; HLAVÍNEK, P.; MACSEK, T.; CHORAZY, T.; SATTURN HOLEŠOV spol. s r. o., Holešov, CZ, Brno University of Technology, Brno, Veveří, CZ: Assembly for monitoring the leakage of wastewater from a double-walled sewer pipe in real time. 35593, utility model. (2021)

Verified technology:

[1] NOVOTNÝ, M.; CHORAZY, T.; RAČEK, J.; HLAVÍNEK, P.; SNĚHOTA, M.; PETREJE, M.: Verified technology for the treatment of greywater – membrane and sand filtration technology. The verified greywater treatment technology consists in verifying the suitability of the abovementioned technologies for subsequent use in the treatment of "whitewater" for irrigation according to ČSN 75 6780. The technology is housed at the laboratories of the AdMaS Centre. (verified technology)

Research summary reports:

[1] HLAVÍNEK, P.; CHORAZY, T.; NOVOTNÝ, M. Koncepční řešení pro modrozelenou infrastrukturu měst a obcí. Brno: Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, 2021. s. 1-172.
[2] RAČEK, J.; CHORAZY, T.; HLAVÍNEK, P.; KUČERÍK, J.; MRAVCOVÁ, L.; PRAX, O.; VRŠANSKÁ, M.; BRTNICKÝ, M. Zpracování gastro odpadu do podoby pevného uhlíkatého produktu k materiálovému využití. Research summary report. 2021. s. 1-36.
[3] ŽIŽLAVSKÁ, A.; CHORAZY, T.; HLAVÍNEK, P.; RAČEK, J.; BRTNICKÝ, M.; LÓNOVÁ, K. Potenciál torefakce k úpravě čistírenských kalů pro jejich další využití. Research summary report. 2021. s. 1-41.
[4] HLAVÍNEK, P.; CHORAZY, T.; RAČEK, J.; ŠEVČÍK, J. Provedení analýz na vybraných vzorcích různého čistírenského kalu z různých čistíren odpadních vod nad 2000 EO. Brno: Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, 2021. s. 1-210.
[5] HLAVÍNEK, P.; CHORAZY, T.; HUBÁČEK, A. Posouzení a srovnání různých druhů šachet splaškového programu. Brno: Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, 2021. s. 1-57.
[6] HLAVÍNEK, P.; CHORAZY, T.; RAČEK, J.; NOVOTNÝ, M. Potenciál upraveného čistírenského kalu a odpadu z potravinářského průmyslu technologií mikrovlnné torrefakce. Brno: Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, 2021. s. 1-147.

[7] HLAVÍNEK, P.; CHORAZY, T.; RAČEK, J.; VELIKOVSKÁ, K.; BOUBÍNOVÁ, M. Posouzení a srovnání bezvýkopových a výkopových technologií při budování vodohospodářské infrastruktury. Brno: Brno University of Technology, Faculty of Civil Engineering, AdMaS Centre, 2021. s. 1-118.
[8] Žoužela, M., Šenková, M.: Optimalizace hydraulických poměrů rozdělovacího objektu UN na ČOV Brno-Modřice (fyzikální modelový výzkum). Research report, LVV – FAST – Brno University of Technology, 2020-21

Publications:

[1] KORYTÁŘ, I.; MRAVCOVÁ, L.; RAČEK, J.; VELIKOVSKÁ, K.; HLAVÍNEK, P. Characteristics of wastewater from tunnel washing: case study from Brno. Athens, Greece: Unit of Environmental Science & Technology, School of Chemical Engineering, National Technical University of Athens, 2021. s. 1-12.
[2] CHORAZY, T.; ROZKOŠNÝ, M.; JUCHELKOVÁ, D.; JURÁŇ, S.; HOLUBÍK, O. Poznatky z výzkumu znovuvyužití čistírenských kalů jako součást hospodaření s bioodpady malých sídel. Sborník přednášek konference s mezinárodní účastí. Městské vody 2021. Urban Water 2021. Údolní 58, 602 00 Brno, Czech Republic: Publisher ARDEC s.r.o., 2021. s. 211-220. ISBN: 978-80-86020-92-1.
[3] RAČEK, J.; CHORAZY, T.; ŽIŽLAVSKÁ, A.; MRAVCOVÁ, L.; HLAVÍNEK, P.; ŠVORČÍK, J. Středněteplotní pyrolýza čistírenského kalu. MĚSTSKÉ VODY 2021. Brno: ARDEC s.r.o., 2021. s. 221-227. ISBN: 978-80-86020-92-1.
[4] CHORAZY, T.; RAČEK, J.; ŽIŽLAVSKÁ, A.; HLAVÍNEK, P.; MRAVCOVÁ, L.; KUČERÍK, J.; VRŠANSKÁ, M.; LÓNOVÁ, K.; BRTNICKÝ, M. Biologická dostupnost fosforu z upraveného čistírenského kalu a gastro odpadu. Vodní hospodářství, 2021, roč. 2021, č. 10, s. 7-12. ISSN: 1211-0760.
[5] CHORAZY, T.; NOVOTNÝ, M.; MACSEK, T.; HLAVÍNEK, P.; RAČEK, J.; SNĚHOTA, M.; PETREJE, M.; RYBOVÁ, B. Recyklace vody a odpadů jako součást řešení modro-zelené infrastruktury v rámci měst do 10 tis. obyvatel. MĚSTSKÉ VODY 2021. Brno: ARDEC s.r.o., 2021. s. 242-251. ISBN: 978-80-86020-92-1.
[6] MACSEK, T.; CHORAZY, T.; HLAVÍNEK, P. Monitoring mikropolutantů v pitných a odpadních vodách. MĚSTSKÉ VODY 2021. Brno: ARDEC s.r.o., 2021. s. 72-78. ISBN: 978-80-86020-92-1.
[7] NOVOTNÝ, M.; CHORAZY, T.; MACSEK, T.; RAČEK, J.; HLAVÍNEK, P.; KOCIFAJOVÁ, M.; PRAX, O.; STEHLÍK, D. Možnosti využití biocharu jako inovativního substrátu pro zelené parkoviště. MĚSTSKÉ VODY 2021. Brno: ARDEC s.r.o., 2021. s. 195-203. ISBN: 978-80-86020-92-1.
[8] VELIKOVSKÁ, K.; ŠEVELA.P.; RAČEK, J.; MRAVCOVÁ, L.; POLÁŠEK P.; HLAVÍNEK, P.; BOUBÍNOVÁ, M. Systém rekuperace tepla a čištění šedé vody k opětovnému využití v laboratorních a reálných podmínkách. MĚSTSKÉ VODY 2021. Brno: ARDEC s.r.o., 2021. s. 228-234. ISBN: 978-80-86020-92-1.
[9] VELIKOVSKÁ, K.; MRAVCOVÁ, L.; ŠEVELA, P.; POLÁŠEK, P.; RAČEK, J.; HLAVÍNEK, P.; ŠVÁBOVÁ, M. Laboratorní testování účinnosti čištění a rekuperace tepelné energie šedé vody pro opětovné využití. Vodní hospodářství, 2021, year 71, č. 6, s. 3-11. ISSN: 1211-0760.
[10] FREMROVÁ, L.; KAISLER, J.; VRÁNA, J.; RACLAVSKÝ, J.; OŠLEJŠKOVÁ, M.; BIELA, R.; HLUŠTÍK, P.; RAČEK, J.; PLOTĚNÝ, K.; BARTONÍK, A. ČSN 75 6780 Využití šedých a srážkových vod v budovách a na přilehlých pozemcích. Prague: Česká agentura pro standardizaci, 2021. s. 1-40.
[11] DUKIC, V.; ERIC, R.; DUMBROVSKÝ, M.; SOBOTKOVÁ, V. Spatio-temporal analysis of remotely sensed and hydrological model soil moisture in the small Jicinka River catchment in Czech Republic. Journal of Hydrology and Hydromechanics, 2021, vol. 69, no. 1, p. 1-12. ISSN: 1338-4333.

[12] Žoužela, M., Šenková, M., Stříteský, L.: Optimalizace hydraulických poměrů rozdělovacího objektu před čtyřmi usazovacími nádržemi na ČOV Brno-Modřice. SOVAK 3/2021, ISSN 1210-3039, str. 24/88 - 31/95. Prague. 2021
[13] Žoužela, M., Stříteský, L.: Usměrňovací prvek pro homogenizaci proudových poměrů v rozdělovacím objektu usazovacích nádrží na ČOV Brno-Modřice. SOVAK 11/2021, ISSN 1210-3039, str. 22/338 - 25/341. Prague. 2021
[14] Žoužela, M., Staněk, A., Hubačíková, V., Šťastná, M.: Nový hydraulický okruhu Agronomické fakulty Mendelovy univerzity v Brně – article in the journal SOVAK ČR – will be published in the first half of 2022.
[15] PETRÁČEK, P.; KRÁTKÝ, V.; PETRLÍK, M.; BÁČA, T.; KRATOCHVÍL, R.; SASKA, M. Large-Scale Exploration of Cave Environments by Unmanned Aerial Vehicles. IEEE Robotics and Automation Letters, 2021, vol. 6, no. 4, p. 7596-7603. ISSN: 2377-3766.
[16] BARTONĚK, D. Automatic Drawing Using Topological Codes. In Research Developments in Geotechnics, Geo-Informatics and Remote Sensing. Advances in Science, Technology & Innovation. Springer Nature Switzerland AG: Springer Nature Switzerland AG, 2021. p. 251-254. ISBN: 978-3-030-72896-0.
[17] KALVODA, P.; NOSEK, J.; KALVODOVÁ, P. Influence of Control Points Configuration on the Mobile Laser Scanning Accuracy. In 7th World Multidisciplinary Earth Sciences Symposium, WMESS 2021 Prague. IOP Conference Series: Earth and Environmental Science. Bristol (UK): IOP Publishing, 2021. p. 1-10. ISSN: 1755-1307.
[18] NOSEK, J.; VÁCLAVOVIC, P. Earthquake Magnitude Estimation using Precise Point Positioning. In 7th World Multidisciplinary Earth Sciences Symposium, WMESS 2021. IOP Conference Series: Earth and Environmental Science. Bristol (UK): IOP Publishing, 2021. p. 1-10. ISSN: 1755-1307.

· description of R&D activities in 2021,

In 2021 Economics and Environment IG staff were involved in a range of research projects connected with, for instance, the Technology Agency of the Czech Republic's (TAČR) National Competence Centre, the Ministry of Industry and Trade Aplikace project, and a project funded by EEA and Norway Grants. The following examples can be mentioned:

- ongoing investigation of the TAČR project "National Competence Centre – Centre of Advanced Materials and Efficient Buildings", identification no.: TN01000056, and the subsidiary project: "Recycling of water and waste in the green infrastructure of cities"; reg. no.: TN01000056/03;

  In 2021, as part of the investigation a hydrological-hydraulic sewage network model was produced for the pilot locality of the town of Třešť. Also, the year saw the completion of the verification of a technology for the treatment of greywater for its subsequent use in irrigation in the context of new legislation (ČSN 75 6780).

Instrumentation: Devices for measuring flow in a sewer network, the technical equipment of Hall P4 (a system for the separate collection of greywater), the equipment of a stationary analytical laboratory for municipal engineering technologies;

- investigation commenced on the TAČR project "National Competence Centre – Centre for Environmental Research: Waste and circular management, and environmental protection", reg. no. SS02030008.

  At the AdMaS Centre work is underway on subsidiary work package 1.C Biologically degradable waste with a focus on the processing and use of water treatment sludge.

In 2021 a specialised conference was held, and work was performed on specialised texts as part of the preparation of Methodology for the Ministry of the Environment.

- commencement of the Ministry of Industry and Trade Aplikace project "Hygienisation of sludge for smaller pollution sources", reg. no. CZ.01.1.02/0.0/0.0/20_321/0024624.

  At the AdMaS Centre, and at selected small pilot water treatment plants, the testing of selected sludge hygienisation technologies is underway – long-term storage, pasteurisation and application of quicklime.

Instrumentation: The equipment of a stationary analytical laboratory for municipal engineering technologies;

- Completion of a project financed from EEA and Norway Grants "Curriculum for the Czech-Norwegian doctoral program in the field of water management and water engineering", reg. no. EHP-CZ-ICP-1-009.

  Within the project, a curriculum was prepared for a shared doctoral degree programme of the double degree type in the area of water management between Brno University of Technology and the Norwegian University of Science and Technology in Trondheim.

Contract research is ongoing in the area of the microwave depolymerisation of wate materials with a focus on the processing of sludge from water treatment plants, carbonaceous waste and other wastes with high organic content. The partner institution is the company Applied Sunrise Technologies, a.s.

Instrumentation: Hall P4 at the AdMaS Centre, the equipment of a stationary analytical laboratory for municipal engineering technologies

Contract research with companies and towns in the area of the optimisation of wastewater treatment plant operations and the remediation of utility networks has been taking place continuously. Some examples of collaborating institutions: Brněnské vodárny a kanalizace, a.s., SATTURN Holešov, s.r.o., VODA CZ, Vodárenská akciová společnost Kroměříž, a.s., and others.

The most important partner as regards cooperation with cities is the town of Třešť, where a set of smart water management methods suitable for smaller municipalities with less than 10 thousand inhabitants is being produced in the course of activities for an NCK project.

The options for the further financing of research projects are being monitored on an ongoing basis, and the researchers in the interest group are preparing scientific projects for both national and international programmes - see cooperation with foreign scientific institutions.

The FAST - EKR (Structural Economics and Management) group completed work on a methodological procedure created as part of the investigation of a TAČR project entitled "Evaluation of the increased safety and reliability of railway infrastructure after its modernisation or reconstruction". The procedure, which was entitled "Methodological procedure for the evaluation of benefits resulting from the implementation of investment measures to increase the reliability and safety of railway infrastructure" is the result of three years of research activities and was developed for the State Fund for Transport Infrastructure for the purpose of its inclusion in the departmental methodology of the Ministry of Transport of the Czech Republic intended for the economic evaluation of transport construction projects. Interim research results were published in (among other publications) the high-impact journal

Applied Sciences, and the final results were sent to the high-impact (Q2) Journal of Civil Engineering Management. The above-mentioned research was carried out in cooperation with the design and engineering organisation Moravia Consult Olomouc, s.r.o., and with the State Fund for Transport Infrastructure in the role of the application guarantor. Správa železnic (the administrator of Czech railways) also took part in consultations regarding the project. As a part of contract research, expert assessments and expert opinions were prepared (e.g. for the State Fund for Transport Infrastructure, the town of Veselí nad Moravou, KAM Brno, the Statutory City of Brno, and the Police of the Czech Republic).

- examples of R&D activities (including figures, graphs, examples of excellent publications, etc.)

In 2021, as a part of the REVOZIM project, the efficiency of sand filtration in greywater treatment was tested and compared with the ČSN 75 6780 Standard (Use of grey and rainwater in buildings and adjacent land) issued in 2021.

When comparing the measured values with the currently valid ČSN 75 6780 Standard, pH, turbidity and BOD5 can be compared in four categories, depending on the type o white water application in question. We will only compare the values for class 2 and class 3 for the treatment technology used. The measured pH of 8.3 falls within the limit values of 6.5 - 9.5 in both categories. The BOD5 value of 4 $mg \cdot l^{-1}$ complies with the limit value of 5 $mg \cdot l^{-1}$ in both categories. The measured turbidity value of 9 NTU does not meet the requirement of 2 NTU.

In comparison with the ČSN 75 6780 [2] Standard, white water can be conditionally used for irrigation according to the class 2 and class 3 categories, though limitations stem from the unsatisfactory turbidity values. However, these do not directly endanger human or animal health.

In 2021, the results were completed from membrane filtration testing carried out in 2020, and a verified greywater treatment technology was completed.

Sand filtration unit (left), and a view of the distribution plate (right)

As a part of the REVOZIM project, a hydrological-hydraulic model of a sewer network was developed. It is a basic version of a model which will enable the future calibration of this model (the calibration will take place as part of a measurement campaign in 2022). The basic and

future calibrated models are designed for the optimisation of the management and planning of critical drainage and wastewater treatment infrastructure.

Simulation of sewer network sections filling during precipitation loading

Students at the Faculty of Agriculture at Mendel University in Brno now have a unique educational technology at their disposal. They can test in practice how flowing water affects various building structures on a hydraulic circuit. Thanks to scale models, students are able to simulate flow across overflows, in culverts or under bridges. They can use their findings in, e.g. subjects related to water retention in the landscape. The whole system was tailor-made by experts from Brno University of Technology.

General counterflow view of a hydraulic circuit with a measuring chute

· information about the use of purchased instrumentation with a link to investigated projects and outputs,

Information on the use of purchased instrumentation is provided above next to the individual activities and projects. The following devices and equipment are most often used by the

Economics and Environment interest group and AdMaS - VHO (Municipal Water Management):

- The equipment of a stationary analytical laboratory for urban engineering technologies (especially equipment for the determination of TOC, drying weight, a multi-parameter measuring device, analytical scales, a washing and disinfection machine, etc.); REVOZIM, Zéta - Gastro, Zéta - Sludge, Zéta - Greywater
- Building P4 (building P4 of the AdMaS Research Centre, which has separate distribution of grey, yellow and black wastewater as part of its installed sanitary system) (REVOZIM, Zéta - Greywater)
- Flow measurement and automated sampling (REVOZIM, Zéta - Gastro, Zéta - Sludge, Zéta - Greywater)
- Equipment for the creation of supporting documentation (REVOZIM, Zéta - Gastro, Zéta - Sludge, Zéta - Greywater)
- The AdMaS Centre's mobile laboratories (REVOZIM, KALOMAN, Zéta - Gastro, Zéta - Sludge)

· examples of collaboration with industrial entities on R&D and contract research projects

In connection with an innovation voucher, an experimental car park was built in area P3 at the AdMaS Centre with car parking places that feature AS - TTE soakaway grids. These are used for the execution of load-bearing layer tests and for simulating the evaluation of car park pollution by oil products.

The experimental car park consists of a "reference" pavement made of interlocking paving slabs and the experimental car park itself, which consists of three parking spaces, all of which are fitted with AS - TTE soakaway grids. Parking space A is completely filled with paving slabs. Parking spaces B and C are half filled with paving slabs and half sown with grass, i.e. they are green parking spaces. The set-up enables the collection of rainwater from each parking space separately.

AS - TTE grids provide a comprehensive solution that enables surfaces to be used for transportation while maintaining the original drainage conditions and other ecological aspects at the site. The use of such grids with grass is suitable for average traffic intensity and vegetation load, e.g. Low-traffic lanes and parking spaces. Grids reinforced with paving stones are designed for high-intensity traffic and loads such as roads with mobile traffic, and high-traffic lanes and parking spaces.

The use of biochar in the structural layer is based on the current trend for the use of innovative solutions within the blue-green infrastructure of urbanised areas. A number of studies show its positive effect on rainwater treatment (it contributes to the removal of pollutants such as heavy metals, pesticides, organic matter, etc.). Biochar is a natural carrier of nutrients and minerals. It is also one of the tools available for sequestering carbon into the soil in the urban environment as part of the regeneration of green areas, tree planting, and the building of green parking lots. Approximately 20 kg of biochar was put into the soil of the green car park built at the AdMaS Centre, which represents the equivalent of removing approximately 50 kg of CO_2.

Performance of static load tests (left); installation of moisture sensors and a drainage system (foreground)

Installation of AS – TTE soakaway grids

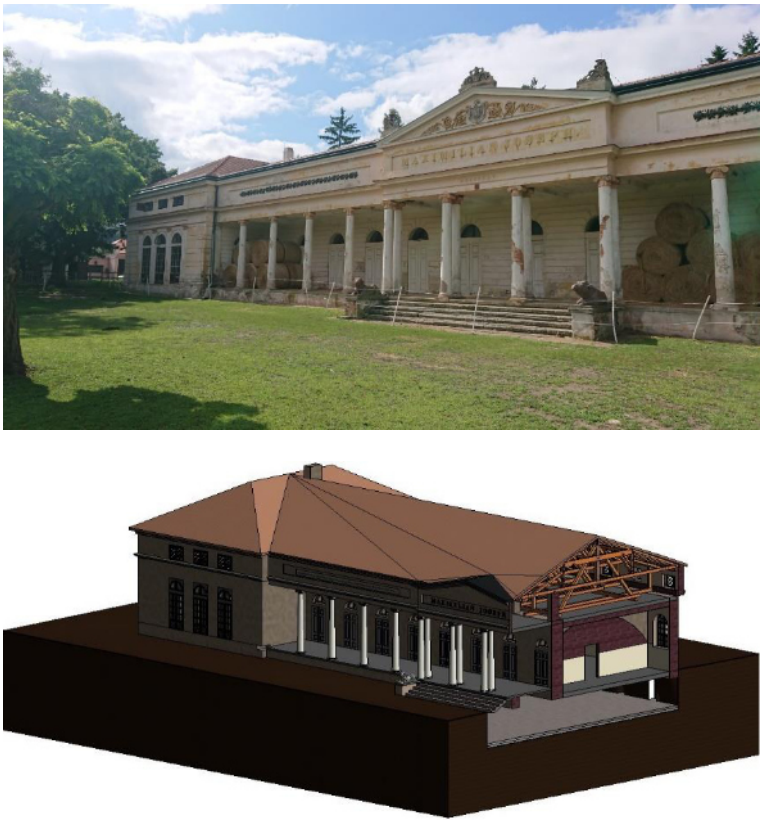
Filling in the grid with concrete blocks; preparation for the planting of a lawn

Completely finished, fully instrumented, experimental green car park at the AdMaS Centre

Cooperation with the company Brněnské vodárny a kanalizace a.s.

2020/21 saw the performance of model research which concerned the homogenisation of flow within a distribution building for settling tanks at Brno-Modřice water treatment plant. With the aid of a physical model, structural alterations were proposed, and then realised in the first half of 2021.

In 2021 collaboration continued with the Zlín Region's ICT Department in the area of the documentation of monuments via Building Information Modelling (BIM). Specifically, complete structural and technical documentation was created, including a Building Information Model of the Hubertcentrum in Kroměříž. See the following photo.



Instrumentation: Faro laser scanners with accessories

8. Conclusion

The AdMaS Centre has its seventh year of full operation behind it on the premises at Purkyňova 651/139, Brno. In 2021 the AdMaS Centre continued the investigation of R&D projects started in previous years, and commenced work on new projects from the areas of both basic and applied research. In 2021 198 projects were investigated, including projects involving collaboration between industry and regional R&D centres, and 10 international projects. The AdMaS Centre continued in its intensive collaboration with industry, both in the area of applied research and in shared R&D projects.

Even in the light of the situation worldwide in 2021, new partnerships were established, along with new areas of international cooperation. The management of the AdMaS Centre considers one of the greatest priorities for the coming years to be the development of international cooperation and internationalisation.

Number of posts (FTE) for R&D staff:	**86,39**
No. of contract research projects:	**618**
No. of R&D projects:	**198 national + 2 international**
Total income from commercial activities:	**52,941 mil. Kč**
From this income from contract research and other economic activities:	**24,793 mil. Kč**
Income from non-commercial activities:	**144,508 mil. Kč**
Total income:	**197,449 mil. Kč**

Generally speaking, there was significant development in collaboration with industry, and the turnover of the AdMaS Centre in the area of contract research was maintained. One positive phenomenon is that contract research is taking place in all the areas of interest of the AdMaS research centre, and the individual projects relate to a number of clients. Because of this, the prosperity of the AdMaS Centre is not linked to just a few clients, enabling the diversification of risk.

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